Object Detection in the Ring Scotoma of a Monocular Bioptic Telescope

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Objective: To evaluate the ability of the fellow eye to detect stimuli in the area corresponding to the ring scotoma (blind area) of a monocular bioptic telescope in simple conditions (conventional perimetry) and in more visually demanding conditions.

Methods: A computerized dichoptic perimeter enabled separate stimuli to be presented to each eye of 7 bioptic users and 7 nonusers. The bioptic ring scotoma was mapped by presenting the stimulus to the telescope eye only. Detection tests were then conducted under binocular viewing, with stimuli presented only to the fellow eye in a $2 \times 2 \times 2$ design with or without telescope, on plain gray or patterned (spatial noise) background, and with passive (looking at cross) or active (reading letters) fixation task.

Results: No significant differences were noted in fellow-eye detection with (86%) and without (87%) a bioptic. The detection rate was significantly reduced on the patterned background and in the active fixation task.

Conclusions: To our knowledge, this is the first study to demonstrate fellow-eye detection in the area of the ring scotoma with a monocular bioptic telescope under more realistic and visually demanding conditions than conventional perimetry. These results should ease the concern that the monocular ring scotoma might cause blindness to traffic outside the field of the telescope.

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MONOCULAR BIOPTIC telescopes enable persons with reduced visual acuity (VA) to see details of distant objects (**Figure 1**). Licensure regulations in 39 US states permit driving with a bioptic telescope, with widely varying requirements (eg, minimum VA without the bioptic and peripheral visual field extent) and an even wider variation in the restrictions imposed (eg, daylight driving only, no highway driving, requirement of side mirrors, and others).[1] Most bioptic drivers report that the telescope is helpful and use it for tasks such as reading road signs and checking the status of traffic light signals.[2] Loss of driving privileges greatly impacts economic and emotional well-being,[3] while lax regulation may subject the driver and the general public to undue risk. Unfortunately, there has been little scientific basis for allowing or restricting bioptic driving.[1] This study attempts to provide rigorous data to inform the debate about the issue of the ring scotoma associated with the use of bioptic telescopes.

Bioptic telescopes are usually mounted on a carrier lens above the primary gaze position tilted upward (Figure 1A). When the wearer wants to examine something more closely, a head tilt of about 10° to 20° and an associated shift of eye position brings the eye, the telescope, and the object of regard into alignment (Figure 1B), offering a magnified view. Normally, only infrequent and brief glances through the telescope are needed.[2,4,5] Nevertheless, driving is a complex and demanding activity, and even brief vision interruptions may degrade performance. Therefore, it is important to understand the hazard detection potential of the fellow (nontelescope) eye when viewing through the telescope.

When viewing through a telescope, the magnified field of view on the retina covers much of the image normally available in the unmagnified view; therefore, a ring scotoma is created around the magnified telescope view (**Figure 2**). When driving, the ring scotoma could block important traffic features. Some states permit binocular bioptics for driving. With binocular bioptics, the ring scotoma is bilateral (and absolute). However, if a monocular bioptic telescope is used, the fellow eye could potentially monitor the scene outside the telescope view. Some have argued that because of the available view with the fel-

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low eye, the ring scotoma does not introduce a hazard for a monocular bioptic,[6-10] while others have insisted that the driver becomes blind to traffic when viewing through the bioptic.[11,12] Neither viewpoint has been supported by a systematic investigation.

Previous work has shown that in the simple visual conditions of conventional perimetry (eg, a spot of light on a plain background), the fellow eye can detect targets presented in the area of the ring scotoma when viewing through a monocular bioptic telescope (Figure 2C).[5,10,13] However, conditions in a conventional perimeter are not representative of the situation during driving; the target is of high contrast, and there is no masking background or competing binocular view. Would the target be detected under conditions more akin to real driving? The answer is not obvious. In particular, suppression or rivalry owing to the difference in image size between the 2 eyes may hinder perception.[14]

Using a bioptic when driving requires active viewing (eg, reading a road sign). Increasing attentional load has been shown to reduce detection performance when driving[15]; therefore, the ability of the fellow eye to detect objects in the ring scotoma may be lower in active viewing than in passive viewing of conventional perimetry.

