Pilot study of a pedestrian collision detection test for a multisite trial of field expansion devices for hemianopia

Alex R. Bowers, MCOptom, PhD, FAAO,[1] Sailaja Manda, MPhil,[1] Sandhya Shekar, MS,[1] Alex D. Hwang, PhD,[1] Jae-Hyun Jung, PhD, FAAO,[1] and Eli Peli, OD, MSc, FAAO[1]*

SIGNIFICANCE: Performance-based outcome measures are crucial for clinical trials of field expansion devices. We implemented a test simulating a real-world mobility situation, focusing on detection of a colliding pedestrian among multiple noncolliding pedestrians, suitable for measuring the effects of homonymous hemianopia and assistive devices in clinical trials.

PURPOSE: In preparation for deploying the test in a multisite clinical trial, we conducted a pilot study to gather preliminary data on blind-side collision detection performance with multiperiscopic peripheral prisms compared with Fresnel peripheral prisms. We tested the hypothesis that detection rates for colliding pedestrians approaching on a 40° bearing angle (close to the highest collision risk when walking) would be higher with 100Δ oblique multiperiscopic (≈42° expansion) than 65Δ oblique Fresnel peripheral prisms (≈32° expansion).

METHODS: Six participants with homonymous hemianopia completed the test with and without each type of prism glasses, after using them in daily mobility for a minimum of 4 weeks. The test, presented as a video on a large screen, simulated walking through a busy shopping mall. Colliding pedestrians approached from the left or the right on a bearing angle of 20 or 40°.

RESULTS: Overall, blind-side detection was only 23% without prisms but improved to 73% with prisms. For multiperiscopic prisms, blind-side detection was significantly higher with than without prisms at 40° (88 vs. 0%) and 20° (75 vs. 0%). For Fresnel peripheral prisms, blind-side detection rates were not significantly higher with than without prisms at 40° (38 vs. 0%) but were significantly higher with prisms at 20° (94 vs. 56%). At 40°, detection rates were significantly higher with multiperiscopic than Fresnel prisms (88 vs. 38%).

CONCLUSIONS: The collision detection test is suitable for evaluating the effects of hemianopia and prism glasses on collision detection, confirming its readiness to serve as the primary outcome measure in the upcoming clinical trial.

(*Optom Vis Sci* 2024;101:408–416)

[1]Schepens Eye Research Institute of Mass Eye and Ear, Department of Ophthalmology, Harvard Medical School, Boston, Massachusetts *alex_bowers@meei.harvard.edu

Submitted: January 5, 2024
Accepted: May 2, 2024
Funding/Support: National Institutes of Health (R01 EY023385; to EP) and National Institutes of Health (P30 EY003790).
Conflict of Interest Disclosure: EP has a patent for oblique peripheral prisms licensed to Chadwick Optical Inc and a patent for multiperiscopic peripheral prisms assigned to Schepens Eye Research Institute. The sponsor provided financial and material support but had no role in the study design, conduct, analysis and interpretation, or writing of the report.
Study Registration Information: The study is registered as a feasibility study on ClinicalTrials.gov (NCT04424979).
Author Contributions: Conceptualization: ARB, ADH, J-HJ, EP; Data Curation: ARB, SM, SS, ADH; Formal Analysis: ARB; Funding Acquisition: ARB, EP; Investigation: ARB, SM, SS; Methodology: ARB, SM, SS, J-HJ; Project Administration: ARB, EP; Resources: ARB, EP; Software: ADH; Supervision: ARB, EP; Validation: ARB, ADH, EP; Visualization: ADH; Writing – Original Draft: ARB; Writing – Review & Editing: ARB, SM, SS, ADH, J-HJ, EP.
Supplemental Digital Content: Direct URL links are provided within the text.

ISSN: 1040-5488/24/10106–0408
DOI: 10.1097/OPX.0000000000002152

Homonymous hemianopia (hereafter, hemianopia) is the loss of one-half of the visual field on the same side in both eyes caused by lesions to the post-chiasmal visual pathways. Hemianopia is frequently a result of brain injury following a stroke, but may also be caused by brain injuries from surgery or trauma.[1] Individuals with hemianopia may encounter difficulties in mobility, both on foot and as drivers, including difficulties in detecting obstacles and hazards on the blind side.[2–4] Peripheral prisms provide field expansion for patients with hemianopia, which may help with detection of blind-side hazards. In prior multisite clinical trials of Fresnel peripheral prism glasses, patients reported that the prisms were helpful for blind-side obstacle avoidance when walking.[5,6] However, there was no objective verification of device efficacy or effectiveness. To address the need for performance-based outcome measures[7] for clinical trials of field expansion devices, we developed a pedestrian collision detection test for deployment at multiple sites. Here, we report a pilot study to evaluate the suitability of the test for a future multisite clinical trial comparing a new type of peripheral prisms (multiperiscopic prisms[8,9]) to commercially available Fresnel peripheral prisms.

Objective measures of pedestrian detection have been implemented in prior laboratory-based studies[10–13] of prism glasses. However, the tasks involved detection of a single pedestrian on a collision course in a virtual space without other pedestrians. Mostly "face-to-face" collision scenarios were used where the approaching pedestrian was facing toward the participant. In this situation, the approaching pedestrian would be able to see the participant and avoid a collision in the real world; therefore, the participant would not have sole responsibility for collision avoidance (Kurukuti NM, Manda S, Peli E. Risk of pedestrian collision for homonymous hemianopia: A computational analysis. *Optom Vis Sci* [under review]). The new test introduced in the current study incorporated two major improvements: (1) it simulated a mobility scenario where the collision did not occur face-to-face, requiring the participant to bear sole responsibility for collision avoidance, and (2) the test involved detecting a colliding pedestrian among multiple noncolliding pedestrians, representing a more challenging and realistic mobility situation. The ability to differentiate between colliding and noncolliding pedestrians in a complex environment is an essential component of real-world collision detection performance; therefore, the new test was set within the virtual environment of a busy shopping mall where pedestrians could approach from any direction.

