Visual Psychophysics and Physiological Optics

The Effect of Presbyopic Vision Corrections on Nighttime Driving Performance

Byoung Sun Chu, Joanne M. Wood, and Michael J. Collins

Purpose. To investigate the effect of various presbyopic vision corrections on nighttime driving performance on a closed-road driving circuit.

Methods. Participants were 11 presbyopes (mean age, 57.3 ± 5.8 years), with a mean best sphere distance refractive error of R+0.23±1.53 DS and L+0.20±1.50 DS, whose only experience of wearing presbyopic vision correction was reading spectacles. The study involved a repeated-measures design by which a participant's nighttime driving performance was assessed on a closed-road circuit while wearing each of four power-matched vision corrections. These included single-vision distance lenses (SV), progressive-addition spectacle lenses (PAL), monovision contact lenses (MV), and multifocal contact lenses (MTF CL) worn in a randomized order. Measures included low-contrast road hazard detection and avoidance, road sign and near target recognition, lane-keeping, driving time, and legibility distance for street signs. Eye movement data (fixation duration and number of fixations) were also recorded.

Results. Street sign legibility distances were shorter when wearing MV and MTF CL than SV and PAL ($P < 0.001$), and participants drove more slowly with MTF CL than with PALs ($P = 0.048$). Wearing SV resulted in more errors ($P < 0.001$) and in more ($P = 0.002$) and longer ($P < 0.001$) fixations when responding to near targets. Fixation duration was also longer when viewing distant signs with MTF CL than with PAL ($P = 0.031$).

Conclusions. Presbyopic vision corrections worn by naive, unadapted wearers affected nighttime driving. Overall, spectacle corrections (PAL and SV) performed well for distance driving tasks, but SV negatively affected viewing near dashboard targets. MTF CL resulted in the shortest legibility distance for street signs and longer fixation times. (*Invest Ophthalmol Vis Sci.* 2010;51:4861–4866) DOI:10.1167/iovs.10-5154

The population of many countries is aging, and this is reflected in growing numbers of older drivers who exhibit a range of declines in sensory, cognitive, and motor skills performance. Although the effects of the age-related declines in visual functions, such as visual acuity, contrast sensitivity and visual field sensitivity, on driving performance have been investigated,[1,2] the effects of presbyopia and presbyopic vision corrections on driving performance have received relatively limited attention. This is of importance because while the optical correction of presbyopia can take many forms, all the current options have some unwanted visual limitations, many of which may impact driving performance.

Surveys of presbyopes have shown that many forms of presbyopic corrections are associated with problems for driving under low-illumination levels.[3,4] Adapted wearers of both monovision (MV) and multifocal contact lenses (MTF CL) report more problems under low-light levels, with reports of increased disturbance from haloes, glare, and decreased clarity of the road ahead.[3,5–7] Monovision is also known to cause some loss of stereoacuity,[5,7–9] but its impact on practical task performance is thought to be limited.[10] The use of progressive-addition spectacle lenses (PAL) is also known to create peripheral spatial distortion in the inferior field,[11,12] but little is known about their effect on driving performance, particularly under nighttime conditions.

It has been reported that degraded visibility during nighttime driving increases the risk of a crash by reducing the driver's ability to avoid a collision because of late recognition of other road users.[13–15] Given that presbyopic corrections can also degrade aspects of visual performance, the aim of this study was to investigate the effect of different presbyopic vision corrections on various measures of driving performance at nighttime.

Methods

Eleven older adults (mean age, 57.25 ± 5.78 years; range, 45–64 years; 5 women, 6 men) whose only experience of wearing presbyopic vision corrections was reading spectacles were recruited for the study. All participants were licensed drivers, and their distance visual acuity (VA) with their habitual correction was better than 20/20. They all were free of ocular abnormalities as assessed by slit-lamp and ophthalmoscopic examinations, had normal visual fields, and were in good general health.

The study was conducted in accordance with the requirements of the Queensland University of Technology Human Research Ethics Committee and followed the tenets of the Declaration of Helsinki.

