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ORIGINAL ARTICLE

Peripheral Prism Glasses: Effects of Moving and Stationary Backgrounds

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ABSTRACT

Purpose. Unilateral peripheral prisms for homonymous hemianopia (HH) expand the visual field through peripheral binocular visual confusion, a stimulus for binocular rivalry that could lead to reduced predominance and partial suppression of the prism image, thereby limiting device functionality. Using natural-scene images and motion videos, we evaluated whether detection was reduced in binocular compared with monocular viewing.

Methods. Detection rates of nine participants with HH or quadranopia and normal binocularity wearing peripheral prisms were determined for static checkerboard perimetry targets briefly presented in the prism expansion area and the seeing hemifield. Perimetry was conducted under monocular and binocular viewing with targets presented over videos of real-world driving scenes and still frame images derived from those videos.

Results. With unilateral prisms, detection rates in the prism expansion area were significantly lower in binocular than in monocular (prism eye) viewing on the motion background (medians, 13 and 58%, respectively, $p = 0.008$) but not the still frame background (medians, 63 and 68%, $p = 0.123$). When the stimulus for binocular rivalry was reduced by fitting prisms bilaterally in one HH and one normally sighted subject with simulated HH, prism-area detection rates on the motion background were not significantly different ($p > 0.6$) in binocular and monocular viewing.

Conclusions. Conflicting binocular motion appears to be a stimulus for reduced predominance of the prism image in binocular viewing when using unilateral peripheral prisms. However, the effect was only found for relatively small targets. Further testing is needed to determine the extent to which this phenomenon might affect the functionality of unilateral peripheral prisms in more real-world situations.

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Key Words: peripheral prisms, EP prisms, hemianopia, detection rates, binocular suppression, binocular rivalry, vision rehabilitation

Homonymous hemianopia (HH) is the loss of half of the visual field on the same side in both eyes due to lesions of the postchiasmal visual pathways. Common causes include stroke, followed by trauma, tumor, and brain surgery.[1] Difficulty detecting obstacles on the side of field loss may result in delayed responses or failures to detect potential hazards when walking[2–4] and driving,[5–9] leading to unsafe mobility. Thus, HH can significantly decrease a patient's quality of life.[3,4]

Rehabilitation for HH has commonly included the use of spectacle-mounted prisms to expand or relocate the visual field by shifting images of objects from the blind hemifield to the seeing hemifield.[10] Peripheral prism glasses[11] use high-power prism segments above and below the pupil to expand the visual field while users view centrally through the prism-free portion of the spectacle lens, thus avoiding central diplopia (Fig. 1). The prism segments are usually fitted unilaterally in front of the eye on the side of the field loss.[11] In the horizontal configuration,[11] the prisms are placed base-out, providing expansion in peripheral areas of the visual field. In the oblique configuration,[12] the prisms are slightly tilted, adding a vertical prismatic effect that shifts the expansion areas more centrally (in areas important for driving). In previous studies, patients have found both designs of the unilaterally fitted prisms helpful for obstacle avoidance when walking.[2,13–15] Furthermore, oblique peripheral prisms improved responses to unexpected blind-side hazards in on-road[5] and simulator-based[16] driving.

When the peripheral prisms are fit unilaterally, different images (the prism-shifted image from the prism eye and the normal view

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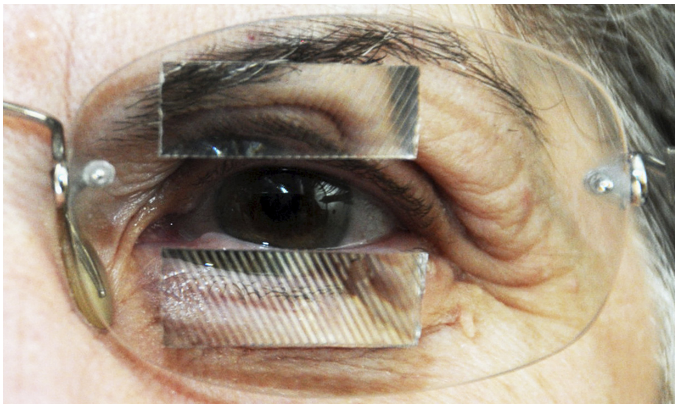

FIGURE 1.

Press-on 40Δ Fresnel peripheral prisms in the oblique configuration on the left lens as fitted for the study to a patient with left hemianopia. The upper prism is base-out and base-down, and the lower prism is base-out and base-up, shown with 10-mm interprism separation, providing expansion in the central area of the visual field used when driving (Fig. 3). The effects of the prisms are notable by the apparent shift of the upper and lower lid margins and iris (imaged by the prism segments). The wearer has an uninterrupted binocular view through the central prism-free area of the lens. A color version of this figure is available online at www.optvissci.com.

of the scene from the nonprism eye) are placed on corresponding peripheral retinal points, leading to peripheral double vision, mostly visual confusion.[17] It is the presence of visual confusion (two different views seen at the same apparent direction by the two eyes) in the combined percept that effectively expands the field of vision.[17] In contrast, when peripheral prisms are fitted bilaterally and the fitting is symmetrical (the prisms are identically aligned with the pupil positions at primary gaze), there is no longer any visual field expansion, only field substitution because both eyes have the same prism views.[17] Hence, bilaterally fitted peripheral prisms only shift the field; they do not provide true expansion.

