Study on Incongruence of Binocular Images for Blue Based on Occlusion Avoidance Behavior When Gazing at the Rim of a Column

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ABSTRACT

We devised a new experimental method that can examine only whether blue is involved in the detection of incongruence of binocular retinal images during occlusion perception, and describe the experiment. As a result, no convergence eye movement occurred during occlusion perception, suggesting that blue processed by the koniocellular could not detect incongruence of binocular retinal images.

1 INTRODUCTION

The left and right retinal images have parallax equivalent to the pupil spacing of the left and right eyes. Disparity varies depending on the distance of the visual target. Stereo images produce depth perception from the disparity of the left and right retinal images, and this disparity is detected as a gap. We have focused on the lateral geniculate nucleus (LGN) of the thalamus, which is a relay location from the optic nerve to the visual cortex. The LGN has a seven-layer structure consisting of three kinds of cells (magnocellular, parvocellular, and koniocellular). Previously, it was thought that magnocellular cells processed luminance, while parvocellular cells processed color signals. Livingstone & Hubel claimed that the parvocellular is insensitive to the depth defined by parallax [1]. However, parvocellular is an opponent color system for low spatial frequencies and low temporal frequencies, and also processes luminance contrast for high spatial frequencies [2,3]. In fact, V1 and the extrastriate cortex (V2、V3、V4、V5) process colors and shapes simultaneously by large neuron overlap. The psychophysical and physiological results of these findings have also been reported [4]. Therefore, we can see depth of Random Dots Stereogram (RDS) by color even at equiluminance.

Depth perception is possible with a single eye. However, binocular stereoscopic vision perceives depth by detecting parallax from the corresponding points of the binocular retinal image. The detection mechanism of corresponding points in binocular retinal images can be verified from occlusion perception. There are three types of occlusion as shown in Fig.1: (1:) the front object hides

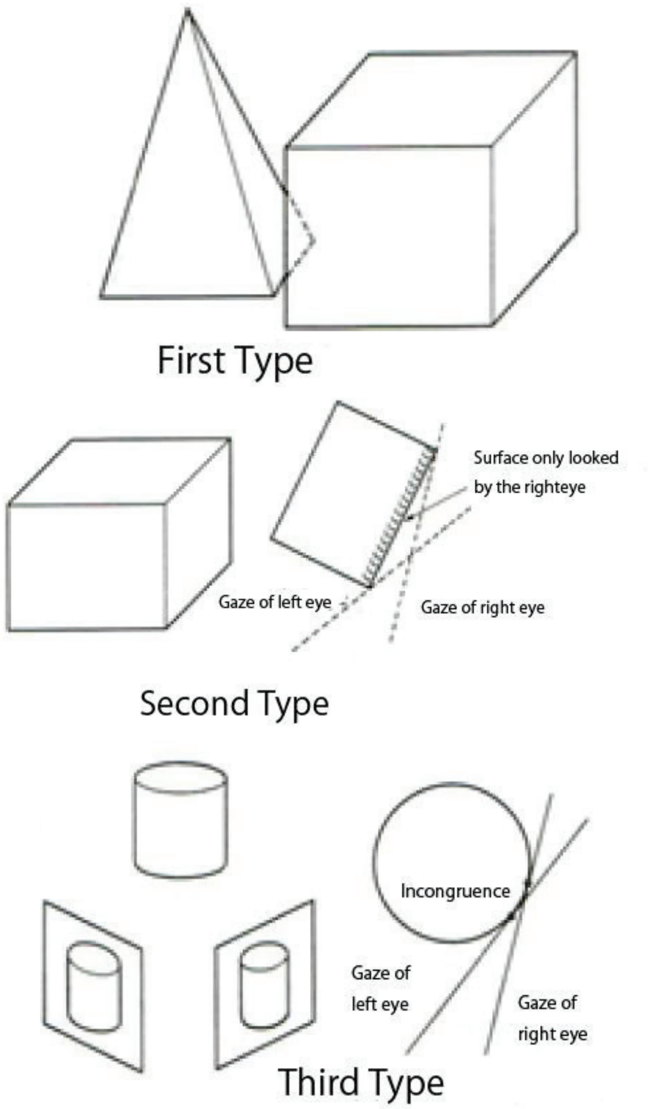


Fig.1 Three type of occlusion

the back object; (2) the object itself hides its face; and (3) the surface is hidden by the curved surface of the object (there are parts that can be seen by the left and right eye. and parts that cannot be seen). The edge of a curved surface such as a column is called a rim. Occlusion for the rim is called “rim occlusion”. Kudo et al. revealed that when the rim has a texture, both eyes detect incongruence between left and right retinal images, causing eye movement to avoid occlusion [5].