We evaluated detection performance of the fellow eye in the area of the ring scotoma on simple (plain gray) and more complex (patterned) backgrounds and in visual conditions of passive viewing and active viewing (reading letters through the bioptic). We also compared detection performance of participants with and without prior experience of using bioptic telescopes. Our primary hypotheses were that fellow-eye detection rates would be lower (1) when using the bioptic than when not using the bioptic, (2) on the patterned background than on the plain gray background, (3) in active viewing than in passive viewing, and (4) for nonusers than for bioptic users (as nonusers would be more likely to suppress the fellow eye).

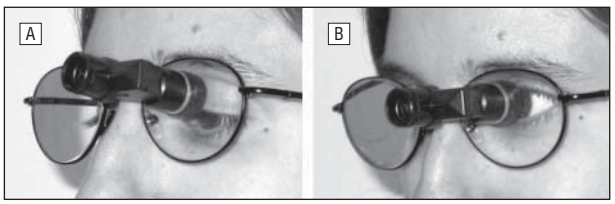

Figure 1. Monocular bioptic telescopes enable persons with reduced visual acuity to see details of distant objects. A, Bioptic users view below the telescope most of the time. B, They look intermittently through the telescope with a downward tilt of the head.

METHODS

PARTICIPANTS

We included younger and older persons having reduced VA with and without central visual field loss. Inclusion criteria were VA of 20/40 to 20/200 in the better seeing (telescope) eye, VA of 20/50 to 20/200 in the worse seeing (fellow) eye, and no manifest strabismus (evaluated with cover test); and for participants with central visual field loss, the position and size of central scotoma in the fellow eye had to enable sufficient area for presenting test stimuli.

In total, 28 participants were recruited from local clinics, including 13 bioptic users (owned and used a bioptic in the last year). Eight of 28 failed to meet the inclusion criteria (2 for VA, 1 for scotoma size, and 5 with strabismus), and 5 did not complete the study (failed to attend the second visit) because of nonvisual reasons. Data for 1 participant were excluded because of unreliable responses. Therefore, 7 bioptic users and 7 nonusers completed the study. All participants completed the battery of vision tests summarized in **Table 1**.

The study was conducted in accord with the tenets of the Declaration of Helsinki. All participants signed a consent form approved by the Schepens Eye Research Institute institutional review board.

BIOPTIC TELESCOPES

In a previous survey of drivers prescribed bioptic telescopes,[2] the 2 most common telescopes were Galilean (Designs for Vision Inc, Ronkonkoma, New York) and Mini Keplerian (Ocutech Inc, Chapel Hill, North Carolina). Therefore, we used both types in this study. Emmetropes and participants with contact lenses were fitted with a 3.0× Galilean telescope, while those with spectacle correction were fitted with a 3.0× Mini Keplerian telescope that has focus adjustment to compensate for ametropia. Four bioptic users and 3 nonusers used the Galilean telescope in the study; the remaining participants used the Mini Keplerian telescope. For the participants in this study, the measured median field of view using the Mini Keplerian telescope was 11.0°, with a median ring scotoma of 44.0° in diameter.

Figure 2. When viewing through a telescope, the magnified field of view on the retina covers much of the image normally available in the unmagnified view. A, The ring scotoma when viewing through a 3.0× bioptic telescope (Mini Keplerian bioptic telescope [Ocutech Inc, Chapel Hill, North Carolina]). The plotted field of view through the telescope has a diameter of 12.0°, and the ring scotoma (gray area) has a diameter of 44.0° with a 75% contrast stimulus (somewhat larger than the computed 36.0°). B, A simulated view of a road sign as viewed through a 3.0× bioptic telescope. The magnified view blocks the view of the intersection. C, The binocular visual field measured when viewing binocularly through the same telescope. The ring scotoma is no longer apparent, as the fellow eye is able to detect the perimetry targets in the ring scotoma area. Only the field corresponding to the physiological blind spot of the fellow eye is recorded as not seen because it overlaps with the ring scotoma.