Rather than using a "face-to-face" collision scenario, the new test used an "overtaken" situation where a colliding pedestrian ahead of the participant was walking more slowly than the participant and had their back to the participant (Kurukuti NM, Manda S, Peli E. Risk of pedestrian collision for homonymous hemianopia: A computational analysis. *Optom Vis Sci* [under review]). In this situation, the colliding pedestrian was being overtaken by the participant and would not be able to see the participant unless they looked back over their shoulder. If the pedestrian ahead was on the blind side of a participant with hemianopia, they would remain unseen unless the participant scanned to the blind side, or the participant was wearing prism glasses and the pedestrian was within an area

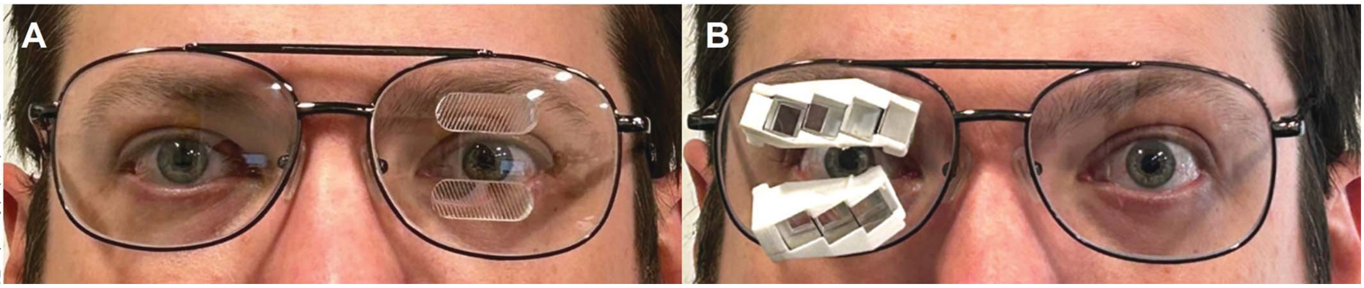

FIGURE 1. Peripheral prism glasses with prisms in the oblique design as used in the pilot study for a participant with left hemianopia. (A) Commercially available 65Δ Fresnel peripheral prisms embedded into the left spectacle lens. (B) New 100Δ multiperiscopic prisms mounted on the front surface of the right spectacle lens.

of field expansion. Therefore, this overtaken pedestrian scenario enabled an evaluation of how much the prisms could improve detection where the only reason for a collision on the blind side would be the participant's failure to detect the possible collision risk.

To evaluate the suitability of the test for the future multisite clinical trial, a pilot study was conducted comparing pedestrian collision detection performance with multiperiscopic prisms to Fresnel peripheral prisms (Fig. 1). The multiperiscopic prism glasses (100Δ) provided about 42° of lateral field expansion compared with the 65Δ Fresnel peripheral prisms that provided about 32° of lateral field expansion (Fig. 2). In a geometrical analysis of the interactions of pedestrians walking in open spaces, Peli et al.[14] calculated the density function of the collision risk and found that it peaked at a bearing angle of about 45°. We therefore tested the hypothesis that multiperiscopic prisms would be better than Fresnel peripheral prisms for detection of colliding pedestrians near to the highest collision risk. To address this hypothesis, the test included colliding pedestrians on two bearing angles, 20 and 40°. We expected that both types of prism glasses would improve detection of colliding pedestrians on the 20° bearing angle because these pedestrians would be within the expansion area of both types of prisms. However, we expected better detection performance with the multiperiscopic prisms than Fresnel peripheral prisms for colliding pedestrians on a bearing angle of 40° (close to the maximum collision risk). The 40° pedestrians were within the expansion range of the multiperiscopic prisms without head and/or eye scanning. However, they were beyond the expansion range of the Fresnel peripheral prisms, requiring head and/or eye scanning toward the blind side to bring them within the expansion area.

METHODS

This research, conducted at the Schepens Eye Research Institute of Mass Eye and Ear, Boston, MA, was reviewed by an independent ethical review board and conforms with the principles and applicable guidelines for the protection of human subjects in

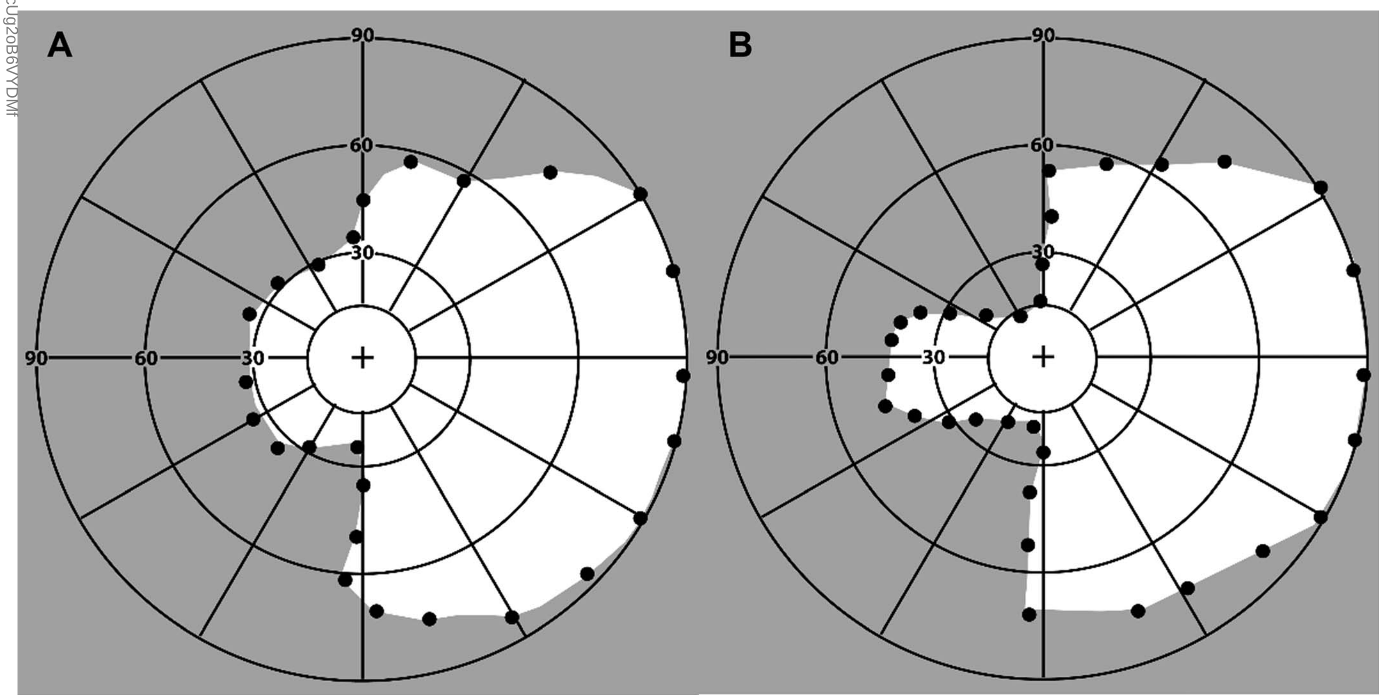

FIGURE 2. Binocular visual field plots (Goldman V4e) for a person with left hemianopia wearing peripheral prism glasses of the oblique design. The expansion areas from the upper and lower prisms are contiguous, covering an area near the horizontal midline. (A) With 65Δ Fresnel peripheral prisms mounted at 25° tilt, the field expansion extends about 32° laterally into the blind hemifield. (B) With 100Δ multiperiscopic prisms at 20° tilt, the field expansion extends about 42° laterally into the blind hemifield.

biomedical research. Informed consent was obtained from all participants. The study is registered as a feasibility study on ClinicalTrials.gov (NCT04424979).

