Changes in Brain Blood Flow by the Use of 2D/3D Games

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Abstract. Recently, with the rapid progress in image processing and three-dimensional (3D) technology, stereoscopic images are not only seen on television but also in theaters, on game machines, etc. However, symptoms such as eye fatigue and 3D sickness may be experienced when viewing 3D films on displays and visual environments. The influence of stereoscopic vision on the human body has been insufficiently understood; therefore, it is important to consider the safety of viewing virtual 3D content. In this study, we examine whether exposure to 3D video clips affects the human body such as brain blood flow. Subjects viewed 3D video clips on the display of portable game machines, and time series data of their brain blood flow was measured by near-infrared spectroscopy (NIRS) with use of FOIRE-3000 (Shimazu Co. Ltd., Kyoto). Our results showed oxyhemoglobin tended to increase throughout the cerebral cortex while operating the game machines on the 3D display in comparison with the 2D display.

Keywords: 3D video · Visually induced motion sickness (VIMS) · Near infrared spectroscopy (NIRS) · Brain blood flow

1 Introduction

The opportunity to see stereoscopic images has increased with the recent spread of 3D TVs and game machines, but these images may have a negative influence on the human body. Specific influences include eye fatigue and visually induced motion sickness. There are various theories of the developmental mechanism of these symptoms which has not been clarified, but the sensory conflict theory is generally known [1]. However, the development of all cases of sickness cannot be explained with this theory, and current knowledge about the influence of stereoscopic images on the body is insufficient.

Near-infrared spectroscopy (NIRS) utilizes the property of hemoglobin which absorbs near infrared light, and it is capable of noninvasively measuring the blood

M. Antona and C. Stephanidis (Eds.): UAHCI 2016, Part III, LNCS 9739, pp. 516–523, 2016.
DOI: 10.1007/978-3-319-40238-3_49

volume in the body. Applying this to the brain, changes in brain blood flow within a 2–3 cm range from the scalp can be measured, and activated local regions can be detected. Thus, NIRS is a test capable of noninvasively detecting the time-course of overall reactivity to activation of the cerebral cortex in subjects in a natural state [2–8]. In NIRS, changes in the hemoglobin level are calculated from the values of irradiation and detection lights, but the distance (effective optical path length) that the light actually forwarded in the head tissue is not measurable at present. The generally used unit of measurement for NIRS values is the product of the hemoglobin concentration and length, such as [mM·mm] (hemoglobin concentration length).

In this study, to increase knowledge about the influence of stereoscopic images on the body, we focused on 3D game machines. To play NINTENDO 3DS (Nintendo, Kyoto) used in the experiment, operation of the controller while gazing at stereoscopic images displayed on a small screen is necessary. In addition, 2D and 3D images can be instantly switched by operating a knob on the side of the screen. Thus, we investigated changes in brain blood flow while playing a game using 2D and 3D displays by measuring NIRS.

2 Materials and Methods

2.1 Experimental Method

The subjects were eight healthy young persons (22.8 ± 0.9 years old (mean ± standard) with no past medical history of diseases of the ear or nervous system. The experiment was sufficiently explained to the subjects and written consent was obtained beforehand.

For NIRS, FOIRE-3000 (SHIMADZU, Kyoto) was used. Channels were arranged as follows: 1–12ch on the frontal lobe, 13–24ch on the left temporal lobe, 25–36ch on the right temporal lobe, and 37–48ch on the occipital lobe (Fig. 1). The probe caps to fix the channels were set to the bilateral preauricular points, plane α covering the nasion (root of the nose), and plane β parallel to plane α. The distance between planes α and β was 3 cm, and plane β was present vertically upward of plane α. The occipital lobe was fixed so as to set the center of the probe cap to the inion in the occipital region (external occipital protuberance) (Fig. 2).

For the 3D game machine, NINTENDO 3DS (Nintendo, Kyoto) was used. NINTENDO 3DS adopted the parallax barrier method, and the liquid crystal screen was 3.53-inch (76.8 mm width × 46.08 mm length). For the game software, TETRiS® (BANDAI NAMCO GAMES, Tokyo), which is relatively simple to operate, was selected from general games.

