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Assessment of Visual Space Recognition in Patients with Visual Field Defects using Head Mounted Display (HMD) System: Case Study with Severe Visual Field Defect *

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Abstract— **For the quantitative assessment of visual field defects of cerebrovascular patients, we developed a new measurement system that could present various kinds of visual information to the patient. In this system, we use a head mounted display as the display device. The quantitative assessment becomes possible by adding the capability to measure the eye movement and the head movement simultaneously by means of a video apparatus of motion analysis. In our study, we examined the effectiveness of this system by applying it to a patient with serious visual field defects. The visual image of the reduced test paper was presented to the patient, the effect on his/her spatial recognition and eye movement was investigated. The results indicated the increase in the ration of visual search in the reduced side. With the reduced image, the decrease of the angular velocity of eye movement was recognized in the visual search in the defected side. In the motion analysis, the head movement was not observed while the eye movements appeared corresponding to each different conditions.**

This fact led us to confirm that the patient coped with this kind of test by the eye movement. In this analysis, the effectiveness and the usefulness of the developed system were confirmed that enables us to evaluate the abnormal and compensation movement of the eyes.

I. Introduction

Approximately 40% of the patients of cerebrovascular disease suffered from visual field defects, and that 50% to 60% of them would see spontaneous recovery [1]. In recent years, there were reports on the effectiveness of the rehabilitation for visual field defects and many of them indicated the effectiveness of the compensation method of the eye movements [2].

A healthy subject has the highest visual resolution at the fovea centralis in the retina. He needs to capture the image in the central part of the visual field to obtain detailed visual information [3]. In the patient with visual field defects, he/she tries to capture the image in the center of the remained view field. This causes the eye movement to capture the image in the healthy view field or the compensation body movement to rotate the head. These actions are called "visual searches."

There are some methods to evaluate the visual search currently reported. They include the method to measure the area of the search for the method to measure the searching time and number of the successful attempts by instructing the subject to search a specified geometric figure [4,5]. However, there are hardly any reports on the eye movements when the head movement was unrestricted, and when various visual information was systematically presented such as the versatile view changes.

In this study, we newly devised a system to create the special environment required for the visual search by the eye movement using the head mounted display (HMD) that enabled to present versatile visual information. To examine the effectiveness and the usefulness of the developed system, we added the capability to measure the eye movement and evaluated the eye movement of the patient with visual defects quantitatively.

II. Method

A. Subject

The patient was a 43 year-old woman with an informed consent for this study. She was not dependent on any helper in her daily life, but had a severe impairment in the left view field. She had only upper right 1/4 view field when we measured with the Goldman perimeter. We analyzed her problems in the activity of daily living (ADL) using the Catherine Bergego Scale (CBS) [6], and observed the effect of the visual field defect as the inability to search the objects on the left side.

B. Common Clinical Test

We used the line cancellation test of the BIT Japanese version which was modified by Ishiai et al [7]. Fig. 1 shows the analysis method of the test. For the line cancellation test (score range from 0 to 36 points), the subjects were presented with a single sheet of paper on which 6 lines in varying orientations were drawn, 18 on each side. They were instructed to make a mark through all of the lines. Left- sided neglect was indicated by a failure to mark more lines on the left side than on the right. Degree of neglect was assessed by

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the proportion of lines omitted relative to the total number of lines. The line cancellation test sheet was divided into right and left portions and a right and then a left correct answer rates were analyzed. We conducted this test with and without the HMD.

C. Special test with HMD

In this system, we capture the image of the test sheet with the two small CCD cameras and present the image on the liquid crystal display (LCD) inside the HMD unit. We can reduce the image size or shift the image on the LCD by means of the control unit of the HMD. The HMD system can produce these images for a patient to be able to see the test sheet easily or not see it in order to evaluate a grade of visual deficit.

In this condition, the image does not move when the subject moves his/her head. This provides us the environment which requires the visual search by the eye movement to carry out the line cancellation test.

