Driving With Hemianopia: III. Detection of Stationary and Approaching Pedestrians in a Simulator

Concetta F. Alberti, Eli Peli, and Alex R. Bowers

Schepens Eye Research Institute, Massachusetts Eye and Ear, Department of Ophthalmology, Harvard Medical School, Boston, Massachusetts

Correspondence: Alex R. Bowers, Schepens Eye Research Institute, 20 Staniford Street, Boston, MA 02114; alex_bowers@meei.harvard.edu.

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Purpose. To compare blind-side detection performance of drivers with homonymous hemianopia (HH) for stationary and approaching pedestrians, initially appearing at small (4°) or large (14°) eccentricities in a driving simulator. While the stationary pedestrians did not represent an imminent threat, as their eccentricity increased rapidly as the vehicle advanced, the approaching pedestrians maintained a collision course with approximately constant eccentricity, walking or running, toward the travel lane as if to cross.

Methods. Twelve participants with complete HH and without spatial neglect pressed the horn whenever they detected a pedestrian while driving along predetermined routes in two driving simulator sessions. Miss rates and reaction times were analyzed for 52 stationary and 52 approaching pedestrians.

Results. Miss rates were higher and reaction times longer on the blind than the seeing side ($P < 0.01$). On the blind side, miss rates were lower for approaching than stationary pedestrians (16% vs. 29%, $P = 0.01$), especially at larger eccentricities (20% vs. 54%, $P = 0.005$), but reaction times for approaching pedestrians were longer (1.72 vs. 1.41 seconds; $P = 0.03$). Overall, the proportion of potential blind-side collisions (missed and late responses) was not different for the two paradigms (41% vs. 35%, $P = 0.48$), and significantly higher than for the seeing side (3%, $P = 0.002$).

Conclusions. In a realistic pedestrian detection task, drivers with HH exhibited significant blind-side detection deficits. Even when approaching pedestrians were detected, responses were often too late to avoid a potential collision.

Keywords: driving, detection rates, response times

Complete homonymous hemianopia (HH), the total loss of half the visual field on the same side in both eyes, affects approximately 40% of people with occipital postchiasmal brain lesions.[1] In 22 states in the USA, people with HH do not meet the minimum horizontal visual field requirement for driving (e.g., 120° in Massachusetts),[2] yet many continue to drive,[3] albeit illegally, to maintain independence and quality of life.[4] While prohibited from driving in some countries, people with HH are permitted in others if they pass a specialized road test (including Belgium,[5] Switzerland, The Netherlands,[6] Canada[4] and the United Kingdom[7]). Nevertheless, a significant concern is whether they are able to detect and respond in a timely fashion to potential hazards that appear in the blind hemifield, as both detection failures and late responses could result in collisions.

To execute a timely response to a potential hazard within the blind hemifield, drivers with complete HH have to scan far enough into that hemifield in order to foveate the object of interest (as there is no peripheral vision on that side). The scan might involve only eye movements, or both eye and head movements, especially when scanning far into the blind hemifield. Thus, peripheral objects that appear at larger eccentricities in the blind hemifield might be detected less frequently or with longer responses times than objects appearing at smaller eccentricities (as found in a prior simulator study[3]), because larger scans would be needed for detection.

Evaluating responses to potential hazards in an open-road driving course provides the greatest real-world validity, but there are a number of challenges and limitations that have to be considered, not the least of which is the lack of control over when and if an unexpected hazard might occur.[5] By comparison, driving simulators offer safe, repeatable conditions in which the effects of HH can be systematically investigated.[3,8–13] However, simulations do not necessarily replicate all of the complexities of real-world situations. Simulator studies in the 1990s either did not include sufficient numbers of unexpected events for a robust analysis of blind-side detection,[9,10] or used detection targets that were not part of the simulated driving scene.[3,8]

