Original Article

Field Expansion for Homonymous Hemianopia by Mobile Application with Virtual Reality Glasses

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Abstract

Introduction: Homonymous hemianopia interferes with the daily living activities of patients.

Objectives: To present a mobile application using the camera function in combination with three-dimensional virtual reality (VR) glasses to expand the visual field by transferring images toward the residual field.

Methods: The authors included patients with homonymous hemianopia who could provide consent and communicate during examinations. The authors prospectively tested patients using an iOS-mobile application with a mobile camera and VR headsets to compare the binocular visual field before and after the test.

Results: Six patients were included in the study. The mean age was 50 (43-57 years). We found that the patients had a range in field expansion from 0 to 39.9 degrees (average of 21.28 degrees). Five patients were satisfied with the expanded visual field in adaptive confrontation testing.

Conclusions: This study has shown some effectiveness, we demonstrated a positive result of field expansion and patient satisfaction.

Keywords: Homonymous hemianopia, Mobile application, Virtual reality glasses, Visual field, Field expansion

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Introduction

Homonymous hemianopia is a visual field defect in which a patient loses the use of the right or left side of both eyes. It is a common visual field defect that is caused by retrochiasmal brain lesions. This hemifield loss has a substantial impact on activities of daily living such as driving and reading, especially the speed of reading. Patients with right homonymous hemianopia have difficulty shifting their eyes from left to right to read letters in words, while patients with left homonymous hemianopia have difficulty finding the beginning of the next line on the left side when starting a new line.

In 2000, Peli, et al. described binocular sector prism glasses, which use the principle of Fresnel prisms to expand the visual field by about 15-20 degrees by placing a base-out prism 30-40 prism diopter (PD) to shift the image into the residual hemifield of each eye.[1] However, no studies have been carried out with these glasses or other methods for expanding the visual field in homonymous hemianopia in Thailand. This study aims to present a mobile application using the camera function on a phone, in combination with three-dimensional virtual reality (VR) glasses, to expand the visual field by transferring images toward the residual field.

Methods

The study was approved by the Medical Ethics Committee of Thammasat University (MTU-EC-OP-1-006/64), Pathum Thani, Thailand, and was conducted in accordance with the tenets of the Declaration of Helsinki. The computerized visual field (CTVF) was measured with the Swedish Interactive Threshold Algorithm (SITA) standard 30-2 program of the Humphrey Field Analyzer (Carl Zeiss Meditec, Dublin, CA). Homonymous hemianopia is considered a localized defect present in the same hemifield (i.e., right or left) of each eye. Congruous homonymous hemianopia was diagnosed if the pattern of visual field defects was nearly identical in each eye. Incongruous homonymous hemianopia was diagnosed if the pattern of visual field defects was less identical in each eye. All patients had at least 6 months of follow-up until the visual field was thought to be stable. We tested the patients in an eye examination room and the lighting in the test room was at comfortable levels for indoor settings. All patients performed neuroimaging and had stable visual field defects defined by performing at least two tests per clinical visit at least 6 months apart before enrolling in the study. Inclusion criteria were 1) patients who were diagnosed with homonymous hemianopia based on examinations by neuro-ophthalmologist and neuroimaging, 2) the age range was between 18 and 70 years old, and 3) the patients had sufficient cognitive awareness to comply with examination procedures. The outcome of the study was to measure how many degrees of field expansion and assess whether the patient is satisfied after the test. To assess patient satisfaction, a Thai-language questionnaire was administered, referring to the 14 measurement items of the previous study that determined user satisfaction with mobile VR Headsets.[2] The authors excluded patients with retinal or optic nerve diseases (prechiasmal and chiasmal lesions) causing visual field defects and those who had problems in language communication or cognitive impairment which could interfere with the use of the application. We collected data including age, gender, etiology, eye examination findings, visual field testing, neuroimaging, problems encountered with field defects in daily activities, and expectations of visual field restoration. All patients were informed about and consented to the research methodology.