Table 1. Vision Tests

Test	Equipment Used	Description
Visual acuity	Test Chart 2000 Pro (Thomson Software Solutions, Herts, England)	Tests monocular and binocular without bioptic, telescope eye with study bioptic
Letter-contrast sensitivity	Custom-designed program	Tests binocular without bioptic
Fundus perimetry	Micro Perimeter MP-1 (NIDEK Co, Ltd, Gamagori, Japan)	Documents retinal lesions and aids in mapping visual fields
Monocular visual fields without bioptic	Dichoptic perimeter without shutter lenses[a]	Maps physiological blind spot and scotoma (if any) of each eye separately, kinetic perimetry on gray background with 75% contrast stimulus
Monocular visual fields with study bioptic	Dichoptic perimeter without shutter lenses[a]	Maps field of view through the bioptic and outer boundary of the ring scotoma, kinetic perimetry on gray background with 75% contrast stimulus

[a] Details are given in the supplementary material (http://www.archophthalmol.com, "ePerimetry Apparatus" section).

The Galilean telescope had a smaller 8.0° median field of view and a median ring scotoma of 38.5° in diameter. Details are given in the "eBioptic Telescopes" section of the online material (http://www.archophthalmol.com).

The telescopes were mounted centrally in the carrier lenses, not in the bioptic position, so that the experiments could be conducted without the strain of maintaining a head tilt and an eccentric gaze position for long periods. The telescopes were mounted in a custom frame with an adjustable bridge. The bridge was adjusted so that the bioptic was centered at the participant's pupil. Bioptic users were fitted with the telescope mounted in front of the same eye as their own bioptics were mounted, and nonusers were fitted with the bioptic on the sighting-dominant eye (determined using the hole-in-the-card test[16]). The fellow eye was fitted with a single-vision lens using the participant's habitual distance prescription, including an additional +1-diopter (D) to focus at the 1-m testing distance. When viewing through the telescope, the focus adjustment on the Mini Keplerian and a +1-D reading cap on the Galilean enabled clear focus at the 1-m testing distance.

PERIMETRY APPARATUS

We used a dichoptic perimetry system[17] developed in our laboratory that enables separate control of the stimuli presented to each eye. Participants wore goggles with ferroelectric liquid crystal shutters (CRS, Rochester, England) suspended in front of the eyes by a modified indirect ophthalmoscope headband to provide sufficient clearance behind the shutters for the telescope (**Figure 3**). Because the shutter lens frame restricted the field of view, the area of the central visual field that could be seen by each eye was about 25° in diameter and was asymmetric, extending farther temporally than nasally, especially in participants with narrow interpupillary distances (interpupillary distance of the shutter lenses was fixed at 68 mm). With this system, the fixation mark and an image background can be presented to both eyes, while the perimetry target is presented only to the fellow (nontelescope) eye. Therefore, there is no chance that a target intended to be in the ring scotoma would be detected by the telescope eye, even if the scotoma is mislocalized by participant eye or head movements. Details are given in the "ePerimetry Apparatus" section of the online material.

BACKGROUND IMAGES

Two different backgrounds were used, a plain light-gray background (level 186 of 255), similar to standard perimetry testing, and a patterned spatial noise background (**Figure 4**), which changed after each trial. The noise background had spatial frequency characteristics similar to those of natural scenes and was used to resemble real-world pictures but without the problems of large areas of varying contrast, luminance, and clutter that could alter the difficulty of the detection task. Details are