More recent simulator studies[3,12,13] addressed some of these limitations, but still failed to replicate some aspects of real-world driving. For example, in the first paper in this series[3] a pedestrian detection paradigm was used in which the virtual pedestrian figures appeared abruptly and remained stationary. When they appeared they did not present an imminent collision risk and rapidly moved farther into peripheral vision as the vehicle approached. Blind-side miss rates were high, median 60%, compared with normally-sighted miss rates, median 0%.[3] A more realistic simulation was subsequently developed,[14] in which walking or running pedestrians approached the road on a collision course, maintaining a constant bearing angle with the participant's vehicle, thereby

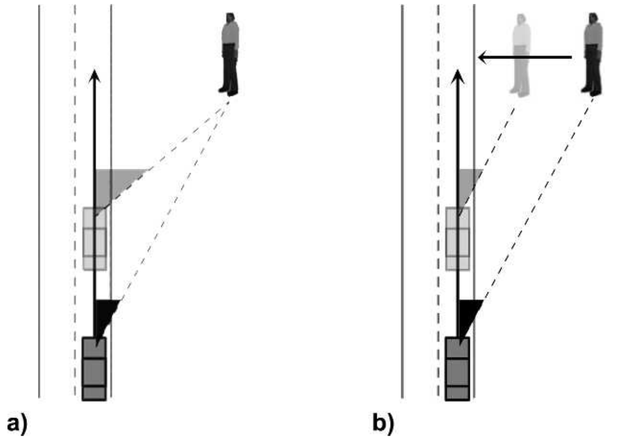

Figure 1. A schematic representation (not to scale) of the eccentricity of a pedestrian as the participant's vehicle advances. (**a**) A pedestrian stationary at the side of the travel lane; and (**b**) a pedestrian approaching the travel lane. In both cases, the pedestrian initially appears at the same eccentricity with respect to the vehicle (represented by the apical angle of the *black-filled triangle*). In (**a**) the eccentricity of the stationary pedestrian then increases rapidly as the car advances (the apical angle of the *grey-filled triangle* is larger than that of the *black-filled triangle*) while in (**b**) the eccentricity of the approaching pedestrian remains approximately constant (the apical angles of the *black* and *grey triangles* are similar).

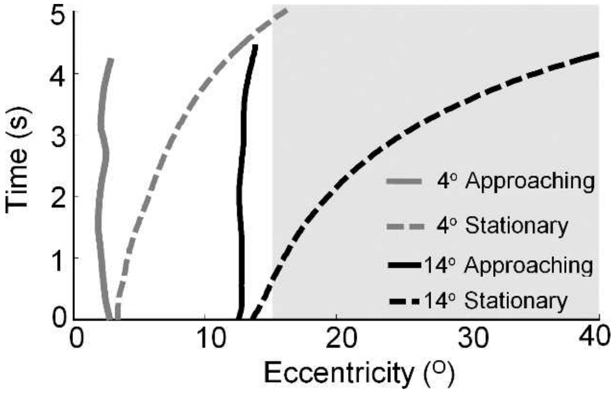

Figure 2. Measured eccentricity with respect to car heading direction (0°) from the time of appearance (0 seconds) for a pedestrian approaching the travel lane and a pedestrian stationary at the side of the travel lane. Data are from one participant with HH. Pedestrians started with an initial eccentricity at the time of appearance of approximately 4° ("small" eccentricity) or approximately 14° ("large" eccentricity). As the car advances, the eccentricity of the stationary pedestrian increases rapidly, especially at the large eccentricity, while that of the approaching pedestrian remains approximately constant, representing an impending collision. For a stationary pedestrian that appears on the blind side, the motion of the approaching car causes the pedestrian to go farther into the blind hemifield, requiring a larger saccade for detection. Similarly, a pedestrian on the seeing side will go farther into the seeing hemifield, but will still be visible in peripheral vision. For reference, eccentricities greater than the maximum amplitude (∼15°) of a typical saccade of a normally-sighted person are marked by the *shaded region*.

representing a real impending collision risk.[15] This approaching pedestrian paradigm has proven sensitive to detection deficits of drivers with paracentral homonymous visual field loss[11] and central field loss,[14] but has not previously been used to evaluate detection of drivers with complete HH.