First, the authors conducted self-tests using an iOS-mobile application with a mobile camera and VR headset (BOBOVR Z6, Xiaozhai technologies). The VR headset can adjust focus to correct the refractive error in the range from +2.00 to -4.00 diopter. The lens used was an aspherical lens with a diameter of 52 mm and a field of view of 120 degrees (Figure 1). The standard confrontation visual field is done at 0.5 meters; however, Kodsi et al. demonstrated a four-meter confrontation test which is useful as a screening test for evaluating paracentral vision. They calculate the approximate area of the blind spot at 0.5 meters and at 4 meters.[3] We tested at an intermediate distance (1.5 meters) due to the limitation of the VR headset lens, which we used to expand a field of view and thus making it unable to focus at closer (0.5 meters) or farther distances (4 meters). Based on this previous study, we will calculate the area using the same principle below: vertical height of the optic nerve head = 1.75 mm; horizontal width of the optic nerve head = 1.50 mm;

and nodal point of the eye from the retina = 17 mm. At 1.5 meters we calculate the vertical height of the blind spot to be 15.4 cm and the horizontal width to be 13.2 cm (Figure 1).

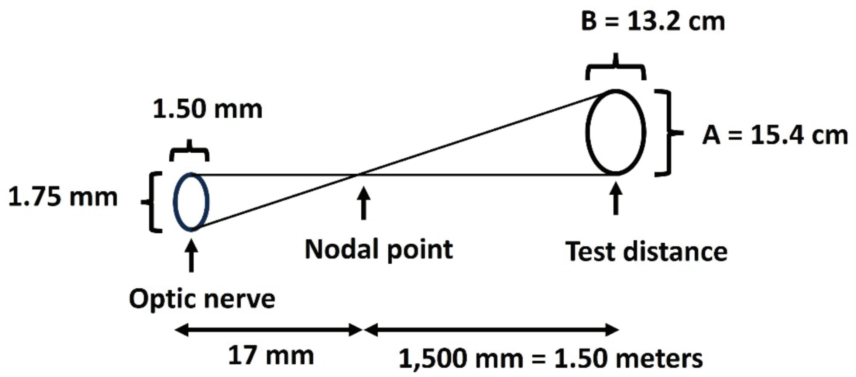


Figure 1 The geometry concept of calculation of the approximate area of the optic nerve head at 1.5 meters compares with a nodal point. (adapted from reference number 3.)

$$1.75\text{ mm}/17\text{ mm} = A/1{,}500\text{ mm}$$

$$A = 15.4\text{ cm}$$

$$1.50\text{ mm}/17\text{ mm} = B/1{,}500\text{ mm}$$

$$B = 13.2\text{ cm}$$

We use the examiner's outstretched hand as a simple measuring device to compare to the examiner's hand (length 15.52 cm ~ 15.4 cm) at arms' length (0.5 meters) and make rough estimates of the binocular field of view in degrees (Figure 2). With the examiner's arms stretched out straight in front of the patient, the width of the examiner's fist measures about 10°. If the examiner moves both arms upward, hand over hand, from the horizon to a point straight above the patient it should take about 9 hands to cover that 90° distance. Therefore, the examiner will use this method of moving the hand in and out of the patient's peripheral vision to the central vision to find the binocular confrontation visual field defect first, and then convert the distance from arm's length to the test distance (1.5 meters) into degrees.

Figure 2 Estimation of the binocular field of view in degrees by comparing the examiner's hand (length 15.52 cm ~ 15.4 cm) at arms' length (0.5 meters).

The steps of testing are described below;

1. Perform a binocular confrontation visual field at 1.5 meters without equipment and record the results.

2. Open the application name “VRex-pandedfield” (our application is currently a demo version: it cannot be downloaded from the apple store or google play store) on the mobile phone and select the parameters setting such as right-sided or left-sided.

3. Instruct the patient to put on the VR glasses, adjust the strap of the glasses, and then have the patient start looking at the surroundings in the room to get used to the glasses first.

4. Perform a binocular confrontation visual field at 1.5 meters with equipment and record the results.

5. Instruct the patient to take a short walk, if possible, in a safely enclosed eye examination room.

6. Ask the patient to describe the quality of the subjective image and answer the satisfaction questionnaire.

7. We compared the binocular confronta-tion visual field at 1.5 meters before and during the use the application. We simulated the binocular confrontation scale for a 120-degree visual field for a total of 9 visualized quadrants (13.3 degrees per quadrant) and recorded the number of expanded fields in the binocular visual field (Figure 4, 5, Table 2).

An ophthalmology resident is a single interpreter who performs binocular confrontation and provides interpretation for all patients. This study is a prospective case series in which the interpreter (single-blinded) does not know which information or neuroimaging results are being given to the patient.