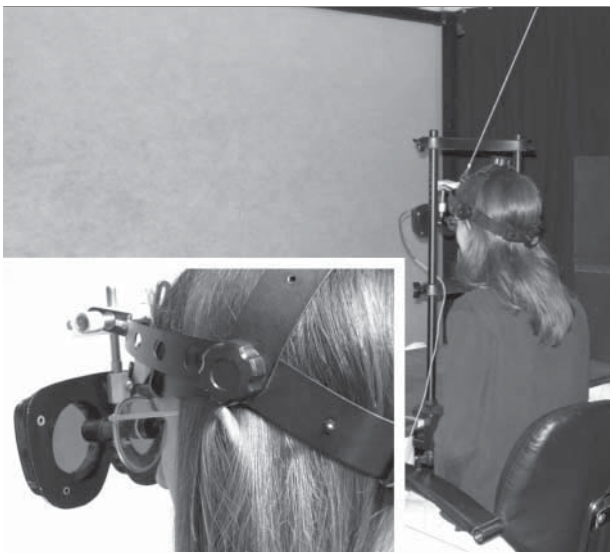

Figure 3. The apparatus used in this study. Participants wore a modified indirect ophthalmoscope headband with the shutter lenses suspended forward, and they sat 1 m from the screen where the fixation target and stimuli were presented. Inset, Shows details of how the shutter lenses were suspended (the chin rest support bar was removed for the inset photograph).

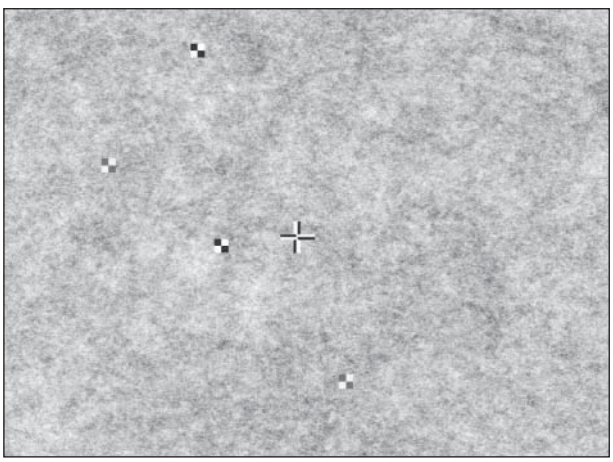

Figure 4. The spatial noise background used in this study with passive fixation cross (2.9°) and 75% and 95% contrast stimuli (1.0°) shown.

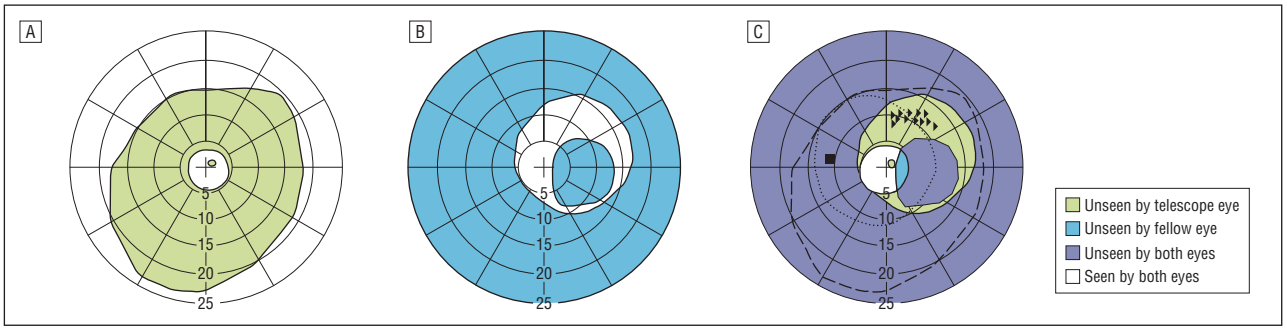

Figure 5. An example of the visual field plots obtained for a participant with age-related macular degeneration wearing a Keplerian bioptic telescope (Ocutech Inc, Chapel Hill, North Carolina) on the left side. A, Monocular viewing without the shutter lenses showing the ring scotoma of the telescope. The participant's scotoma appears minified through the bioptic. B, Binocular viewing with the shutter lenses showing the participant's fellow-eye scotoma and the restriction in visual field size due to the shutter lens housing. The fixation and background were shown to both eyes, and the kinetic stimulus was presented to the fellow eye only. C, Binocular viewing with the shutter lenses; fixation and background were shown to both eyes. The kinetic stimulus was presented to the fellow eye only and then to the telescope eye only. The right-facing triangles show the position of the static test stimuli presented to the fellow eye as the participant focused on the fixation target through the telescope. The square shows the position of control static stimuli presented to the telescope eye. The dashed line shows the outer boundary of the ring scotoma as measured in A. The dotted line indicates the restriction of the telescope-eye shutter lens.