Therefore, in this study we evaluated detection performance (miss rates and reaction times) of drivers with complete HH for stationary and approaching pedestrians initially appearing at small (4°) and large (14°) eccentricities. Our aim was to replicate the prior study that used only the stationary pedestrian paradigm[3] and compare with performance of the same participants in the more realistic approaching pedestrian paradigm.[14] Based on the prior study,[3] we anticipated that stationary pedestrians at the larger eccentricity would either be detected shortly after appearance or not detected at all, because pedestrian eccentricity would increase rapidly as the vehicle approached (Figs. 1, 2). Thus, stationary pedestrians appearing within the blind hemifield would quickly move farther into the periphery of that field making them more difficult to detect because even larger scans would be needed.[3] By comparison, in the approaching paradigm, pedestrians would maintain an approximately constant eccentricity[11,14] as the participant's vehicle advanced, keeping an overall smaller eccentricity for a longer period of time than stationary pedestrians (Figs. 1, 2). Thus, the time available for approaching pedestrians to be detected would be longer than for stationary pedestrians, especially at large eccentricities, with more time during which a scan might be sufficiently large for detection to occur. We tested the hypotheses that miss rates (failed detections) at larger eccentricities would be lower for the approaching than the stationary pedestrian paradigm, but that reaction times would be longer. By comparison, at smaller eccentricities, we expected that miss rates and reaction times would be more similar for the two paradigms. Even with the more realistic approaching pedestrian paradigm, we still expected that detection performance on the blind side would be worse (higher miss rates and longer reaction times) than on the seeing side.

METHODS

The study followed the tenets of the Declaration of Helsinki and was approved by the institutional review board at the Schepens Eye Research Institute. Voluntary, written informed consent was obtained from all participants after a full explanation of the study procedures.

Participants

Participants were recruited from neuro-ophthalmology clinics and rehabilitation centers within the Greater Boston area. Inclusion criteria were: complete HH, defined as no more than 7° horizontally of residual vision on the hemianopic side of the vertical meridian within 20° above and below fixation, as measured with a kinetic V4e target in a Goldmann perimeter; no visual neglect (Bells test and Schenkenberg line bisection test[16,17]); visual acuity of at least 20/40 in each eye with the habitual correction; previous driving experience (at least 1 year); and no physical impairments that could prevent the use of the standard vehicle controls (gas and brake pedals, steering wheel, and horn). Twenty-eight potential participants were screened, of which 12 met all the criteria and completed the study (the remaining 16 participants were excluded either because they had incomplete HH or neglect).

Apparatus

The driving simulator (LE-1500; FAAC Corp., Ann Arbor, MI) comprises five 42-in liquid crystal display (LCD) monitors (LG M4212C-BA, native resolution of 1366 × 768 pixels; LG Electronics, Seoul, South Korea), providing a 225° horizontal field of view. It has a motion seat with 3 degrees of freedom, a force-feedback steering wheel, and all the usual controls found in an automatic transmission car. The rear- and side-view mirrors are inset on the LCD monitors. The simulator runs a

1600 × 800 m virtual world. A scenario development toolbox was used to create events by programming the movement of pedestrians and vehicles based on the location of the participant's vehicle within the virtual world. Data were recorded at 30 Hz, including the location and status of all programmed objects and the driver's car in the virtual world.

Research Procedures

The study involved three visits. Compliance with inclusion criteria were verified at the first screening visit. The second and third visits were for driving simulator assessments. The two sessions (one with stationary and one with approaching pedestrians) were conducted on separate days, approximately 1 week apart. The order of the two conditions (stationary and approaching) was counterbalanced across participants. Each session lasted approximately 2.5 hours.

