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Influence of presbyopic corrections on driving-related eye & head movements

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Purpose

To investigate whether wearing different presbyopic vision corrections alters the pattern of eye and head movements when viewing and responding to driving-related traffic scenes.

Methods

Participants included 20 presbyopes (mean age: 56.1 ± 5.7 years) who had no experience of wearing presbyopic vision corrections, apart from single vision reading spectacles. Each participant wore five different vision corrections: distance single vision lenses (SV), progressive addition spectacle lenses (PAL), bifocal spectacle lenses (BIF), monovision (MV) and multifocal contact lenses (MTF CL). For each visual condition, participants were required to view videotape recordings of traffic scenes, track a reference vehicle and identify a series of peripherally presented targets. Digital numerical display panels were also included as near visual stimuli (simulating the visual displays of a vehicle speedometer and radio). Eye and head movements were measured and the accuracy of target recognition was also recorded.

Results

The path length of eye movements while viewing and responding to driving-related traffic scenes was significantly longer when wearing BIF and PAL than MV and MTF CL (both $p \leq 0.013$). The path length of head movements was greater with SV, BIF and PAL than MV and MTF CL (all $p<0.001$). Target recognition and brake response times were not significantly affected by vision correction, while target recognition was less accurate when the near stimulus was located at eccentricities inferiorly and to the left, rather than directly below the primary position of gaze (all $p=0.008$), regardless of vision correction.

Conclusions

Different presbyopic vision corrections alter eye and head movement patterns. The longer path length of eye and head movements and greater number of saccades associated with the spectacle presbyopic corrections, may affect some aspects of driving performance.

Key words: Eye and head movements; driving; presbyopic vision correction; progressive addition lens; bifocal spectacles; monovision; multifocal contact

lens.

Text

Most developed countries across the world are experiencing a rapid and disproportionate growth in the number of older adults, leading to an increasingly aged population.[1] With increasing age, visual functions such as visual acuity (VA),[2] contrast sensitivity,[2, 3] stereopsis[2] and visual field sensitivity[4] are impaired. These visual changes may be relevant to the driving safety of the elderly population, given that it is estimated that vision is used to acquire more than 90% of the information required for driving.[5]

In addition to these visual function changes, presbyopia affects individuals from the age of 40-45 years, resulting in difficulty in accurately focusing on near objects.[6] A range of optical aids are available to provide clear near vision for presbyopes. Spectacle options include bifocal spectacle lenses (BIF), progressive addition lenses (PAL), while contact lens options include monovision (MV) and multifocal contact lenses (MTF CL). Each type of vision correction has different optical characteristics aimed at providing functional near vision in addition to providing clear distance vision.

While presbyopic corrections are designed to improve visual performance, they can also affect the eye and head movement patterns of wearers. Han et al[7] found that horizontal and vertical head movements were greater with PAL and reading eye movement parameters such as reading rate, number of saccades and fixation was significantly worse with PAL than with single vision lenses (SV). Progressive addition lenses also resulted in a slowing of eye movement velocities and longer times to stabilize the gaze for fixation than did SV.[7, 8] When BIF were worn for reading small-sized print, head movements were smaller compared to those recorded with PAL.[9]

These changes in eye and head movement patterns are likely to have implications for driving safety, given that the visual tasks for driving include a range of dynamic search tasks. Eye and head movements are important for monitoring of the forward traffic scene in order to avoid potential hazards, allowing the driver to obtain information from their visual field that is useful to driving.[10] In addition, detection and recognition of specific traffic signs requires a combination of both eye and head movements to maintain sufficient stability of the retinal image. This is assisted through the vestibular-ocular reflex (VOR) which generates eye movements in the opposite direction to head movements, thus maintaining the image on the fovea. It has been suggested that some optical aids may interfere with the operation of VOR, for example, PAL wearers may compensate by using fewer eye movements and more head movements.[11] Steering performance is also believed to be highly related to eye movements.[12]