Participants

Six participants with complete homonymous hemianopia (Goldman perimetry, V4e) participated in the study; four were recruited from local clinics and two from a database of subjects from prior studies. Their characteristics are summarized in Table 1. None tested positive for spatial neglect (Schenkenberg line bisection test[16] and Bells test[16]), and none had cognitive decline (all had <2 errors on the Short Portable Mental Status questionnaire[17]). Stroke was the cause of the hemianopia for all participants.

Study design

A crossover design was used where each participant was fitted with and used each type of prism glasses. Participants were randomly assigned to receive either multiperiscopic or Fresnel peripheral prisms first. The schedule of study visits with core procedures at each visit is summarized in Table 2. Participants used each type of prism glasses for their daily walking mobility tasks for a minimum of 4 weeks before completing an in-laboratory evaluation of collision detection performance without and with the prisms.

Prism glasses

Details of the fitting and training procedures for the prism glasses are given in Appendix 1, available at http://links.lww.com/OPX/A751. Both types of prism glasses were manufactured by Chadwick Optical, Inc. (Schwenksville, PA) and consisted of an upper and lower obliquely oriented prism segment/module mounted on a distance vision carrier lens (Fig. 1). The Fresnel peripheral prisms were rigid Fresnel prism segments (65Δ) with an 11-mm vertical separation between the segments, embedded into the lens on the side ipsilateral to the field loss (i.e., left eye for left hemianopia). The upper prism was placed base out and down, whereas the lower prism was placed base out and up, with the base-apex line tilted at 25° to the horizontal. In contrast, the multiperiscopic prism modules (100Δ), with an 8-mm vertical separation,[9] were mounted on the front surface of the lens on the side contralateral to the field loss (i.e., right eye for left hemianopia). This positioning was necessary due to insufficient width on the nasal side of the lenses to accommodate the module if mounted ipsilaterally. The upper module used a cascade of four 8 × 8-mm half-penta prisms, and the lower module used three 8 × 8-mm half-penta prisms and one 4 × 8-mm half-penta prism. The upper module provided a prism "base" in and down, whereas the lower module provided a prism "base" in and up, with the base-apex line at 20° to the horizontal.[9] The field expansion (see Appendix 1, available at http://links.lww.com/OPX/A751) was measured as a median (interquartile range) of 31° (30 to 34°) laterally by 43° (40 to 45°) vertically for the Fresnel peripheral prisms and a median of 44° (39 to 45°) by 38° (30 to 40) for the multiperiscopic prisms.

TABLE 1. Demographics of the study participants

Subject number	Gender	Age (y)	Side of hemianopia	Duration (y)	Visual acuity Right eye	Visual acuity Left eye
S1	Male	24	Left	5	20/16	20/16
S2	Female	52	Left	5	20/32	20/32
S3	Male	59	Right	3	20/25	20/60
S4	Male	56	Left	2	20/20	20/25
S5	Female	76	Left	3	20/40	20/20
S6	Male	30	Left	7	20/20	20/20

TABLE 2. Summary of core procedures at each visit

Visit	Procedures
1	Record ocular history. Measure visual acuity and visual fields without prisms. Conduct spatial neglect and cognitive status tests. Conduct spectacle measurements and prism fitting measurements.
2	Dispense the first pair of prism glasses and train the participant in how to use them. Complete an introduction to the collision detection test and practice without prism glasses.
3*	Measure visual fields with the first pair of prism glasses (Fresnel or multiperiscopic). Perform the collision detection test without and with the first pair of prism glasses. Dispense the second pair of prism glasses and train the participant in how to use them.
4*	Measure visual fields with the second pair of prism glasses (multiperiscopic or Fresnel). Perform the collision detection test without and with the second pair of prism glasses. Decide which pair of prism glasses to keep.

*There was a minimum of 4 weeks between visit 2 and visit 3, and between visit 3 and visit 4.

Pedestrian collision detection test

The pedestrian collision detection test was developed in-house with the Unity 3D engine (Unity 3D; Unity Technologies, San Francisco, CA), set in a virtual mall (100 × 45 m) with multiple shops and mall items (seats, signs, etc.; Fig. 3 and Appendix 2, Fig. A2.1, available at http://links.lww.com/OPX/A751). The test was presented on a large television screen (75″ Samsung AU8000; Samsung, Suwon, Korea; see Fig. 4 and Appendix 2, Fig. A2.2, available at http://links.lww.com/OPX/A751) with participants standing at 25″ from the screen. They watched the forward-walking video that simulated a walking speed of 1 m/s (2.2 mph) along a straight path, denoted by green markers on the mall floor (Fig. 3), and pushed a joystick to the right or left with their preferred hand to indicate the direction from

FIGURE 3. Screenshot of the virtual mall as seen by the participant with the walking path denoted by the green markers on the floor, an overtaken colliding pedestrian on the left, multiple noncolliding pedestrians on both sides, and the gaze fixation target (yellow square with a letter in the middle) used to attract gaze toward the forward and slightly down direction.

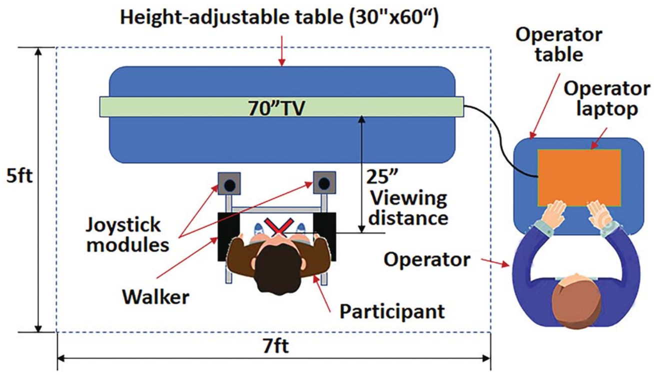

FIGURE 4. Schematic diagram (view from above) of the pedestrian collision detection test setup. A dual-screen system was used so the participant did not see what was on the operator's screen. The upright walker provided support and kept the participant at a fixed distance of 25″ from the display. Custom joystick modules attached to the arms of the upright walker served as the participant response device.

which a colliding pedestrian approached (Fig. 4 and Appendix 2, Fig. A2.2, available at http://links.lww.com/OPX/A751). With the correct viewpoint setting, the display covered 104°(H) × 70°(V) field of view, where the upper and lower visual field spanned 30 and 40°, respectively (Appendix 2, Fig. A2.3, available at http://links.lww.com/OPX/A751). The eye-height calibration marker was positioned at about three-fifths of the screen height (Appendix 2, Fig. A2.2 and A2.3, available at http://links.lww.com/OPX/A751) so that more of the lower portion of the simulated scene (the mall floor) was visible during the virtual walking. The position and orientation of the pedestrians and virtual participants in the virtual world were logged at 30 frames per second. When the participant responded with the joystick, their response direction was logged with a timestamp. Additional details regarding the virtual mall setup are given in Appendix 2, available at http://links.lww.com/OPX/A751.