With unilateral prisms, both the normal view and the prism image (shifted from the blind hemifield) must be seen to experience peripheral field expansion. Confusion, however, is also a stimulus for binocular rivalry where perception alternates between the two images (or parts of the images) with one dominant while the other is suppressed, and then the roles are reversed.[18] The predominant image is the one that dominates more often during the rivalry and is perceived for a greater portion of time.[18] In the case of peripheral prisms, two areas (''islands'') of peripheral binocular rivalry may result. Because high-powered Fresnel prisms reduce contrast,[19,20] and the relative weighting of an eye in the binocular percept can be reduced with lower contrast,[18,21] reduced predominance during binocular rivalry (or even persistent local suppression) of the prism image is a possibility. Both reduced predominance and persistent suppression could reduce the functionality of the peripheral prism glasses.

In a study of HH patients with normal binocular vision fitted with unilateral peripheral prisms, Ross et al.[22] found no evidence of local suppression of images from the prism eye in binocular viewing when targets were presented over stationary textured backgrounds and uniform gray backgrounds (equivalent to standard perimetry). However, in that study, the backgrounds lacked motion, which is known to be a strong stimulus for predominance in binocular rivalry[18] and is also an important component of real-world dynamic environments in which peripheral prism glasses are normally used. Conflicting motion in binocular viewing between the prism-shifted image from the blind hemifield and the normal (nonshifted) view of the scene from the fellow-eye seeing hemifield could induce a decrease in predominance of the prism image, which might reduce the utility of the device. For example, although oblique peripheral prism glasses were found to improve detection of blind-side hazards in dynamic driving situations,[5,16] detection rates were still significantly lower on the blind side than on the seeing side.[16] Whether decreased predominance of the prism image might have adversely affected blind-side detection was not investigated because performance was only evaluated for binocular viewing (not monocular viewing).

As a first step in investigating the important question of whether conflicting binocular motion reduces the predominance of the prism image, we evaluated detection performance of patients with HH wearing unilateral peripheral prism glasses for targets presented over motion videos of natural-image driving scenes. For comparison, detection performance was also measured over static still frame images from the same video segments. Our aim was to evaluate the effects of motion on blind-side detection using a paradigm that minimized confounding factors such as variations in scanning behaviors and attentional load, which might also affect blind-side detection. For these reasons, and to enable direct comparison to the work of Ross et al.,[22] we used static perimetry over driving video backgrounds rather than detection of hazards during simulator driving.

By comparing detection rates for monocular and binocular viewing, we examined whether there was decreased predominance (partial local suppression) of the unilateral prism image in binocular viewing. We predicted that conflicting motion in the dynamic conditions (motion background) would serve as a stimulus for reduced predominance as evidenced by reduced detection rates in binocular relative to monocular viewing. However, based on the results of the Ross et al. study,[22] we also predicted that there would be no reduction in predominance of the prism image in binocular viewing for targets presented over static images.

METHODS

This study was conducted in accordance with the Declaration of Helsinki and approved by the Schepens Eye Research Institute Institutional Review Board. All participants gave voluntary, informed consent.

Participants

Participants had homonymous visual field loss of at least 3 months duration (spontaneous recovery is unlikely to occur after 3 months[23]). Other inclusion criteria were as follows: visual acuity of 20/40 or better in each eye, no clinical indications of spatial neglect (Bells Test[24] and Schenkenberg Line Bisection Test[25]), no significant cognitive decline (≥24 on the Mini-Mental State Examination[26]), normal binocular vision (Randot polarized stereo and suppression tests), and no other ocular pathology that would limit the visual field or ability to use the prisms. Participants with amblyopia or strabismus were excluded.

Fifteen potential participants were screened, three of whom did not meet the inclusion criteria and three were unable to complete all test sessions. Thus, nine participants completed the study (Table 1), including five who had not previously worn peripheral prisms and four who had previous experience (three had started wearing prisms 2 to 3 months before the start of the study and the fourth had worn prisms intermittently for 5 years). One participant (S6) had previously completed the Ross et al. study.[22]

Peripheral Prism Fitting

Participants were fitted with unilateral peripheral prisms on spectacles primarily used for distance vision. The results of the Ross et al. study[22] suggested that, for patients with normal binocularity and without strong ocular dominance, peripheral prisms could be fitted in front of either eye. Participants in this study met these criteria; therefore, the prisms were mounted on the lens on the side of the field loss, as is common in clinical practice.[11] The prisms were fitted in the oblique[12] (Fig. 1) rather than in the horizontal configuration to provide visual field expansion in relevant areas of the driving-scene backgrounds. (If horizontal prisms had been used, field expansion would have been in irrelevant areas of the driving scene such as the sky.) Eight participants were fitted with 40Δ press-on Fresnel prisms, and the ninth was fitted with permanent peripheral prism glasses with 57Δ Fresnel prisms (because he was also participating in another study that was evaluating the permanent 57Δ prism glasses). The results for this participant (S9) were similar to those for the other participants and were, therefore, included in analyses.