In this study we aimed to investigate the influence of different presbyopic corrections on driving-related eye and head movements. A range of approaches have been used in previous studies to investigate driving performance. These have included driving simulators,[13, 14] open-road assessments[15, 16] and closed-road circuit assessments,[17, 18] each with their own advantages and disadvantages in terms of validity, accessibility and convenience. For the purposes of this study, we selected a laboratory-based driving simulator which allowed us to track the eye and head movements of participants while they viewed and responded to projected video images of real traffic scenes on a wide screen. The tracking quality of eye and head movements in this environment was high because vibrations and lighting conditions can be controlled and stabilised to an extent that is not possible under real world driving conditions. However, it is acknowledged that simulators do not necessarily represent all aspects of real world driving, particularly the environmental lighting conditions and level of risk involved. However, despite these drawbacks, simulators have been widely used because of their advantages of control of weather, lighting and different road traffic conditions, and because they are economical to run.[13, 19]

Eye and head movements were measured when wearing different presbyopic corrections, while viewing and responding to dynamic moving stimuli composed of video recordings of real traffic scenes and simulated in-vehicle devices (radio and speedometer). In addition, suburban road and freeway conditions were examined to reflect the variety of driving conditions encountered by drivers. Day and night-time video recordings were also used as there have been reports of poorer visual performance for presbyopic contact lens wearers at night due to haloes and ghosting.[20, 21]

METHODS

Participants

Twenty two individuals were recruited to participate in this study, however, two participants were unable to complete the experimental sessions because they reported sensations of motion sickness when watching the videotape recordings of dynamic traffic scenes. The age range of the 20 participants for whom complete data were collected was between 47 and 67 years (mean age of 56.1 ± 5.7). All participants were screened for their suitability to participate in the study by clinical examination and none of the participants had previously worn contact lenses. Inclusion criteria were (1) no previous experience of wearing any types of presbyopic vision correction except for single vision reading spectacles, (2) no ocular pathology such as cataract, glaucoma or age-related maculopathy which might influence driving performance,[22] (3) no head or neck mobility problems, (4) holding a valid driver's licence, (5) aged 45 to 70 years, (6) best sphere refractive error within the range of ±1.00D with less than -0.75D of astigmatism, (7) unaided visual acuity better than 20/30 in each eye and (8) no visual field defects as assessed using the 76-point suprathreshold visual field test (Humphrey Field Analyzer). Informed consent was obtained from all participants and the research protocol was approved by the Queensland University of Technology, Human Research Ethics Committee.

Presbyopic vision corrections

The study involved a repeated measures design using five different visual optical corrections; SV, PAL, BIF, MV and MTF CL. Participants were required to view videotape recordings of dynamic traffic scenes, to identify peripherally presented targets and to report numbers presented on two simulated in-vehicle devices (radio and speedometer). They were allowed to move their eyes and head freely while their head and eye movements were recorded. Eye and head movements were compared across vision corrections.

As five visual corrections were assessed for each participant, it was not feasible to make individual prescriptions for each participant. Instead, plano lenses were prescribed for distance viewing and a +2.50 D addition was prescribed for near for all participants (note that participants were selected to have best sphere refractive error < ± 1D). All spectacle lenses were mounted in the frames provided with the “Essilor Presbyte demonstration kit”. As every individual had a slightly different interpupillary distance and optical centre height, the use of the frame from the demonstration kit allowed these two variables to be easily adjusted for each participant.

While it is acknowledged that the optical corrections were not optimal for all participants, group mean vision measured for the participants with the presbyopic vision corrections used in the study was $20/20^{-3}$ ± 2 letters (0.06 logMAR ± 0.04) for the MTF CL, $20/20^{-1}$ ± 1.5 letters (0.02 logMAR ± 0.03) for the MV CL and $20/20^{-1}$ ± 1.5 letters (0.02 logMAR ± 0.03) for the spectacles. The vision of all participants met driver licensing standards of 20/40 when wearing all of the presbyopic corrections.

Given that the maximum viewing distance of each participant to the screen was 2 m and the smallest target size was 2 cm, the minimum acuity required to discriminate the peripheral targets in the driving videotapes was $20/125^{-1}$ (0.82 logMAR), so all targets were above threshold for all participants for all viewing conditions.

