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Research Article

Bioptic Telescope Use and Driving Patterns of Drivers with Age-Related Macular Degeneration

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Purpose: To investigate the telescope use and driving patterns of bioptic drivers with age-related macular degeneration (AMD).

Methods: A questionnaire addressing telescope use and driving patterns was administered by telephone interview to three groups of bioptic drivers: AMD ($n = 31$; median 76 years); non-AMD first licensed with a bioptic ($n = 38$; 53 years); and non-AMD first licensed without a bioptic ($n = 47$; 37 years). Driving patterns of bioptic AMD drivers were also compared with those of normal vision (NV) drivers ($n = 36$; 74 years) and nonbioptic AMD drivers ($n = 34$; 79 years).

Results: Bioptic usage patterns of AMD drivers did not differ from those of the younger bioptic drivers and greater visual difficulty without the bioptic was strongly correlated with greater bioptic helpfulness. Bioptic AMD drivers were more likely to report avoidance of night driving than the age-similar NV drivers ($P = 0.06$). However, they reported less difficulty than the nonbioptic AMD drivers in all driving situations ($P \leq 0.02$). Weekly mileages of bioptic AMD drivers were lower than those of the younger bioptic drivers ($P < 0.001$), but not the NV group ($P = 0.54$), and were higher than those of the nonbioptic AMD group ($P < 0.001$).

Conclusions: Our results suggest that bioptic telescopes met the visual demands of drivers with AMD and that those drivers had relatively unrestricted driving habits.

Translational Relevance: Licensure with a bioptic telescope may prolong driving of older adults with AMD; however, objective measures of bioptic use, driving performance, and safety are needed.

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Introduction

The onset of visual impairment in older adults results in changes in driving habits including avoidance of difficult driving situations, reduced frequency of driving, and reduced mileages.[1–6] In particular, some drivers with age-related macular degeneration (AMD) exhibit very restricted driving habits.[7,8] When visual acuity falls below the requirement for an unrestricted license (e.g., 20/40 in many states and countries), individuals will automatically be denied a license, which may lead to social isolation, loss of independence, depression, and decreased quality of life.[9–12] In many states in the United States,[13,14] the province of Quebec in Canada,[15] and the Netherlands,[16] people with moderately reduced visual acuity may be permitted to drive on a restricted license with the aid of a bioptic telescope. This small telescope, which is usually mounted at the top of the spectacle lens before one eye (although occasionally bioptic telescopes are mounted binocularly),[17] is used intermittently for tasks such as reading road signs and determining the status of traffic light signals.[18,19] Bioptic drivers view through the carrier lenses below the telescope(s) most of the time when driving, dipping their head only briefly (e.g., for 1–2 seconds) to look through the telescope(s) to gain a magnified view.

In prior surveys,[18–22] retrospective chart reviews[23] and on-road studies of bioptic drivers,[15,16,24,25] the majority of participants were under 60 years of age suggesting that bioptic telescopes are more likely to be prescribed for people with congenital, juvenile, or middle-aged vision loss than seniors with AMD. In a recent retrospective review of 237 licensed bioptic drivers who received their initial evaluation to determine visual eligibility for bioptic driving in a university-based clinic, only 4% had a diagnosis of AMD.[26] Yet, AMD is a major cause of central vision impairment in the United States.[27,28] With the advent of new antivascular endothelial growth factor treatments for neovascular AMD[29,30] there will be increasing numbers[31,32] of older people with AMD who retain visual acuity sufficient to meet the vision requirements for driving with a bioptic telescope (visual acuity without the telescope can be as low as 20/200 in some states). Given the importance of driving to maintaining independence and quality of life in older age, there is clearly a need to better understand the bioptic use habits and driving patterns of people with AMD who are already licensed to drive with a bioptic.

In a prior paper,[18] we reported results of a telephone survey of bioptic use behaviors of drivers with central vision loss; however, the majority of participants had congenital vision loss with only 12% (7/58) having AMD. In a second phase of the study, we therefore recruited additional older bioptic drivers mainly with AMD or other causes of central vision loss. Here, we analyze the self-reported bioptic use behaviors, driving difficulties, and driving patterns of bioptic drivers who have AMD compared with younger bioptic drivers without AMD. We predicted that AMD bioptic drivers would have similar bioptic use patterns to the younger non-AMD bioptic drivers, but would report greater visual difficulty when driving and would have more restricted driving patterns.

In addition, we compared the driving patterns of AMD bioptic drivers to those of age-similar, normally-sighted drivers and to those of people with AMD driving without bioptic telescopes.[7] We expected that AMD bioptic drivers would have more restricted driving patterns than fully-sighted older drivers but would have less restricted driving patterns and report lower levels of perceived visual difficulty when driving than nonbioptic AMD drivers with similar levels of visual acuity.

Methods

Participants

A convenience sample of drivers with recent bioptic driving experience were recruited from four main sources across the United States (Table 1): vision rehabilitation clinics in diverse geographic locations; the practice of a mobility instructor in a rural area; the participants of a bioptic driving training program (West Virginia Low Vision Driving Program[33]); and responders to an advertisement placed on the Bioptic Driving Network website. Data for the first 58 participants, who mostly had congenital vision loss, were reported in an earlier paper.[18] The second phase of recruitment focused mainly on older bioptic drivers (>50 years) with AMD or other causes of central vision loss, primarily from vision rehabilitation clinics. A total of 116 bioptic drivers who completed the questionnaire are reported in this paper, including the 58 participants from the first phase of recruitment and 58 from the second phase. For subjects recruited from vision rehabilitation clinics and the West Virginia Program, acuity, diagnosis, and telescope data were confirmed from clinical records. The remaining subjects either referred us to their eye care practitioner or we had to rely on their recall.

Two recent studies of bioptic drivers, mostly without AMD, reported differences in training hours[23] and accident rates[26] between participants with prior nonbioptic driving experience (first licensed without a bioptic) and participants without any prior nonbioptic driving experience (first licensed with a bioptic). We therefore divided the younger, non-AMD bioptic drivers who responded to our survey into two groups: persons first licensed without a bioptic and persons first licensed with a bioptic. Thus, we had three groups: an AMD group (drivers with AMD, all licensed first without bioptic); and two non-AMD groups, those first licensed without a bioptic and those first licensed with a bioptic.

In addition, a group of 36 older current drivers with normal vision (visual acuity of at least 20/40 and field extent of at least 120°) were recruited from participants of ongoing studies at Schepens Eye Research Institute. They were selected to have a similar age distribution to the group of bioptic AMD drivers and provided comparison data for the analysis of the driving habits of the AMD participants.

All subjects provided informed consent in accordance with institutional review board approval at Schepens Eye Research Institute. The study was conducted in accordance with the tenets of the Declaration of Helsinki.