The study involved a repeated-measures design using four vision corrections: single vision distance lenses (SV), PAL, MV and MTF CL. Subjective refraction was performed to ensure that their vision was best corrected for distance and near, and the spherical equivalent prescription was applied for all contact lens vision corrections for the distance power and near addition. The mean best sphere refraction of the participants was R+0.23±1.53 (range, −3.50 DS to +2.00 DS), L+0.20±1.50 DS (range, −3.50 DS to +2.00 DS), mean astigmatism was R−0.41±0.30 DC and L−0.43±0.34 DC with a maximum of 0.75 DC, and mean near addition power was +1.95±0.33 D, and six of the participants habitually wore a distance refractive correction as well as reading spectacles.

The PAL selected for the study was a commonly worn multicoated design that has an intermediate corridor width of 3.5 mm for a typical +2.00D near addition.[12] For MV, a disposable soft contact lens was

---

From the School of Optometry and Institute of Health and Biomedical Innovation, Queensland University of Technology, Brisbane, Australia.

Supported by a Research Capacity Building Award.

Submitted for publication January 3, 2010; revised February 16, 2010; accepted March 18, 2010.

Disclosure: **B.S. Chu**, None; **J.M. Wood**, None; **M.J. Collins**, None

Corresponding author: Byoung Sun Chu, School of Optometry and Institute of Health and Biomedical Innovation, Queensland University of Technology, Kelvin Grove, Brisbane, QLD 4059, Australia; b.chu@qut.edu.au.

used. The sighting-dominant eye was fitted for distance vision and the nondominant eye was fitted with the near prescription, as has been previously recommended.[16,17] The MTF CL selected was a simultaneous vision design—a commonly prescribed multifocal contact lens with aspheric center-near design in which the maximum plus power is in the center of the lens (near correction), progressing to more minus (distance correction) in the periphery of the optical zone. Two addition powers are available for this MTF contact lens, low additions (for near addition powers up to +1.50 D) and high additions (for near addition powers +1.75D to +2.25D). The appropriate addition power was chosen for each participant (two participants wore the low-addition and nine participants wore the high-addition power). Trial disposable contact lenses were worn for approximately 15 minutes at the initial visit to ensure that participants were able to tolerate CL wear; this amount of settling time was also allowed before the driving-related assessments were begun.

Visual acuity was measured under the conditions of the driving track using a high-contrast Bailey-Lovie vision chart. The low headlight beam from the research vehicle illuminated the chart (measured illumination of the chart on white background area was 39 cd/m^2; TOPCON BM-7, Tokyo, Japan).

Nighttime driving performance was measured on a closed-road circuit that has been used for a number of driving-related studies.[18,19] The experiment was only undertaken on nights when it was not raining and the road surface was dry. A 4-km circuit of the driving circuit was used that consists of a bitumen road with two and three lanes including hills, bends, straight stretches, and standard road signs and is representative of driving on rural roads. To simulate oncoming headlamp beams, a stationary vehicle with its headlamps on high beam was positioned in the opposite lane (two locations) on a stretch of straight road and facing the oncoming vehicle (Fig. 1).

The experimental vehicle had automatic transmission, and low-beam headlamp settings were used during all testing conditions. A roof-mounted global positioning system sampled the speed, position of the vehicle, and time to complete course, and two roof-mounted cameras recorded the position of the vehicle front right and left fenders for measurement of lane position (VigilVanguard driver training system; Vigil Systems, Brisbane, Australia).

Eye movements were recorded during driving using a mobile eye tracking system (ASL Mobile Eye; Applied Science Technologies, Bedford, MA) consisting of an eye and scene camera (30 Hz) mounted over the spectacle frames to compute gaze within a scene by tracking the pupil and corneal reflections in one eye.[20] A calibration procedure was conducted for each participant while seated in the driver's seat before data collection began for each vision correction. Fixation duration and number of fixations made during viewing of distance and near targets were recorded and analyzed using commercially available software (Gaze Tracker; Eye Response Technologies Inc, Charlottesville, VA) which defined fixation as a static eye position lasting >0.1 second.