In this study, we installed two extra small CCD cameras in the HMD unit. This enabled us to record the eye movement of each eyes from the front lateral sides. During the examination, we recorded the head movement with a digital video camera, and saved the video-image in synchronous with the eye movement using a monitor splitter (Fig. 2).

D. Analysis of eye movements with HMD

We analyzed the recorded eye movement using a movement analysis software, Frame-DIAS IV. In the analysis, we identified the center position (X, Y) of the eye from the ellipse of the pupil obtained in the image processing (binarization) of the eye image (Fig. 3). In our experiment, we evaluated the pixel of the eye position with the sampling frequency of 20 Hz.

We analyzed the eye position when the subject fixed his/her eye on the center of the test sheet, and made it as a reference position. Then, we obtained the frequency ratio of the right view to the left view during the test (total 100%). We determined the right and left views according to the area of the right and the left regions in the histogram of the eye movement angle (Fig. 4). In addition, we calculated the velocity of the angular movement from the angular positions of the eye at the rate of 1/20 second. We evaluated this angular velocity of the eye movement in the line cancellation test. The difference between the right and the left, and between the patient and healthy subject were analyzed. Among the measured angular velocity data, those of the rapid eye movement were included. So, we eliminated the data more than 100 deg/s according to the preceding study[8].

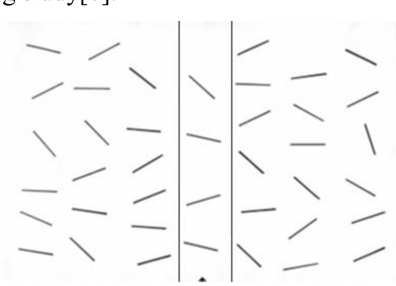

Figure 1. Analysis method for the line cancellation test.

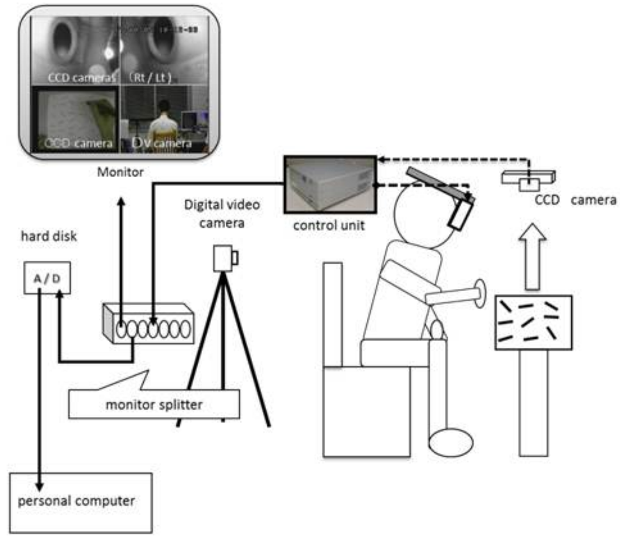

Figure 2. Experimental apparatus.

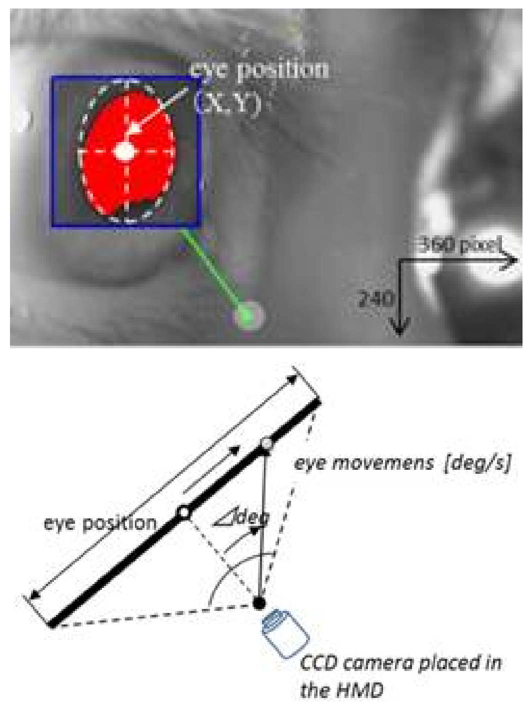

Figure 3. Method of eye movement measurement.