Questionnaires

The questionnaire for bioptic drivers was administered by telephone interview, lasting 30 to 60 minutes. The majority of interviews were carried out by a trained research assistant and the rest by author

Table 1. Summary of Recruitment Sources

Recruitment Source	Number Contacted	Number Excluded	Reasons for Exclusion	Number Completed: Non-AMD FLwB	Non-AMD FLwoB	AMD	Total	Geographic Location
Patients prescribed bioptic telescopes at 8 vision rehabilitation clinics*	76	17	4 unable to contact 5 no bioptic license 3 declined 3 did not drive 1 did not use bioptic 1 unable to complete questionnaire	9	20	30	59	16 states of the USA
Clients of a Certified Orientation and Mobility Specialist	12	2	1 did not use bioptic 1 did not drive	4	6	0	10	New Hampshire, USA
Graduates of the West Virginia Low Vision Driving program[33]	33	20	19 declined 1 did not use bioptic	10	2	1	13	W. Virginia, USA
Advertisement on Bioptic Driving Network website (biopticdriving.org)	34	0		24	10	0	34	16 states of the USA 1 province of Canada

* One of the sites was the vision rehabilitation clinic of author EP.
AMD: Age-related macular degeneration; FLwB: first licensed with bioptic; FLwoB: first licensed without bioptic.

ARB. Due to scheduling difficulties, three subjects completed a printed questionnaire.

The questionnaire addressed three main areas (Table 2): perceived visual difficulty for driving without a bioptic; bioptic usage patterns; and driving habits (quantified using the Driving Habits Questionnaire[1]). The questionnaire also included background questions about demographic factors, visual acuity and diagnosis, bioptic training received, and years driving experience with and without bioptic. Questions were primarily of a yes/no format, a 5-point scale format (e.g., to grade level of difficulty or degree of helpfulness), or required only a short response. The complete questionnaire is available at http://serinet.meei.harvard.edu/faculty/peli/shared/Bioptic_Qaire_Web_2.pdf. For more detail about the development of the questionnaire, please see Bowers et al.[18]

Normally-sighted drivers completed the Driving Habits Questionnaire[1] and background questions during a study visit at Schepens Eye Research Institute.

Rasch Analyses

Rasch analyses were used to estimate item and person measures for each of three sets of questions (see Supplementary materials and Table 2). The first set, visual difficulty without bioptic, included nine items about the difficulty drivers experienced performing specific tasks without their bioptic telescope. The second set, bioptic helpfulness, included nine items about the helpfulness of the bioptic telescope for those same tasks. The third set, driving difficulty, included nine items about the perceived difficulty drivers experienced in specific driving situations. Only data from bioptic drivers were included in the Rasch analyses.

Rasch analysis was used to examine response category functioning, person, and item separation statistics, infit and outfit mean-square statistics, and item targeting for each set of questions (see Supplementary materials). All Rasch analyses were performed with Winsteps software version 3.90[34] according to the Andrich rating scale model for polytomous data using joint likelihood estimation.[35]

Table 2. Summary of Variables for Visual Difficulty, Bioptic Usage, and Driving Habits Sections of Questionnaire

Section	Variables	Details
Visual difficulty without bioptic	Person and item measures of difficulty without bioptic	Rasch analysis of 9 items (see Supplementary Table S1) Higher item measure = more difficult item Higher person measure = less visual difficulty
Bioptic usage when driving	Overall rating of bioptic helpfulness	Scale: 0 (no help) to 5 (extremely helpful)
	Estimate time wearing bioptic	Scale: 1 (all the time) to 5 (never)
	Person and item measures of bioptic helpfulness	Rasch analysis of 9 items (see Supplementary Table S1) Higher item measure = bioptic less helpful for item Higher person measure = bioptic less helpful to person
	Bioptic use in each of 9 driving situations	Binary response (yes/no) for each situation (see Supplementary Table S1)
	Percent time looking through bioptic	Estimate between 0 and 100%
Driving habits*	Quality of driving; speed relative to flow	Self-ratings for each item on 5-point scale Higher score represents higher self-rating
	Anybody suggest stop driving	Binary response (yes/no)
	Estimate time use visual assistance from a passenger	Scale: 1 (all the time) to 5 (less than 25%) (Item added to DHQ)
Driving exposure*	Trips per week; miles per week; days per week; places per week	Estimate of numbers of trips, miles, days, and places driven in a typical week
Driving space*	Whether drove to specific locations	Locations from immediate neighborhood to out of region Binary response (yes/no) for each location
Driving difficulty*	Person and item measures of driving difficulty	Rasch analysis of 9 items (see Supplementary Table S1) Higher item measure = more difficult item Higher person measure = less driving difficulty

* Questions from Driving Habits Questionnaire (DHQ)[1] to which a few items were added.

Statistical Analyses

Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS, Inc., Chicago, IL) version 11.5; $\alpha = 0.05$ was used to define statistical significance. Differences between groups were analyzed using Kruskal-Wallis tests for rating scales and continuous variables, and χ^2 tests for categorical variables. The Wilcoxon rank-sum test or paired *t*-test was used to analyze differences between two groups when appropriate.

Two main sets of between-group analyses were conducted. The first addressed differences in bioptic usage and driving patterns between the three groups of bioptic drivers: AMD, non-AMD first licensed without a bioptic, and non-AMD first licensed with a bioptic. The second set addressed differences in driving patterns, quantified using the Driving Habits Questionnaire, between bioptic AMD drivers, nonbioptic AMD drivers, and age-similar normally-sighted drivers. The nonbioptic AMD group included data for 34 participants from the prior study by DeCarlo et al.[7]

For bioptic drivers, the relationship between potential independent predictor variables and dependent measures of (1) visual difficulty without the bioptic telescope, and (2) bioptic helpfulness were analyzed using hierarchical linear regression analyses.

Table 3. Characteristics of Bioptic Drivers

	Non-AMD				
	FLwB	FLwoB	AMD	χ2	*P* Value
N	47	38	31		
Male, %	62%	60%	71%	0.96	0.62
Age (y), median (IQR)	37.5 (31.5–46.7)	52.4 (46.9–59.1)	75.5 (69.9–81.8)	70.87	**0.00**
Visual acuity without telescope (logMAR), median (IQR)	0.78 (0.60–1.00)	0.78 (0.60–0.90)	0.78 (0.60–0.90)	0.94	0.63
Age of onset (y), median (IQR)	0.0 (0.0–0.0)	26.4 (0.0–39.8)	66.7 (60.0–75.0)	88.36	**0.00**
Diagnosis, %				54.89	**0.00**
Albinism	53%	8%	0%		
AMD	0%	0%	94%		
JMD (Stargardt's)	9%	45%	0%		
Optic Atrophy	15%	11%	0%		
Other	23%	37%	6%		
Area, %				4.97	0.08
Big city	11%	8%	19%		
Medium town	21%	16%	32%		
Small town	23%	32%	23%		
Suburban	19%	32%	13%		
Rural	26%	13%	13%		
Walk to public transport, %	40%	35%	55%	2.81	0.25
Education, %				2.82	0.24
High school	17%	11%	32%		
College	49%	42%	32%		
Post-graduate	32%	45%	29%		
Other	2%	3%	6%		
Employment status, %				35.95	**0.00**
Unemployed	4%	5%	3%		
Employed	87%	76%	23%		
Retired	9%	18%	74%		

IQR: interquartile range; AMD: Age-related macular degeneration; FLwB: first licensed with bioptic; FLwoB: first licensed without bioptic.

Bold text indicates significant *P* values.