Table 2. Summary of Diagnoses Among Bioptic Users and Nonusers

Diagnosis	No. of Participants	
	Bioptic Users (n=7)	Nonusers (n=7)
CFL	**4**	**3**
AMD with CFL	1	1
Stargardt disease	2	1
Chorioretinitis	0	1
Doyne familial honeycombed choroiditis	1	0
No CFL	**3**	**4**
Early AMD without CFL	0	1
Nystagmus	1	0
Optic atrophy	1	2
Rod monochromat	0	1
Diabetic retinopathy	1	0

Abbreviations: AMD, age-related macular degeneration; CFL, central visual field loss.

given in the "eBackground Images" section of the online material. The mean luminance of all backgrounds was 38 candela (cd)/m^2 (8 cd/m^2 through the shutter lenses).

FIXATION TASKS

Two types of fixation tasks were used—passive and active. The fixation target for the passive task was a static black-and-white cross, with arms 8.4 mm (0.5°) thick (4.2-mm white and 4.2-mm black, switching sides at the crossing point) and overall length and width of 50.4 mm (2.9°) (Figure 4). For the active task, a single black letter on a white square was fixated, with the letter changing every 2 seconds. For trials in which the bioptic telescope was used, the letters were 12.6 or 16.8 mm (0.7° or 1.0°) in height on a 1.0° or 1.4° square background, and when the bioptic telescope was not used, the letters were 31.5 or 37.8 mm (1.8° or 2.2°) on a 2.0° or 2.7° square background, respectively. In each case, the letter size was selected to enable comfortable reading.

PERIMETRY TARGET STIMULI

The probe stimulus was a 2×2 black-and-white checkerboard 16.8-mm square (1.0°). The stimulus was presented with internal Michelson contrast of 75% or 95%. Details are given in the "ePerimetry Target Stimuli" section of the online material. Stimuli were presented for 250 milliseconds (ms), followed by a grace period of 600 ms for accepting a participant button-press response. To avoid onset predictability (and any chance of responding based on timing rather than detection of the stimulus), a randomized delay of 1000 to 1950 ms occurred between stimulus extinction and the next stimulus.

TEST CONDITION SEQUENCE

The experiment involved 8 test conditions in a 2×2×2 design with or without telescope, with passive or active fixation task, and on plain gray or noise background. Testing was divided into 2 blocks of 4 conditions. Half of the participants used the telescope for the first 2 conditions of each block and half for the last 2 conditions of a block. The order of fixation task and background type was counterbalanced within each block and across participants. The total time to complete the 8 test conditions was about 1 hour.

PROCEDURES

All trials were conducted in dichoptic mode, with the background and fixation targets shown to both eyes. Each condition contained 5 repetitions of 13 stimuli sequentially presented within the area corresponding to the individual's ring scotoma (**Figure 5**) and not blocked by the shutter lens or the participant's fellow-eye central scotoma (if any). The order of the 13 stimulus positions was randomly changed for each of the 5 repetitions. Details are given in the "eProcedures" section of the online material.

Participants were instructed to fixate on the fixation target and to press a handheld button when a stimulus was detected. For the active fixation trials, they were required to verbally report each letter in the fixation target and to press the button when a stimulus was detected. This ensured that they were maintaining fixation and attention.

DATA ANALYSIS

Detection performance (number of detections as a fraction of the total number of stimulus presentations) for each test condition was the primary dependent variable. A probit transform was applied to convert the percentile to z scores to avoid the truncation effect.[18,19] A value of 2.4 was used in cases where 100% of the stimuli were detected and −2.4 in cases where no stimuli were detected.