A 28 mm diameter flat top design bifocal lens was used for the BIF condition. For the PAL lens condition we used a commonly used design, which is reported to have an intermediate corridor width of 3.5 mm when the near addition reaches +1.25D,[23] (for a typical +2.00 near addition) with the width of the distance zone being approximately 10.5 mm at the level of the fitting cross.

For the MV condition, a disposable soft contact lens was used. The dominant eye was fitted with a plano contact lens for distance vision and the non-dominant eye with the near prescription (+2.50 D), following the conventional approach for prescribing monovision.[24] Eye dominance was determined by the directional dominance (sighting test), where participants were asked to extend their arms and form a small hole with both hands and binocularly centre a distance target in that hole.[25]

The MTF CL selected was a simultaneous vision multifocal contact design with a plano power for distance and an addition for near which is the spherical equivalent of the near spectacle prescription. This design has an aspheric center-near design, where the maximum plus power is in the centre of the lens, progressing to more minus in the periphery.

During the contact lens assessments, 15 minutes of settling time was allowed before commencing the driving-related assessment and new lenses were used for each participant.

Distance targets

Participants were required to view videotape footage of real, moving traffic scenes projected onto a screen. The reason for using real moving traffic scenes rather than abstract moving patterns was to create a realistic dynamic driving environment including retinal flow,[26] where the eye and head fixations reflect those made in the real world. To further enhance the realism of the visual simulation, the participant was also provided with a brake pedal and steering wheel from a gaming set. Participants were asked to press the brake pedal when the brake lights of the reference car were applied to maintain their concentration on the reference car; braking reaction times were recorded for each vision correction condition.

The video recordings were made using a digital camcorder (DCR-TRV 30E PAL, SONY) mounted on the roof of a research vehicle (1998 Nissan Maxima). Day and night-time (headlamps on low beam) recordings of real traffic scenes were made of the same routes in a local suburban road and on a freeway. Although the traffic conditions during day and night-time were different, the same route was followed and the same peripheral targets were selected. The video recordings were made while following another car which was a white station wagon (Holden Commodore), defined here as the reference car, which the participants had to track throughout the experimental procedures. This approach of using a reference car has been used in previous studies. For example, Roge et al[14] incorporated a “car-following” task in a simulator, where participants focused on the back window of a leading car and were required to detect colour changes in a luminous signal presented in the visual field. In this study, the reference car served as a uniform start and end point for all eye and head movement measurements to maximise comparability of visual tasks across participants. The video recordings of the traffic scenes were edited into approximately 1.5 minutes long sequences using computer software (Adobe Premiere Pro V2.0) based on the frequency of road signs present in the footage and other targets-of-interest such as traffic lights and pedestrians. Yellow rings (of diameter 15cm subtending a visual angle of 4.3°) were superimposed on sections of the video footage to highlight objects which were important to driving safety (i.e. speed and stop signs), and served as dynamic peripheral targets which participants were required to identify. The yellow rings were presented for 1.6 seconds as it has been reported that drivers do not usually look away from the road ahead for more than an average of 1.6 seconds.[27] The number of signs in the suburban and freeway footage which could be highlighted in each 1.5 minute clip was slightly different (five targets for suburban and seven targets for freeway). Out of these targets, four different peripheral targets that were presented more than 15° from the reference car in each video recording were selected.[28] The remaining targets (one in the suburban videorecording and two in the freeway videorecording) were located less than 15° from the reference car and served to maintain participant attention.

In total, four sets of video recordings were made with the following combinations (day-suburban, night-suburban, day-freeway, night-freeway). In addition, a one minute video sequence was created to instruct the participants and provide a practice run for participants.

In summary, the participant was instructed to fixate and track the reference car, and to report the type/identity of the traffic signs along the road side (e.g. stop sign or speed limit), defined here as the peripheral targets (encircled by the yellow ring), when they appeared in the video recordings. Reaction times in response to the onset of the brake lights of the reference car were measured by calculating the time between the onset of the brake light of the reference car on the video recordings and activation of a light-emitting-diode (LED) connected to the brake pedal and pressed by the participants.