The subjects sat on a chair and played the game in a comfortable position. They first played TETRiS® for 60 s using the 2D display (early 2D), and continued the game for 60 s using the 3D display (3D). The displayed was then returned to 2D and the game was continued for 30 s (late 2D). Regarding this procedure as one set, NIRS was measured while they continuously played 5 sets. Changes in the oxygenated hemoglobin level over the early 2D, 3D, and late 2D periods in the above 5 trials were recorded at 12 channels on the frontal, occipital, and temporal lobes at 7.7 Hz.

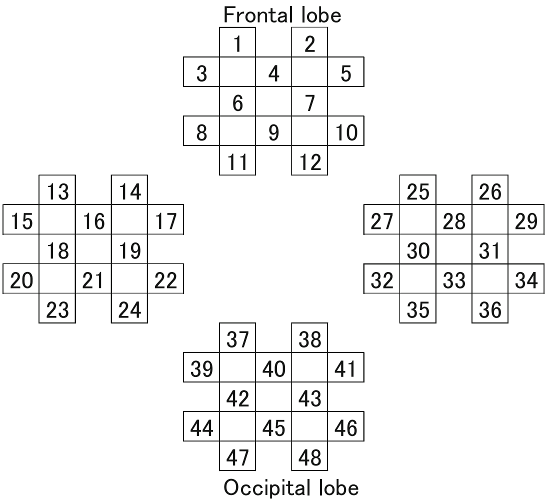

Fig. 1. Channel arrangement

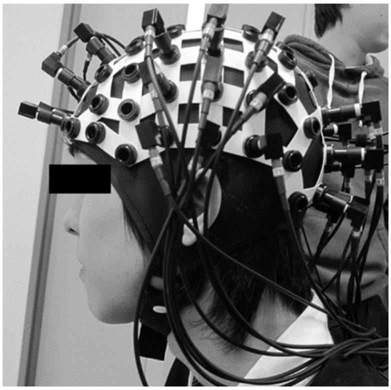

Fig. 2. Probe cap attachment

2.2 Investigation Items

Regarding the oxygenated hemoglobin level determined by NIRS, the high-frequency component was smoothed by the mean movement every 5 s and the average of the five trials, and the integrated values in the 60s-early 2D, 60s-3D, and 30s-late 2D periods were calculated for each channel. To compare early 2D and 3D, the integrated value in late 2D was doubled and recorded. Increases in brain blood flow from early 2D to 3D and from 3D to late 2D were calculated using the formula below:

$$\text{early 2D} - \text{3D increase}[\text{mM} \cdot \text{mm}] = \text{integrated values in the 3D } [\text{mM} \cdot \text{mm}] \\ - \text{early 2D}[\text{mM} \cdot \text{mm}]$$

$$\text{3D} - \text{ late 2D increase}[\text{mM} \cdot \text{mm}] = \text{integrated values in the late 2D}[\text{mM} \cdot \text{mm}] \\ - \text{3D}[\text{mM} \cdot \text{mm}]$$

The oxygenated hemoglobin level on NIRS was compared between early 2D and 3D and between 3D and late 2D using the Wilcoxon signed-rank sum test setting the significance level at $p < 0.05$.

3 Results

The value at each channel was compared between early 2D and 3D and between 3D and late 2D using the Wilcoxon signed-rank sum test. Channels at which significant changes were observed were colored in Figs. 3 and 4.