Table 3. Characteristics of Participants

Characteristic	Bioptic Users (n=7)	Nonusers (n=7)	Test for Difference Between Groups	*P* Value
Male sex, No. (%)	4 (57)	4 (57)	$\chi^2 = 0.000$[a]	>.99
Age, median (IQR), y	59 (44 to 70)	53 (35 to 74)	$U = 18.0$[c]	.42
Visual acuity, median (IQR)[b]				
Telescope eye without bioptic	20/60 (20/58 to 20/191)	20/96 (20/76 to 20/126)	$U = 19.0$[c]	.48
Fellow eye	20/91 (20/83 to 20/174)	20/120 (20/115 to 20/126)	$U = 19.0$[c]	.48
Contrast sensitivity, median (IQR)	1.53 (1.38 to 1.60)	1.33 (1.28 to 1.50)	$U = 11.5$[c]	.10

Abbreviation: IQR, interquartile range.
[a] By χ^2 test.
[b] Visual acuity was measured and analyzed in logarithm of the minimum angle of resolution (logMAR) units; logMAR values were converted to Snellen values for ease of interpretation in the table.
[c] By Mann-Whitney test.

Repeated-measures analysis of variance was used, as the detection *z* scores in each condition did not differ significantly from a normal distribution ($P > .05$, Shapiro-Wilk). Because there was a wide range in participants' ages, we included age as a covariate in the analysis.[20,21] For ease of interpretation, age-adjusted detection *z* scores were converted back to percentiles, and detection rate data are reported this way in the results.

RESULTS

SAMPLE CHARACTERISTICS

Participants had a wide variety of diagnoses (**Table 2**), including 7 with central visual field loss (median fellow-eye and telescope-eye scotoma diameter of 16.0°; range, 6.0°-28.0°). There were no significant differences between bioptic users and nonusers for age, VA in the telescope eye, VA in the fellow eye, and contrast sensitivity (**Table 3**).

For bioptic users (n=7), the median time using a bioptic was 7 years (range, 0.7-22 years). Five of them used the bioptic when driving (primarily for reading street names and traffic signs and for viewing traffic signals). In addition, 3 participants used the bioptic when spectators at events, such as plays, theater shows, or sports. All participants reported the bioptic as helpful on a 5-point scale (ranging from 1 [not at all] to 5 [very helpful]), with 86% (6 of 7) reporting that it was at least moderately helpful and 29% (2 of 7) very helpful. The frequency of bioptic use varied widely among bioptic users. Details are given in the "eBioptic Telescopes" section of the online material.

FELLOW-EYE DETECTION ABILITY

Detection rates under different conditions are shown in **Figure 6**, and results of repeated-measures analysis of variance are summarized in **Table 4**. Contrary to our expectations, no significant differences were noted between the mean age-adjusted fellow-eye detection rates with the bioptic (86%) and without the bioptic (87%) (means were determined from data pooled across both backgrounds and fixation tasks). However, as expected, the detection rate decreased significantly from 92% on the plain background to 78% on the noise background (data were pooled across both fixation tasks and with and without the bioptic). A significant reduction was also noted in the detection rate with the active fixation task,

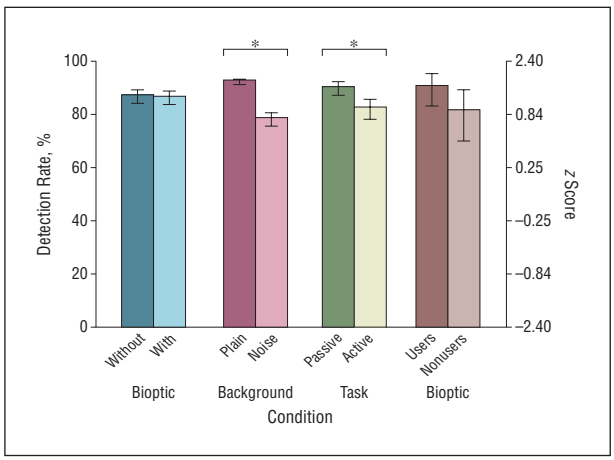

Figure 6. The mean age-adjusted fellow-eye detection rates for the primary factors in the repeated-measures analysis of variance. Fellow-eye performance was not significantly different with and without a bioptic telescope, was higher on the plain background than on the noise background, was higher in the passive fixation task than in the active fixation task, and was not significantly different between bioptic users and nonusers. Error bars are the within-subject 95% confidence interval of the mean for all comparisons[22,23] except for bioptic users vs nonusers, where between-subject 95% confidence intervals are given. *$P < .05$.

