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A reduction of visual fields during changes in the background image such as while driving a car and looking in the rearview mirror

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Objective: We attempted to measure visual fields during changes in background image to simulate driving a car using the new virtual reality system.
Methods: Twenty-nine healthy young volunteers were enrolled in this study to experience visual perceptions, like being surrounded by visual images, which is a feature of the "CyberDome" hemispherical visual display system. Visual images to the right and left eye were projected and superimposed on the dome screen, allowing test images to be seen independently by each eye with polarizing glasses. Visual fields were measured during changes in background image. Background image speed was changed between 0, 60, 150, and 300 km/h. Subjects gazed at the center and pushed a button when a target presenting from the top, bottom, left, or right was perceived.
Results: With dynamic background images, visual fields were smaller (about 7%) than during standstill (0 km/h). Visual field reduction (lower, left, and right visual fields) increased with increased speeds (60, 150, and 300 km/h) of the background image. Upper visual field reduction tended to be somewhat greater than that at 0 km/h, but the difference was not significant.
Conclusions: These findings suggest that visual fields are reduced when viewing dynamic background images such as while driving a car looking forward and then suddenly looking in the rearview mirror.

Key words: virtual reality, hemispherical visual display system, dynamic visual field test

Introduction

Static and kinetic perimetry are used for most visual field testing in modern ophthalmology. Static perimetry measures the threshold for visibility of a static target in a grid (retinal sensitivity), and kinetic perimetry maps a visual field by an illuminated moving target in a grid (movement from nonvisible to visible). Both differ in terms of target presentation and methods of measurement, but apart from the target image, other test conditions are similar in the sense that surrounding objects are static. However, in the everyday environment, surrounding objects are moving, so whether current visual field tests accurately evaluate realistic visual perception remains unclear.

In everyday life, the brain processes far more moving visual information than static visual information. For example, perception of moving images is extremely important when driving, given the constant movement of background images outside of the central vision. Intact peripheral vision is also essential to drive safely and be constantly aware of surrounding traffic signals, signs and pedestrians. Cognitive scientific research has found that useful visual fields reduce as vigilance increases, such as when driving a car. Relationships between traffic accidents and driving ability, age, visual acuity, contrast sensitivity and useful visual field have been extensively investigated. Results show that the most important factor associated with traffic accidents is useful visual field.[1] Useful visual field is defined as central vision and the surrounding spatial area from which one gets information to perform a visual task. In clinical ophthalmology, "visual range" and "retinal sensitivity" measured as visual fields differ. To date, however, visual field tests have been determined only under static conditions (surrounding objects other than the target image are static). Little ophthalmological research has been performed under dynamic conditions (i.e., surrounding objects other than

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the target image are also moving) as experienced in daily life, such as when driving. Due to the obvious difficulty in evaluating visual function when actually driving a car, we devised an effective visual function test system in the dynamic conditions as experienced daily life using the CyberDome 1400 virtual reality display system.[2] In present study, we investigated the changes of the visual fields by driving car using a virtual reality display system.

Subjects and Methods

Sample

Subjects comprised 29 volunteers without ocular disorders (mean age, 20.97 years; range, 18-24 years). Selected subjects were able to understand the test procedure and test results were reproducible. Corrected visual acuity was -0.08 (Log MAR) or better and near stereopsis was evaluated with the Titmus stereo test (Stereo Optical, IL, USA) to confirm that all subjects had stereoacuity better than 60 seconds of arc. There was no significant abnormality in the visual field test using a Humphrey Field Analyser (Carl Zeiss Meditec, CA, USA), like that determined from the criteria proposed by Anderson and Patella.[3] All subjects provided written informed consent before participating in this study and the tenets of the Declaration of Helsinki were followed. We certify that all applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed during this research.

Test apparatus

The CyberDome 1400 virtual reality display system (Panasonic Electric Works) was used in this study to change background image speed while measuring visual fields with both eyes open. The CyberDome 1400 is a hemispherical visual display system for widescreen projection.[4] Two liquid crystal projectors are used to display polarization images at horizontal and vertical viewing angles of 100° on a dome-shaped screen with a diameter of 1.4 meters. Corrected images are reflected by a flat mirror in front of the projectors, and the compact image is projected on the dome screen. Figures 1 and 2 depict the display and system configuration. Synchronous processing is performed by two slave computers and one master computer to project a 3-dimensional image.