Near targets

Two digital numeric display panels (alphanumeric dot matrix liquid crystal display module, Electus distribution Pty Ltd, Australia) were created as near targets to simulate the numbers on a radio and speedometer in a vehicle. The visual display area of the module was 65 (width) x 16 (height) mm and the character size of each number was 2.78 (W) x 4.89 (H) mm (which reflects the character size of the odometer in our research vehicle of approximately 3 (W) x 5 (H) mm) corresponding to a visual angle of 0.2 x 0.3 degrees, with a 5:1 luminance ratio (i.e. number to background). The digital numeric display panel was then programmed to present a series of two or three random numbers for 1.6 sec duration. One panel was placed in the typical location of the speedometer (22 degrees downwards with the assumption that the eyes were 120 cm above ground level) and located behind the steering wheel so that it was viewed through the gap in the steering wheel, thereby enhancing the realism of the speedometer simulation. The other panel was placed in the typical location of a radio, in the centre panel (37 degrees down and 48 degrees to the left from the eye position of a right-hand drive car) (Fig. 1). The digital numeric display panels were each activated twice (i.e. four times in total) during each video clip and this was accompanied by a computer-generated voice saying either “radio” or “speedometer” to prompt the participant to view the relevant near target. The participant’s task was to view the appropriate display panel and report the number presented. We intended to measure eye and head movements for this task but this was not feasible, as the participants’ eye and head movements were frequently beyond the measurement range of the recording instrumentation.

Laboratory set-up and procedures

The participants were seated 2 m away from the screen on which the video footage was presented by digital projector (NEC, VT540G, Japan) placed 1.4 m behind the participant (Fig. 1). Screen dimensions were 2 m horizontal and 1.3 m vertical, subtending a horizontal visual angle of 52° and a vertical angle of 36° at the participant. Instructions regarding the tasks were given to each participant and a practice video recording was viewed to allow familiarization with the tasks. The order of wearing the presbyopic vision corrections and type of video footage (night, day, suburban, freeway) was randomly assigned for each participant to minimize order and learning effects. When a daytime video recording was viewed, the laboratory overhead light was turned on giving a room illuminance of 236 lux. During night-time recording viewing, the same light was turned off giving a room illuminance of 1.3 lux (Topcon IM-2D photometer, Japan). These lighting conditions were used to simulate as closely as possible those pupil sizes encountered when driving under day and night-time conditions. Mean pupil sizes of all participants under day and night-time simulated driving conditions were 3.8 ± 0.8 (SD) mm and 5.1 ± 0.7 (SD) mm respectively, which are similar to those reported by Hough[29] for a similar age group for day and night conditions.

Figure 1 to appear here.

Recording of eye and head movements

Eye and head movements were recorded using the faceLAB® V4.5 system at a rate of 60Hz (Seeing Machines Pty Ltd, Lyneham, ACT).[30, 31] This system consists of a pair of cameras (Sony FCB-EX480B) for eye and head tracking and a SceneCamera (1/4" Charged-Coupled Device (CCD) camera) to record the front viewing scenes.

The cameras were positioned approximately 70cm from the participants with 20cm separation to view the participant’s face from different angles. The participant’s face was illuminated by two sets of lighting pods (emitting infrared radiation) and the system captured the details of the participant’s face using templates on the basis of luminance contrast (i.e. edge of lips, eyes or other features such as black dots which were drawn on participant’s faces to improve tracking). Head tracking was achieved by the system finding the relative position of these templates and facial features and calculating head position. For eye tracking, the system tracks the iris and/or the pupil, depending on which anatomical feature provides the best contrast. By combining the information of eye tracking with head position, the eye direction was determined.

