DRIVING HAZARD DETECTION WITH A BIOPTIC TELESCOPE

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Summary: Driving by visually impaired people using bioptic telescopes is permitted in 43 states, yet their use remains controversial. One of the concerns is that the ring scotoma (blind area caused by the telescope magnification) may block the field-of-view, impacting detection of potential hazards when looking through the telescope. We evaluated the ability of the non-telescope eye to detect hazards in the field-of-view covered by the ring scotoma. Three participants watched a series of 54 real world driving videos that included 45 potential hazardous events and pressed a button as soon as a hazard was detected, in three conditions: just watching the videos, and while performing a reading task without or with a bioptic telescope. Results showed that all participants had either reduced detection rates or increased reaction times to hazards when performing the reading task with a bioptic telescope. These preliminary results suggest that attention demanding tasks and viewing through the telescope might impair hazard detection ability. Additional study is needed to fully understand the safety of bioptic driving.

BACKGROUND AND OBJECTIVES

Bioptic telescopes are small, spectacle mounted telescopes that enable drivers with vision impairments to see details of distant objects such as road signs and traffic lights (Bowers, Apfelbaum & Peli, 2005). Forty-three states in the US permit the use of bioptic telescopes for driving by people with reduced visual acuity (Owsley, 2012). For instance, a person with a visual acuity of 20/200 may legally drive with a bioptic in New Hampshire. When viewing through the telescope, the magnification creates a ring scotoma or blind area around the region magnified which could impair detection of important events (Peli & Vargas-Martin, 2008). This raises a concern about the safety of bioptic driving.

Scientific evidence supporting or disputing the safety of bioptic driving is far from sufficient, and as a result the requirements for licensure with a bioptic vary widely between states (Peli, 2002; Peli & Peli, 2002). Some have expressed concerns that the driver becomes blind to traffic when viewing through the telescope (Fonda, 1983; Keeney, 1974). Indeed if using a binocular telescope, the ring scotoma would be expected to impair detection. However, with monocular fitting as required in many states and widely practiced (95% of participants in a bioptic questionnaire drove with a monocular bioptic),(Bowers et al., 2005) the fellow (non-telescope) eye could potentially detect hazards lost to the ring scotoma of the telescope eye. This had been demonstrated with conventional perimetry (Lippmann, Corn & Lewis, 1988), and in recent studies we found that bioptic users are able to detect targets in the ring scotoma area also on more visually complex backgrounds (Doherty et al., 2013, 2011). Our prior studies used checkerboard high contrast targets on a spatial noise (static) background and had participants

view continuously through the bioptic. The present study extends our previous work to more realistic driving scenes with motion and the detection of real traffic hazards.

The UK and some states in Australia require drivers to pass a hazard perception test to obtain a license (https://www.gov.uk/driving-theory-test). This test has participants watch driving scenes and respond when they see potential hazards appear. A driver passes the test by scoring a required number of points (44 out of a possible 75), based on timely detection of hazards. We used similar hazard perception materials to create more realistic stimuli and situations to evaluate the ability of bioptic users to detect hazards in the ring scotoma area. Here we present preliminary results obtained for 3 bioptic users.

METHODS

The study was approved by the institutional review board and was conducted according to the tenets of the Declaration of Helsinki.

Procedure

Single letter visual acuity with and without bioptic (using Test Chart 2000 Pro, Thomson Software Solutions, Herts, England) and binocular contrast sensitivity were measured. Participants watched a short, two minute video clip introducing the concept of hazard perception and indicators of upcoming hazards. After a practice session, participants completed the 3 conditions in a counterbalanced order. In one condition they pressed a response button as soon as they detected a potential hazard. In the other two conditions they performed a reading-like task at pseudo random times (that may or may not overlap with a hazard) throughout the video in addition to responding to hazards. The reading task was performed in one condition through the bioptic telescope and in another without the telescope. Table 1 describes participant vision characteristics and bioptic use.