Pedestrian event details and collision modeling

The simulation scenarios included three types of pedestrians: (1) overtaken colliding pedestrians, used for evaluation of the effects of the prism glasses; (2) face-to-face colliding pedestrians, included for variety but not analyzed; and (3) noncolliding pedestrians, incorporated to create a busy, multiple pedestrian environment. Collision events comprised multiple noncolliding pedestrians and one colliding pedestrian (from the left or right), whereas null events (catch trials) consisted solely of multiple noncolliding pedestrians. In collision events, noncolliding pedestrians were programmed so that their appearance and walking paths did not occlude the colliding pedestrian. To reduce predictability, a wide range of pedestrian models, including males and females of various ages with differing clothes, were used (Fig. 3). The position and speed of the noncolliding pedestrians were randomly selected within predefined parameter ranges so that, even if multiple collision events were created with the same collision parameters, the events would appear slightly different. Ambient sound (people talking, etc.) recorded in a real shopping mall enhanced immersion in the virtual environment.

In the collision scenarios, the colliding pedestrian and the participant each walked on a straight line at a fixed speed; hence, the bearing angle between them was constant throughout the event.[12,14] In the overtaken events (Fig. 5A), the colliding pedestrian appeared

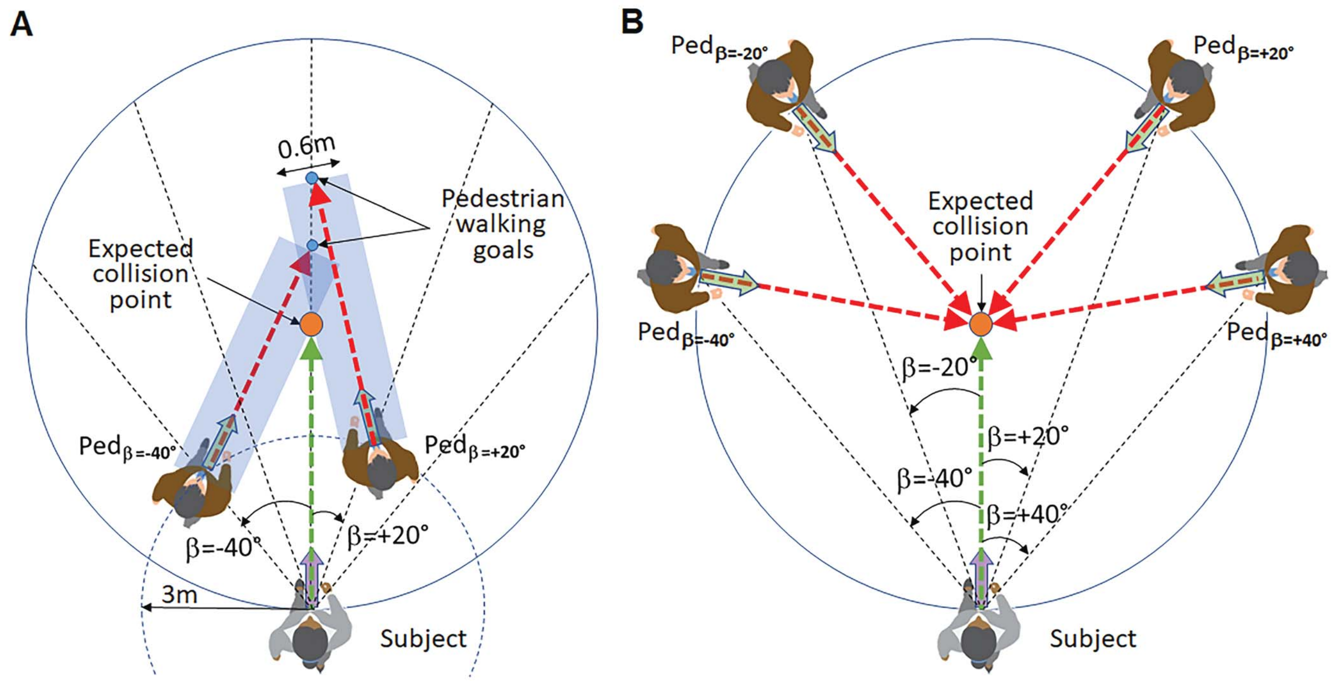

FIGURE 5. Schematic diagrams showing the design of the pedestrian collision events. (A) Overtaken pedestrians, with a colliding pedestrian on the 40° bearing angle (β) from the left and another on the 20° bearing angle from the right. (B) Face-to-face pedestrians, showing a colliding pedestrian from each of the two bearing angles on both the left and right. The overtaken pedestrian ahead of the participant walked more slowly than the participant such that the shoulder of the pedestrian and the participant's body center would have arrived at the expected collision point simultaneously. In a face-to-face collision, the colliding pedestrian walked at the same speed as the participant toward the collision point.

3 m away from the participant's initial location at one of the two bearing angles (i.e., β> = 20 or 40°) on the left or right and walked in a straight line toward their intended goal, walking more slowly than the participant. The collision event with an overtaken pedestrian was designed to simulate a collision between the pedestrian's shoulder and the participant's body center, assuming the pedestrian had a body width of 0.6 m. Thus, the bearing angle of the pedestrian's shoulder on the blind side of the participant was kept at the fixed bearing angle so the looming of the pedestrian (the increment of the angular size of an object when it gets closer to the viewer) extended farther into the participant's blind hemifield, not toward their seeing hemifield. In the unscored face-to-face collision events (Fig. 5B), the colliding pedestrian started at 5 m from the expected collision point and walked toward the collision point at the same speed as the participant.