from 90% in the passive task to 82% in the active task (data were pooled across both backgrounds and with and without the bioptic). Furthermore, there was a significant interaction of task with background. Although both the active task and the noise background lowered detection, the difference in detection rates between the passive and active fixation conditions was greater on the plain background (from 96% to 86%) than on the noise background (from 79% to 77%) (**Figure 7**).

There was a trend for the bioptic users to have better fellow-eye detection performance than the nonusers (on average, 91% vs 81%); however, this did not reach statistical significance. The interaction between user group, fixation task, and viewing with or without a bioptic was significant ($F_{1,11} = 4.89$, $P = .049$). Post hoc tests demonstrated that, in the active fixation task when using the bioptic, bioptic users had higher detection rates than nonusers, approaching significance (91% vs 67%, $P = .06$).

Finally, as might be expected, the age covariate had a significant effect: fellow-eye detection rates decreased with increasing age, and age had a stronger effect on the noise background than on the plain background. However, there

Table 4. Analysis of Variance Results Among 14 Participants[a]

Variable	Bioptic	Background	Task	Bioptic User	Age
Bioptic					
Without vs with	**$F_{1,11}$ = 0.06**	$F_{1,11}$ = 0.41	$F_{1,11}$ = 0.09	$F_{1,11}$ = 1.93	$F_{1,11}$ = 0.00
P value	**.81**	.54	.77	.19	.99
Background					
Plain vs noise		**$F_{1,11}$ = 85.13**	$F_{1,11}$ = 21.46	$F_{1,11}$ = 0.53	$F_{1,11}$ = 5.54
P value		**.001**[b]	.001[b]	.48	.04[b]
Task					
Passive vs active			**$F_{1,11}$ = 8.70**	$F_{1,11}$ = 1.78	$F_{1,11}$ = 1.66
P value			**.01**[b]	.21	.22
Bioptic user					
User vs nonuser				**$F_{1,11}$ = 3.41**	
P value				**.09**	
Age					
As covariate					**$F_{1,11}$ = 8.38**
P value					**.02**[b]

[a] Boldface data are main effects. The others are interactions.
[b] Significant at $P < .05$.

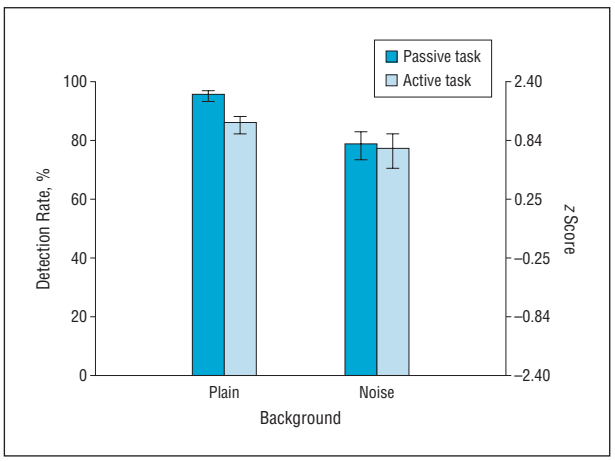

Figure 7. The mean age-adjusted fellow-eye detection rates for the passive and active fixation tasks on the plain and noise backgrounds. Although both the active fixation task and noise background lowered detection, the effect of the active fixation task was less on the more complex noise background. Error bars are the within-subject 95% confidence interval of the mean.[22,23]

were no significant interactions between age and fixation task or viewing with or without a bioptic.