The upper prism was placed base-out and base-down, and the lower prism was placed base-out and base-up, with the base-apex line at an angle of tilt to the horizontal of 30 degrees for the 40Δ prisms (25 degrees for the 57Δ prisms). Participants with HH were fitted with upper and lower prisms; participants with quadranopia were fitted with only one prism segment in the blind quadrant. Participants were encouraged to wear the prism glasses as much as possible (except during prolonged near work for which the prisms were not designed or when driving because people with HH do not meet the visual field extent requirement for driving in Massachusetts). They all wore the prisms for at least 4 weeks before the first set of detection tests was administered; wearing times ranged from 2 to 9 hours per day.

TABLE 1.

Characteristics of the nine study participants

Male, n (%)	6 (67)
Age, median (range), y	55 (18–70)
Time since onset, median (range), y	0.9 (0.4–31)
Homonymous field loss, n (%)	
Complete HH	5 (56)
Incomplete HH	1 (11)
Quadranopia	3 (33)
Left-sided loss, n (%)	6 (67)
Stroke etiology of HH, n (%)	7 (78)
Snellen binocular visual acuity, median (range)	20/20 (20/16–20/32)
MMSE score, median (range)	29 (28–30)

Mini-Mental State Examination.

Detection Test

A computerized tangent-screen perimetry system[27] was used to display targets over backgrounds for kinetic and static perimetry on a 1.67- by 1.25-m rear projection screen at a 1-m viewing distance. (The dichoptic display capability of the system was not applied in this study.) The test paradigm and target were similar to those used in the Ross et al. study[22]; only the viewing backgrounds differed; that is, driving-scene images rather than plain or textured backgrounds were used. Participants fixated on a bipolar fixation cross at the center of the screen (Fig. 2) and pressed a response button whenever they saw a target.

Viewing Backgrounds

Dynamic conditions that patients might experience in natural viewing were simulated by using a motion video background that was a series of driving-scene clips concatenated into one video. The clips were taken from the UK hazard perception test practice videos,[28] used as part of the UK driver licensing test. The hazard perception test was simply used as a commercially available source of natural driving scenes; we did not evaluate hazard perception. Each clip was about 30 seconds, selected to avoid curves, changes in speed of traffic, dashboard reflections, and target-mimicking distractors such as birds. The final video length was 5 minutes and included clips of driving in urban areas and on highways. The clips were mirrored so that the driver appeared to be driving on the right-hand side of the road, as in the United States. The video played on a continuous loop.

As a comparison, still frame images (Fig. 2) were extracted from the video clips. These images were similar in complexity to the videos but lacked the motion component. Static images changed after each target presentation. Both the videos and static images were displayed in color.

Test Zones

Kinetic perimetry was conducted on the computerized perimetry system to map the extent of the central visual field and prism expansion areas in monocular and binocular viewing. Two test zones were then created for presentation of static targets (Fig. 3): one in the blind hemifield in a prism expansion area, either the upper or lower (most commonly the lower), and one in an area of the seeing hemifield that was not impacted by field loss or the prism in either eye. Each test zone was about 6 degrees (vertically) by 8 degrees (horizontally), deliberately smaller than the expansion areas of about 24 by 19 degrees for the 40Δ prisms (24 by 26 degrees for 57Δ prisms). This ensured that, even if there were some head movement during testing, the test targets would still be presented within the expansion area.

The test zone locations were determined individually for each participant. Within each test zone, there was a high density of test points (20 per zone). An additional 16 targets were placed in arbitrary positions across the seeing hemifield to ensure that the participants did not expect targets to appear in only specific areas (Fig. 3). Catch trials were provided by eight targets presented

FIGURE 2.
A still frame image presented to participants during testing with bipolar (black and white) central fixation cross and a peripheral bipolar (black and white) 1.4-degree checkerboard target (shown here at high 95% contrast). Only the central portion of the screen is shown. Still images and videos were displayed in color in the study.

beyond the boundary of the seeing hemifield and outside the prism zones (false alarm rates were 0% for all participants). Thus, each test sampled detection at 64 unique locations; each displayed twice for a total of 128 trials. Detection rates were computed for the trials within each test zone.

Test Target

As in the Ross et al. study,[22] a 2-by-2, black-and-white square checkerboard target was presented for a duration of 250 milliseconds. Pilot testing determined that a grace period of 600 milliseconds after the target extinguished provided sufficient time for capturing responses before the next trial. The interval between the end of the grace period and the next target presentation varied randomly between 1000 and 1950 milliseconds.