Each session started with a period of familiarization and practice in the driving simulator (approximately 30–45 minutes). All participants then completed five test drives (each approximately 10 minutes), in which they performed the pedestrian detection task while driving along predetermined routes guided by audio cues (similar to global positioning system [GPS] directions). To simulate realistic driving conditions there was other traffic on the road and the routes included a variety of maneuvers (such as turns and curve-taking) in city and rural environments.[3,18] Participants were instructed to obey all the normal rules of the road, to try to maintain the posted speed limit (30 mph for city roads and 60 mph for rural roads), and to press the large horn area (in the center of the steering wheel) whenever they saw a pedestrian figure.

Pedestrian Detection Task

Life-size pedestrian figures (2 m tall, with a white shirt and blue trousers) appeared at pseudorandom intervals (every 15–60 seconds) either on the right or left of the road at small (approximately 4°) or large (approximately 14°) eccentricities with respect to the car heading. They appeared at a distance of 67 m along city roads and 134 m along rural undivided highways. When driving at the posted speed limit, these distances were equivalent to 5 seconds, twice the 2.5-second perception-brake time used in the calculation of minimum recommended stopping sight distances for safe roadway design.[19] Pedestrians initially subtended 1.7° vertically in city drives and half that in rural highway drives. Small eccentricities (−4° and 4°) represented hazards approaching from an adjacent lane, or the sidewalk beside the participant's lane, while larger eccentricities (−14° and 14°) represented hazards approaching more quickly and from a greater distance (e.g., a jogger, a bicyclist, or a running animal).

After appearing, pedestrians either remained stationary in the initial position as the participant's car approached (stationary condition)[3] or walked/ran (exhibiting salient biological motion) toward the road, as if to cross the travel lane (approaching condition).[11,14] Approaching pedestrians always stopped before entering the participant's travel lane to avoid collisions; however, they were programmed such that if the car had continued at the posted speed limit and the pedestrian had not stopped before entering the travel lane, a collision would have occurred. The eccentricity of the approaching pedestrians under this condition was approximately constant with respect to the car heading for at least 3 seconds after appearance (Figs. 1, 2), providing the car was driven within ±10 mph of the speed limit; thus, the approaching pedestrians represented an impending collision.[15] By comparison, the eccentricity of stationary pedestrians increased rapidly as the car approached (Figs. 1, 2), reducing the likelihood of detection with time, and thus did not represent an imminent collision threat.

Data Analysis

Detection performance for 52 stationary and 52 approaching pedestrians that appeared on straight-road segments were analyzed. The main dependent variables were the proportion of misses (number of failed detections as a proportion of the total number of pedestrian events) and reaction times when detected (latency from pedestrian appearance to horn press).

Taking into consideration the reaction time, the speed of the car and the hypothetical braking time needed to bring the car to a stop, we categorized the response to each pedestrian appearance as either a missed detection (did not see), a late reaction, or a timely reaction. Braking time calculations took into consideration the distance from the pedestrian at the time of reaction (horn press) and assumed a braking deceleration of 5 m/s^2, representing a dry road and a car in good condition.[20] Late reactions were those situations where the reaction time was so long that there would have been insufficient time to stop if a braking reaction had started at the time of the horn press; timely reactions were those in which the driver detected a pedestrian with enough time to stop if necessary. Misses and late reactions together were collectively labeled as untimely reactions and represented potential collisions. For both stationary and approaching pedestrians, the virtual pedestrian did not actually enter the participant's travel lane; therefore, a hypothetical collision point was assumed at the intersection of the paths of the pedestrian and the participant's vehicle. For approaching pedestrians, the assumption was that the pedestrian would have continued into the travel lane, rather than stopping at the edge of the lane. For stationary pedestrians, the assumption was that the pedestrian would have moved on a course perpendicular to the driver's heading direction, at sufficient speed (depending on driver's speed) to cover the gap distance (which is always a possibility in the real world).