COMMENT

Both bioptic users and nonusers were able to detect most stimuli in the ring scotoma area with the fellow eye on complex backgrounds when engaged in an active viewing task through a monocular bioptic. Furthermore, fellow-eye detection rates were similar with and without the bioptic (86% and 87%, respectively). This suggests that the use of the monocular bioptic (and the different magnification in each eye) did not cause a reduction in fellow-eye detection performance and that the fellow eye was not suppressed to any extent when using the bioptic in our test conditions. Suppression of 1 eye during binocular viewing is a common sensory adaptation in strabismus. Strabismus is not rare among patients with low vision (we found 5 cases among 28 participants we screened for this study). Suppression could affect fellow-eye detection in the area of the ring scotoma. Strabismus might also affect the eccentricity of the field area in the fellow eye overlapping the ring scotoma and also affect detection. Therefore, we are investigating fellow-eye detection performance with monocular bioptics in persons with strabismus.

The finding that fellow-eye detection rates were similar with and without the bioptic seems promising for easing the concerns that the ring scotoma might cause blindness to traffic outside the field of the telescope.[11,12] Peli[24] describes the ability to use both the fellow eye and the telescope eye as biocular multiplexing. The high-resolution image (seen through the bioptic) is multiplexed with the available wide field of view (of the fellow eye) in a manner that permits the visual system to separate them and use them in a useful way. Although no mechanism for such multiplexing is apparent, it seems that such biocular multiplexing is possible, at least for the detection task tested herein.

The use of the noise background with spatial frequency characteristics similar to those of natural scenes caused an overall reduction in detection from 92% on the plain background to 78% on the noise background, confirming our concern that standard perimetric evaluation (as previously performed[10]) is insufficient to determine the effect of the ring scotoma on detection. Real-world scenes are more complex and change dynamically. Therefore, we are conducting further studies to investigate the effect of a real-world moving background.

Our active fixation task more closely simulated the attention required when using a bioptic for tasks, such as reading signs, than the typical passive fixation in conventional perimetry. Monocular bioptic use is a type of dual, tasking (divided attention) situation. Users must attend to the information seen through the telescope while also being aware of the information seen with the fellow eye, where both images usually fall on corresponding retinal areas. We found an overall reduction in detection from 90% in the passive fixation task to 82% in the active fixation task to be consistent with the literature showing reduced performance with increased attentional load.[15,25] However, there was no significant interaction of fixa-

tion task with viewing with or without a bioptic; overall, the active fixation task had a similar effect on fellow-eye detection with and without a bioptic.

Although the noise background and the active fixation task significantly reduced fellow-eye detection performance, the effect of the active task was lower on the more complex noise background than on the simple plain background (Figure 7). In other words, even with the combination of active viewing and complex background, participants still achieved 77% detection, and the active task did not reduce detection as much as might have been expected when combining the 2 most difficult conditions. Attentional load is probably higher in real driving than in our experimental setup, as users have to see the object of regard quickly and deal with other driving activities, such as controlling the steering, gas, brake, and others. In contrast, observers in this study looked through the bioptic continuously for several minutes at a time.

We hypothesized that participants who had not used bioptics would be more likely to suppress the fellow eye than bioptic users. Although the bioptic users had higher overall detection than nonusers (91% vs 81%), the difference was not significant ($P = .09$). However, consistent with our hypothesis, bioptic users had higher detection rates than nonusers (91% vs 67%) in the most demanding condition (active task viewing through the bioptic), and the difference approached significance ($P = .06$).

In summary, this is the first study to demonstrate fellow-eye detection in the area of the ring scotoma when viewing through a monocular bioptic in more visually complex conditions than those of conventional perimetry. Our finding of no difference in fellow-eye detection with and without a bioptic provides preliminary but strong evidence against the opinion that a driver becomes blind to traffic when viewing through a monocular bioptic[11,12] but needs to be further confirmed in test conditions that more closely simulate real-world use of a bioptic. We plan to conduct future studies to evaluate biocular multiplexing ability in conditions involving more natural bioptic use, including using dynamic motion backgrounds (real traffic videos), viewing through the bioptic for brief glances when detail is needed, and testing the fellow eye over a larger area of the ring scotoma.

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