To enable measurement of detection performance within a range that was limited by neither floor effects in the prism expansion zone nor ceiling effects in the seeing hemifield test zone, the size and contrast of the test target were carefully determined for each subject using the same detection test procedures as for the experimental data collection. The goal was to select a target for which there was at least 10% detection in the prism expansion zone but no more than 95% detection in the seeing hemifield under binocular viewing conditions. Because targets were inherently less visible when presented over the video than the still images, larger and/or higher contrast targets were needed for the moving background. Targets were selected from a range of diameters (0.5, 0.7, 1.0, and 1.4 degrees angular subtense) and internal Michelson contrast (either 75 or 95%). For each background, target selection commenced with a 1.0-degree target of 75% contrast. If either floor or ceiling effects occurred in the prism expansion or seeing hemifield, respectively, the size was increased or decreased by one step accordingly. If floor or ceiling effects were still present, then either the size or contrast was further changed, as needed. The target that was selected for use in experimental data collection was the one that provided the best compromise between floor and ceiling effects. As detection in the prism expansion area was of primary interest, the compromise was biased toward selecting the target that best fulfilled the criteria for avoiding floor effects in that area (hence, detection rates were sometimes close to 100% during experimental data collection in the seeing hemifield).

Once a test target was selected for each subject and each background, it was then used in all experimental trials for that background. Details of the targets used for each participant for each background are given in the legends to Figs. 4 and 5. The median target angular subtense was 0.7 degrees (range, 0.5 to 1.4 degrees) for the static image backgrounds and 1.4 degrees (range, 1.0 to 1.4 degrees) for the video backgrounds. The between-subject differences in target size and contrast would likely have had minimal effects on our results as the primary analyses were all paired comparisons conducted separately for each background where the same target was used for each subject.

Main Test Conditions and Procedures

Detection performance was evaluated under four conditions: motion video and still frame backgrounds for binocular and monocular (prism-eye only) viewing. The order of backgrounds and viewing conditions was counterbalanced as far as possible across participants to control for confounding factors such as fatigue. For monocular viewing conditions, an eye patch was used to occlude the eye not tested. Presbyopic participants were optically corrected for the 1-m test distance either with clip-on +1-diopter lenses or with

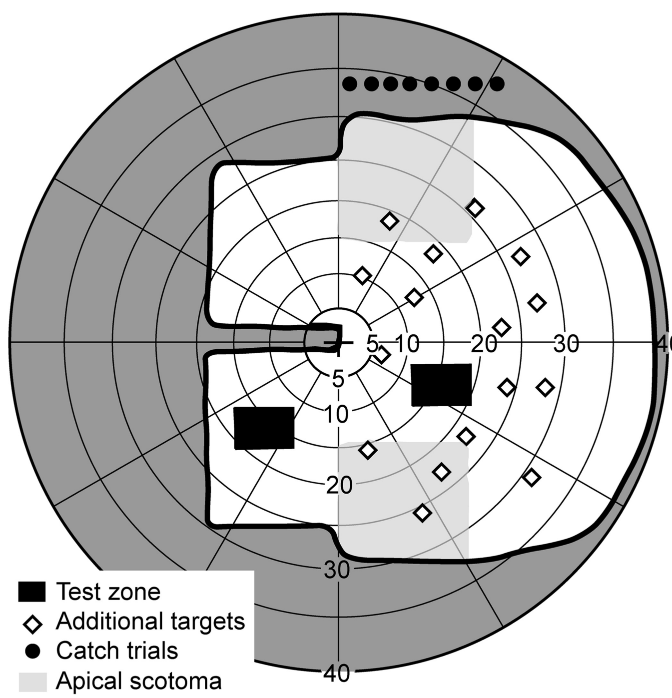

FIGURE 3.
Binocular central visual field plot and static detection test zones for a patient with left HH fitted with unilateral oblique 40Δ peripheral prisms. Thick black lines mark the kinetic isopter. The outer boundaries of the seeing hemifield are limited by the display screen to 34 degrees vertical by 40 degrees horizontal eccentricity. Black-filled rectangles represent test zones in the lower prism expansion area and the seeing hemifield (20 targets per zone). Open diamonds represent arbitrary positions of additional targets (16) included to prevent anticipation of a target's location. Black-filled circles outside the seeing hemifield represent catch trial targets (8). Light gray–shaded areas within the seeing hemifield illustrate the optical apical scotomas, which are compensated for by the nonprism eye in binocular viewing.