At the start of each event (indicated by a "ding-dong" sound), the participant's simulated walking began. When they passed a trigger point (at a random distance of 2 to 4 m from the initial position), the scripted noncolliding pedestrians and a colliding pedestrian (in collision events) appeared and started walking. In collision events, the colliding pedestrian and participant were programmed to arrive at the collision point 5 seconds after the colliding pedestrian started moving. To avoid an actual collision, the colliding pedestrian disappeared when it was within 0.5 m of the participant, whereas the participant and the noncolliding pedestrians continued walking for an additional 1 or 2 seconds until the event ended. The scene then transitioned to the next event location, and the entire process started over.

Four versions of the scenarios were developed for experimental data collection. To minimize test duration and maximize data collection on the blind side, the scenarios (about 4 minutes each) had more overtaken colliding events on the blind than the seeing side. Each version comprised a total of 22 events, including 7 overtaken events at each of the two bearing angles on the blind side, 2 overtaken events, 1 face-to-face event at each of the two bearing angles on the seeing side, and 2 null events without a colliding pedestrian on either side. The event order within each scenario was randomized. Additional collision detection scenarios were developed for practice sessions before experimental data collection (see Appendix 2, available at http://links.lww.com/OPX/A751, for details).

Gaze fixation task

When walking in the real world, the gaze of pedestrians with hemianopia is mainly directed toward the forward direction with occasional scanning to both sides (Pundlik S, Tomasi M, Houston KE, et al. Gaze scanning during mid-block walking in homonymous hemianopia patients with and without spatial neglect. *Invest Ophthalmol Vis Sci* [under review]).[18] However, in pilot testing of the walking simulation, we found that participants with hemianopia scanned very frequently to the blind side and/or adopted a very eccentric gaze position toward the blind side (Bowers AR, et al. IOVS 2022;63:ARVO E-Abstract 845). These gaze behaviors would not be possible when walking (or driving) in the real world. A gaze fixation target was therefore implemented to attract gaze and attention toward the walking direction while also allowing some scanning to both sides, as would be the case in the real world. The fixation target (1° yellow square) floated in front of the participant, 1 m away (Fig. 3), moving slowly (0.3 m/s) in random directions within a 2.5 × 2.5° area centered 8.2° below the straight-ahead calibrated viewpoint, simulating a slightly downward direction of gaze often used when walking.[19] A string of alphanumeric characters (0.5° vertical height, about 20/120) was presented within the square. Each character was displayed for a random duration varying between 0.5 and 1.0 second. The string contained mostly letters (randomly selected from among 24 letters, except "I" and "O") with an occasional number (randomly selected from "1," "2," "3," "4," and "5"); the ratio of numbers to letters displayed was about 1 to 5. Participants were required to call out any numbers they saw. These parameters were determined through pilot testing.

Pedestrian collision detection test procedures

Before experimental data collection, participants were given training and practice in performing the collision detection task while standing in the experimental setup (see Appendix 2 for details, available at http://links.lww.com/OPX/A751). During experimental data collection, they were instructed to push the joystick to indicate the approach direction of any colliding pedestrians they detected while also calling out any numbers they saw in the yellow square. They were told they could take quick scans to the blind side in between calling out the numbers to confirm whether a pedestrian might collide with them. If they detected a pedestrian in the prisms (which would appear shifted toward the seeing side), they were instructed to look toward their blind side through the central prism-free portion of the spectacle lens (i.e., the way the glasses would be used when walking) to confirm whether it was a colliding pedestrian before making a response.

After at least 4 weeks of using the prism glasses in daily walking ("home use"), participants returned to the laboratory and performed the collision detection tests without prisms first and then with prisms. They completed two of the four experimental scenarios for each condition, with scenario order counterbalanced across participants. Practice and data collection typically took about 60 minutes with breaks.

Data analysis

In total, there were 801 events with overtaken pedestrians (Table 3), 97 null events without a colliding pedestrian, and 154 events with face-to-face pedestrians (included for variety but not analyzed). Rates of responding in null events (false positives) were

TABLE 3. Summary of responses for all overtaken pedestrian events on the blind and seeing sides (total 801 events), for data pooled across subjects (n = 6), bearing angles and prism types

	Blind side			Seeing side		
	Without prisms	With prisms	Total	Without prisms	With prisms	Total
No response, missed detection	159 (64%)	46 (18%)	205 (41%)	0 (0%)	1 (1%)	1 (<1%)
Wrong-side response	3 (1%)	2 (1%)	5 (1%)	1 (1%)	4 (2%)	5 (2%)
Correct-side late response*	29 (12%)	19 (8%)	48 (10%)	0 (0%)	1 (1%)	1 (<1%)
Correct-side timely response	58 (23%)	183 (73%)	241 (48%)	149 (99%)	146 (96%)	295 (98%)
Total	249	250	499	150	152	302

*Counted as "no response" in analyses.

relatively low (a total of 8 of 97 events [8.2%]). Each overtaken pedestrian event was classified as follows: no response, wrong-side response (pushed the joystick in the wrong direction), or correct response (pushed the joystick in the correct direction). For correct detections of colliding pedestrians, we were primarily interested in timely responses (could have avoided the collision) rather than late responses (too late to avoid a collision). Responses were classified as late when there was less than 1 second to the collision (Fig. 6), which would likely have been too late to execute any maneuver to avoid a collision in the real world. Correct-but-late responses were treated as missed responses in data analyses as there would likely have been a collision in the real world (although the colliding pedestrian disappeared before a collision in the simulation).

Two measures of collision detection performance were derived from the logged joystick responses. The percentage of correct detections was computed as the number of correct detections with a timely response out of the total number of overtaken pedestrian events for each condition and bearing angle. Response times for correct-timely detections were measured from the time at which the colliding pedestrian appeared to the joystick response. For each participant, a median response time was computed across all correct-timely detections for each condition and bearing angle.

Statistical analysis

Differences in detection rates and response times between pairs of conditions and bearing angles were evaluated using nonparametric, within-subject comparisons (Wilcoxon signed rank test) because of the small sample size and potential nonnormality of the data. In addition to group analyses, the individual performance of each subject was evaluated in terms of improvement (binary, yes/no) in blind-side detection rates with each type of prism glasses at each bearing angle. Improvement was defined as blind-side detection rates that were significantly higher ($p<0.05$) with than without prisms (z test for two proportions).

