Vergence Eye Movements Measured by an Advanced Real-Time Binocular Eye Tracking System

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Summary

We measured human vergence eye movements using a newly-developed binocular eye tracking system. The system adopts a wide-field, high-resolution (2048x2048 pixels), and high-frame-rate, USB-3.0 digital camera that provides high sensitivity, resolution, and frame rate. Infrared light illuminates both eyes and the reflected image of the illumination on the corneas and the black image of the pupil of each eye are captured by the camera. The center of the pupil is calculated by fitting an ellipse and tracked over time. The reflected image of the illumination on the cornea is used to compensate head-movements. The positions of both eyes are estimated at each frame and can be read out on line via computer network and DAC (Digital Analog Converter). The adoption of the WINDOWS 7/8 1 x 64 as the operation system makes this binocular eye tracking system user-friendly. Because of the high frame rate of the digital camera, the sampling rate of the system can be as high as 320 Hz.

To assess the quality of this system, we developed a new “real 3-D visual display system” that presents two wide-field visual images placed at different distances but at the same visual angle from the subject. The visual images are alternatively presented on two liquid crystal displays (LCDs), either “near LCD” or “far LCD”. A half mirror is suspended at 45° in the light path of the “far LCD” so as to allow the substitution of images on the “near LCD”. The sizes of the near and far LCD screens are selected so that the angles of the view are the same.

By using the binocular eye tracking system and the real 3-D visual display system, we characterized vergence eye movements of humans when ocular fixation shifted between two visual stimuli of the same view angles placed at different distances in 3-D space.

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Methods

We calculated the horizontal/vertical gaze angle of each eye by processing its video-image. The origin was set on the center of the views. The horizontal gaze angle of the left eye (HL) and that of the right eye (HR) were calculated by our original software. “HL” is positive and “HR” is negative in the figure. C represents the inter-ocular distance (500mm), which can be adjusted for each subject. According to the law of small, the target position of the gaze in the 0.0 plane can be described as follows. Then we calculated the vertical position. The vertical gaze angle of the left eye (VL) and that of the right eye (VR) were calculated by our original software. We used average of them.

Experiments

We measured gaze positions in 3-D space and the sampling frequency was 333Hz. The subject moved his gaze between the far and near visual stimuli about 20 times. The far stimulus was displayed on the monitor-1 and seen through the half mirror. The near stimulus was displayed on the monitor-2 and its image reflected by the half mirror was seen on the virtual screen.

1) Large visual stimulus
2) Small visual stimulus
3) Same visual stimulus

Conclusion

By using this system, we succeeded in characterizing vergence eye movements of humans when ocular fixation shifts between two targets placed at different distances in 3-D space.