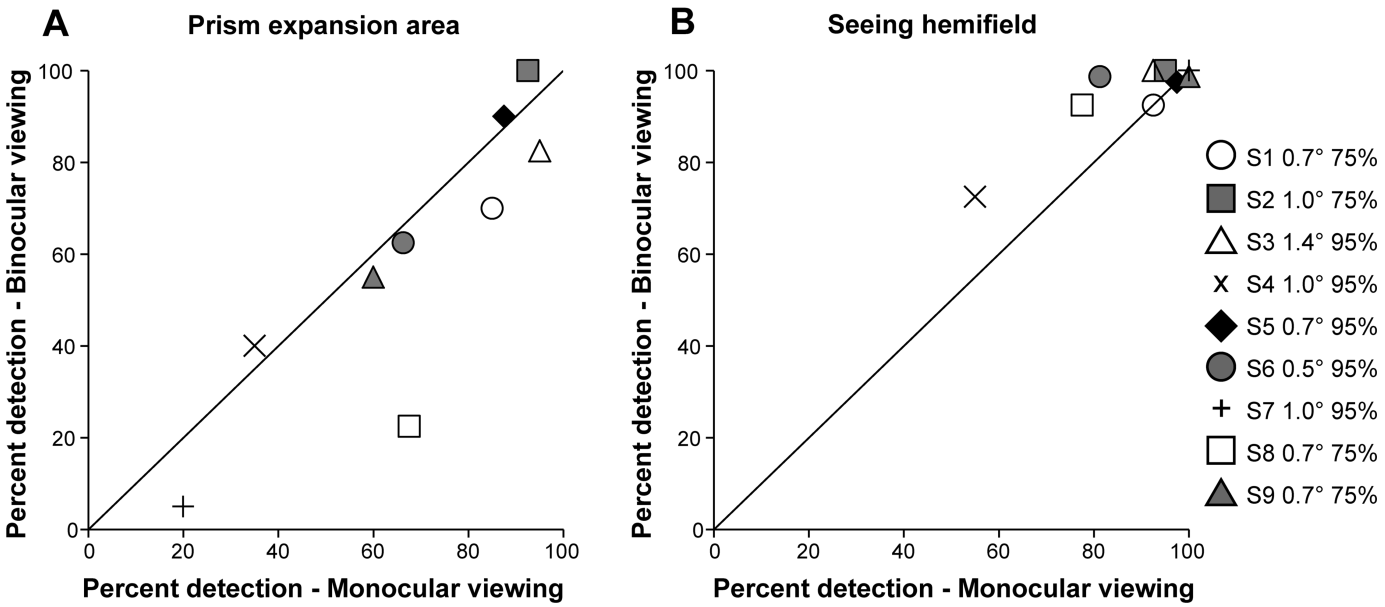

FIGURE 4.

Detection rates for each participant under binocular and monocular viewing on the still frame background: (A) prism expansion area test zone and (B) seeing hemifield test zone. Detection rates were not significantly different in binocular and monocular viewing in the prism expansion area but were slightly higher in binocular viewing in the seeing hemifield ($p = 0.046$). Legend includes target diameter and contrast for each subject. S9 wore 57Δ prisms; all other subjects wore 40Δ prisms.

study glasses prescribed for that distance (these were in addition to the distance-vision study glasses used at home). Kinetic perimetry was used at the start of every condition to ensure that the test zones were within the intended areas of the visual field. Usually, there were three visits for detection tests, each about 90 minutes with breaks between tests as needed. The first visit was for determining which target size and contrast to use, and the second and third visits were for experimental data collection. The first visit also provided participants with extensive opportunity to practice and become familiar with the detection task before the two visits for experimental data collection.

Bilateral Fitting to Reduce Binocular Rivalry

To test the hypothesis that binocular rivalry caused reduced predominance of the prism image in binocular viewing, we conducted