Two experimenters were seated in the research vehicle (one in the passenger seat and the other in the back seat) to record driving performance and to activate visual stimuli (near targets). Each participant was required to wear the eye tracker with their habitual vision correction. One practice run of the course was completed along a route different from that of the experimental run to familiarize the participant with vehicle handling, vehicle size, in-vehicle devices, and the driving task (none of the participants had any experience driving the circuit before participation in this study). After this, participants drove around the circuit once with each vision correction. To control for the effects of learning, the order of wear of each vision correction type was randomized among participants.

Performance Measures

Road Sign Recognition. Forty road signs were located along the route and contained a total of 67 pieces of information; participants were asked to report each sign they observed. These signs included warning signs, regulatory signs, and street signs. The number of road signs correctly identified was recorded.

Road Hazard Recognition and Avoidance. Eight large, low-contrast foam road hazards (~95 cm × 170 cm and 5 cm thickness; reflectance, ~10%) were positioned in the path of the car on the road circuit at different positions for any given run. The position of the road hazards was changed between runs in a predetermined order to minimize familiarity effects (total of 11 potential positions; Fig. 1). Those represented in white remained the same between laps, while those represented in gray were varied in position between laps. Participants were asked to report whenever they saw a road hazard and to avoid it (steer around it) if it was safe to do so. The number of road hazards hit was recorded.

Lane Keeping. Lane keeping was recorded with two roof-mounted cameras. Videotapes were analyzed by calculating the time spent out of the lane for the left and right line markings separately, as a percentage of the total driving time.

Near Target Recognition. A simulated radio and speedometer (two digital numeric display panels) were mounted in the research vehicle at the typical location of the radio and speedometer. Random numbers were presented three times at each location for 2 seconds (six times for each lap), with the experimenter saying either "radio" or "speedometer" to prompt the participant to view the relevant near target. The number of targets correctly recognized was recorded.

Distance to Recognize Standard Street Signs. In addition to the number of road signs recognized correctly, road sign visibility was also measured at the end of each driving run by assessing the distance required to read a standardized street name sign. Participants were asked to drive slowly (<5 km/h) toward the sign until they could first clearly read it and then to stop; the distance from the vehicle to the sign was measured with a digital ruler (Laser Rangefinder DLE 50

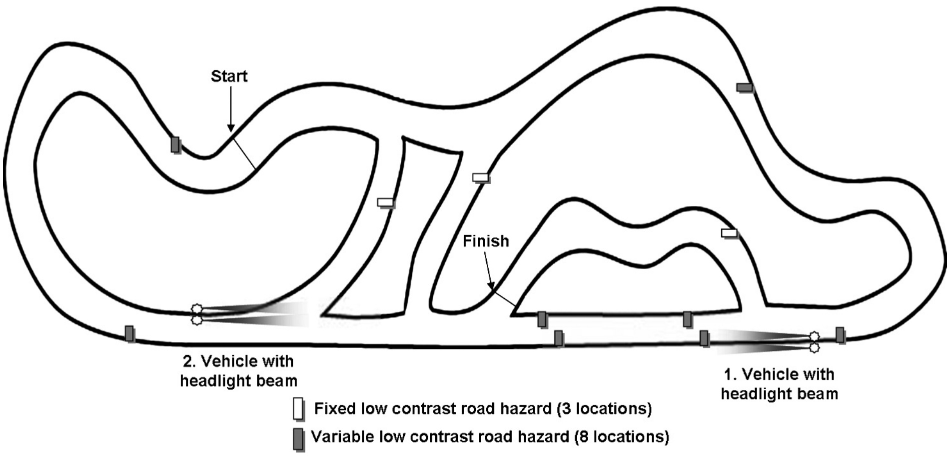

FIGURE 1. Schematic diagram of the closed-road circuit.