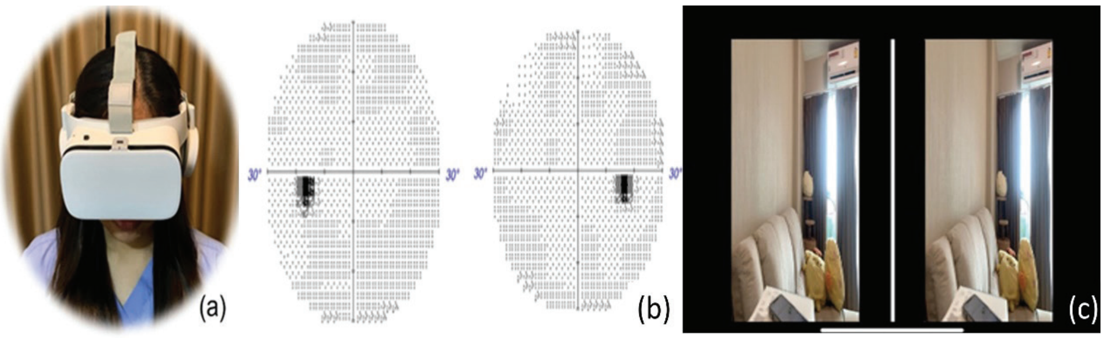


Figure 3 (a) A self-test, (b) CTVF 30-2 of a normal visual field, and (c) a normal VR view

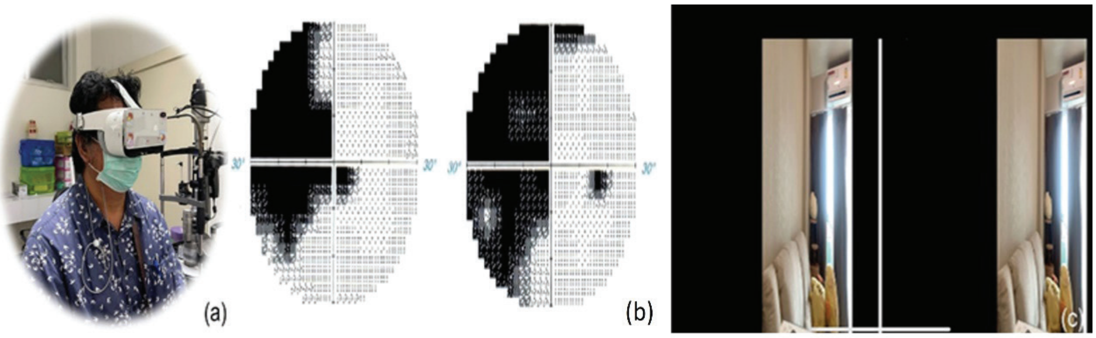


Figure 4 (a) A patient test, (b) CTVF 30-2 of left homonymous hemianopia, and (c) a VR view in left homonymous hemianopia

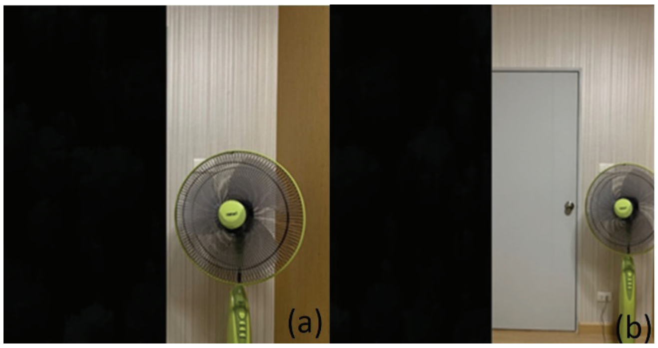


Figure 5 (a) VR view in left homonymous hemianopia, and (b) VR view of field expansion in left homonymous hemianopia