The independent predictor variables entered in regression analyses for the visual difficulty without the bioptic were visual acuity, age, and diagnosis (AMD, JMD, Albinism, and other). The same independent predictor variables were entered in the regression analyses for the bioptic helpfulness with the addition of visual difficulty without the bioptic and a rating of the extent to which being permitted to drive with a bioptic improved quality of life. In initial analyses age, total years of driving, and years of bioptic driving were evaluated as predictors. The number of years of bioptic driving was not predictive; however, age and total years driving were predictive of visual difficulty without the bioptic. As expected, these two variables were highly correlated and the regression results were essentially identical irrespective of whether total years driving or age was included; only age was included in the final model.

Results

Characteristics of Bioptic Drivers

The three groups of bioptic drivers did not differ in sex distribution, visual acuity, type of area in which they lived, availability of public transportation within walking distance, and education status (Table 3). However, as expected, they did differ in diagnosis, age

Table 4. Summary (Median [IQR]) of Driving Experience without and with Bioptic

	Non-AMD				
	FLwB	FLwoB	AMD	χ2	*P* Value
Age first license (y)	24.6 (19.6–31.0)	16.5 (16.0–18.1)	16.0 (16.0–18.0)	43.68	**0.00**
Age bioptic license (y)	24.6 (19.6–31.0)	46.7 (36.5–53.0)	70.2 (66.4–77.8)	70.92	**0.00**
Total years driving	12.0 (7.7–17.2)	35.8 (36.4–41.3)	57.5 (53.8–64.6)	86.71	**0.00**
Years bioptic driving	12.0 (7.7–16.9)	5.1 (1.2–9.2)	2.6 (1.0–4.8)	26.18	**0.00**

of vision impairment onset, age at the time of the interview, and employment status (Table 3). The AMD group was significantly older than each of the two non-AMD groups at the time of the interview and also at the time of vision impairment onset (Table 3). Among the non-AMD participants, the main diagnoses were albinism in those first licensed with a bioptic and juvenile macular dystrophy in those first licensed without a bioptic (Table 3). The majority of participants in the non-AMD groups were employed, whereas the majority of participants in the AMD group were retired (Table 3).

Participants who were first licensed with a bioptic were, on average, 9 years older when first licensed to drive than participants in the other two groups. They had the greatest number of years driving with a bioptic, but the fewest total years of driving (Table 4). By comparison, participants in the AMD group were significantly older than the other two groups when they were first granted a license to drive with a bioptic. They had the fewest years driving with a bioptic, but the greatest total years of driving (Table 4).

The majority ($n = 69$; 59%) of participants used a monocular telescope of 3.0× or 4.0× magnification. The remainder either used monocular telescopes of other powers ($n = 15$, 13%), binocular telescopes ($n = 19$; 16%), or did not know the level of magnification ($n = 13$; 11%). Those first licensed with a bioptic reported a greater number of hours of general training in how to use the bioptic and a greater number of hours of on-road training with the bioptic than the other two groups (Table 5). Only 23% of the AMD group had participated in any kind of on-road training with the bioptic (either behind-the-wheel or passenger-in-car), compared with approximately 50% of the other two groups (Table 5, $P < 0.01$).

Perceived Visual Difficulty without the Bioptic

Participants reported the greatest visual difficulty (least visual ability) without the bioptic for reading street signs followed by reading road signs and the least visual difficulty (greatest visual ability) for judging when it was safe to merge and judging the distance to the car in front (Fig. 1). There were no significant differences in the mean level of perceived visual ability among the three groups (mean [SD]; first licensed with bioptic: 0.45 [0.94] logits; first licensed without bioptic: 0.62 [1.29] logits; AMD: −0.09 [2.03] logits; $\chi^2 = 2.56$, $df = 2$, $P = 0.28$). In multiple regression analyses, worse visual acuity and older age were associated with lower ability levels, that is, greater difficulty without the bioptic (Table 6, Models 1, 2, and 3); however, they accounted for only a low proportion (16%) of the variance in this measure. Diagnosis was not predictive (Table 6, Model 3).

Table 5. Summary of Training with the Bioptic Telescope

	Non AMD				
	FLwB	FLwoB	AMD	χ2	*P* Value
Hours general bioptic training, median (IQR)	2.0 (0.4–31.8) $n = 28$*	1.0 (0.7–7.6) $n = 21$	0.5 (0.5–2.0) $n = 27$	5.56	0.06
Participated in on-road training, %	51% (24/47)	55% (21/38)	23% (7/31)	10.46	**0.00**
Hours on-road training, median (IQR)	45.0 (20.0–50.0) $n = 23$	13.5 (7.0–32.5) $n = 21$	16.0 (4.0–30.0) $n = 7$	14.11	**0.00**

* Not all subjects remembered the details of the training they had received; therefore, sample size is given for each question and group.

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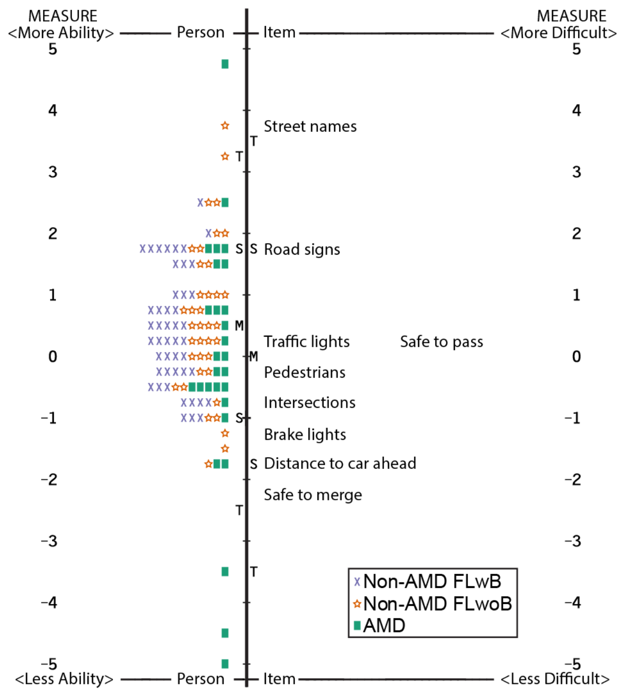

Figure 1. Plot showing mapping of person ability and item difficulty measures in logits for the set of questions about perceived visual difficulty without the bioptic telescope. Participants (color-coded by group) are on the *left* of the vertical line and items (visual driving tasks) are on the *right*. Participants are ordered from those with least ability (greatest perceived visual difficulty) at the *bottom* of the scale to those with most ability at the *top*. Items are ordered from the least difficult tasks at the *bottom* to the most difficult at the *top*. The distributions of person abilities and item difficulties overlap reasonably well, but the spacing of the item difficulties is not even across the range with a concentration of items that were perceived to be relatively easy. Reading street names and reading traffic signs were by far the most difficult tasks. M, mean; S, 1 SD from the mean; T, 2 SD from the mean. FLwB, first license with bioptic; FLwoB, first license without bioptic