Figure 1. The CyberDome 1400 virtual reality display system (Panasonic Electric Works)

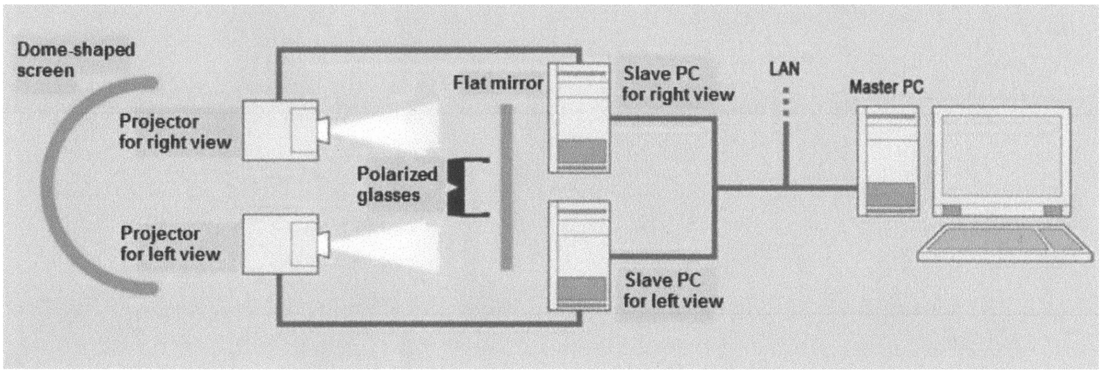

Figure 2. CyberDome 1400 system configuration

Corrected images are reflected by a flat mirror in front of the projectors, and the 3-D image is projected on the dome screen.

Projector angle of view, screen configuration and placement represent input parameters for software used for image correction to provide distortion-free images on the dome screen.

Test design

Subjects, after complete correction of refraction, wore polarized glasses and fixed the gaze on a central target on the dome screen 1 m in front of the eyes. The size of a central target is 1° and a luminance is 7 cd/m^2. Visual fields were measured with both eyes open. A test target (luminance 17 cd/m^2; size 5°) from one of 4 directions (top, bottom, left or right) moving at a speed of 5 degrees/second was presented and subjects pushed a button when they saw the target. The size of test target is 5° and a luminance is 17 cd/m^2. During testing, the head of the subject was restrained by chin and forehead supports. Figure 3 shows the test apparatus. The background image was a straight road in an urban area. The four background image speeds were 0, 60, 150, and 300 km/h. Visual fields were measured under each condition. Test target direction and background image speeds were randomized into 16 different patterns.

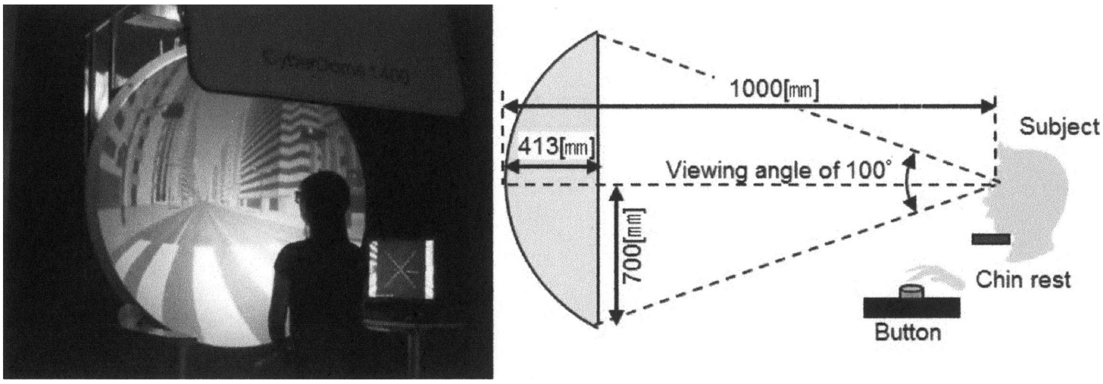

Figure 3. (Left) Test image displayed by virtual reality display system using the CyberDome 1400; (right) test apparatus setup: Subjects fixed the gaze on a central target and pushed a button when they saw the test target.