Three main within-subjects factors were considered in detection performance analyses: side (blind or seeing), eccentricity (small or large), and condition (approaching or stationary). Proportions of misses and untimely reactions were analyzed with the Wilcoxon Signed Rank test. Blind-side reaction time medians were normally distributed and analyzed with a repeated measures ANOVA with a 2 (blind–seeing side) × 2 (small–large eccentricity) × 2 (stationary–approaching) design. With the exception of the reaction time ANOVA, data from all 12 participants were included in analyses. Only 10 were included in this ANOVA as two had insufficient blind-side detections for median reaction times to be calculated (medians were only calculated when there were at least three detections). Parametric tests were used for continuous demographic variables that were normally distributed (age and years of driving experience); nonparametric were used for all other variables. The alpha level was 0.05 for all analyses.

RESULTS

Sample Characteristics

The sample varied widely in terms of age, time since onset of the lesion and driving experience (Table). Cerebrovascular accident was the main cause of the HH. Two of the 12 participants were current drivers, driving on average 82 miles per week. Eight had stopped driving following the onset of the HH and had last driven a median of 3 years (range, 0.5–6) before participating in the study. The remaining two had never

TABLE. Characteristics of the 12 Participants in This Study

Characteristic	Value
Female, *n* (%)	5 (42)
Age, y, mean (range)	39 (18–82)
Total years driving experience, mean (range)	20 (1–66)
Current driver, *n* (%)	2 (16)
Right HH, *n* (%)	6 (50)
Years since onset, median (range)	4.5 (0.5–31)
Hemianopia cause, *n* (%)	
Stroke	8 (67)
Tumor	3 (25)
Trauma	1 (8)

obtained a driving license, but had been driving regularly on private land for at least 1 year. Two participants had hemiparesis (one right and one left) but were able to steer the vehicle and press the horn button without any difficulties.

Missed Pedestrians

Overall, miss rates were significantly higher on the blind than the seeing side (medians: 22% vs. 0%, $P = 0.003$). This was true for the stationary condition at both the small (medians: 8% vs. 0%, $P = 0.01$) and the large eccentricity (54% vs. 0%, $P = 0.003$), and the approaching condition at both the small (9% vs. 0%, $P = 0.01$) and the large eccentricity (20% vs. 0%, $P = 0.005$). The effects of condition and eccentricity were further examined for the blind side only. Blind-side miss rates were significantly higher for the stationary than the approaching condition (29% vs. 16%, $P = 0.01$; Fig. 3), and were significantly higher at the large than the small eccentricity (stationary: 54% vs. 8%, $P = 0.002$; approaching: 20% vs. 9%; $P = 0.01$). However, as predicted, there was an interaction between eccentricity and condition: the proportion of blind-side misses was significantly lower in the approaching than the stationary condition at the large eccentricity (20% vs. 54%, $P = 0.005$), but not the small eccentricity (9% vs. 8%, $P = 0.59$; Fig. 3).

Reaction Times for Detected Pedestrians

Overall, reaction times were significantly longer on the blind than the seeing side (means: 1.99 vs. 1.15 seconds; $F(1,9) = 72.29$ $P < 0.001$), at the large than the small eccentricity (1.76 vs. 1.38 seconds; $F(1,9) = 12.43$, $P = 0.01$), and in the approaching than the stationary condition (1.72 vs. 1.41 seconds; $F(1,9) = 6.90$, $P = 0.03$). Reaction times to pedestrians on the blind side were significantly longer for the approaching than the stationary condition at the large eccentricity (2.82 vs. 1.80 seconds, $P = 0.02$; Fig. 4), but not the small eccentricity (1.82 vs. 1.51 seconds, $P = 0.16$). By comparison, on the seeing side, differences in reaction times between the two conditions were much smaller at both the large eccentricity (1.21 vs. 1.20 seconds, $P = 0.89$; Fig. 4) and the small eccentricity (1.06 vs. 1.14 seconds, $P = 0.02$). Furthermore, for the approaching condition (but not the stationary condition), reaction times were significantly longer at the large than the small eccentricity on both the blind and seeing sides (2.82 vs. 1.82 seconds, $P = 0.01$; and 1.21 vs. 1.06 seconds, $P = 0.008$, respectively; Fig. 4). This three-way, side-by-condition-by-eccentricity interaction was significant ($F[1,9] = 5.93$, $P = 0.04$). When data for only timely responses were considered, blind-side reaction times were still significantly longer in the approaching than the stationary condition at the large eccentricity (2.20 vs. 1.59 seconds, $P = 0.03$).