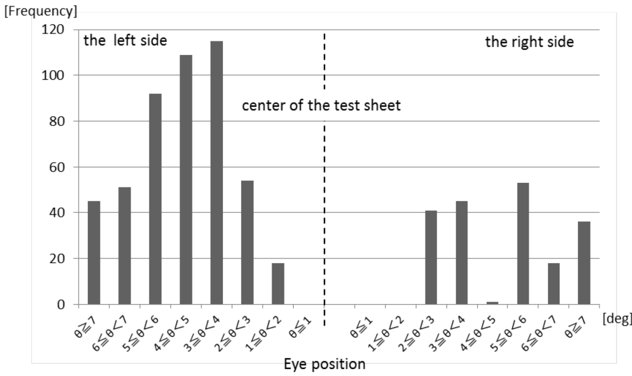

Figure 4. Example of frequency distribution of eye-position.

E. Procedure

The subjects sat on a chair as the starting point. The test sheet was placed on a desk with its midline aligned with that of the subject body. All tasks were carried out without any restriction on the test time. First, the subject performed the line cancellation test of the common clinical test without HMD on the subject. To prepare the HMD, the examiner wore the HMD unit, and adjusted the inside CCD camera so that the image of the right eye appeared in the center of the monitor display. Then, the subject wore the HMD unit and the measurement started. After instructing the subject to fix his/her eye on the center of the test sheet, the video image of the eye on the center of the test sheet, the video image of the eye movement was recorded during the examination. The subject performed the line cancellation test using the HMD in the following three conditions. They are: the condition with no reduction in the test sheet image, the condition of right reduction (80% reduction toward the right end of LCD as shown in Fig. 5), and the condition of the left reduction (80% reduction toward the left end of LCD). The subject carried out the tests in this order of the conditions.

III. Analysis of Eye Position

The scores of the line cancellation test are shown in Fig. 6. Apparent decrease in the scores ascribed to wearing HMD was not observed, but the scores tended to be lower when the image of the test sheet was reduced. This result shows that the developed system has a significant impact on the visual input of the patient. The subjects attention was biased towards the defects side (left side), and the number of missed the line cancellation in the opposite side (right side) became larger.

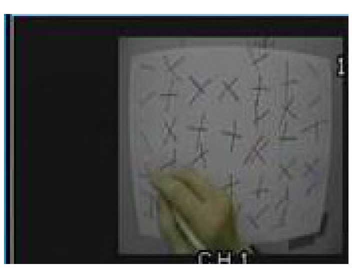

Figure 5. The condition of right reduction

Fig. 7 shows the ratio of the right and left eye ball positions. The ratio of the eye ball positions was greater for the left side of the test sheet in the no-reduction condition It was also greater for the right side of the test sheet in the right reduction condition and for the left side in the left reduction condition. We consider the following reasons for the results. In the no reduction condition, the subject turned her attention to the left side of the test sheet where her visual field defects were serious and eye positions were more in the left side. The eye position increased in the right side for the right reduction and in the left side for the left reduction because the attention of the subject was directed to the reduced side. In this way a versatile analyses on the visual defects became possible owing to the presentation of versatile visual information using the developed system.

IV. Analysis of Eye Movements

Fig.8 shows the measured results of the angular velocity of the eye movement. In healthy subjects, we found no significant differences between the angular velocities in the right and left view fields under whatever conditions of reduction. On the other hand, in the case of the patient, the following differences were observed. When the image of the test sheet was reduced, the angular velocity of the eye movement tended to increase in the side of the impaired view. This seemed to be from the following reason. When the image was reduced and became hard to see, the patient moved the line of sight quickly to cope with the situation in the side of the remained view. In the impaired view, however, the eye