Results

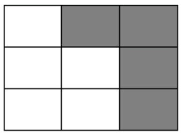
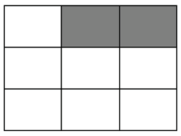
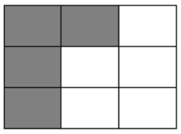
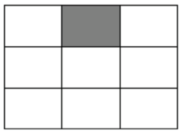
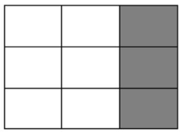
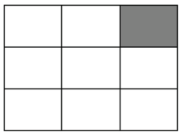
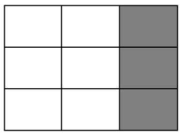
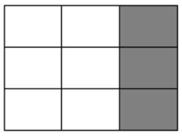
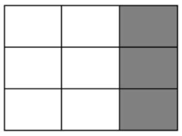
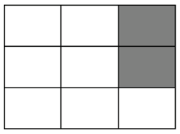
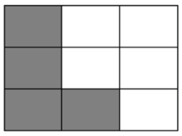
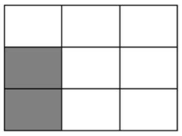
Initially, eleven patients were enrolled in the present study, but five patients did not test the application because of non-visual related problems such as bedridden status and poor communication skills. Thus, six patients were included in the study. The mean age was 50 years with a range of 43 to 57 years. Three were male and three were female. Etiologies of homonymous hemianopia were ischemic stroke in 5 patients (83.3%) and a brain tumor in one patient (16.7%). In the test, the patients had to wear VR glasses on the head, so they were unable to wear glasses, meaning we had to record the central acuity as uncorrected visual acuity (UCVA). Patients had UCVA between 20/20 and 20/50 in both eyes. All patients received neuroimaging such as computed tomography (CT) or magnetic resonance imaging (MRI) of the brain. Neuroimaging results were compatible with CTVF measured with the SITA standard 30-2 program of the Humphrey Field Analyzer. From asking the patients about the problems they encountered from the abnormal visual field, it was found that everyone felt the abnormal visual field was a problem in their daily lives. Two of them had experienced a car accident and three understood that they had to acclimate to having an abnormal visual field. In terms of expectations, most patients expressed a desire to have a device or glasses to help improve their visual fields (Table 1).

Table 1 Demographics and characteristics of patients using the application

No	Age (years)	Gender	Etiologies	UCVA	CTVF30-2	Neuroimaging (CT/MRI brain)	Problems in daily activities	Expectations of VF restoration
1	43	Female	Stroke	OD 20/30 OS 20/20	Complete right homonymous hemianopia	Severe atrophy of the left optic tract	I have difficulty reading inconsistent texts.	I want to restore my visual field defect to a normal field.
2	44	Male	Stroke	OD 20/20 OS 20/20	Incomplete left homonymous hemianopia	Hypodensity lesion at the right occipital lobe	I have difficulty seeing and finding things, even if the things are near me.	I am familiar with abnormal VF defects, but if I have glasses or a device that can see near normal people, it would be good.
3	51	Male	Stroke	OD 20/30 OS 20/20	Incomplete right homonymous hemianopia	Hypodensity lesion at the left occipital lobe	I have difficulty seeing things. I had an accident because I couldn't see the obstacles.	I want my normal visual field. I also want an instrument that can protect me from accidents caused by abnormal field defects.
4	53	Male	Sphenoid wing meningioma	OD 20/40 OS 20/50	Incomplete right homonymous hemianopia	Left medial sphenoid wing meningioma	I have difficulty seeing things and people.	I want the normal visual field I had in the past.
5	55	Female	Stroke	OD 20/50 OS 20/30	Incomplete right homonymous hemianopia	Encephalomalacia with old hemorrhage at the left inferior temporal-occipital lobes	I had an accident with a defect in the visual field, but I have adapted myself.	I want to restore my visual field defect.
6	57	Female	Stroke	OD 20/20 OS 20/20	Incomplete left homonymous hemianopia	Subacute infarction involving the cortical gray and white matter of the right occipital lobe with cortical laminar necrosis	I have difficulty seeing things. I am used to living with an abnormal visual field.	I hope that there will be an instrument that increases the field of view, and we can use it in our daily life.

A normal person has a total visual field of approximately 180 degrees, with each eye seeing a peripheral field of approximately 150 degrees, with an overlap binocular visual field of roughly 120 degrees. The human field of view is not square. Since the present study was tested through VR, however, the visualized image seen is divided into 9 small quadrants. In interpreting the test results, we calculated the binocular visual field expansion and found that the patients had a mean change in the increased field of view of 1.6 quadrants (ranging from zero to 3 quadrants) (Table 2). Five patients were satisfied with the expanded visual field in adaptive confrontation testing.