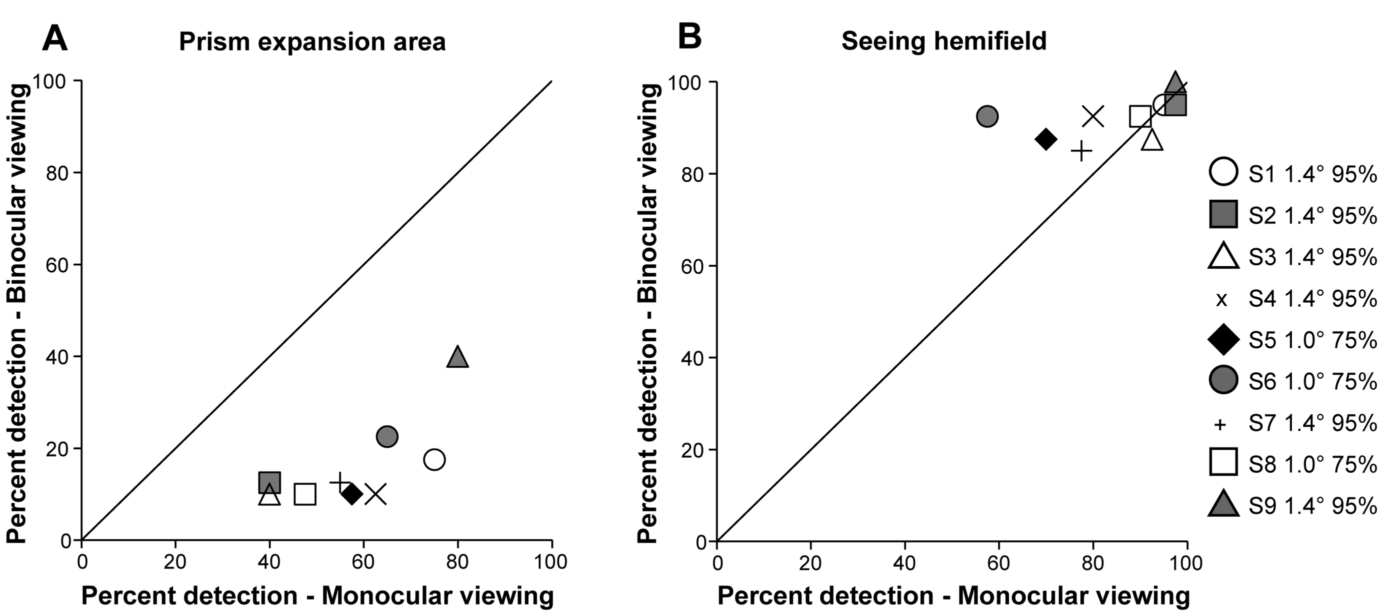

FIGURE 5.

Detection rates for each participant under binocular and monocular viewing on the motion video background: (A) prism expansion area test zone and (B) seeing hemifield test zone. Detection rates were significantly lower ($p = 0.008$) in binocular than in monocular viewing in the prism expansion area (points all below the diagonal) but not the seeing hemifield. Legend includes target diameter and contrast for each subject. S9 wore 57Δ prisms; all other subjects wore 40Δ prisms.

additional detection tests over the video background with peripheral prisms fitted both unilaterally and bilaterally. The methodology for the detection test was identical to that for the main study with 40 presentations in the prism expansion area and 40 in the seeing hemifield test zone for each condition. One participant with HH (S6) who had already worn unilateral prisms in the main study and one normally sighted participant with simulated HH completed this additional testing. The normally sighted participant wore unilateral and bilateral prisms during the test sessions (including practice trials and experimental data collection). The participant with HH only wore bilateral prisms during the test sessions (but the unilateral prisms had been worn at home).

The bilateral prisms were fitted with the bases yoked in the same direction in front of each eye (e.g., upper prisms both base-left and base-up and lower prisms both base-left and base-down for a patient with left HH). Thus, corresponding images from the prism views of the two eyes fell on corresponding peripheral retinal points and there would be little or no stimulus for rivalry in binocular viewing. We therefore expected that there would be no difference in prism expansion area detection rates for binocular and monocular viewing with the bilateral fitting.

Data Analysis

Detection rates (percentage of detected presentations out of the total number of target presentations) were determined for each condition and test zone. As described above, to avoid floor and ceiling effects, different targets were used for testing on motion video and still frame backgrounds; therefore, detection rate data were analyzed separately for each background. A Friedman test followed by Wilcoxon signed rank tests (if the Friedman test was significant) were used to analyze the raw percentage detection rates for monocular and binocular viewing in the prism expansion and seeing hemifield test zones. An α value less than or equal to 0.05 was considered to indicate statistical significance. Data were analyzed using SPSS version 11.5 (Chicago, IL).

RESULTS

Detection on the Still Frame Background -Unilateral Fitting

There was a significant difference among the distributions of the detection rates for the viewing conditions and test zones on the still frame background (χ^2_3 = 18.035, $p < 0.001$). As expected, detection rates in the expansion area were not significantly different in binocular and monocular viewing (medians, 63 vs. 68%, p = 0.123; Fig. 4A). One subject, S8, was an outlier with higher detection rates in monocular than in binocular viewing (absolute difference, 45%; Fig. 4A). Similar results were obtained on repeat testing, although the difference was not as large (absolute difference of 35%).

By comparison, detection rates in the seeing hemifield were slightly higher in binocular than in monocular viewing (medians, 99 vs. 93%, p = 0.046; Fig. 4B). Note, however, that there may have been some ceiling effects in the former condition as three subjects had 100% detection (Fig. 4B). Detection rates were significantly lower in the prism expansion area than in the seeing hemifield in both binocular (63 vs. 99%, p = 0.012) and monocular (68 vs. 93%, p = 0.013) viewing.

Detection on the Video Background -Unilateral Fitting

There was also a significant difference among the distributions of the detection rates for the viewing conditions and test zones on the motion video background (χ^2_3 = 23.697, $p < 0.001$). In the prism expansion area, detection rates were significantly lower in binocular than in monocular viewing (medians, 13 vs. 58%, p = 0.008; Fig. 5A), suggesting that the prism image was partially suppressed in binocular conditions. In contrast, detection rates in the seeing hemifield were more similar in binocular and monocular viewing (93 vs. 90%, p = 0.09; Fig. 5B). Again, in both binocular and monocular viewing, detection rates were significantly lower in the prism expansion area than in the seeing hemifield (binocular, 13 vs. 93%, p = 0.007; monocular, 58 vs. 90%, p = 0.01).