In the Kudo et al. experiment, random dot patterns were pasted on a column of a real object. For this reason, the luminance could not be made equal, and it is considered that the influence of the color component was included with the luminance component. We wanted to investigate whether color information alone detects the incongruity between the left and right retinal images. We considered it was possible to conduct experiments with equiluminance by generating a column with equiluminance textures by 3-D CG. In our first experiment, we generated random dots with the equiluminance of red and green, which are said to be processed by the parvocellular. We measured binocular eye movements when gazing at the rim of a column generated by 3-D CG. We were able to clarify that the incongruence of binocular retinal images generated on the rim could be avoided by the convergence of eye movement [6].

We also focused on koniocellular cells, which are reported to be the third pathway of LGN [7]. The koniocellular responds to blue cones with an ON response and red / green cones with an OFF response [8,9]. It was recently confirmed that bistratified cells project into the koniocellular. Ten percent of the retinal ganglion cells are koniocellular bistratified cells. Bistratified cells process S-cone information and are sensitive to blue [9]. Previously, blue-yellow (red + green) opposing colors were thought to be processed by the parvo system [8,10]. In order to clarify the nature of koniocellular cells, in our second experiment, we generated random dots with equiluminance of blue and yellow, mapped them onto a column generated by 3-D CG, and measured binocular eye movements during rim gaze. We found that converging eye movements to avoid incongruence of binocular retinal images were not observed in the opposite colors of blue and yellow [11].

However, since yellow is a mixed color of red and green and is processed in a parvo system, the above results are not necessarily the result of the koniocellular only. In addition, the MTF of random dots used in the second study could exceed the spatial resolution of the koniocellular. Therefore our second study approach has not always been suitable for measuring the properties of the koniocellular.

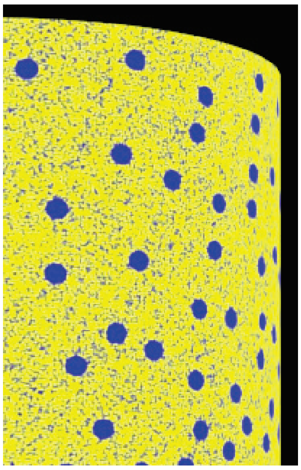
Therefore, we devised a new experimental method that can examine only whether blue is involved in the detection of incongruence of binocular retinal images during occlusion perception, and describe the results of the experiment.

2 EXPERIMENT

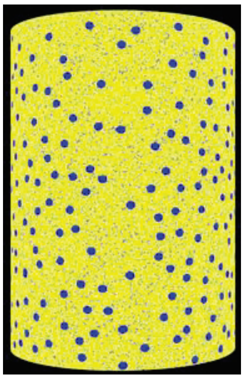
In order to map to a cylinder as a texture, we first generated a random dot pattern of equiluminance blue and yellow. However, since yellow is a mixed color of red and green, it is processed by the parvocellualr system. Therefore, considering that the CSF in which the parvocellular system functions as an opposite color system is at most 2 cpd [12, 13], 10~20 cpd random dots that function as a higher luminance signal processing system were used. At this spatial frequency, the koniocellular system again does not function as an opposite-color system. Therefore, when blue and yellow random dots are combined in this size to obtain equal luminance, an image that is not processed by the opposite-color system of the parvo system or koniocellular system can be generated. Patterns of blue, which had equiluminance as blue and yellow random dots, with a low spatial frequency of 0.5 cpd [12,13] that could be processed with koniocellular cells were mapped onto the entire cylinder, with blue and yellow random dots smaller than 10~20 cpd dot. We also prepared blue patterns of one cpd and 1.5 cpd for comparison. Fig. 2 shows examples of the image of the column. By using this cylinder to examine eye movements during gazing at the rim, it was possible to verify whether or not the blue processed by the koniocellular system detected the incongruence between the binocular retinal images due to occlusion without being affected by the opposite-color system of the parvocellular system.

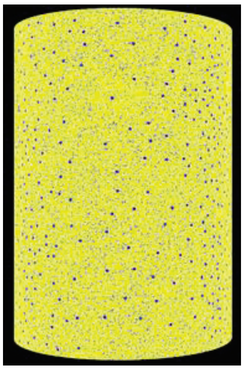
As in our previous study [6], we applied the method of subjectively obtaining equiluminance and presented subjects with the images shown in Fig. 3. The subject changed the luminance of blue and selected the luminance at which the boundary with yellow was most difficult to see, and that value was then set as the value of equiluminance. In order to prevent the color of the subject's clothing from being reflected on the display screen and affecting the measurement result, subjects were covered with a black cloth during measurements. Study subjects were 10 students 21–22 years old. In the experiment, the viewing distance was 60 cm, and a Panasonic TH-P46VT2 was used for the display. The chromaticity values of blue were x = 0.1503 and y = 0.0591, and the chromaticity values of yellow were x = 0.4282 and y = 0.5229. The screen illuminance was unified at 1.93 cd / m^2 for the black peak, 147.4 cd / m^2 for the white peak, and 67.75 cd / m^2 for yellow.