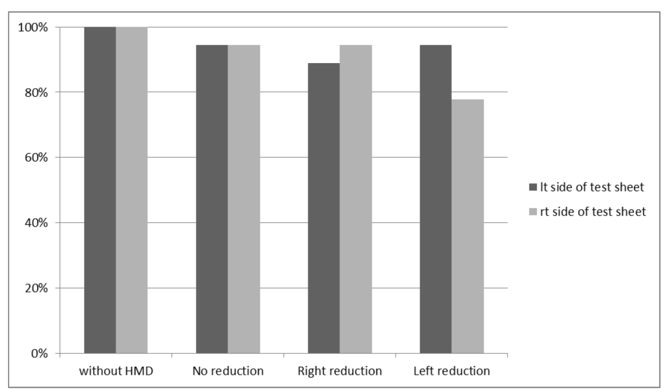

Figure 6. Percentage of correct answers in the line cancellation test.

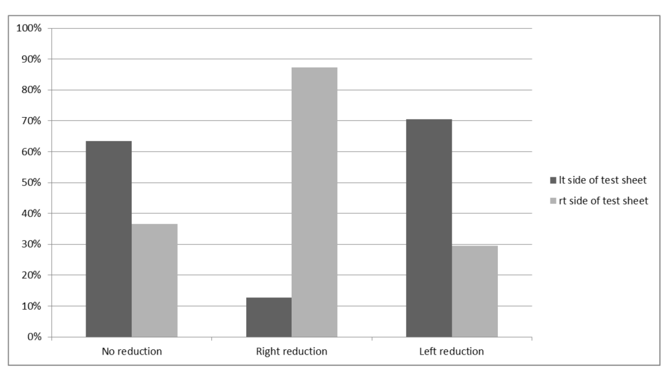

Figure 7. Percentage of eye position in the line cancellation test.

movement required more time to search the target on the test sheet than that of remained view.

In addition, we measured the head movement together with the eye position and the eye movement. The results indicated that there was no head movement accompanied with the eye movement in this patient. With these results, we confirmed that the patient coped with the test by the eye movement. This verified that we can evaluate the abnormal and compensation movement of the eye using the developed system.

V. CONCLUSIONS

Using the HMD, we developed a measurement system that enables us to present versatile visual information and to measure the movement of the eyes and the head simultaneously. In experiments, the effectiveness and the usefulness of the developed system to evaluate the abnormal and compensation movement of the head and the eyes in the patients with an impaired view field were verified.

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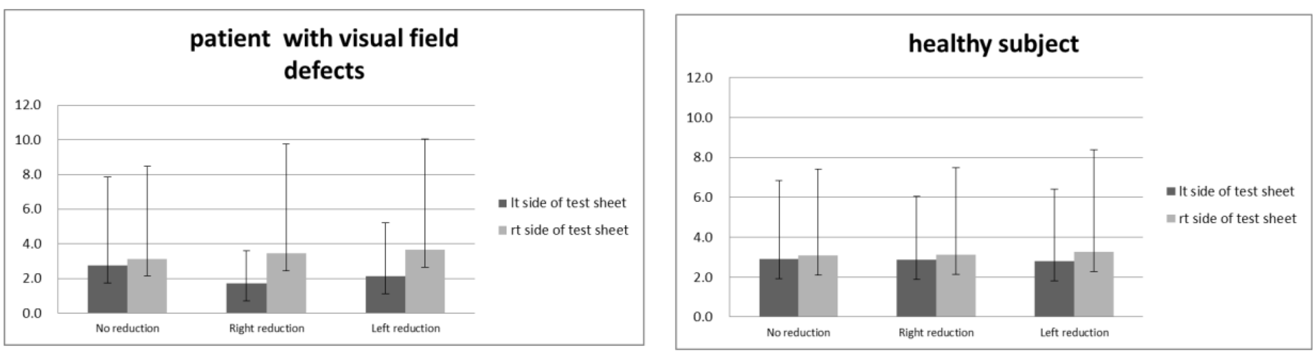

Figure 8. Angular velocity (mean and standard deviation) of eye movement in the line cancellation test.