Videos

Video clips were extracted from a commercially available DVD (Driving Test Success Hazard Perception: Imagitech Ltd, Swansea, UK) designed to prepare drivers for the hazard perception portion of the UK licensure test. Only videos with pedestrian or vehicle hazards in daylight conditions were used. Most videos were in city centers with a few videos on the highway and on country roads. Videos were mirrored using Adobe Premiere so that cars appear to drive on the right side of the road. A total of 54 videos were used; 18 video clips in each group. Fifteen of the 18 videos in each group included a hazard. All clips were different; each approximately one minute long. Each participant saw a different combination of video group and test condition.

Hazards

Hazards were defined as pedestrians or vehicles that would cause the driver to change speed, course, or direction. Hazards could appear anywhere in the scene and at random times throughout the duration of the clip.

Reading-like Task

One or two sequences of single characters appeared during each clip. The sequences were numeric, except for one or two letters that could occur during a sequence. The participant was tasked with calling out each letter when a letter appeared within the numeric sequence. The size of the black characters was at least 4x each participant's visual acuity. They appeared on a white square background with an easily identifiable red border, and the characters changed every 320ms. With the bioptic telescope, participants A and C saw 0.5° high characters and participant B saw 0.8° high characters. Without the bioptic participants A and C saw 1.2° high characters and participant B saw 1.8° high characters. A custom MATLAB program was used to randomize the time of letters appearance within the block, with the constraints that the first letter appeared sometime after 1 sec, the second letter (if present) within the last 2 seconds and a minimum of 960ms between letters. Each video contained 1 or 2 blocks of numbers/letters for the participant to read. The MATLAB program randomized the time of blocks within the video clips with the following constraints: start a minimum of 5 seconds after the start of the clip, a minimum of 5 seconds between blocks, at least 5 seconds after the last block so that the block does not appear at the very end of the clip. Blocks were of the same duration as the hazard when coincident with a hazard appearance (50% of the time). For blocks without hazards, average block duration was 5.7s with a standard deviation of 1.7s (the average and standard deviation of hazard durations).

The blocks of characters were placed within the scene in such a position that the hazard fell into the ring scotoma area if the telescope was centered on the letter (Figure 1). The MATLAB program randomly chose 1 of 8 directions 15° from the center of the hazard area for presenting the letters. Hazard areas subtended an average of 13° (standard deviation 8°) horizontally and 10° (standard deviation 4.5°) vertically.

Figure 1. Illustration of a hazard situation in one video. Letters to be read through the bioptic were placed in such a place that hazards (the intruding car) fell in the ring scotoma area (gray shaded area) of the telescope eye. The ring scotoma area remains visible to the other eye

Data Analysis

Detection rates and reaction times were calculated based on the hazard appearance time (taken from the DVD) and the participant response time. The score test (Newcombe, 1998) was used to compare detection rates between conditions, and nonparametric (Mann-Whitney) test used to

compare reaction times between conditions for each participant. The UK scoring method was also used: the time window for each hazard was divided into 5 equal-length segments. A maximum of 5 points were given for each hazard with the number of points scored dependent on the participant response time. Earlier responses received higher scores.

Table 1. Participant Characteristics

Participant	Age (years)	Telescope Eye Visual Acuity Without Bioptic	Fellow Eye Visual Acuity Without Bioptic	Visual Acuity With Bioptic	Contrast Sensitivity (log units)	Length of time with bioptic	Frequency using bioptic
A	22	20/96	20/76	20/30	1.7	2 months	Biweekly
B	84	20/83	20/145	20/38	1.38	16 years	Biweekly
C	43	20/63	20/126	20/28	1.78	8 years	Daily