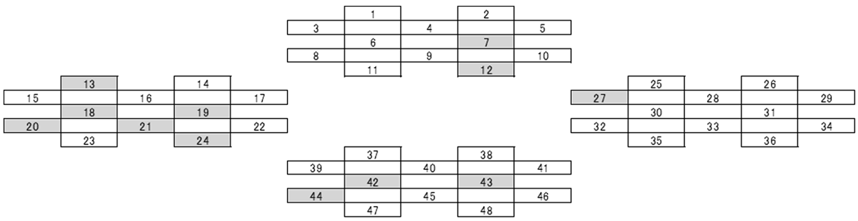

Fig. 3. Channels at which significant changes were observed between early 2D and 3D

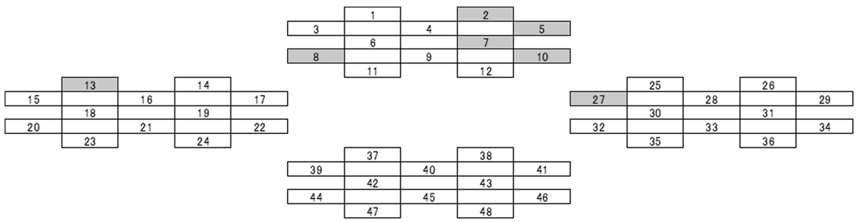

Fig. 4. Channels at which significant changes were observed between 3D and late 2D

On the comparison between early 2D and 3D, in the frontal lobe, the 3D integrated value was significantly greater in 3D at ch17 and ch12. In the left temporal lobe, the integrated value was significantly greater in 3D at ch13, ch18–ch21, and ch24. In the right temporal lobe, the integrated value was significantly greater in 3D at ch27. In the occipital lobe, the integrated value was significantly greater in 3D at ch42–ch44.

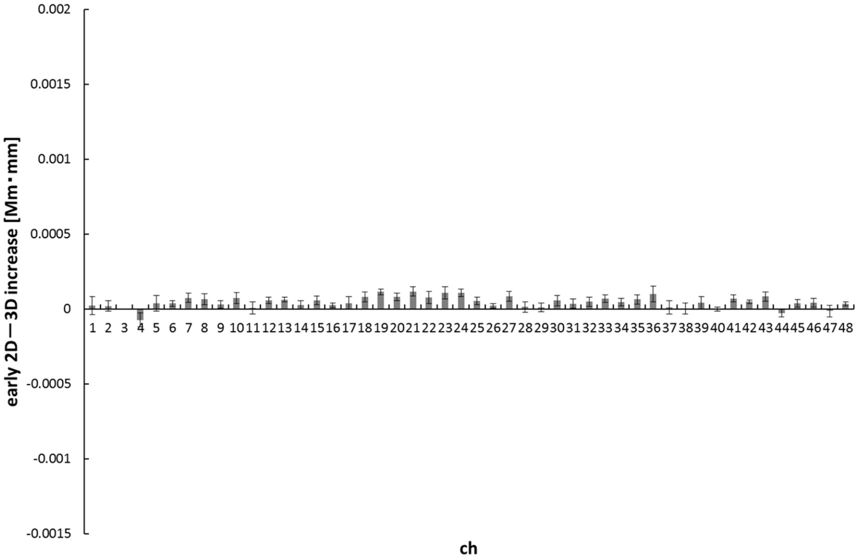

Fig. 5. Changes in the oxygenated hemoglobin level from early 2D to 3D [Mm·mm]