Table 1. Mean (SD) of Driving Performance Measures

Driving Performance Measures	Vision Corrections				ANOVA	Significant Differences ($P < 0.05$)
	SV	PAL	MV	MTF CL		
Road signs recognized, *n*	48.64 (5.55)	48.09 (3.45)	48.36 (3.61)	46.82 (4.02)	F (3,30) = 0.854 P = 0.476	NS
Road hazards hit, *n*	0.64 (0.92)	0.91 (1.14)	1.27 (1.01)	1.73 (1.56)	F (1.74, 17.37) = 3.25 P = 0.069	NS
Lane crossing time, %	10.74 (1.93)	10.06 (1.73)	9.81 (2.77)	10.25 (3.08)	F (1.86, 18.59) = 1.23 P = 0.312	NS
Near target recognition, %	60.60 (26.11)	93.94 (11.24)	87.88 (15.08)	92.42 (11.46)	F (3, 30) = 9.732 $P < 0.001$	SV < PAL, MV, MTF CL
Time to complete the circuit, s	424.45 (65.41)	426.18 (50.01)	447.64 (47.23)	449.82 (63.90)	F (3, 30) = 2.955 P = 0.048	MTF CL < PAL
Distance to recognize standard street sign, m	60.62 (10.13)	59.50 (8.94)	48.48 (13.76)	38.45 (16.58)	F (1.88, 18.83) = 21.19 $P < 0.001$	MV, MTF CL <SV, PAL MTF CL < MV
Distance VA, logMAR	−0.05 (0.06)	−0.05 (0.04)	0.05 (0.08)	0.12 (0.09)	F (3, 30) = 24.88 $P < 0.001$	MV, MTF CL < SV, PAL MTF CL < MV

N = 11 participants. NS, not significant.

Professional; Bosch, Framington Hills, MI). Four different street name signs (100-mm high black letters on white backgrounds) were used for this task and were changed between each driving run so that each vision condition was tested using a different sign. The signs were positioned at a height of 1 m so that they were evenly illuminated by the low headlamp beam.

Fixation Duration and Number of Fixations. Number and duration of fixations when viewing the road signs along the closed-road circuit and near targets (a simulated radio and speedometer) were recorded (ASL Mobile Eye; Applied Science Technologies). For road signs, four easily visible road signs (two text signs 100 mm high, two speed limit signs 200 mm high) that were correctly identified by all participants were selected for analysis.

Driving performance outcome measures were analyzed using repeated-measures ANOVA with correction type (SV, PAL, MV, MTF CL) as the within-subjects variable. When participants viewed the near targets, some eye movement data were missing because of loss of tracking by the system, usually from poor visibility of the pupil when it was covered by the lids; therefore, data from only 8 of 11 participants could be used for this analysis.

RESULTS

Group mean data for driving performance are presented in Table 1, and eye movement data are presented in Table 2.

Vision correction had a significant effect on total driving time to complete the course (F(3, 30) = 2.955; P = 0.048); participants drove more slowly when wearing MTF CL (mean, 7 minutes and 29 seconds) than when wearing PAL (mean, 7 minutes and 6 seconds). Multifocal CL also resulted in a greater number of road hazards hit, followed by MV, then PAL, and then SV. The effect of correction type on the number of road hazards hit also approached significance, showing higher numbers of hazards hit when wearing MTF CL (F(1.74, 17.37) = 3.25; P = 0.069).

Although there was no significant effect of vision correction on the number of road signs correctly recognized when the percentage of correctly recognized signs ranged between 61% and 64% for the different vision corrections, the duration of fixations when the signs were correctly recognized varied between conditions (F(3, 30) = 3.370; P = 0.031). Interestingly, there was a significant interaction between type of distance sign (speed sign and text sign) and vision correction (P = 0.017), so the analysis was repeated for the different sign types separately. This indicated that differences in fixation duration were evident only when viewing the text signs. Monovision and MTF CL resulted in significantly longer fixation durations when the participant correctly recognized the sign than did PAL (F(3, 30) = 5.465; P = 0.004). Multifocal CL also resulted in significantly longer fixation durations than did MV (P = 0.02; Fig. 2). There were no significant differences in total fixation duration among vision conditions when viewing speed signs (F(3, 30) = 1.511; P = 0.232). The total number of fixations did not vary among vision corrections (F(1.53, 15.34) = 1.86; P = 0.193), and there was no interaction between vision correction type and the type of distance sign (P = 0.089).