The SceneCamera records the scene which the person is viewing. The eye and head position data generated by the faceLAB® is then overlayed onto the recorded scene from the SceneCamera and data is produced in x, y coordinate format (Fig. 2). Typical static accuracy provided by the manufacturer (under ideal conditions) is ± 1° of rotational error for head tracking, and ± 5° rotational error for eye tracking, when there are no head movements. The faceLAB® system generated a tracking confidence level, which indicated how well eye position was being tracked, with the four levels of confidence from 3 (highest) to 0 (lowest); only data having the two highest confidence levels (2 and 3) were used for analysis.

Figure 2 to appear here.

Analysis

There were five primary outcome measures derived in the analysis.

1. Path length of eye and head movements for distance peripheral targets,
2. Number of saccades made for distance peripheral targets,
3. Percentage of distance peripheral targets (encircled by the yellow ring) correctly recognized,
4. Percentage of near targets (radio and speedometer numbers) correctly recognized, and
5. Braking reaction times.

The path length of eye and head movements when searching and naming the peripheral targets encircled by yellow rings was calculated by summation of the distances between the individual x, y coordinates data generated sequentially by the faceLAB® system. The data for analysis were extracted from a time period commencing 0.5 seconds before the yellow rings (highlighting the distance peripheral target) appeared and ending 0.5 seconds after they disappeared. Thus, a total of 2.6 seconds of data (as the yellow rings were displayed for 1.6 seconds), were analysed for each stimulus using separate repeated measures ANOVAs.

The number of saccadic eye movements were counted using an automatic saccadic detection algorithm (proprietary to faceLAB®) based on a difference in gaze rotation angle between two successive frames.

The number of distance peripheral targets correctly recognized was counted and converted into a percentage correct value. In addition, the number of near targets correctly recognized (speedometer and radio) was recorded, rather than path length of eye and head movements due to the limited tracking range of the system.

The outcome measures were analysed using repeated measures ANOVAs with correction type (SV, BIF, PAL, MV and MTF CL) as the within-subjects variable. Where Mauchly's test was significant, and sphericity could not be assumed, the Greenhouse Geisser correction was used.

RESULTS

Path length of eye and head movements when tracking the distance targets

Initial multivariate ANOVA analysis indicated that the day and night results for eye and head movements were not significantly different (eye path length: mean 3.44 ± 0.27 m (SE) for day and 3.23 ± 0.22 m for night; head path length: mean 1.71 ± 0.17 m for day and 1.61± 0.17 m for night) and there were no interactions between correction type and day versus night (eye: F(4,16)=0.93, p=0.47; head: F(4,16)=0.56, p=0.70). In addition, no effect was found between the suburban and freeway driving scenes on eye (F(1,19)=2.27, p=0.15) and head (F(1,19)=0.561, p=0.46) path length. Therefore, all data were subsequently pooled.

The type of correction worn had a significant effect on eye movements (F (2.59, 49.17) =6.04, p=0.002, Greenhouse-Geisser correction). The path length of eye movements was significantly greater when wearing BIF and PAL than MV and MTF CL (p≤ 0.013). Also, SV resulted in significantly more eye movements than MV (p=0.028) (Fig. 3).

Head movements were also significantly affected by the vision correction worn (F (2.21, 42.01) =13.95, p<0.001, Greenhouse-Geisser correction), such that the path length of head movements was greater when wearing PAL, BIF and SV than MV and MTF CL (all p<0.001). However, there were no significant differences in eye or head movements between the different spectacle lenses, even though there was a trend for greater head movements with PAL than BIF and the least head movement with SV (Fig. 3).

Figure 3 to appear here.

Number of saccades

Overall, the effect of correction type on the number of saccades made to view the distance peripheral stimuli approached significance (p=0.058 with a Greenhouse-Geisser correction). If significance is accepted, then pairwise comparisons indicated that PAL and BIF resulted in a significantly greater number of saccades than MV (p≤ 0.043).

Table 1 to appear here.

Accuracy of identification of distance targets

There was no difference in the accuracy of recognition of distance peripheral targets between correction types (p=0.52). For all vision correction types more than 91% of distance targets were correctly identified with an overall mean of 92.4 ± 1.6 (SE) % correctly identified.