RESULTS

Table 3 summarizes responses for all overtaken pedestrian events on the blind and seeing sides. There were very few wrong-side responses (a total of 10 out of 801 events [1.2%]). The number of missed detections on the blind side without prisms was relatively high (159 out of 249 [64%]) but decreased when wearing prisms (46 out of 250 events [18%]). For 10% of all blind-side events, there was a correct-but-late detection response (Fig. 6). In contrast, on the seeing side, there was only one missed detection and one correct-but-late response (Fig. 6). For 23% of all blind-side events without prisms, there was a correct-timely response; these responses were likely a result of gaze scanning into the blind hemifield, including eye and head scanning, confirming that, as planned, participants were able to scan occasionally while calling out the numbers in the gaze fixation task. For events with prisms, blind-side response times were significantly longer than seeing-side response times (median, [interquartile range], 2.4 [2.1 to 2.8] seconds vs. 1.8 [1.3 to 2.2] seconds; z = 1.99, p=0.046). For events without prisms, there were insufficient blind-side responses to compute medians, whereas seeing-side response times were a median of 1.5 seconds (1.3 to 1.6 seconds).

For multiperiscopic prisms, blind-side detection rates were significantly higher with than without prisms at both the 40° (median, 88 vs. 0%; z = 2.20, p=0.028) and the 20° bearing angles (75 vs. 0%; z = 1.99, p=0.046; Fig. 7A). For Fresnel prisms, blind-side detection rates were not significantly higher with than without prisms at the 40° bearing angle (38 vs. 0%; z = 1.48, p=0.14) but were significantly higher with prisms at 20° (94 vs. 56%; z = 2.20, p=0.028; Fig. 7B). For these comparisons, detection rates without and with each type of prisms were taken from tests performed at the same visit.

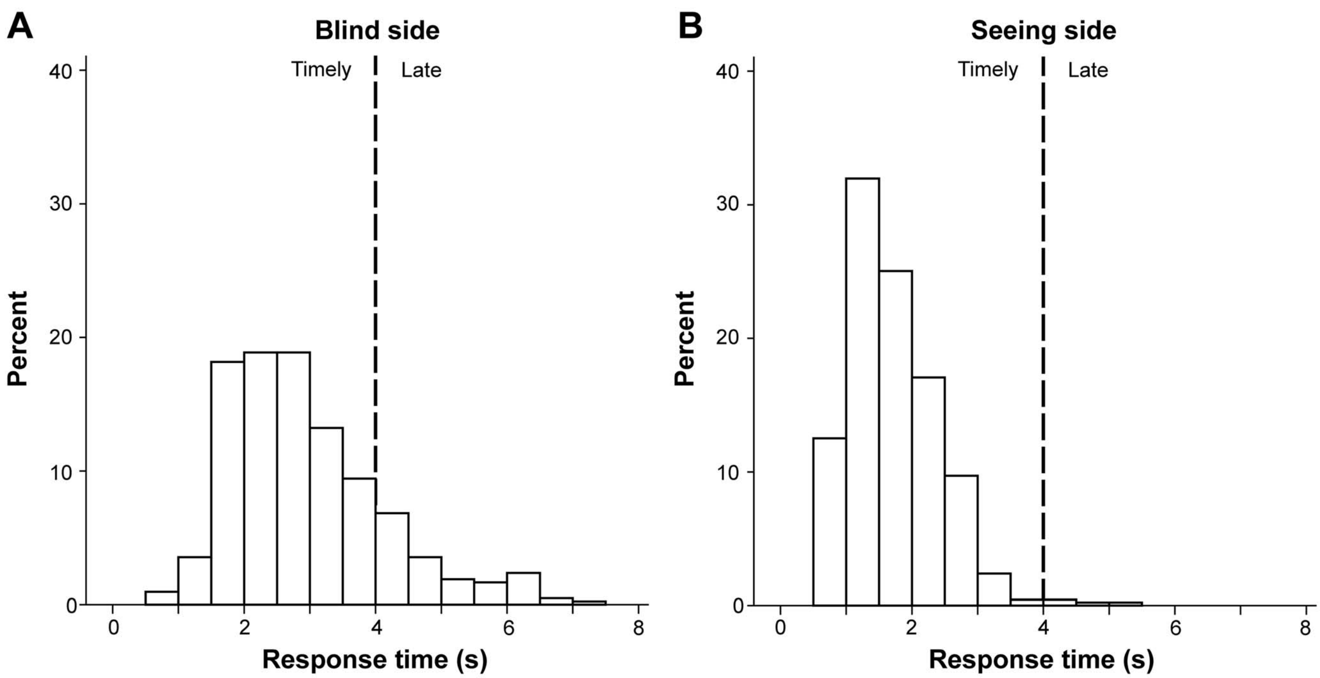

FIGURE 6. Histogram of response times for all correct detections (timely and late) for overtaken pedestrians on (A) the blind side and (B) the seeing side, in 0.5-second bins. There was only 1 late response (less than 1 second to the collision point) on the seeing side compared with 48 late responses on the blind side. Late responses were classified as missed responses in data analyses. Data are pooled across subjects, prism conditions, and bearing angles. Vertical dashed line indicates 1 second to the collision.