The distance at which a standard street sign was recognized was significantly affected by vision correction type (F(1.88, 18.83) = 21.19; $P < 0.001$). The street sign could be recognized at significantly longer distances when wearing SV, PAL, and MV than MTF CL ($P \leq 0.03$), and the recognition distance was shorter when wearing MV than wearing SV and PAL (P = 0.002; Fig. 3).

Table 2. Mean (SD) of Eye Movement Parameters

Eye Movement Parameters	Vision Corrections				ANOVA	Significant Differences ($P < 0.05$)
	SV	PAL	MV	MTF CL		
Fixation duration when observing near targets, s	0.89 (0.28)	0.52 (0.16)	0.57 (0.17)	0.51 (0.17)	F (3, 21) = 10.795 $P < 0.001$	PAL, MV, MTF CL < SV
Fixations when observing near targets, *n*	2.65 (0.79)	1.77 (0.58)	1.97 (0.42)	1.72 (0.35)	F (3, 21) = 6.964 P = 0.002	PAL, MV, MTF CL < SV
Fixation duration when viewing distance targets, s	1.33 (0.39)	1.04 (0.32)	1.18 (0.41)	1.44 (0.49)	F (3, 30) = 3.370 P = 0.031	PAL < MTF CL
Fixations when viewing distance targets, *n*	2.64 (0.86)	2.93 (0.42)	2.73 (0.49)	3.21 (1.09)	F (1.53, 15.34) = 1.86 P = 0.193	NS

N = 8.

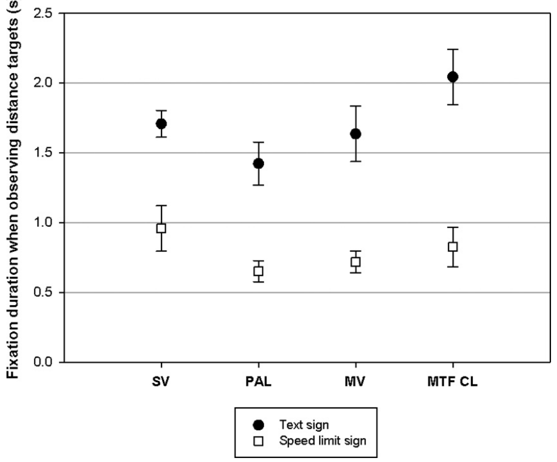

FIGURE 2. Mean (SE) of the total fixation duration when viewing distance targets.

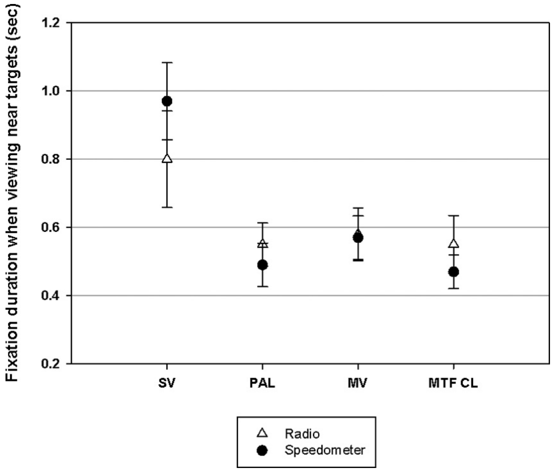

FIGURE 4. Mean (SE) of the total fixation duration when observing near targets.

Vision correction type significantly affected recognition of the near targets ($F(3, 30) = 9.732$; $P < 0.001$), but there was no interaction between vision correction and type of near target. Pairwise comparisons revealed that near target recognition was poorer with SV (distance correction) than with all other vision corrections ($P \leq 0.013$); however, there was no significant difference among the PAL, MV, and MTF CL. Vision correction type significantly affected total fixation duration and number of fixations when viewing the near targets (radio and speedometer) (($F(3, 21) = 10.795$; $P < 0.001$) and ($F(3, 21) = 6.964$; $P = 0.002$) respectively). Single vision resulted in significantly more fixations ($P \leq 0.032$) and longer fixation durations ($P \leq 0.007$) than all other vision correction types; however, there was no significant difference among the other corrections and no interaction between vision correction type and type of near target (i.e., radio or speedometer location; Fig. 4).