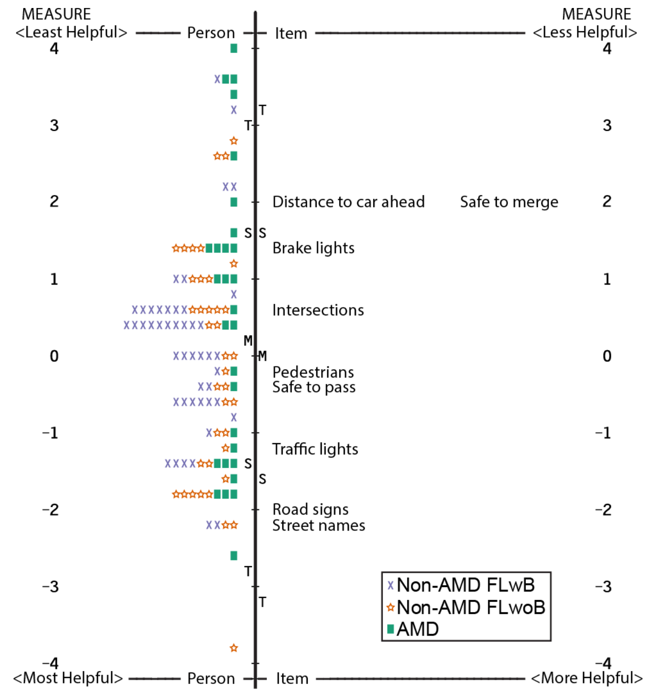

Figure 2. Plot showing mapping of person and item measures in logits for the set of questions about perceived helpfulness of the bioptic telescope. Participants (color-coded by group) are on the *left* of the vertical line and items (visual driving tasks) are on the *right*. Participants are ordered from those who perceived the bioptic to be very helpful at the *bottom* of the scale to those who perceived it to be of little help at the *top* of the scale. Items are ordered from the tasks for which the bioptic was most helpful at the *bottom* to the least helpful at the *top*. The telescope was most helpful for reading street names and traffic signs. The distributions of person abilities and item difficulties are well matched (overlapping).

Table 6. Summary of Hierarchical Regression Analysis for Variables Predicting Perceived Visual Ability without the Bioptic Telescope (Person Measure from Rasch Analysis)

	Model 1			Model 2			Model 3		
Variable	*B*	*SE B*	β	*B*	*SE B*	β	*B*	*SE B*	β
(Constant)	1.16	0.31		1.9	0.42		2.09	0.66	
Visual acuity	−1.38	0.38	**−0.33****	−1.50	0.38	**−0.36****	−1.53	0.39	**−0.37****
Age				−0.01	0.01	**−0.23***	−0.01	0.01	**−0.26***
Diagnosis							−0.03	0.09	−0.04
R^2		0.11			0.16			0.16	
F for change in R^2		**12.89****			**6.42***			0.13	

B, unstandardized coefficient; *SE*, Standard Error; β, standardized coefficient.
*$P < 0.05$.
**$P < 0.01$.
Bold values are significant.

Table 7. Summary of Hierarchical Regression Analysis for Variables Predicting Perceived Helpfulness of the Bioptic Telescope (Person Measure from Rasch Analysis)

	Model 1			Model 2			Model 3			Model 4		
Variable	*B*	*SE B*	β	*B*	*SE B*	β	*B*	*SE B*	β	*B*	*SE B*	β
(Constant)	−1.26	0.49		−2.26	1.06		−0.20	0.89		−3.34	1.06	
Visual acuity	1.80	0.61	**0.28****	1.96	0.63	**0.30****	0.45	0.53	0.07	0.14	0.49	0.02
Age				0.01	0.01	0.17	0.00	0.01	0.01	0.00	0.01	0.04
Diagnosis				0.05	0.15	0.04	0.02	0.12	0.02	−0.01	0.11	−0.01
Perceived visual ability							−0.99	0.13	**0.63****	−0.98	0.12	**−0.63****
Telescope improve QoL										0.70	0.15	**0.32****
R^2		0.08			0.10			0.43			0.53	
F for change in R^2		**8.66****			1.21			**61.02****			**21.56****	

*$P < 0.05$.
**$P < 0.01$.
Bold values are significant.

Bioptic Use When Driving

The majority of participants reported that the telescope was very helpful overall (90/116; 78%), that they wore the telescope all the time when driving (84/112; 75%), and that they would still use the bioptic telescope, even if not required for licensing (96/109; 88%). There were no group differences in the distribution of responses to these questions (χ^2 = 2.59, 1.26, 3.21; P = 0.53, 0.27, 0.20, respectively). More than half of the participants (67/115; 58%) estimated that they used the telescope for 5% or less of driving time and approximately one-fifth (24/115; 21%) between 6% and 10% of driving time, with no significant group differences ($\chi^2 = 4.02$, $P = 0.13$).

Bioptic telescopes were found to be most helpful for reading street signs followed by reading road signs and the least helpful for judging when it was safe to merge or the distance to the car in front (Fig. 2). The ordering of tasks by helpfulness ratings was the same as the ordering by visual difficulty; bioptic telescopes were rated as most helpful for tasks perceived as most visually difficult without the telescope and vice versa. Correspondingly, telescopes were used most commonly for reading road signs (108/113; 96%) and street names (104/110; 95%), and used least commonly when judging the distance from the car in front (26/112; 23%), judging when it was safe to merge (20/95; 21%), and seeing signal/brake lights on the car in front (38/115; 33%) (the number of subjects varies because subjects who responded "not applicable" were not counted).

There were no significant group differences in the overall mean level of perceived bioptic helpfulness (mean [SD]; first licensed with bioptic: 0.12 [1.13] logits; first licensed without bioptic: −0.11 [1.50] logits; AMD: 0.46 [1.84] logits; $\chi^2 = 1.34$, $df = 2$, $P = 0.51$), or in the proportions of participants using the bioptic for each task (all tasks: $\chi^2 \leq 4.69$, $df = 2$, $P \geq 0.10$). The only exception was for judging when it was safe to overtake another car. Participants who were first licensed with a bioptic were more likely to report using the bioptic for this task (first licensed with bioptic [33/43; 77%]; first licensed without bioptic [13/27; 48%]; AMD; $\chi^2 = 6.54$, $df = 2$, $P = 0.04$).

In multiple regression analyses, visual acuity (without telescope) was a significant predictor of perceived helpfulness of the bioptic telescope (Table 7, Models 1 and 2); worse visual acuity was associated with greater helpfulness. Age and diagnosis were not predictive (Table 7, Model 2). However, it was the perceived visual ability without the telescope that best

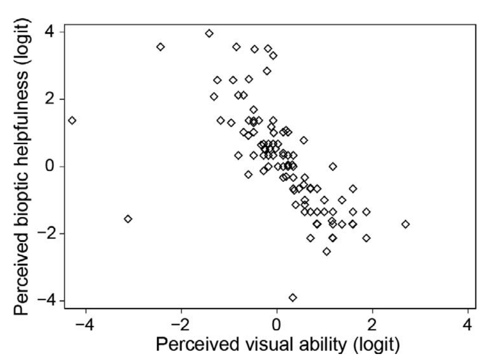

Figure 3. Perceived visual ability (difficulty) without the bioptic and perceived bioptic helpfulness were strongly correlated; those with lower levels of visual ability reported higher levels of bioptic helpfulness.