RESULTS

We report here preliminary data obtained from 3 bioptic users, two males and one female. Detection rate for the 3 normally sighted (NS) observers with no reading task ranged from 47% to 97%. Figure 2 shows detection rates and Figure 3 shows reaction times for each participant. Detection rate for participant C was significantly lower in the reading task with the bioptic compared to no reading task ($p = 0.005$). Reaction times for participants A and B were significantly longer in the reading task with the bioptic compared to no reading task ($p < 0.049$). If the ring scotoma is a cause for missed or delayed detection, the effect should appear when comparing between the with- and without-bioptic conditions. Participant A (the least experienced) showed no significant difference in detection rate ($p= 0.161$) or reaction time ($p= 0.185$) between the with- and without-bioptic reading task conditions. Participant B had no difference in detection rate between the two reading task conditions ($p=0.345$); however, had significantly longer reaction time with the bioptic ($p=0.043$). The difference in detection rate between with- and without-bioptic reading task conditions for participant C approached significance ($p=0.069$) and there was no significant difference in reaction time ($p= 0.147$).

The effect of attention should be apparent by the difference between no reading task and the reading task without the bioptic. Participant A had lower detection rate with no reading task, however the difference was not significant ($p= 0.077$). Reaction time was longer with the reading task without the bioptic than no reading task, however the difference was not significant ($p= 0.373$). Participant B had significantly lower detection rate with the reading task without the bioptic ($p= 0.047$) though no significant difference in reaction time ($p= 0.209$). Participant C had lower detection rate with the reading task however the difference was not significant ($p= 0.116$, and there was no significant difference in reaction time ($p=0.277$).

Table 2 shows performance for each participant computed using the UK scoring method. All participants scored below the 44 point passing mark in all conditions. Performance declined with use of the bioptic. Table 2 also includes hazard detection scores under the no reading task condition (same as the way tested in UK) for 3 normally sighted people who have an active driving license. Only one of them scored above 44 point passing mark.

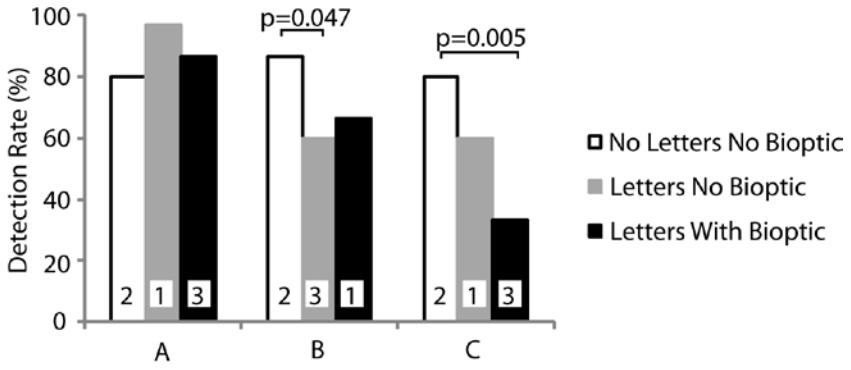

Figure 2. Detection rates for 3 bioptic users. Participant C showed significantly lower detection rate in the reading task with the bioptic than no reading task, however the reduction in detection rate in the reading task with and without the bioptic only approached significance. Participant B showed significantly lower detection rate in the reading task without the bioptic than no reading task. The numbers in the bars represent the test order

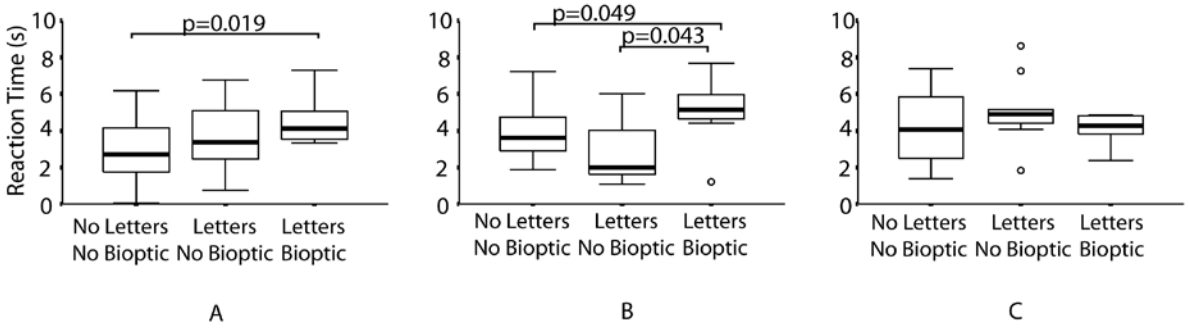

Figure 3. Reaction times for 3 bioptic users. In the two reading conditions, only participant B showed increased reaction time to hazards with the bioptic. The thick black horizontal line within each box is the median, the vertical extent of the box is the interquartile range (IQR); the vertical lines at the box ends represent the largest deviating non-outlier data points, open circles are outliers