Table 2 Comparison of the binocular confrontation visual field before and during testing (the gray color shows a quadrant of the field that cannot be seen on either side)

No.	Binocular confrontation VF before testing	Binocular confrontation VF during testing	Binocular visual field expansion
1			Two quadrants = 26.6 degrees
2			Three quadrants = 39.9 degrees
3			Two quadrants = 26.6 degrees
4			Zero quadrant = 0 degrees
5			One quadrant = 13.3 degrees
6			Two quadrants = 26.6 degrees

Discussion

The principle of helping patients with homonymous hemianopia is to shift the visual field from the invisible side to the remaining side, with or without increased magnification.[4,5] A previous study used a base-out binocular sector prism placed in a specific quadrant area of the visual field by locating it on that part of the spectacle lens.[1] These prism glasses have the advantage of convenience and can correct their refractive error but are not available in Thailand. In 2008, Lane AR et al. evaluated visual restoration training (VRT), optical aids, and compensatory training, which aimed to restore the residualvisual field in homonymous hemianopia. They found that randomized placebo-controlled studies were lacking, making it difficult to establish which ones were clinically useful.[6] In 2018, Jung JH et al. relied on the basic principles of full-field prisms to shift a portion of the blind side to the residual seeing side by applied meniscus and flat full-field 7 PD and 12 PD yoked prisms and compared kinetic visual field by Goldmann perimetry in patients with homonymous hemianopia and acquired monocular vision. They found that full-field prisms that filled the entire spectacle eye width did not effectively expand the visual field because patients had to turn their faces away from the blind side for foveal fixation on the object of interest, thereby negating the image shift to the blind side.[7]

In the present study, the patients wore VR glasses, so it was not possible to test each eye separately. Moreover, the patients could not wear VR glasses while testing the CTVF due to the limitation of the size of the device used. We could not interpret in detail how many degrees the visual field of each eye was expanded by the device or how much change there was compared to automated CTVF. In fact, the visual field should have been able to compare more clearly if we tested with the Goldmann kinetic visual field. However, our hospital does not have Goldmann perimetry, so a simulation of the degrees that the patient sees must be used to compare how much the patient sees. We found that patients had a range in field expansion from 0 to 39.9 degrees (average of 21.28 degrees; 13.3 degrees per quadrant). The patient who had the widest binocular visual field expansion said he was already familiar with homonymous hemianopia. This probably explains why he saw the most because the test had to adjust the visualized image through VR glasses as well. Five patients were satisfied with the expanded visual field in adaptive confrontation testing, but one patient was unable to adapt to the binocular visual field expansion. Consequently, we did not record any increase in the binocular visual field.

Normal reading requires a sufficient visual field wherein patients can simply sweep their eyes from left to right or vice versa.[8] Previous studies have found that reading in a horizontal direction requires at least 5 degrees to the right of fixation and 1-2 degrees to the left, while reading in a vertical direction tends to be slower than horizontal reading, in part because most patients are unfamiliar with rolling their eyes vertically in a saccadic way.[9,10] Previous studies have shown that patients with homonymous hemianopia have difficulty reading because they require at least 5 degrees of visual space to read, and the scotoma in homonymous hemianopia covers the central visual field.[11] Driving requires that the field of vision be at least 120 degrees horizontally and at least 20 degrees vertically according to the Department of Land Transport regulations applicable to visually impaired patients. In clinical application to activities for daily living, the average binocular visual field expansion from our study might be insufficient for driving but could be sufficient to aid in horizontal reading. Unfortunately, there are limitations of the lens used, making it impossible to apply VR glasses near work distances.

The limitations of this application were as follows: (1) VR glasses could not sufficiently correct patients' refractive error and presbyopia, so patients could not tolerate the long durations of use for this application and experienced eye discomfort; (2) Motion sickness was triggered by the motion of the VR glasses, which is a common occurrence among people who use VR headsets. It has been reported that people usually find themselves feeling overwhelmingly nauseous, even after a short session, while testing this technology for the first time; (3) Patients must adapt to the expanded visual field; (4) Small sample sizes make it difficult to determine if etiology of visual field defect may affect the results because only one patient with sphenoid wing meningioma failed to show field expansion using VR glasses. Recruitment for the study was difficult because of the low incidence of homonymous hemianopia. The authors suggested that further studies are needed to address the limitation of using VR glasses to improve the patient's quality of life and should be done with a larger sample size.

In conclusion, this mobile application did not enable a significant improvement in activities for daily living and also had limitations in clinical practice. However, this study has shown some effectiveness, we demonstrated a positive result of field expansion and patient satisfaction, even though we did not study the relationship between the achievement of field expansion and satisfaction. The authors believe that future technological developments will lead to new instruments for expanding the visual field and/or training patients with homonymous hemianopia.

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Conflicts of interest. The authors report no conflicts of interest relevant to this article.

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