Table 8. Driving Habits of Bioptic Drivers

	Non-AMD				
	FLwB	FLwoB	AMD	χ2	*P* Value
Quality of driving, %				0.77	0.68
≥Good	77%	84%	87%		
≤Average	23%	16%	13%		
Driving speed, %				6.72	**0.04**
Same/faster	93%	79%	74%		
Slower	7%	21%	26%		
Suggestion to stop driving, %	6%	18%	26%	5.69	0.06
Drive with visual assistance,%	60%	53%	42%	2.32	0.32

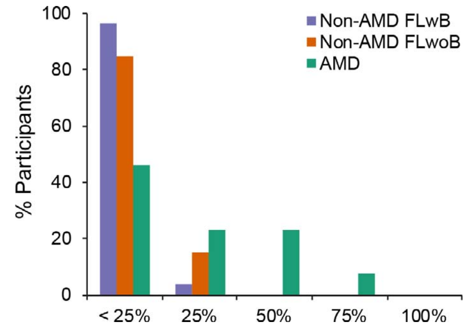

Figure 4. Estimated percent time using visual assistance from a sighted passenger. AMD participants reported using visual assistance for a greater proportion of driving time than the other two groups.

predicted the reported bioptic helpfulness (Table 7, Model 3); lower levels of perceived visual ability were strongly associated with higher levels of bioptic helpfulness (Fig. 3). In addition, participants' ratings of how much being permitted to drive with a bioptic improved their quality of life were also predictive of bioptic helpfulness; higher quality of life ratings were associated with higher levels of bioptic helpfulness. Inclusion of the quality of life rating in the regression equation accounted for an additional 10% of the variance (Table 7, Model 4).

Driving Habits – Comparison among the Three Groups of Bioptic Drivers

Most of the bioptic participants reported that they were above average drivers (95/116; 82%) and drove at approximately the same speed as other traffic (93/115; 81%). Driving at the same speed or faster than the general flow was a more common response among participants first licensed with a bioptic than among participants in the other two groups (Table 8), and a lower proportion of the group first licensed with a bioptic reported that someone had suggested they stop driving in the last year (Table 8). Just over half of the participants (61/116; 53%) said they made use of visual assistance from a passenger – mainly, reading traffic signs (29/61; 48%). AMD participants reported using visual assistance for a greater proportion of driving time than the other two groups ($\chi^2 = 16.46$, $P = 0.00$; Fig. 4).

Participants in the AMD group made significantly fewer trips and drove significantly fewer miles per week than the other two groups (Table 9). However, there were no group differences for the number of days and places driven per week. Of the total sample (n = 116), only 27% drove no farther than the neighboring town (i.e., had a restricted driving area[1]), whereas 73% drove to distant towns, 49% drove outside their state, and 31% outside their region of the United States. There were no significant group differences in the proportions driving to neighboring and distant towns ($\chi^2 = 3.59$, $P = 0.17$; and $\chi^2 = 4.96$, $P = 0.08$, respectively). However, of the AMD group, only 29% drove outside their state and 10% outside their region compared with 53% and 32%, respectively, in the non-AMD group first licensed without a bioptic, and 60% and 45%, respectively, in the non-

Table 9. Driving Exposure Measures for Bioptic Drivers

	Non-AMD				
	FLwB	FLwoB	AMD	χ2	*P* Value
Trips/wk	9.0 (8.0–12.0)*	7.0 (5.0–9.5)	5.5 (3.0–7.8)	14.88	**0.00**
Miles/wk	234 (98–425)	106 (46–257)	56 (25–150)	17.89	**0.00**
Days/wk	7.0 (5.0–7.0)	6.5 (5.0–7.0)	6.0 (3.0–7.0)	3.14	0.21
Places/wk	4.0 (2.0–4.2)	3.0 (2.0–4.0)	3.0 (2.0–4.0)	2.55	0.28

* Median (IQR).
Bold text indicates significant *P* values.

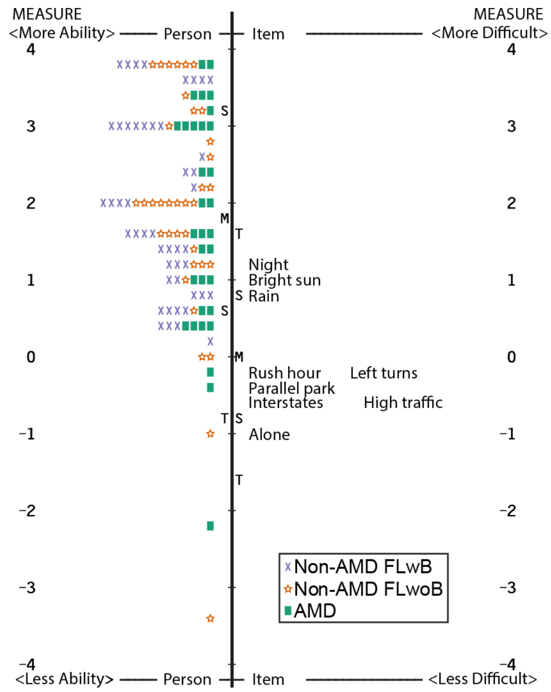

Figure 5. Plot showing mapping of person ability and item difficulty measures in logits for the set of questions about perceived difficulty with driving. Participants (color-coded by group) are on the *left* of the vertical line and items (driving situations) are on the *right*. Participants are ordered from those with least ability (greatest perceived visual difficulty) at the *bottom* of the scale to those with most ability at the *top*. Items are ordered from the least difficult situations at the *bottom* to the most difficult at the *top*. Driving at night, in bright sunlight and in rain were perceived as the most difficult. The mean person measure (1.88 logits) far exceeded the mean difficulty level of the items (0.00 logits) with at least half the participants falling above the items rated as the most difficult, indicating that the item difficulties were not well matched to the participants' abilities.

AMD group first licensed with a bioptic ($\chi^2 = 7.18$, $P = 0.03$; and $\chi2 = 10.61$, $P = 0.005$, respectively).

In general, participants reported relatively little difficulty with driving and avoidance levels were low (Figs. 5, 6). The overall mean level of perceived ability was relatively high in each group (i.e., little difficulty) with no significant group differences (first licensed with bioptic = 1.95 [1.14] logits, first licensed without bioptic = 1.94 [1.45] logits, AMD = 1.69 [1.44] logits; $\chi^2 = 0.89$, $df = 2$, $P = 0.64$). Adverse environmental conditions (driving at night, in bright sunlight, and when raining) were the only situations where at least 50% of participants reported either difficulty or avoidance (Fig. 6). Avoidance levels were highest for driving at night. Nearly half of the AMD group had stopped driving at night due to their vision compared with less than 15% in the other two groups

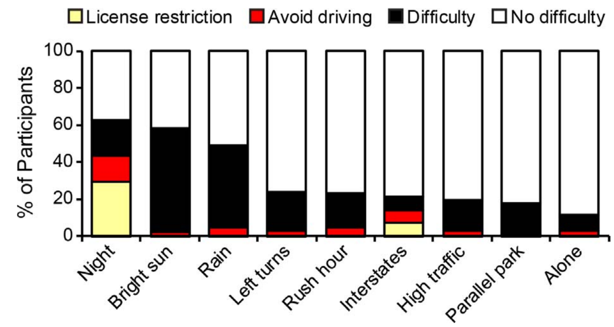

Figure 6. Percentage of bioptic drivers reporting driving difficulty and driving avoidance due to vision impairment in each of nine driving situations. With the exception of driving in rain and bright sunlight, only a low percentage of subjects reported driving difficulty. Avoidance levels were highest for driving at night with 28% (*yellow shading*) not driving at night due to a daytime-only license restriction.