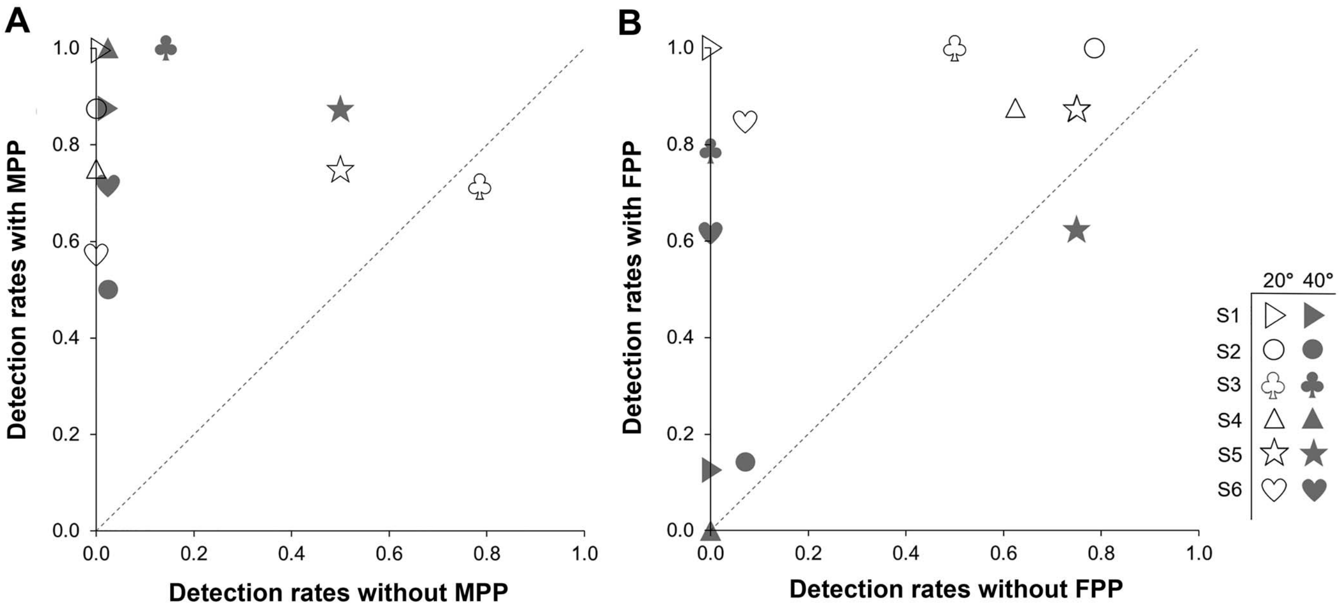

FIGURE 7. Blind-side detection rates for each subject (A) with and without multiperiscopic prisms (MPP) and (B) with and without Fresnel peripheral prisms (FPP). Detection rates were significantly higher with than without multiperiscopic prisms at 40° (all points above the diagonal) and 20° (5 points above the diagonal). Detection rates were significantly higher with than without Fresnel peripheral prisms at 20° (all points above the diagonal) but not 40° (only 4 points above the diagonal).

Directly comparing the two types of prism glasses at the 40° bearing angle, blind-side detection rates were significantly higher with multiperiscopic than Fresnel prisms (88 vs. 38%; z = 2.20, p=0.028; Fig. 8A), and response times were significantly faster with multiperiscopic than Fresnel prisms (median, 2.6 vs. 3.0 seconds; z = 2.20, p=0.043; Fig. 8B). However, at the 20° bearing angle, blind-side detection rates were significantly lower with multiperiscopic than Fresnel prisms (75 vs. 94%; z = 2.11, p=0.035; Fig. 8A), whereas response times did not differ (2.4 vs. 2.5 seconds; z = 1.15, p=0.25; Fig. 8B).

Table 4 summarizes the number of subjects who showed significant improvement in blind-side detection rates with each type of

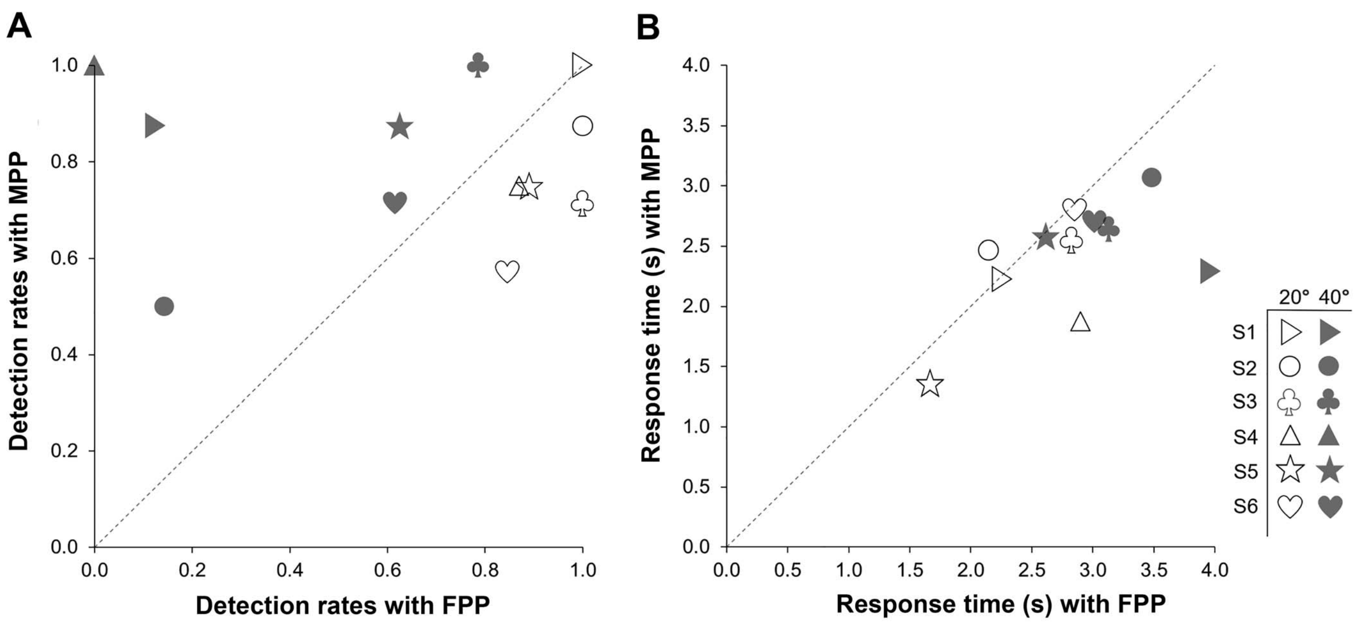

FIGURE 8. (A) Blind-side detection rates and (B) median blind-side response times for each subject for multiperiscopic (MPP) compared with Fresnel peripheral prisms (FPP). At 40°, detection rates were significantly higher, and response times were significantly faster with multiperiscopic prisms. At 20°, detection rates were significantly higher with Fresnel prisms, whereas response times did not differ.

TABLE 4. Number of subjects with significant improvement in blind-side detection rates with MPP and FPP at each bearing angle

40° Bearing angle		With MPP Yes	With MPP No	Total FPP	20° Bearing angle		With MPP Yes	With MPP No	Total FPP
With FPP	Yes	2	0	2	With FPP	Yes	3	1	4
	No	4	0	4		No	1	1	2
Total MPP		6	0		Total MPP		4	2	

FPP = Fresnel peripheral prism; MPP = multiperiscopic prism.

prism. At the 40° bearing angle, six subjects improved with the multiperiscopic prisms compared with only two with the Fresnel prisms. At the 20° bearing angle, four subjects improved with the multiperiscopic prisms, and four improved with the Fresnel prisms.

Additional analyses addressing detection performance with multiperiscopic prisms before and after home use and the participants' final choice of prism glasses are given in Appendix 3, available at http://links.lww.com/OPX/A751.

DISCUSSION

Peripheral prisms were designed to aid mobility. A key question therefore is whether the field expansion is helpful in everyday walking. To address this question, we developed a test with realistic simulations of pedestrian collisions in a virtual open-space environment presented on a large television screen for use as the primary outcome measure in a multisite clinical trial. The results confirmed the test's face validity. As expected, detection rates (timely responses) for colliding pedestrians on the seeing side were very high, whereas detection rates on the blind side were relatively low without prisms and improved markedly with prisms. Although blind-side detection improved with prisms, overall detection rates were still lower than on the seeing side, and response times were longer.