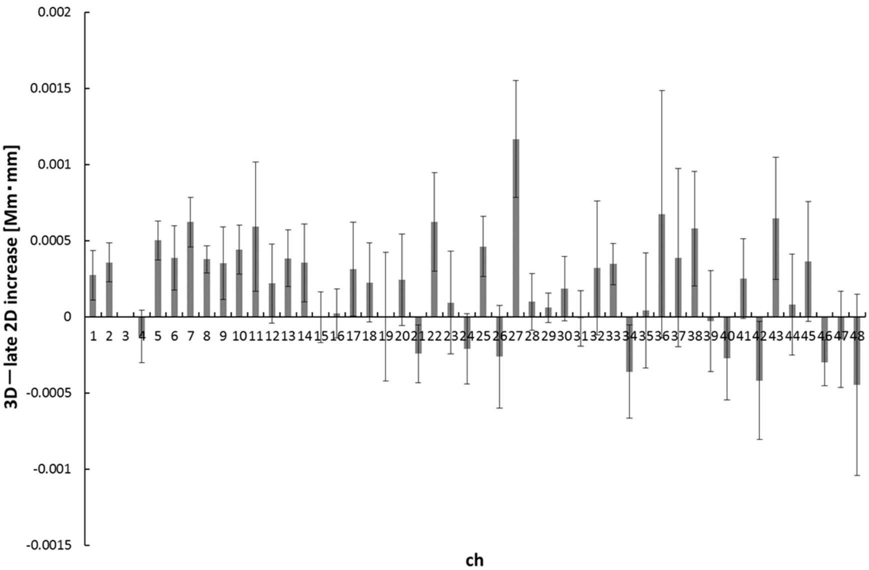

Fig. 6. Changes in the oxygenated hemoglobin level from 3D to late 2D [Mm·mm]

On the comparison between 3D and late 2D, the integrated value was significantly greater in late 2D at ch2, ch5, ch7, ch8, and ch10 in the frontal lobe. In the left and right temporal lobes, the integrated value was significantly greater in late 2D at ch13 and ch27. No significant difference was noted in the occipital lobe.

Increases in brain blood flow from early 2D to 3D and from 3D to late 2D are shown in Figs. 5 and 6 (values at ch3 were not presented due to measurement failure). Brain blood flow increased from early 2D to 3D at many channels. The increase in brain blood flow from 3D to late 2D was greater than that from early 2D to 3D, but a sharp reduction in brain blood flow was observed in several channels.

4 Discussion

From early 2D to 3D, brain blood flow increased at many channels, suggesting that the blood oxygenated hemoglobin level in the brain increases while playing the 3D game compared to that while playing the 2D game. However, brain blood flow also increased from 3D to late 2D at several channels, for which two reasons are considered: The influence of 3D images remains for a specific time after switching 3D to 2D, or the increase was due to concentration on the operation of the game and thinking. The increase turned to a decrease in ch21, ch24, ch26, ch31, ch34, ch39, ch40, ch42, ch46, and ch48, suggesting that the influence of 3D images was marked at these channels.

In the frontal lobe, a significant difference between early 2D and 3D was noted at ch17 and ch12, and a significant difference between 3D and late 2D was noted at ch2, ch5, ch7, ch8, and ch10. An increase in ch12 was also noted between 3D and late 2D, and blood flow consistently increased from early 2D to late 2D at many channels. Since the frontal lobe controls psychogenesis, such as emotion, attention, thinking, and voluntary movement, brain blood flow may have continued to increase due to thinking and concentration on the game operation [9–11].

In the occipital lobe, a significant difference between early 2D and 3D was noted at ch42–ch44. No significant difference was noted on a comparison between 3D and late 2D. Therefore, the oxygenated hemoglobin level increased in the occipital lobe when 2D was switched to 3D. The oxygenated hemoglobin level turned to decrease at ch42 from 3D to late 2D, suggesting that it was markedly influenced by 3D images. Since the visual area responsible for vision is present in the occipital lobe [9–11], it may have been strongly influenced when 2D was switched to 3D.

In the temporal lobe, on a comparison between early 2D and 3D, the integrated value was significantly higher in 3D at ch13, ch18–ch21, and ch24 in the left temporal lobe. On the comparison between 3D and late 2D, the integrated value was significantly higher in late 2D at ch13, but differences at other channels became insignificant. In addition, the oxygenated hemoglobin level tended to increase from 2D to 3D in the left temporal lobe but turned to decrease from 3D to late 2D at some channels, being markedly influenced by 3D images. Various sensory areas are present in the left temporal lobe, and, in contrast to the right temporal lobe which memorizes sounds and shapes, the left temporal lobe memorizes and understands speech [9–11]. Since TETRiS® is a game requiring thinking, 3D images may have a large influence on the left temporal lobe.