DISCUSSION

The findings demonstrate that nighttime driving performance on a closed-road circuit is significantly affected by the use of different types of presbyopic vision correction. Overall, MTF CL negatively affected more of the driving performance measures, and spectacle corrections (SV and PAL) performed better overall than the contact lens (MV and MTF CL) corrections. Single vision distance lens wearers showed significant loss of performance for recognition of near targets, such as the radio and speedometer.

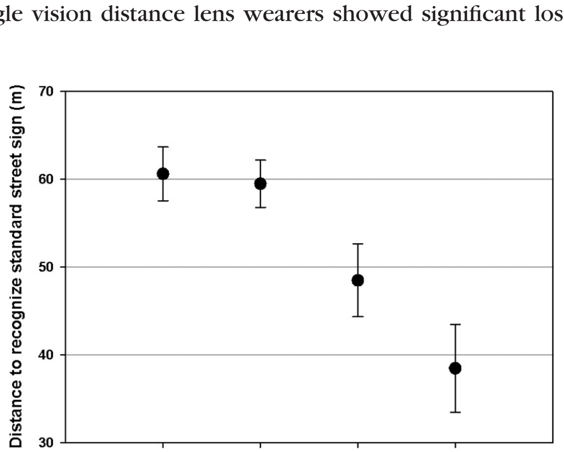

FIGURE 3. Mean (SE) of distance to recognize standard street signs.

Wearing MTF CL resulted in significantly slower driving speeds than did PAL wear, presumably as a result of poorer overall vision leading to more cautious driving. It would thus be expected that slower driving when wearing MTF CL would have reduced the number of low-contrast road hazards hit. However, MTF CL wear still increased the likelihood of hitting a low-contrast object on the road, with the difference between MTF CL and SV wear approaching statistical significance. Studies by Higgins et al.[21] and Higgins and Wood[22] also indicated that drivers with poorer vision tend to slow their driving speeds to compensate for their degraded vision; however, this slower driving speed was not always sufficient to avoid errors in sign recognition and road hazard avoidance.

The mean distance to read a street sign was approximately 60 m with SV and PAL and 48 m with MV and 38 m with MTF CL. This reduction in recognition distance may have important safety implications because a longer distance to recognize a sign allows a driver more preparation time to make navigational decisions and to undertake a maneuver. It has been calculated that when driving at a speed of 40 km/h on a dry road, a stopping distance of 38 m (including perception and response time) is required[23] and that this stopping distance is longer under dim lighting conditions because of increases in reaction time.[24] However, even though the measure of distance to identify the street name sign was affected by the type of vision correction, the number of road signs correctly identified along the closed-road circuit was not. Drivers with degraded vision were able to see the road signs, but at much shorter distances (e.g., with MTF CL). This hypothesis is supported by the finding that wearing MTF CL resulted in longer fixation durations than wearing PAL when reading traffic signs, and this difference was greater with the smaller letter signs (100-mm letter height) than with larger signs (200-mm letter height).

Maintaining lane position is important for avoiding collisions with other road users, and peripheral vision is used to keep the vehicle within the lane boundaries and for detecting peripheral hazards.[25] Despite PAL wear being associated with blur in the periphery[12] and peripheral vision being considered to be related to the task of lane keeping,[19] steering within the lane lines was not affected when wearing this correction type. It may be that the peripheral blur from PAL in the lower half of the lens is not important for steering tasks, such as fixation of the tangents of curved roads.[26] Alternatively, lane keeping might not have been affected by type of correction because it is robust to visual blur, as noted previously by Wood et al.[19] and Owens and Tyrrell.[27]

Not surprisingly, when wearing PAL, MV, and MTF CL, participants were better able to perform the near target recognition task (simulated radio and speedometer) (85% correct) than when they wore the SV distance correction (60% correct). This result is consistent with previous laboratory driving simulator findings.[28] In addition, the eye movement data indicated that SV wear resulted in significantly longer fixation durations and higher numbers of fixations than all the other vision corrections when viewing near targets.