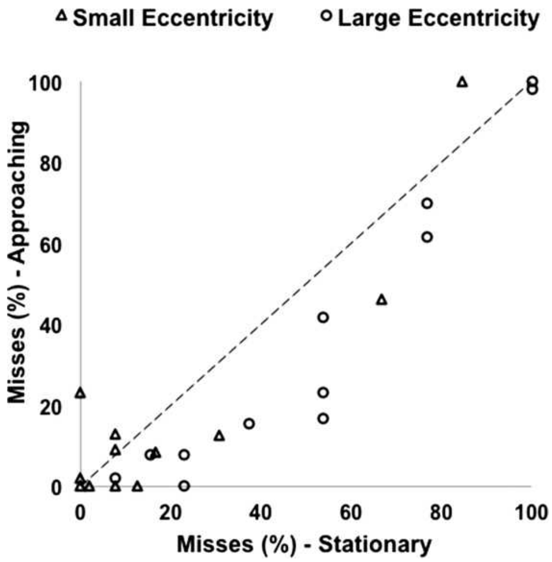

FIGURE 3. Proportion of blind-side misses for each participant in the approaching compared with the stationary condition. As predicted, at large eccentricities, miss rates were lower for approaching than stationary pedestrians (*open circles* all on or below the *diagonal*). By comparison, at small eccentricities, miss rates were similar for the two conditions (*open triangles* above, below, and on the *diagonal*).

Untimely Reactions (Potential Collisions)

Overall, the proportion of untimely reactions (combined missed and late responses) was significantly higher on the blind than the seeing side (medians: 34% vs. 3%, $P = 0.002$). This was true for the stationary condition at both the small (14% vs. 0%, $P = 0.01$) and large eccentricities (62% vs. 8%, $P = 0.002$), and the approaching condition at both small (15% vs. 0%, $P = 0.01$) and large eccentricities (50% vs. 4%, $P = 0.003$). However, the proportion of untimely blind-side reactions was not different between the approaching and stationary conditions for both the small (15% vs. 14%, respectively, $P = 1$) and large eccentricities (50% vs. 62%, $P = 0.47$; Fig. 5).

DISCUSSION

Participants with HH exhibited blind-side detection deficits in both the stationary and approaching pedestrian paradigms. Miss rates were significantly higher on the blind than the seeing side, and reaction times significantly longer. Approximately one in three blind-side responses were untimely (participants either did not see the pedestrian or would have been unable to stop in time to avoid a collision) compared with 1 in 30 on the seeing side. At the small 4° eccentricity, approximately one in six blind-side responses was untimely compared with approximately one in two at the large 14° eccentricity. Although a pedestrian at the small eccentricity represents a more imminent hazard (about to step off the curb) than a pedestrian at the larger eccentricity, drivers still need to be able to detect hazards at these larger, yet modest, eccentricities with sufficient time to be able to respond.

As predicted, miss rates were lower but reaction times longer for approaching than stationary pedestrians at the 14° eccentricity. Although approaching pedestrians were more likely to be detected at this eccentricity, their detection was often too late to avoid a collision, with the net result that the proportion of untimely reactions (potential collisions) was not significantly different for the two paradigms. Untimely reactions at the 14° eccentricity were mainly a result of late