($\chi^2 = 4.90$, $P = 0.09$; Fig. 7a). An additional 33 participants had a day-time only license restriction and were not permitted to drive at night (10 AMD, 13 first licensed without bioptic, and 10 first licensed with bioptic). Parallel parking was the only situation for which there was a significant group difference: a higher proportion of participants first licensed with a bioptic reported difficulty than in the other two groups ($\chi^2 = 7.21$, $P = 0.027$; Fig. 7b).

Bioptic drivers who reported greater levels of perceived driving difficulty drove fewer miles per week and fewer days per week than those who reported lower levels of perceived driving difficulty (Spearman's rho = 0.23 and 0.33, respectively, $P \leq 0.01$).

Driving Habits of Bioptic Drivers with AMD Compared with Nonbioptic Drivers

This analysis compared the driving patterns of bioptic AMD drivers with those of age-similar NV drivers and nonbioptic AMD drivers. The characteristics of the three groups are summarized in Table 10. The two AMD groups did not differ in visual acuity or age, but participants in the bioptic AMD group were, on average, 5 years younger when first diagnosed. The majority of participants in each group were first licensed to drive between the ages of 16 and 19 years.

Almost 90% of both the NV and bioptic AMD groups reported that they were above average drivers compared with only 58% of the nonbioptic AMD group (Table 11). Furthermore, only about 25% of the NV and bioptic AMD groups said they drove more slowly than the traffic compared with approx-

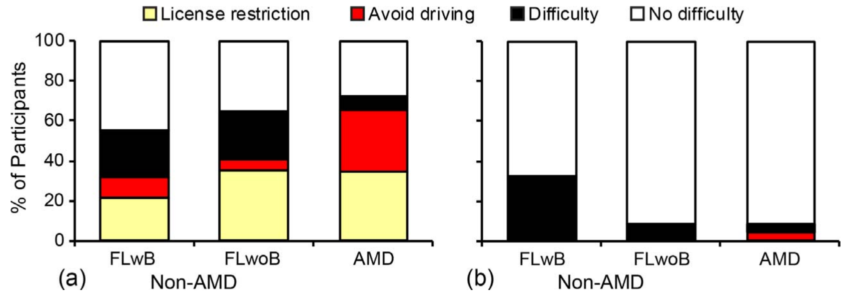

Figure 7. Percentage of bioptic drivers in each group reporting driving difficulty and avoidance for (a) driving at night and (b) parallel parking. The AMD group reported the highest levels of driving avoidance at night while those first licensed with a bioptic reported more difficulty with parallel parking than the other groups.

imately 58% of the nonbioptic AMD group (Table 11). In each case, the distribution of responses in the bioptic AMD group was significantly different from the nonbioptic AMD group ($Z = -2.17$, $P = 0.03$; $Z = -2.54$, $P = 0.01$) but did not differ from the NV group ($Z = 0.00$; $Z = -1.41$, $P = 0.12$). Although the proportion of participants reporting that someone had suggested they stop driving in the last year was higher in the bioptic and nonbioptic AMD groups than the NV group (Table 11), only the difference between the nonbioptic AMD and NV groups was significant ($Z = -2.96$, $P = 0.003$).

Participants in the bioptic AMD group drove on significantly more days and for significantly more miles per week than the nonbioptic AMD group (Table 12). However, they did not differ from the NV group for any of the driving exposure measures (Table 12). Driving space data were available for only six of the nonbioptic AMD group; therefore, comparisons were only made between the other two groups. The bioptic AMD and NV groups did not differ in the proportions driving beyond their immediate neighborhood (90% and 100%, respectively), but a significantly lower proportion of the bioptic AMD group drove to neighboring towns (87% vs. 100%; $Z = -2.21$, $P = 0.03$), distant towns (58% vs. 89%; $Z = -2.87$, $P = 0.004$), outside of their state (29% vs. 67%; $Z = -3.05$, $P = 0.002$), and beyond their region (10% vs. 39%; $Z = -2.72$, $P = 0.007$). Overall, the nonbioptic AMD group reported the greatest difficulties and had the highest levels of driving avoidance compared with the NV and bioptic AMD groups (Fig. 8). For the majority of situations, there were no significant differences in the distributions of responses between the bioptic AMD and NV groups. However, there was a trend for the bioptic AMD group to report higher avoidance levels for driving at night ($P = 0.058$). By comparison, differences between the two AMD groups were significant for all driving situations (all $P \leq 0.02$).

Discussion

Sample Characteristics

The bioptic drivers in this survey were a diverse group from 24 states across the United States, resident in rural areas, towns, and major cities. They included young people with congenital visual impairment driving 900 miles per week to elderly with acquired

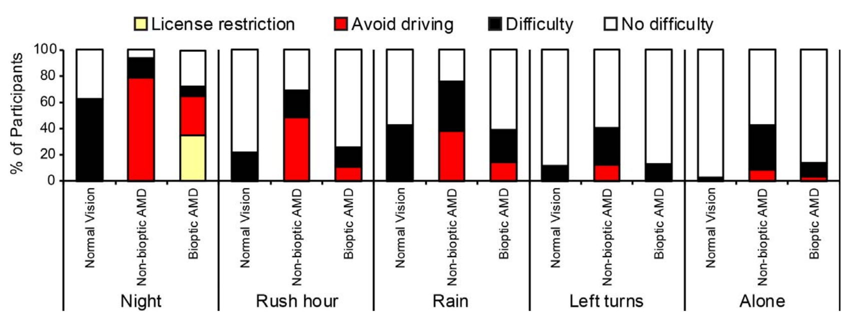

Figure 8. Percentage of bioptic and nonbioptic AMD drivers and NV drivers reporting driving difficulty and driving avoidance due to vision in five of nine driving situations. Nonbioptic AMD drivers reported significantly more difficulty than bioptic AMD and NV drivers in all situations (trends were similar for the other 4 situations not shown).

Table 10. Characteristics of the Bioptic AMD, Nonbioptic AMD, and Normal Vision (NV) Groups

	Normal Vision	Nonbioptic AMD	Bioptic AMD	Kruskal-Wallis		Wilcoxon Rank-Sum[a]	
				$\chi 2$	*P* Value	*Z*	*P* Value
N	36	34	31				
Male, %	61%	53%	71%	2.20	0.33	−1.48	0.14
Age (y), median (IQR)	73.6 (62.5–80.1)	79.0 (73.8–82.8)	75.5 (69.9–81.8)	6.18	**0.046**	−1.34	0.18
Visual acuity (logMAR), median (IQR)	0.01 (−0.06–0.10)	0.60 (0.38–1.00)	0.78 (0.60–0.90)	67.02	**0.00**	−1.36	0.17
Age of onset (y), median (IQR)	-	72.0 (67.0–77.0)	66.7 (60.0–75.0)			−2.47	**0.01**
Area, %[b]						−0.58[c]	0.56
Big city	33%		19%				
Medium town	14%		32%				
Small town	6%		23%				
Suburban	36%		13%				
Rural	0%		13%				

[a]Comparing nonbioptic AMD and bioptic AMD.
[b]Normal vision $n = 32$; data not available for nonbioptic AMD.
[c]Comparing normal vision and bioptic AMD.
Bold text indicates significant *P* values.

visual impairment driving only 5 miles per week. As such, they represented a wide cross-section of the bioptic driving population, estimated to number only 4000 to 5000 in 2004.[36] By comparison, the majority of prior surveys of bioptic drivers focused on only one state and included mostly younger drivers.[19–22]

The main aim of the study was to compare the bioptic use behaviors and driving habits of bioptic AMD drivers with two other groups of non-AMD bioptic drivers likely to be encountered by clinicians: people with congenital or childhood onset vision impairment who were never licensed without a bioptic and people with onset of vision impairment in early adulthood or in middle-age who were previously licensed and experienced in driving without a bioptic. Importantly, these three groups did not differ in visual acuity, perceived visual ability without the telescope, sex, or the range of areas (city/town/rural) where they lived. However, as would be expected, they differed in age, diagnosis, years of vision impairment, and extent of driving experience without and with the bioptic. These cofactors were interrelated, which limited our ability to draw conclusions about which factors might have been responsible for between-group differences.