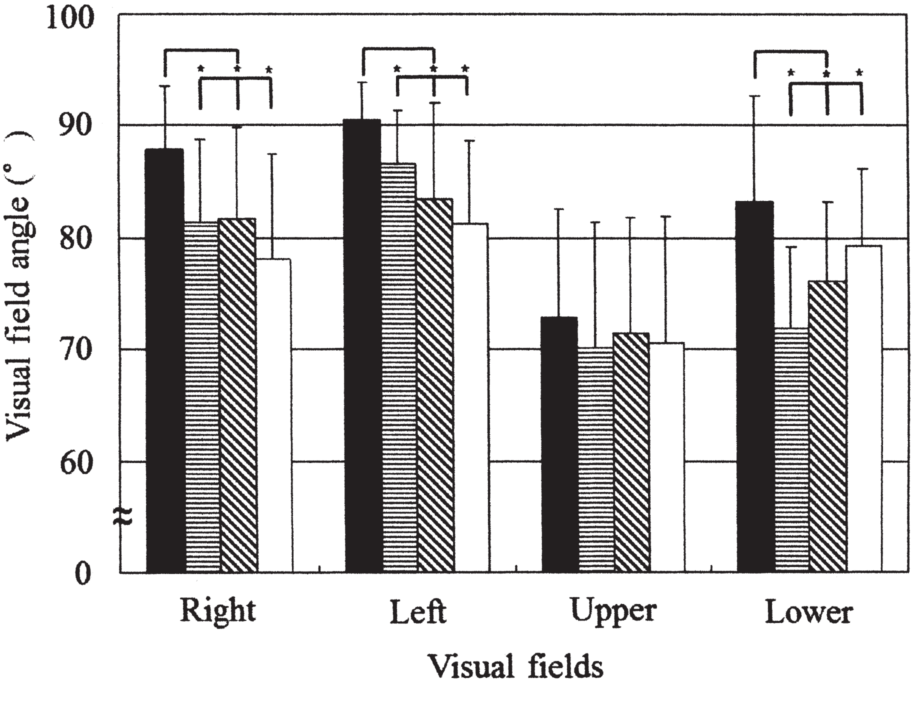

Figure 4. Visual field results with changes in background image speed.

Black, 0 km (standstill); horizontal hatching, 60 km; diagonal hatching, 150 km; white, 300 km.
*P < 0.05; Fisher's PLSD

Statistical analysis

Data were examined by one-way analysis of variance and Fisher's protected least significant difference (PLSD). The level of statistical significance was less than 5%.

Results

Visual field testing using this apparatus could be performed for all subjects. Figure 4 shows the upper, lower, left and right visual field results for each background image speed. A change in speed of the background image (60, 150, and 300 km/h) resulted in reduction of the lower, left and right visual fields as compared to standstill (0 km/h) (Fisher's PLSD, $P < 0.05$). In the upper visual field, a change in speed of the background image (60, 150, and 300 km/h) resulted in was no significant difference compared to standstill (0 km/h) (Fisher's PLSD, $P > 0.05$). Total visual field angle for both eyes (upper, lower, left, and right) was 334.7° at standstill, 310.2° at 60 km/h, 312.9° at 150 km/h and 310.3° at 300 km/h. Compared to standstill, visual field reduction was 7.3% at 60 km/h, 6.5% at 150 km/h, and 7.2% at 300 km/h.

Discussion

In this study using virtual reality display system to simulate driving a car, we confirmed that visual fields reduced with changes in background image, as compared to standstill (0 km/h). However, visual field reduction is not significant increased with a rise in background image speed.

In current ophthalmology practice, visual field testing is usually performed using a Humphrey Field Analyzer (Carl Zeiss Meditec, CA, USA) for static perimetry and a Goldmann perimeter (Haag-Streit International., Switzerland) for kinetic perimetry. However, measurements in both tests are performed under conditions in which surrounding objects other than the target image are static. Furthermore, measurements under conditions where surrounding objects are actually moving, as when driving a car, are obviously difficult.

This study used a CyberDome 1400 hemispherical visual display system to simulate the experience of driving a car. Compared to standstill, the overall visual field (left, right, upper, and lower) reduced about 7% with changes in background image. The reasons for visual field reduction include effects in attentional capacity (useful visual field), an apparent increase in target speed due to movement of the background image in a direction opposite to the target,[5] decreased detection of motion in peripheral visual fields[6] and peripheral visual field reduction with changes in background image. The background image in the upper visual field was always "blue sky." Subjects, therefore, may not have perceived as much motion of this background image or apparent increases in speed. This is probably the reason why the upper visual field was the only field not to display significant reduction. In present study, the lower visual field in background speeds at 150 and 300 km/h was superior to that of background speed at 60 km/h. Because the lower visual field play an important part in daily life, for example, in jogging and driving a car. Therefore, under high speed at 150 and 300 km/h, the spatial visual attention of the lower visual field improved for crisis prevention.

With only a change in background image, visual field reduction was still about 7%. When driving a car in real life, other factors are involved that may further increase visual field reduction, including operating the vehicle, acceleration, possible fear or anxiety and aging. A higher risk of traffic accidents with visual field reduction as compared to age-matched normal controls, and a higher risk of falls and traffic accidents in moderate or severe glaucoma as compared to normal controls[7] have been reported. Our test results performed under dynamic conditions as seen when driving a car detected greater visual field reduction than during conventional testing using a Goldmann perimeter. This highlights the need in clinical ophthalmology to measure visual fields in elderly patients with abnormalities under more realistic conditions. The static perimetry is not necessarily evaluating the practical visual field. In the future, we aim to develop a realistic visual test system that estimates the practical visual fields which can actually be used in daily life.

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