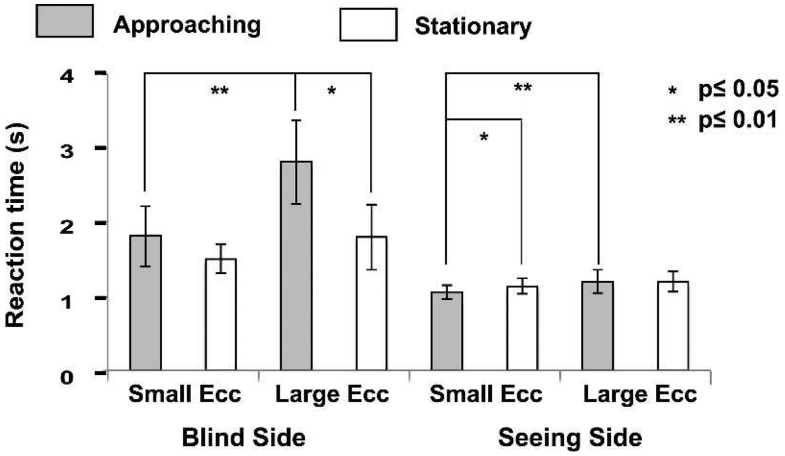

FIGURE 4. Mean reaction times in the approaching and stationary conditions for the small and large eccentricities on the blind and seeing sides. As predicted, at the large eccentricity on the blind side, reaction times were longer for the approaching than the stationary condition. *Error bars* represent the within-subjects 95% confidence limits.[21]

responses for approaching pedestrians, but failed detections for stationary pedestrians. For example, Figure 2 shows that the eccentricity of an approaching 14° pedestrian was likely to be within the range of a typical eye saccade (rarely greater than 15° in normally-sighted observers[22]) for approximately 4 seconds compared with only approximately 1 second for an approaching 14° pedestrian, providing more time for a sufficiently large scan to occur with a correspondingly longer response time. Our findings suggest that blind-side scans larger than a typical eye saccade were infrequent in most participants in this study when driving along straight road segments where pedestrians appeared.

Drivers with HH could scan to the blind side using only eye movements, or a combination of eye and head movements, especially when scanning far into the blind hemifield. However, in a small driving simulator study, head scans of HH drivers ($n = 2$) were relatively infrequent.[13] It might be expected that, on average, scan amplitudes to the blind side would be larger than those of normally-sighted observers. However, there is no guidance from peripheral vision as to when to scan or how far to scan. With the exception of one study that used observer-based ratings of scanning from video footage,[23] there is little data on eye and head scanning of people with HH in real world driving. However, recent simulator studies of people with HH suggest that fixation distributions and scan amplitudes were either similar to, or smaller than, those of normally-sighted participants in various attention-demanding virtual mobility tasks.[13,24-26] Similar results have also been reported for patients with moderate-to-severe peripheral field loss from retinitis pigmentosa in a naturalistic walking task.[27,28]

Other factors also need to be considered when accounting for the differences in the responses to the stationary and approaching pedestrians. Firstly, the perceived collision risk may have been different; however, we suggest that this was unlikely to affect responses as participants were instructed to press the horn button as soon as a pedestrian was detected. They were not required to make an evaluation of the risk associated with the situation or to discriminate between pedestrians that were potential collisions and those that were not. Secondly, in the seeing hemifield, approaching pedestrians might have been easier to detect than stationary pedestrians, because a moving object segregates from the background during simulated self-motion[29,30] and/or biological motion increases the feature salience of animations.[31] Indeed, reaction times were slightly, but significantly, shorter (by 0.08 seconds) for the approaching than the stationary pedestrians at the small eccentricity in the seeing hemifield. However, there was no difference in reaction times for seeing-side pedestrians in the two paradigms at the large eccentricity. It is unlikely that motion segregation or biological motion would have increased the salience of approaching relative to stationary pedestrians appearing in the blind hemifield as there was no peripheral vision on that side.