With the increasing number of in-vehicle devices available, including navigation and entertainment systems, drivers' interactions with these devices will become more frequent, which is of concern given that they are associated with increased physical and visual distraction.[29] If allocation of visual attention on these in-vehicle devices increases, the result will be longer periods of time looking away from the road, which may have a detrimental impact on driving safety.[30] Importantly, in this study, drivers wearing the distance SV correction exhibited longer fixations to interpret the visual information from near devices, whereas those wearing PAL, MV, and MTF CL demonstrated shorter times to acquire the necessary information. Therefore, correcting near vision for driving is another way to reduce the visual demand from in-vehicle devices.

It should be noted that the visual function and driving performance measures used in this study reflect those obtained when contact lens prescribing criteria are based strictly on the spectacle equivalent prescription for distance and near addition. This was intentional so that comparison of correction types could be made with equivalent powers. Using this method, the difference in VA between spectacles and MV was 0.1 logMAR and 0.17 logMAR worse for MTF CL when measured at the driving track. There are alternative ways of prescribing presbyopic contact lenses that may result in better distance vision results, such as reducing the near addition power in the MTF CL in one or both eyes, using a single vision contact lens in one eye and a MTF CL in the fellow eye (modified MV), or reducing the near lens power in MV.[9] Therefore, modification of powers in the prescribing of presbyopic contact lenses to optimize vision may result in different outcomes.

The findings should also be considered in the context of some study limitations. The sample size was relatively small, so that though there were a number of differences in driving performance between the different presbyopic vision corrections, some of these failed to reach significance. In addition, the participants in this study were not adapted contact lens wearers and had no experience wearing spectacle or contact lens presbyopic vision corrections except for reading spectacles. The results must therefore be considered representative of the impact of unadapted presbyopic correction wear on aspects of driving performance and may not necessarily reflect that of drivers who have adapted to their presbyopic correction because the subjective impressions of visual performance can change after a period of MV wear, even though objective measures failed to show significant improvements over the same period.[31] In future studies it would be interesting to examine the driving performance of a larger sample of participants that includes wearers of presbyopic corrections fully adapted to the correction.

In summary, this study demonstrates that wearing different presbyopic vision corrections affected real-world measures of driving performance at night. Overall, the spectacle corrections performed better than did the contact lens corrections. Single-vision distance lens wearers performed well for all distance driving tasks but were at a disadvantage for recognition of near targets, such as the radio and the speedometer. Given that this study was conducted using naive, unadapted wearers who had no experience wearing spectacle or contact lens presbyopic vision corrections except for reading spectacles, further research is required to investigate whether these effects persist in longer-term adapted wearers. In conclusion, this study highlights that it is important to optimize vision correction when prescribing for presbyopia to ensure the highest level of road safety.

Acknowledgments

The authors thank the staff of the Queensland Transport for allowing use of the facilities at the Mt Cotton Driver Training Centre, the staff of the Mt Cotton Centre for their generous cooperation and support, and Phillippe Lacherez for advice on statistical analysis.