Under monocular viewing conditions, the detection rates with the larger targets used for the motion video background were not significantly different from those obtained with the smaller targets used for the still frame background. This was true for the prism expansion area (medians, 58 and 68%, respectively, p = 0.407) and the seeing hemifield (medians, 90 and 93%, respectively, p = 0.673).

Detection on the Video Background -Bilateral Fitting

As predicted, when binocular rivalry was eliminated/reduced by the bilateral prism fitting, detection rates in the prism expansion area over the video background were not significantly different in binocular and monocular viewing with the fellow eye totally occluded ($p > 0.6$ both subjects; Fig. 6). By comparison, detection rates were significantly lower for binocular viewing with the original unilateral prism fitting ($p < 0.001$ both subjects), where there was a stimulus for binocular rivalry.

DISCUSSION

In agreement with our hypotheses, prism expansion area detection rates were significantly reduced in binocular viewing compared with monocular viewing over the motion video background for the unilateral prism fitting, suggesting reduced predominance (partial suppression) of the prism image in binocular viewing. By comparison, there was no difference in prism expansion area detection rates between binocular and monocular viewing over the still image background for the unilateral prism fitting, similar to the results of the Ross et al. study[22] with stationary textured backgrounds. In the additional bilateral fitting condition that retained the motion of the background in binocular viewing, but reduced the stimulus for binocular rivalry, there were again no differences in prism expansion area detection rates between binocular and monocular viewing. Taken together, these findings suggest that it was conflicting motion (rather than other characteristics of the natural images) that was the stimulus for rivalry in binocular viewing and which reduced the predominance of the prism image.

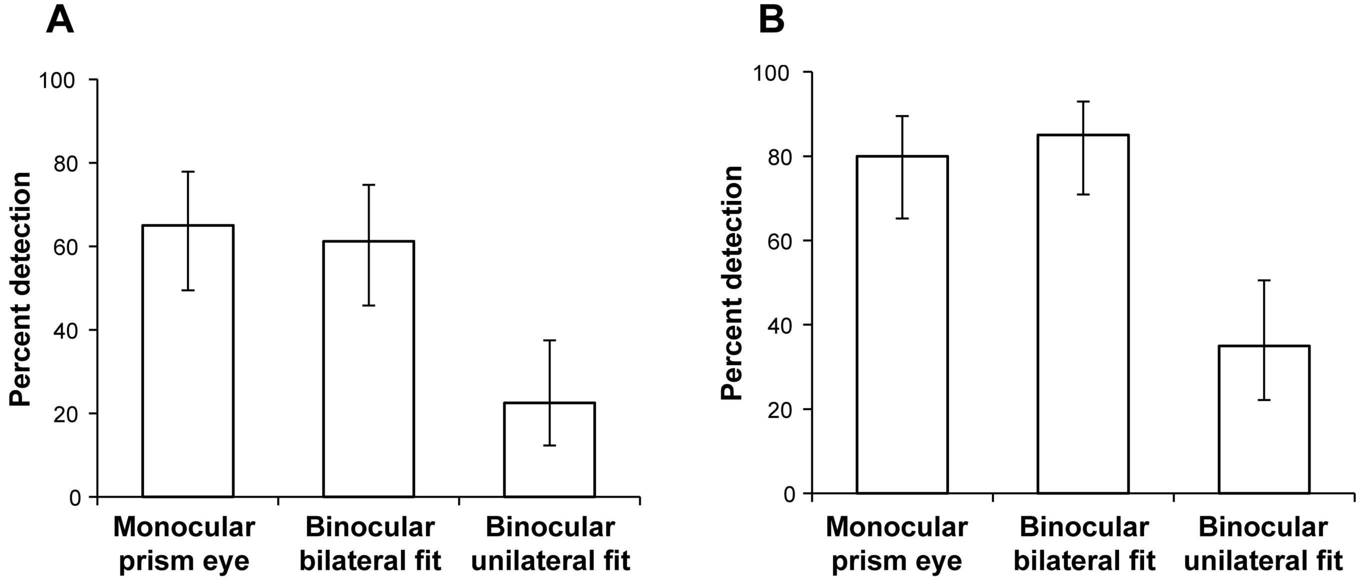

FIGURE 6.

Detection rates in the prism expansion area test zone over the video background for bilateral and unilateral prism fittings. (A) Participant with left hemianopia (S6 in Figs. 4 and 5) and (B) normally sighted participant with simulated left hemianopia. For both subjects, detection rates were as good in binocular viewing as in monocular viewing when binocular rivalry was reduced with the bilateral fit but were lower under the condition with a stimulus for rivalry (binocular unilateral fit). For each condition, there were 40 presentations in the prism expansion zone. Error bars are 95% confidence limits.