A control group of normally-sighted participants was not included in this study as our primary aim was to compare detection of blind-side pedestrians in the stationary and approaching paradigms for a cohort of drivers with HH. Nevertheless, an important question is the extent to which seeing-side detection performance of HH drivers differs from

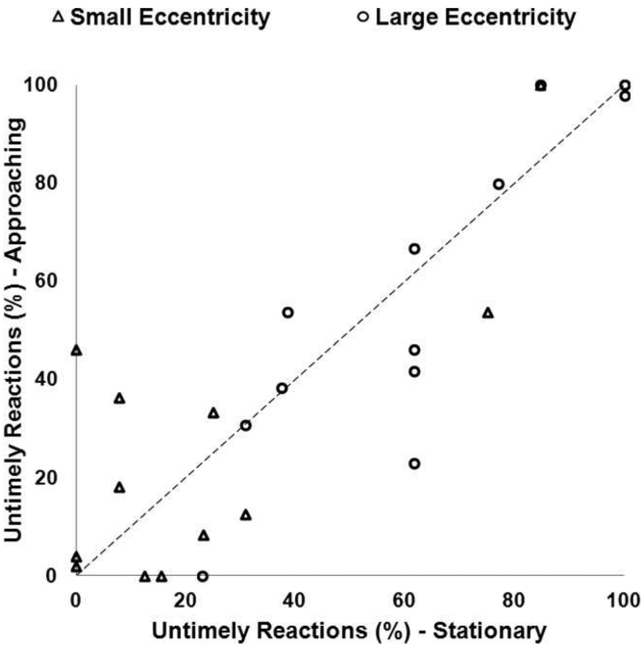

FIGURE 5. Proportion of blind-side untimely reactions for each participant in the approaching compared to the stationary condition. Proportions of untimely reactions were not different for the two conditions.

that of normally-sighted drivers. In this study, the HH drivers had seeing-side miss rates and reaction times that were, on average, either similar to or slightly worse than that of normally-sighted participants for the stationary[3] and approaching[14] paradigms in prior studies conducted in our labs.

Several recent studies have evaluated detection performance of people with HH in virtual mobility-related tasks.[3,12,13,24] However, only limited comparisons can be drawn as the experimental paradigms were very different. Nevertheless, the general trends in the data are similar to those found in the current study, with greater numbers of collisions or failed detections on the blind than the seeing side, and seeing-side performance that was similar to or slightly worse than that of controls. The relationship between detection performance in virtual mobility tasks and real world situations has not been established for the current study or any other simulator study.[3,12,13,24] However, there is evidence that some drivers with HH do demonstrate detection deficits in real world driving. In an on-road study, conducted on busy city-center streets with many opportunities for potential hazards to appear, approximately 60% of interventions by the driving examiner were for failures to notice other traffic and pedestrians.[5]

In agreement with prior simulator studies,[3,8,12] participants in this study demonstrated widely differing abilities to compensate for their hemifield loss with miss rates ranging from 0 to 100%. Yet they all had very similar levels of visual field loss and were screened to exclude significant neglect or cognitive decline. This study was not designed to evaluate predictors of detection performance; nevertheless, we did include a secondary analysis of factors that might affect blind-side detection performance (see Supplementary Material). Age was the best predictor of blind-side miss rates, but accounted for only 20% of the variance. Older age has also been associated with poorer performance in prior studies involving attention-demanding detection and collision avoidance virtual mobility tasks,[3,9,12] and with more pronounced visual exploration impairment.[32]

In summary, we replicated the findings for the stationary pedestrian detection paradigm reported in the first study in this series[3] (see Supplementary Material), doubling the number of subjects. We also extended our evaluation to a more realistic task with approaching pedestrian figures that walked or ran with biological motion and represented potential collision hazards. However, even using this more realistic paradigm, the majority of participants still had blind-side detection deficits (missed detections or delayed responses) that could potentially result in a collision in real world driving. Our findings emphasize the need to consider blind-side detection performance when assessing fitness to drive of patients with HH and to provide individualized evaluations. A standardized test in a driving simulator including detection of potential approaching hazards may be a useful adjunct or precursor to a road test, providing controlled, repeatable conditions with many opportunities to evaluate blind- and seeing-side detection performance.

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