References

1. Owsley C, McGwin G Jr. Vision impairment and driving. *Surv Ophthalmol.* 1999;43:535–550.
2. Wood JM. Age and visual impairment decrease driving performance as measured on a closed-road circuit. *Hum Factors.* 2002; 44:482–494.
3. Chu BS, Wood JM, Collins MJ. Effect of presbyopic vision corrections on perceptions of driving difficulty. *Eye Contact Lens.* 2009; 35:133–143.
4. Josephson JE, Caffery BE. Monovision vs. aspheric bifocal contact lenses: a crossover study. *J Am Optom Assoc.* 1987;58:652–654.
5. Back AP, Grant T, Hine N. Comparative visual performance of three presbyopic contact lens corrections. *Optom Vis Sci.* 1992; 69:474–480.
6. Collins MJ, Goode A, Tait A, Shuley V. Monovision: the patient's perspective. *Clin Exp Optom.* 1994;77:69–75.
7. Papas E, Young G, Hearn K. Monovision vs. soft diffractive bifocal contact lenses: a crossover study. *ICLC.* 1990;17:181–187.
8. Kirschen DG, Hung CC, Nakano TR. Comparison of suppression, stereoacuity, and interocular differences in visual acuity in monovision and Acuvue bifocal contact lenses. *Optom Vis Sci.* 1999;76: 832–837.
9. Richdale K, Mitchell G, Zadnik K. Comparison of multifocal and monovision soft contact lens corrections in patients with low-astigmatic presbyopia. *Optom Vis Sci.* 2006;83:266–273.
10. Wood JM, Wick K, Shuley V, Pearce B, Evans D. The effect of monovision contact lens wear on driving performance. *Clin Exp Optom.* 1998;81:100–103.
11. Sheedy JE. Correlation analysis of the optics of progressive addition lenses. *Optom Vis Sci.* 2004;81:350–361.
12. Sheedy JE, Hardy RF, Hayes JR. Progressive addition lenses—measurements and ratings. *Optometry.* 2006;77:23–39.
13. Owens DA, Wood JM, Owens JM. Effects of age and illumination on night driving: a road test. *Hum Factors.* 2007;49:1115–1131.
14. Rice TM, Peek-Asa C, Kraus JF. Nighttime driving, passenger transport, and injury crash rates of young drivers. *Inj Prev.* 2003;9:245–250.
15. Williams AF. Nighttime driving and fatal crash involvement of teenagers. *Accid Anal Prev.* 1985;17:1–5.
16. Evans BJ. Monovision: a review. *Ophthalmic Physiol Opt.* 2007; 27:417–439.
17. Jain S, Arora I, Azar DT. Success of monovision in presbyopes: review of the literature and potential applications to refractive surgery. *Surv Ophthalmol.* 1996;40:491–499.
18. Tyrrell RA, Wood JM, Chaparro A, Carberry TP, Chu BS, Marszalek RP. Seeing pedestrians at night: visual clutter does not mask biological motion. *Accid Anal Prev.* 2009;41:506–512.
19. Wood JM, Chaparro A, Hickson L. Interaction between visual status, driver age and distracters on daytime driving performance. *Vis Res.* 2009;49:2225–2231.
20. Wilson MR, Vine SJ, Wood G. The influence of anxiety on visual attentional control in basketball free throw shooting. *J Sport Exerc Psychol.* 2009;31:152–168.

21. Higgins KE, Wood JM, Tait A. Vision and driving: selective effect of optical blur on different driving tasks. *Hum Factors.* 1998;40:224–232.
22. Higgins KE, Wood JM. Predicting components of closed road driving performance from vision tests. *Optom Vis Sci.* 2005;82: 647–656.
23. Leibowitz HW, Owens DA, Tyrrell RA. The assured clear distance ahead rule: implications for nighttime traffic safety and the law. *Accid Anal Prev.* 1998;30:93–99.
24. Plainis S, Murray IJ, Pallikaris IG. Road traffic casualties: understanding the nighttime death toll. *Inj Prev.* 2006;12:125–128.
25. Crundall D, Underwood G, Chapman P. Driving experience and the functional field of view. *Perception.* 1999;28:1075–1087.
26. Land MF, Tatler BW. Steering with the head: the visual strategy of a racing driver. *Curr Biol.* 2001;11:1215–1220.
27. Owens DA, Tyrrell RA. Effects of luminance, blur, and age on nighttime visual guidance: a test of the selective degradation hypothesis. *J Exp Psychol Appl.* 1999;5:115–128.
28. Chu BS, Wood JM, Collins MJ. Influence of presbyopic corrections on driving-related eye and head movements. *Optom Vis Sci.* 2009; 86:1267–1275.
29. Haigney D, Westerman SJ. Mobile phone use and driving: a critical review of research methodology. *Ergonomics.* 2001;44: 132–143.
30. Wikman A-S, Nieminen T, Summala H. Driving experience and time sharing during in-car tasks on roads of different width. *Ergonomics.* 1998;41:358–372.
31. Collins MJ, Bruce A, Thompson B. Adaptation to monovision. *ICLC.* 1994;21:218–224.