Oblique peripheral prisms image objects from paracentral areas of the visual field onto more peripheral regions. In optic flow fields, there is relatively little motion straight ahead with a greater amount of motion in the periphery. Therefore, the actual speed of movement in the driving videos might not have been too important. Rather, it was the conflict in motion between the paracentral areas of prism-shifted image from the blind hemifield and the more peripheral nonshifted views of the scene from the fellow-eye seeing hemifield that was the key factor leading to reduced predominance of the prism image.

Our findings are consistent with the results of a recent study by Haun and Peli[29] in which a binocular rivalry paradigm was used to investigate the predominance of unilateral peripheral prism images relative to the direct view in normally sighted participants with simulated HH. When there was moving high-contrast texture in both the prism and the direct view, the prism view predominated for less time than the direct view; however, when the moving texture was presented to the prism view only, the prism view predominated for a greater proportion of time than the direct view. Although the prism image predominated less when the moving texture was present in both views, it was still able to compete for visibility; exclusive suppression of the prism image did not occur. Similarly, the results of the present study with patients with HH (rather than simulated HH) suggest reduced predominance, but not total suppression, of the unilateral prism image in binocular viewing when motion was present in the background.

Detection rates were significantly lower in the prism expansion area than in the seeing hemifield for both monocular and binocular viewing on both backgrounds. Under conditions where there was no stimulus for binocular rivalry (i.e., monocular viewing), the lower detection rates in the prism expansion area were most likely caused by the contrast degradation of the high-powered Fresnel prisms reducing the visibility of the stimulus.[19,20] Ross et al.[22] also reported prism expansion area detection rates that were significantly lower than seeing hemifield detection rates in monocular viewing for checkerboard targets presented over stationary textured backgrounds. Under conditions where there was a stimulus for binocular rivalry (binocular viewing on the motion video background), both reduced target visibility and reduced predominance of the prism image would have contributed to the large detection rate difference between the seeing hemifield and the prism expansion area in the current study (medians, 93 and 13%, respectively).

Rather than using the same target for all subjects, targets were individually determined to ensure that detection rate measurements fell within about a 10 to 95% range for each subject on each background. This approach enabled measurement of within-subject performance differences without limitations from floor or ceiling effects. In general, we achieved our goal, although some ceiling effects were present in the detection rates for the seeing hemifield on the static image background (Fig. 4B). Although targets were, on average, larger for the moving than for the still image background (medians, 1.4 vs. 0.7 degrees), detection rates in monocular viewing were similar. To provide some context, the 1.4-degree target approximated the angular size of a motorcycle at about 70 m, which is relevant when driving (e.g., detection of a speeding motorcycle at sufficient distance to avoid a collision). Drivers with HH frequently miss objects of this size (on the blind side) when not using prism glasses.[6–8]

In the real world, however, peripheral prism users will encounter obstacles of a wide range of sizes, not just the relatively small targets used in this study. Detection of larger objects, often imminent hazards, is important when both driving (other vehicles) and walking (e.g., a pedestrian at 5 m subtends about 20 degrees vertically). If we had used larger targets in this study, prism expansion area detection rates would have been higher (as found during the target selection process), but seeing area detection rates would all have been at ceiling. Thus, it is possible that the reduced predominance of the prism image that we found with the small targets might not occur to such an extent with larger, more suprathreshold, or more realistic stimuli in real-world situations. Furthermore, when oblique peripheral prisms are fitted for driving, the shifted prism images tend to fall outside the field of the windshield,[17] within relatively bland areas of the car interior (the visor and dashboard areas) that contain little motion information, and may compete less for predominance in binocular viewing than the motion video background used in this study. Thus, in the driving situation, the predominance of the prism image may be much higher than that found in our study.

It might seem that the results of our additional testing support the idea of fitting peripheral prisms bilaterally rather than unilaterally. However, the binocular field with the bilateral prisms is not any larger than the binocular field without the prisms because the prisms cause optical apical scotomas in the binocular field that are not compensated for by the other eye (as with a unilateral fitting).[17] Nevertheless, with oblique bilateral peripheral prisms, the apical scotomas are mostly located outside the field of view through the windshield[17] and, thus, are unlikely to adversely affect driving performance or safety. As the view through the prisms is binocular and free of visual confusion or rivalry, a bilateral fitting may prove useful when driving, but this approach to fitting prisms has yet to be tested clinically.

To our knowledge, this is the first systematic investigation of the effects of motion on detection in binocular and monocular viewing in patients with HH using unilateral peripheral prism glasses. The results suggest that conflicting binocular motion reduces the predominance of the peripheral prism image in binocular viewing. However, the effect was only found for relatively small targets and we did not find exclusive local suppression of the prism image, which is encouraging. The findings open up a number of avenues for future research, including follow-up studies with more realistic detection tasks to investigate the extent to which conflicting binocular motion might limit the functionality of unilateral peripheral prism glasses in more real-world situations. In particular, detection performance needs to be evaluated in the driving situation for both unilateral and bilateral oblique prism fittings with the vertical field of view of the moving background restricted to that of a typical windshield.

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