Table 2. Performance computed based on UK scoring method (# out of 75 points)

Participant	No Letters No Bioptic	Letters No Bioptic	Letters Bioptic
A	35	34	20
B	26	24	15
C	24	13	6
NS1	14		
NS2	50		
NS3	34		

DISCUSSION

Our preliminary data suggests that bioptic users are able to detect realistic hazards in the peripheral field when performing a reading task using the bioptic telescope. However, 2 of the 3 bioptic users showed significantly increased reaction times using the bioptic telescope compared to not performing a secondary task and the other showed a significant reduction in detection rate. To disentangle the effect of the bioptic telescope from the secondary reading task, we also tested a reading-like attention demanding condition without the bioptic. The ring scotoma might have

impacted performance for participant B who had longer reaction time with the bioptic. Performance with the bioptic was reduced for the other 2 participants (lower detection rate for participant C and longer reacting time for participant A), however the difference was not significant. Note that the roughly 6 second long reading task in our study is much longer than the recommended glance duration (1 to 2 seconds) through the telescope. Our task also might be considered more demanding when compared to just spotting a road sign or a traffic light. Our previous pilot natural driving recording also showed that bioptic drivers look through the telescope for approximately 1 second (Luo & Peli, 2011). The effect of the bioptic found in our experiment may, therefore, overestimate the impact in real world driving.

It is known that detection performance is reduced with the addition of a secondary task (Chaparro, Wood & Carberry, 2005). While reading through the telescope seemed to reduce hazard detection performance, as discussed above, an effect of the secondary reading task without the telescope on performance was found for only 1 participant. Participant B had significantly reduced detection rate in the reading task without the bioptic compared to no reading task (Figure 2), but his reaction time was also faster in the reading task (Figure 3). For participants A and C, the differences in detection rate and reaction time were all insignificant. Taken together, it might be suggested that the increased attentional load associated with reading through the telescope may impair performance, as a result of the rivalrous suppression caused by two different images in both eyes.

It is of note that none of the participants detected all hazards when watching videos without the reading task or bioptic telescope. Hazards were generally large (average 13° x 10°) and should be easily visible even with reduced visual acuity. However, unlike our previous study, this task involved perception (and recognition) of hazards and not a simple detection task. Though hazards were in general defined as pedestrians or vehicles that would cause the driver to slow down or change direction, individual participants may judge differently at what point a situation would be considered a hazard.

Under the UK testing and scoring paradigm (no reading task or bioptic use), 5 out of 6 participants, including 2 out of 3 normally sighted, scored below the 44 point passing mark. We believe that this is mainly because this type of testing is unfamiliar to them. In the UK, people need to receive training in order to pass the test. The video clips used in this study are produced for the training program. However, our participants received only a brief practice session. Therefore, the low scores of bioptic users do not necessarily suggest they would not qualify for license in the UK. Data collected in calibration and creation of the UK hazard perception tests was used to help establish the passing mark(Grayson & Sexton, 2002), however, we do not know the specific criteria used in setting the passing mark at 44 points.

This preliminary data extends previous work by evaluating detection of potential hazards in real world driving videos. Performance for all 3 bioptic users declined with the addition of a reading task and bioptic telescope suggesting that for some bioptic users the bioptic may impair hazard detection. Order effects cannot be reliably evaluated with only 3 subjects. With the completion of this study currently enrolling more subjects we expect to have a better understanding of the impact of the ring scotoma on hazard detection and thus on the safety of bioptic driving.

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