Participants whose first license was with a bioptic telescope were not licensed until the age of 29, whereas drivers in the other two groups were 16 to 18 years of age when they were first licensed without a telescope. The AMD group had the fewest years of bioptic driving experience and the lowest participation in any kind of on-road training with a bioptic telescope (only 23%). By comparison, approximately half of the other two groups had participated in on-road bioptic training. Those first licensed with a bioptic had the greatest amount of bioptic driving experience and the greatest number of hours of general bioptic and on-road training (though some of those on-road training hours were likely related to learning to drive). The difference in the number of training hours between those first licensed with and without a bioptic are consistent with the findings of the retrospective review by Dougherty et al.[23] of the 237 bioptic drivers who participated in the Ohio bioptic program. Regulations governing the amount of training required before taking a road test to drive with a bioptic vary widely across the states[36]; this diversity was reflected within each group of bioptic drivers in our study.

Visual Difficulty without Bioptic

Participants perceived reading street names and road signs to be the two most visually difficult tasks to perform without a bioptic. These two tasks were

Table 11. Driving Habits of Bioptic and Nonbioptic AMD Drivers and NV Drivers

	Normal Vision	Nonbioptic AMD	Bioptic AMD	χ2	*P* Value
Quality of driving, %				7.36	**0.02**
≥Good	89%	58%	87%		
≤Average	11%	42%	13%		
Driving speed, %				14.42	**0.001**
Same/faster	78%	42%	74%		
Slower	22%	58%	26%		
Suggestion to stop driving, %	8%	38%	26%	8.65	**0.01**

markedly more difficult than the other tasks: reading street names was 2 SD above the mean task difficulty while reading road signs was 1 SD above the mean (Fig. 1). By comparison, seeing traffic light signals and judging when safe to pass were only just above the mean and all other tasks were below. Despite more recent onset vision impairment and fewer years of bioptic driving, the ordering of task difficulties did not differ for the AMD group relative to the two younger groups (i.e., there were no significant differential item functioning effects across groups). However, as might be expected, those with better visual acuity reported lower levels of perceived difficulty without the bioptic.

Reading road signs was also rated as one of the most visually difficult driving tasks by a heterogenous group of low vision patients attending the Wilmer Low Vision Rehabilitation Service in a study conducted by Massof et al.[37] However, while our bioptic drivers rated seeing traffic lights and pedestrians as more difficult than judging the distance to the car ahead or judging when safe to merge, low vision patients in the Massof et al.[37] study rated maintaining an appropriate distance from the car ahead and merging into traffic as more difficult than identifying traffic signals and seeing pedestrians. Visual acuity of low vision patients in the Massof et al.[37] study was on average better (median 20/60) than that of bioptic drivers in our study (median 20/120), which may explain why bioptic drivers found seeing pedestrians and traffic signals more difficult. Furthermore, there were differences in the participant characteristics that limit comparisons. The median age of participants (75 years) in the Massof et al.[37] study was similar to that of our bioptic AMD group (75 years), but much higher than the overall median age of our three bioptic groups (52 years). Furthermore, Massof et al.[37] included both drivers and nondrivers with a range of eye conditions likely to cause reduced acuity (42% AMD, 11% diabetic retinopathy, 6% optic atrophy), as well as eye conditions likely to cause peripheral field loss but with good visual acuity (12% glaucoma, 4% cerebral vascular accidents). By comparison we included only current drivers with reduced visual acuity and about 50% had congenital or childhood onset vision impairment.

Bioptic Usage When Driving

Despite differences in training and bioptic driving experience, the bioptic use patterns of the AMD drivers were, in general, not significantly different from those of the two younger groups. The majority of participants reported that the telescope was very helpful overall, that they wore the telescope all the time when driving and that they would still use the bioptic telescope, even if not required for licensing.

Telescopes were used most commonly for reading road signs and street names (the tasks reported to be most difficult without the bioptic) and least commonly when judging the distance from the car in front, judging when to merge and seeing brake or signal lights on the car in front (the tasks reported to be least difficult without the bioptic). Judging when to overtake another car was the only task for which there was a significant group difference. A higher proportion of those first licensed with a bioptic reported using a bioptic for this task, while the proportions in the other two groups were similar. It is possible that this difference might be related to the lack of prior driving experience with normal vision.

In general, the tasks for which the bioptic was least and most commonly used are in agreement with prior surveys.[18,19] However, there was one notable difference in the findings between this study and a study by Owsley and colleagues.[19] Whereas approximately 70% of participants in that study reported using the bioptic for seeing brake/signal lights on the car in front, only 33% did so in our study. This difference might be related to specific training that the participants in the Owsley et al.[19] study received because they had all

Table 12. Driving Exposure of Bioptic and Nonbioptic AMD Drivers and NV Drivers

	Normal Vision	Nonbioptic AMD	Bioptic AMD	Kruskal-Wallis		Wilcoxon Rank-Sum[a]	
				$\chi 2$	*P* Value	*Z*	*P* Value
Days/wk	5.0 (2.0–7.0)	3.5 (1.9–5.0)	6.0 (3.0–7.0)	5.35	0.07	−2.31	**0.02**
Places/wk	4.0 (2.0–4.0)	2.0 (1.0–3.0)	3.0 (2.0–4.0)	4.99	0.08	−1.90	**0.06**
Trips/wk	4.5 (2.0–9.0)	4.0 (1.5–7.0)	5.5 (3.0–7.8)	1.92	0.38	−1.40	0.16
Miles/wk	61 (16–112)	17 (4.5–44)	56 (25–150)	14.38	**0.001**	−3.62	**0.00**

[a]Comparing nonbioptic AMD and bioptic AMD.

prepared for bioptic licensure at the same driving assessment clinic. By comparison, in our study, participants had received differing amounts of training at various locations across the United States.

The majority of participants reported viewing through the telescope for 5% or less of driving time, which is consistent with recommendations[38] that the bioptic should be used no more than 10% of the driving time, even in the most demanding areas. However, estimating either the frequency of telescope use or how much time is spent looking through the telescope is not easy and there are only limited objective data available from video recordings of bioptic drivers. In a naturalistic driving study, Luo and Peli[39] recorded telescope usage of two bioptic drivers in their own cars for 5 and 10 days, respectively; the telescopes were used for only 0.03% and 1% of driving time.[39] In a 14.6 mile on-road driving evaluation, Wood et al.[25] found wide variability in the number of times bioptic drivers looked through their telescope, ranging from 0 to 318 times (mean 77).

Did the Bioptic Telescopes Meet the Visual Demands of the Visually Impaired Drivers?