Accuracy of targets correctly identified for near visual display

Vision correction type had a significant effect on the accuracy of recognizing the near targets (F (4, 16) =9.04, p=0.001). Pairwise comparisons revealed that accuracy of recognizing the digital number on the near targets was poorer with SV than with all other vision corrections (p≤ 0.014). Progressive addition lenses led to significantly better accuracy than MTF CL (p=0.043), while there was no difference found amongst the BIF, MV and MTF CL. Overall, the recognition accuracy for the speedometer target was significantly higher than for the radio target for all correction types (F (1, 19) =8.88, p=0.008, mean difference = 11%, p=0.008). However, there was no interaction between vision correction type and the type of near target (i.e. radio or speedometer location) (Fig. 4).

Figure 4 to appear here.

Reaction time to brake

There was no significant difference in braking time in response to braking of the reference car between vision corrections (F (4, 76) =0.80, p=0.53), with an overall mean braking time of 0.72 ± 0.17 seconds.

DISCUSSION

This study demonstrates that presbyopic correction wear can affect the extent of eye and head movements when viewing dynamic stimuli that represent normal driving environments. The type of correction also influences the accuracy of identifying targets in the near peripheral field (simulating the location of the radio and speedometer), but not for distance targets.

When the participants wore a spectacle correction (including SV, BIF and PAL), the path lengths of head and eye movements were longer than when wearing presbyopic contact lenses. However, there were no significant differences amongst the spectacles lens types. This may be explained in part by the fact that presbyopic contact lenses have a wider corrected field of view than presbyopic spectacle corrections.[32] Also the absence of a spectacle frame in the peripheral field may contribute to the smaller range of head and eye movements required to identify peripheral targets with contact lens options, because the spectacle frames obscure parts of the visual field.[33] Proudlock et al[34] also failed to find significant differences in eye and head movements amongst SV wearers and PAL wearers.

Conversely, Han et al[7] reported that PAL wear resulted in larger head movements compared with SV when reading near text, despite there being no significant differences in eye movements. However, in Han et al's[7] study, participants viewed reading materials at 60 cm, requiring them to view through the intermediate section of the lens (corridor) to achieve clear focus, which limited the visual field and increased head movements when reading horizontal text. Another study indicated that performance on wide field reading tasks at intermediate distances (64cm) was poorer when wearing PAL than SV.[35] In our study, distance targets were presented at 2 m, allowing participants to look through the distance portions of the PAL, where the field of view would be equivalent to that of a SV lens.

When comparing the day and night-time data, no significant differences were found in the path length of eye and head movements. Conversely, in a simulator study by Crundall et al,[36] search patterns were greater during the day than the night-time for normal driving tasks, but when a car-following task was introduced, the search pattern was more restricted during daytime than night-time.

As all participants in this study were naïve wearers, having not previously worn a presbyopic vision correction, their results may not necessarily reflect those of adapted presbyopic correction wearers. There have, however, been only a limited number of studies which have considered how adaptation to presbyopic corrections might impact on performance. Han et al[7] found no significant differences in reading eye and head movements for either adapted or novice PAL wearers, however, their sample size was relatively small. Hutchings et al[37], however, found that as participants adapted to PALs wear they employed more head movements when undertaking a discrimination task at distances of 2 m and 45 cm and when reading text.

Both MV wearers[38] and MTF CL wearers[39] report significantly improved subjective visual performance after a period of lens wear ranging from days to weeks. However various objective measures of visual performance fail to show significant improvement over similar time periods.[38-40] It is thus conceivable that subjects' visual performance with presbyopic contact lens corrections do improve after adaptation in ways that have not yet been established. It is possible that this improvement in visual performance and perceptual adaptations may alter eye and head movement patterns in adapted wearers.

The increased number of saccadic eye movements made when wearing BIF and PAL compared to MV might be predicted to delay target recognition as the visual system suppresses perception during each saccade.[41] Our failure to find any differences in the accuracy of target recognition between correction types may have arisen because the size of the targets was typically large (requiring a VA of approximately 20/125), all were conspicuous because of the yellow ring highlighting the target, with ample time given for target recognition. Previous studies have shown slight reductions in VA and contrast sensitivity associated with MV and MTF CL compared to spectacle lens wear.[24, 42, 43] However, these reductions are small compared to the size of the distance targets used in this study.