As expected, detection rates for colliding pedestrians from the blind side were higher with than without the multiperiscopic prisms for both the 40 and 20° bearing angles, but only higher with than without the Fresnel prisms for the 20° bearing angle. In comparing the two types of prisms, blind-side detection rates were higher, and response times were faster with multiperiscopic than with Fresnel prisms for the 40° bearing angle, consistent with the expectation that detection of the 40° pedestrian with the Fresnel prisms would only be possible with scanning to the blind side. Interestingly, detection rates for the 20° pedestrian were higher with Fresnel than with multiperiscopic prisms, whereas response times did not differ. The seemingly lower detection rates with the multiperiscopic prisms might be explained by the fact that the image of the 20° pedestrian falls on the retina closer to the vertical midline with Fresnel prisms than with multiperiscopic prisms. With multiperiscopic prisms, the image is shifted about 20° further into the periphery where retinal sensitivity is substantially lower.

Finally, we conducted individual analyses for each participant to determine if they achieved a statistically significant improvement in detection performance with each type of prism glasses. Again, the clear superiority of the multiperiscopic prisms for detection of the 40° pedestrian is evident, with all six participants showing a significant improvement in detection rates at that bearing angle compared with only two participants showing significant improvement with the Fresnel prisms. In contrast, for the 20° pedestrian, the same number of participants (four) showed significant improvement with multiperiscopic and Fresnel prisms.

The pilot study was primarily designed to evaluate suitability of the collision detection test as an outcome measure for evaluating the effects of hemianopia and the effects of field-expanding prism glasses. As such, the study included a convenience sample of six participants. They were all highly motivated, and two had previously participated in studies in the laboratory. Therefore, they might not have been totally representative of patients likely to participate in the future clinical trial. It is possible that improvements in performance with the prisms may not be as pronounced in a more typical clinical population of patients with hemianopia. There were some limitations in using a simulation of walking, not least that participants could make large, frequent scans, or adopt very eccentric gaze positions toward the blind side while watching the video of forward walking. This was possible only because they were standing instead of physically walking. We therefore implemented a gaze fixation task to introduce some of the attentional load of path monitoring during physical walking and to attract gaze toward the forward and slightly downward direction used in real-world walking (e.g., to check for uneven terrain).[19] Although this could be considered a limitation, it is important to note that the scenarios were developed to evaluate and compare the efficacy of the two types of prism glasses in a relevant mobility task, not to compare real-world and simulated walking.

In summary, the pilot study confirmed the suitability of the new collision detection test as the primary outcome measure for the future clinical trial. Despite the small sample size of six subjects, the results supported our hypothesis that detection performance would be better with multiperiscopic than Fresnel peripheral prisms for colliding pedestrians on a 40° bearing angle. The findings suggested that the collision detection test was well suited to evaluate the effects of both hemianopia and prism glasses on collision detection, confirming its readiness to serve as the primary objective outcome measure in the upcoming (now ongoing) clinical trial.

REFERENCES

1. Zhang X, Kedar S, Lynn MJ, et al. Homonymous hemianopias—Clinical-anatomic correlations in 904 cases. *Neurology* 2006;66:906–10.
2. de Haan GA, Heutink J, Melis-Dankers BJ, et al. Difficulties in daily life reported by patients with homonymous visual field defects. *J Neuroophthalmol* 2015;35:259–64.
3. Bowers AR, Mandel AJ, Goldstein RB, Peli E. Driving with hemianopia: I. Detection performance in a simulator. *Invest Ophthalmol Vis Sci* 2009;50:5137–47.
4. Papageorgiou E, Hardiess G, Ackermann H, et al. Collision avoidance in persons with homonymous visual field defects under virtual reality conditions. *Vision Res* 2012;52:20–30.
5. Bowers AR, Keeney K, Peli E. Community-based trial of peripheral prism visual field expansion device for hemianopia. *Arch Ophthalmol* 2008;126:657–64.
6. Bowers AR, Keeney K, Peli E. Randomized crossover clinical trial of real and sham peripheral prism glasses for hemianopia. *JAMA Ophthalmol* 2014;132:214–22.
7. Pollock A, Hazelton C, Rowe FJ, et al. Interventions for visual field defects in people with stroke. *Cochrane Database Syst Rev* 2019;5:CD008388.

8. Peli E, Vargas-Martin F, Kurukuti NM, Jung JH. Multi-periscopic prism device for field expansion. *Biomed Opt Express* 2020;11:4872–89.
9. Falahati M, Kurukuti NM, Vargas-Martin F, et al. Oblique multi-periscopic prism for field expansion of homonymous hemianopia. *Biomed Opt Express* 2023;14:2352–64.
10. Houston KE, Bowers AR, Peli E, Woods RL. Peripheral prisms improve obstacle detection during simulated walking for patients with left hemispatial neglect and hemianopia. *Optom Vis Sci* 2018;95:795–804.
11. Jung JH, Castle R, Kurukuti NM, et al. Field expansion with multiplexing prism glasses improves pedestrian detection for acquired monocular vision. *Transl Vis Sci Technol* 2020;9:15.
12. Qiu C, Jung J-H, Tuccar-Burak M, et al. Measuring pedestrian collision detection with peripheral field loss and the impact of peripheral prisms. *Transl Vis Sci Technol* 2018;7:17.
13. Houston KE, Peli E, Luo G, et al. Effects of perceptual-motor training on collision judgments with peripheral prism expanded vision. *Optom Vis Sci* 2022;99:875–84.
14. Peli E, Apfelbaum H, Berson EL, Goldstein RB. The risk of pedestrian collisions with peripheral visual field loss. *J Vis* 2016;16:5.
15. Schenkenberg T, Bradford DC, Ajax ET. Line bisection and unilateral visual neglect in patients with neurologic impairment. *Neurology* 1980;30:509–17.
16. Vanier M, Gauthier L, Lambert J, et al. Evaluation of left visuospatial neglect: Norms and discrimination power of two tests. *Neuropsychology* 1990;4:87–96.
17. Pfeiffer E. Short portable mental status questionnaire for assessment of organic brain deficit in elderly patients. *J Am Geriatr Soc* 1975;23:433–41.
18. Pundlik S, Tomasi M, Houston KE, et al. Gaze scanning at street crossings by pedestrians with homonymous hemianopia with and without hemispatial neglect. *Invest Ophthalmol Vis Sci* 2023;64:26.
19. Matthis JS, Yates JL, Hayhoe MM. Gaze and the control of foot placement when walking in natural terrain. *Curr Biol* 2018;28:1224–1233.e5.