The responses to the bioptic usage questions, in particular, the helpfulness ratings, indicate that the bioptic telescopes did meet the visual demands of the majority of bioptic drivers in this study, both participants who had previously driven without a bioptic (middle-aged and older) and younger participants who had never driven without a bioptic. Although we only asked participants to rate visual difficulty without the bioptic, and not with the bioptic, the rating of bioptic helpfulness for each task is likely related, at least in part, to the difference in the amount of visual difficulty experienced with the bioptic compared to without the bioptic. For the bioptic to be "helpful," one would expect that the task would have to be difficult without using the bioptic and become less difficult with the bioptic and it would depend on matching the telescope to the demands of the participant's visual impairment. In our study, higher levels of perceived difficulty without the bioptic were strongly related to higher levels of perceived bioptic helpfulness (Fig. 3) suggesting that the telescopes met the visual demands of the bioptic drivers. Furthermore, participants who gave higher ratings of bioptic helpfulness also gave higher ratings of the extent to which being permitted to drive with a bioptic improved quality of life.

Driving Habits of AMD Bioptic Drivers Compared with Other Bioptic Drivers

The three bioptic groups did not differ in their above-average self-reported ratings of the quality of their driving. However, a higher proportion of participants who were first licensed without a bioptic reported driving more slowly than the general traffic flow. This prior experience of driving with good vision without a bioptic might have made them more cautious in their bioptic driving than participants in the group who had no such prior experience.

Driving more slowly has been considered a good compensatory strategy for drivers with central vision impairment because it provides more time for visual processing of the roadway environment and more time for responses when needed.[19,40] However, driving too slowly can also be dangerous. Interestingly, the overall proportion of bioptic drivers (17%) that reported driving more slowly in our survey is lower than the 56% in the survey by Owsley et al.[19] Again this difference may reflect the fact that all participants in the Owsley et al.[19] study prepared for licensure at the same clinic, whereas participants in our study had received training at various locations across the United States, or may be related to the fact that Owsley's participants had fewer years of bioptic driving experience (mean 3.7 ± 5.8 years).

Approximately half of the participants reported making use of visual assistance from fully-sighted passengers, most often for reading traffic signs. The proportion that used visual assistance did not differ between the three bioptic groups. AMD participants did, however, report using this kind of assistance for a greater proportion of driving time than the other two groups; 30% of the AMD group who used assistance did so for more than 50% of driving time. These findings suggest that some of the AMD bioptic drivers relied heavily on a sighted passenger for tasks that might otherwise have been performed with the bioptic telescope. This calls into question how much some of these participants actually used the telescope, especially when there was a sighted passenger in the car. Making use of visual assistance (or "copiloting") has also been reported as a strategy used by people with AMD when driving without bioptic telescopes.[41] However, whether it is an effective strategy and whether it is a safe strategy (especially if the passenger is not licensed to drive) is unknown.

Overall, the bioptic drivers reported relatively unrestricted driving patterns, averaging 191 miles per week; only 27% drove no further than the neighboring town. As might be expected, the AMD group drove fewer miles and made fewer trips per week than the two younger non-AMD groups. Although the proportions driving to neighboring and distant towns were similar in the three bioptic groups; a lower proportion of AMD drivers drove outside of their state.

In general, bioptic drivers reported little perceived visual difficulty across a range of driving situations (Fig. 6). Consistent with prior surveys,[18,19] driving in rain, in bright sunlight, and at night were the situations with the highest levels of perceived driving difficulty. These are all situations in which aspects of the visual impairment, not compensated for by the bioptic telescope, would be likely to cause visual difficulty and bioptic drivers self-restricted accordingly. Driving at night was the only situation where AMD drivers reported greater avoidance levels than the other two groups, which may be related to impairments in dark adaptation that accompany AMD.[42] Those reporting higher levels of driving difficulty also reported lower levels of driving exposure and a small driving space, which further suggests that bioptic drivers self-restrict their driving in relation to their perceived limitations, as reported for nonbioptic drivers with early cataract[1] and peripheral field loss.[43,44]

Comparison of Bioptic AMD Drivers with Nonbioptic AMD and NV Drivers

In agreement with our hypotheses, bioptic AMD drivers exhibited less restricted driving habits, lower levels of perceived visual driving difficulty, and lower levels of driving avoidance in difficult situations than nonbioptic drivers with AMD[7] (of a similar age with similar levels of visual acuity). In particular, nonbioptic AMD drivers reported high levels of driving avoidance at night, in rain, in the rush hour, and on interstates. Bioptic AMD drivers were also more positive than nonbioptic AMD drivers when rating the quality of their driving and were less likely to report driving more slowly than the general flow.

By comparison, there were fewer differences between the driving habits of bioptic AMD drivers and age-similar NV drivers; the main difference was in their driving space. Bioptic AMD drivers reported a smaller driving space than NV drivers as they were less likely to drive to distant towns or out of their state. There was also a trend for the bioptic AMD drivers to report higher levels of avoidance when driving at night. The percentage of bioptic and nonbioptic AMD drivers who had been advised to limit or stop their driving was higher than for NV drivers. This suggests that family members or caretakers might have had concerns about the safety of driving for older persons with acquired visual impairment.

Targeting of Questionnaire Items

Rasch analyses were used to estimate item and person measures for three sets of questions (see Supplementary materials). For the bioptic helpfulness questions, the items (tasks) were very well matched to the ability of the participants as demonstrated by the overlapping distributions in Figure 3 and the small difference (0.13 logits) between the mean helpfulness of the items and the mean ability of the persons, and the relatively even distribution of item difficulty. The distributions of person and item measures also overlapped well for the visual difficulty without bioptic questions (Fig. 1); however, the spacing of the item difficulties was not even across the range with a concentration of items that were perceived to be relatively easy. By comparison, the driving difficulty questions (mostly taken from the Driving Habits Questionnaire[1]) were very poorly targeted to the ability of the participants; the mean person measure (1.88 logits) far exceeded the mean difficulty level of the items (0.00 logits) with at least half the participants falling above the items rated as the most difficult. In other words, the majority of participants reported little or no difficulty in most of the driving situations. These findings can be used to guide the selection of items for future questionnaires addressing visual and driving difficulties of bioptic drivers.

Summary

This study provides the first detailed reporting of the bioptic use patterns and driving habits of older drivers with AMD who are licensed to drive with a bioptic telescope. However, limitations need to be considered, including: the use of convenience samples of bioptic drivers; the size and characteristics of the source populations were not fully known (especially for those recruited through the advertisement placed on the Bioptic Driving Network website); between-group differences in age, diagnoses, years of vision impairment, and driving experience; self-selection bias in terms of those who responded (as with any survey study); the likelihood that responses might have been influenced by participants being strong proponents of bioptic driving; and the use of a retrospective comparison with nonbioptic AMD drivers.

Despite these limitations, our results clearly demonstrate the extent to which prescription of a bioptic telescope can potentially alleviate driving restrictions resulting from visual impairment acquired in later life. Drivers with AMD found bioptic telescopes useful when driving, reported enhanced quality of life through being permitted to drive with a bioptic telescope, and had relatively unrestricted driving habits. However, further research is required to establish the extent to which bioptic telescopes improve driving performance and safety in this age group with objective recordings to quantify telescope usage during habitual driving.

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