Not surprisingly, more errors were made when reporting the digital numeric display panels (near targets) when SV distance corrections were worn compared to the other presbyopic corrections, but there were no significant differences between presbyopic corrections. Similarly Markovits,[44] found the accuracy of target recognition at 280cm, 83cm and 40cm was not affected by either PAL or BIF wear for targets within the central 10.6°, even though PALs resulted in a significantly shorter time to recognize the target at the intermediate viewing distance (83cm). Instead, the location of near targets is a more important factor. When the near target was located vertically downwards (speedometer), recognition accuracy was higher than when the near target was located both vertically downward and horizontally to the left (radio). Wittman et al[45] also found that when the display is not positioned near the line of sight, it can have a detrimental effect on reaction times. This finding has implications for the in-vehicle environment as the number of in-vehicle devices, such as navigation and audio systems, is increasing. These devices are often controlled by touch, which requires eye, head and hand coordination. Under normal driving conditions, if more time is spent looking at areas other than the forwards scene, and at least one hand is used for controlling devices rather than steering, the driver will have less ability to avoid potential collisions. Therefore, not only is attention divided amongst several tasks (poor divided attention ability is known to be associated with unsafe driving),[46] but the time required to physically bring fixation back to the forward traffic scene and the hands to the appropriate steering movements may be enough to affect response times when a hazard appear, given that slower response times are associated with unsafe driving.[46]

Reaction times to the onset of the reference car braking light were not significantly different between correction types in this study. Brown et al[47] also found no difference in reaction times when wearing six types of presbyopic contact lens correction, BIF and trifocal spectacle lenses, where participants were required to report the configuration of three-dot LED targets at three different distances.

Real-world driving involves the processing of a combination of sensory inputs including visual, auditory, vestibular and tactile. The difference between the simulated laboratory environment and the real driving condition is an important limitation of this study. For example, the simulation used in this study did not seek to replicate the sensation of vehicle motion experienced while driving and the visual representation of the night-time driving environment lacks fidelity in terms of the glare and reduced contrast experienced under these conditions. However, the data from this study provides high quality eye and head movement data for participants viewing footage of real driving scenes when wearing different presbyopic corrections. This study thus provides important baseline data and motivation for future studies undertaken in real world driving environments aimed at better understanding the role of presbyopic corrections on driving performance and to investigate these effects in both adapted and unadapted wearers.

CONCLUSIONS

Different presbyopic vision corrections can alter eye and head movement patterns in a simulated driving environment. The larger eye and head movements resulting from different corrections may negatively impact on the driver's attentional load and reaction times. As aging is associated with increased restrictions in eye and head movements,[34, 48] this may make it physically more difficult for older drivers who have impaired oculomotor and head function to make the larger eye and head movements required by some presbyopic corrections during driving. Higher numbers of saccades may also impact on target recognition, because of suppression of perception during saccades. Moreover, although driving is mainly a distance vision task, frequent gaze changes occur to view in-vehicle devices and these need to be considered when prescribing presbyopic vision corrections. The effect of different presbyopic vision corrections on real world driving performance and older driver characteristics is therefore an important area for further research.

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Figures Legend

FIGURE 1. Experimental set-up and relative location of screen and near targets

FIGURE 2. Eye and head movement paths superimposed on the scene as viewed by a typical participant when looking at the speed limit sign (peripheral target indicated by the yellow ring). The blue circles indicate eye position and the red triangles indicate head position.

FIGURE 3. Mean (SE) of path length of eye and head movement when looking at distance targets (SV=Single vision lenses, BIF=Bifocal spectacle lenses, PAL=Progressive addition lenses, MV=Monovision, and MTF CL=Multifocal contact lenses)

FIGURE 4. Mean (SE) of accuracy of targets correctly recognized for near digital numeric display

Table Legend

Table 1. Means (SD) of measures