5 Conclusion

Aiming at increasing knowledge about the influence of stereoscopic images on the body, we focused on a 3D game machine. Changes in brain blood flow while playing the game were compared between playing using the 2D and 3D displays by measuring NIRS.

On the comparison between early 2D and 3D, the integrated value was significantly greater in 3D at ch17 and ch12 in the frontal lobe. In the left temporal lobe, the integrated value was significantly greater in 3D at ch13, ch18–ch21, and ch24. In the right temporal lobe, the integrated value was significantly greater in 3D at ch27. In the occipital lobe, the integrated value was significantly greater in 3D at ch42–ch44. On the comparison between 3D and late 2D, in the frontal lobe, the integrated value was significantly greater in late 2D at ch2, ch5, ch7, ch8, and ch10. In the left, right temporal lobe, the integrated value was significantly greater in late 2D at ch13 and ch27. No significant difference was noted in the occipital lobe.

A marked increase in brain blood flow was noted in the frontal, occipital, and left temporal lobes. In the frontal lobe, brain blood flow consistently increased from early 2D to late 2D at many channels. Since the frontal lobe controls psychogenesis, such as emotion, attention, thinking, and voluntary movement, brain blood flow may have continued to increase due to thinking and concentration on the game operation. In the occipital and left temporal lobes, brain blood flow increased from early 2D to 3D, and no significant difference was noted between 3D and late 2D. The visual area responsible for vision is present in the occipital lobe, and various sensory areas are present in the left temporal lobe. Thus, sensory areas, such as the visual area, may have been activated when playing the game with 3D images compared to activation by 2D.

Acknowledgements. This work was supported in part by the Japan Society for the Promotion of Science, Grant-in-Aid for Scientific Research (C) Number 26350004 and Research Activity Start-up Number 50760998.

References

1. Saito, S.: Safety image for all: the evaluation method and international standard. J. Inst. Image Inf. Telev. Eng. **58**, 1356–1359 (2004)
2. Fukuda, M., Mikuni, M.: A study of near-infrared spectroscopy in depression. J. Clin. Exp. Med. **219**, 1057–1062 (2006)
3. Zardecki, A.: Multiple scattering corrections to the Beer-Lambert Law. Proc. SPIE **1983**, 103–110 (1983)
4. Wray, S., Cope, M., Delpy, D.T., Wyatt, J.S., Reynolds, E.O.: Characterization of the near infrared absorption spectra of cytochrome AA 3 and hemoglobin for the non-invasive monitoring of cerebral oxygenation. Biochemica et Biophysica A **933**, 184–192 (1988)
5. Elwell, C.E., Cooper, C.E., Cope, M., Delpy, D.T.: Performance comparison of several published tissue near-infrared spectroscopy algorithms. Anal. Biochem. **227**, 54–68 (1995)
6. Hoshi, Y., Tamura, M.: Detection of dynamic changes in cerebral oxgenation coupled to neural function during mental work in man. Neurosci. Lett. **150**, 5–8 (1993)

7. Kato, T., Kamei, A., Takashima, S., Ozaki, T.: Human visual cortical function during photic stimulation monitoring by means of near-infared spectroscopy. J. Cereb. Blood Flow Metab. **13**, 516–520 (1993)
8. Hazeki, O., Tamura, M.: Quantitative analysis of hemoglobin oxygenation state of rat brain in situ by near-infrared spectroscopy. J. Appl. Physiol. **64**, 796–802 (1988)
9. Sugihara, I.: Audition and equilibrium. In: Sakai, T., Kawahara, K. (eds.) Normal Structure and Function of Human Body, vol. 9, Nervous System 2, pp. 66–77. Nihon-Ijishinpo, Tokyo (2005)
10. Netter, F.H.: Netter Atlas of Human Anatomy, 6th edn. Saunders Elsevier, Philadelphia (2014)
11. Dox, I.G., Melloni, B.J., Eisner, G.M., Melloni, J.: Illustrated Medical Dictionary, 4th edn. Collins Reference, Glasgow (2001)