The left-eye and right-eye images of the cylinder shown in Fig. 3 were generated by 3dSMAX, which is 3-D CAD software. Aberrations between random dots and the background color can cause perception of dot outlines and lead to stereoscopic vision [14]. Therefore, both the right-eye and left-eye images were blurred with a Gaussian filter in Adobe Photoshop (radius 1.0 pixel), and used as a cylindrical image. A side-by-side video was created using the right-eye and left-eye images of the three types of cylindrical images (white, equiluminance, non-equiluminance) using Premiere Pro as the experimental video. EMR 9 (Nac Imagin Technology, Tokyo) was used to measure eye movement. A 3-D cylindrical image was viewed through the 3-D LCD shutter glasses attached to the plasma display. The subject gazed first at the rim of the white cylinder incapable of occlusion perception, switched to the created equiluminance cylinder, and continuously gazed at the rim while eye movements were recorded. For comparison, a cylinder created with non-equiluminance yellow and blue was also used.



(a) Enlarged view of part rim





(b)Size of Blue dot: 0.5cpd **(c)Size of Blue dot: 1.5cpd**

Fig. 2 Examples of the image of the column.

Fig.3 Experiment of equiluminance

3 RESULTS

When incongruence of the binocular retinal image is detected by occlusion, an action deflecting one eye from the rim occurs, and convergence eye movements take place toward the convergent divergent direction. Fig. 4 shows examples of changes in the convergence angle. The convergence angle was obtained from the difference between the eye movement value of the left and right eyes. When the subject is gazing, fixation eye movement between 0.5 ~1° occur constantly in each eye. Considering the size of the fixation eye movement, we judged that the convergence angle changed due to occlusion perception when the convergence angle changed 0.5° or more [6]. From this criterion, it could not be determined whether the convergence eye movement caused by occlusion perception occurred during the three types of column gaze.

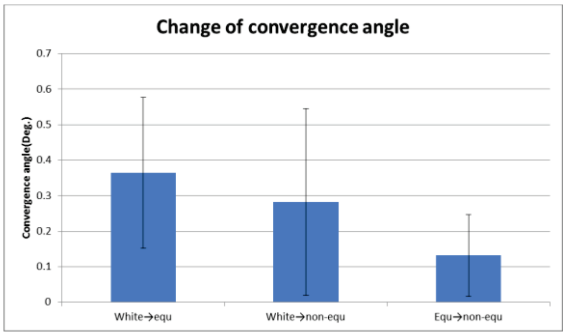


Fig.4 Change of convergence angle (white→ equiluminance, white→non-equiluminance, equiluminance→non-equiluminance)

4 DISCUSSION and SUMMARY

We are investigating whether the color difference signal contributes to the incongruence of the binocular retinal image, based on the changes in convergence eye movement that occurs when gazing at the rim of column. In our first study, we analyzed convergence eye movement during rim gaze using an equiluminance column generated by red and green random dots, said to be processed by the parvocellular of LGN. We clarified that the parvocellular detects incongruence of binocular retinal images [6]. In a second study, we focused on blue, which is said to be processed by the koniocellular, and analyzed convergence eye movement during gazing at the rim using an equiluminance column generated by random blue and yellow dots. As a result, the koniocellular showed smaller changes in convergence eye movement than in the parvocellular, suggesting that incongruence of binocular retinal images by the koniocellular was different [11]. However, since yellow used as a color difference is a mixed color of red and green in this experiment, it is a problem that the involvement of parvocellular cannot be eliminated.

In this experiment, blue and yellow equiluminance was created using random dots with higher spatial frequencies, which could not be processed as the color-opponent system in parvocellular and koniocellular. Only the involvement of the koniocelluler was investigated by mapping random dots of equiluminance with low spatial frequencies processed by koniocellular on the blue and yellow random dots with higher spatial frequencies. In this way, we devised a new experimental method and measured the convergence eye movement during rim gaze. Results showed that no convergence eye movement occurred during occlusion perception, suggesting that blue processed by the koniocellular could not detect incongruence of binocular retinal images. This time we measured with one kind of luminance, but the visibility of blue is lower than that of green, and we believe that it will be necessary to verify with higher luminance blue using the same experimental method. We would like to investigate the mechanism of congruence detection of binocular retinal images in the brain, which is deeply related to stereoscopic vision, using occlusion perception in more detail.

4.1 Acknowledgments and Legal Responsibility

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