Bioptic Telescopes Meet the Needs of Drivers with Moderate Visual Acuity Loss

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Purpose. Visually impaired people are permitted to use bioptic telescopes for driving in many states in the United States. However, it has been suggested that the telescope is used only to meet the visual acuity criteria for licensure. In this study, a survey was used to establish the extent to which bioptic telescopes are used by and meet the driving needs of people with moderately reduced visual acuity.

Methods. A cross-sectional survey of a convenience sample of 58 bioptic drivers was administered by telephone interview. Bioptic telescope usage patterns were quantified with questions designed specifically for the study. Driving patterns were quantified by use of the Driving Habits Questionnaire. Subjects were recruited from four sources across the United States to ensure a range of bioptic training and driving experience.

Results. The majority (74%) rated the bioptic telescope as very helpful, and almost all (90%) would continue to use it for driving, even if it were not required for driving licensure; however, only 62% reported always wearing the bioptic when driving. Subjects had relatively unrestricted driving habits, driving a mean of 222 ± 211 miles per week, and 85% aged ≤65 years drove to work. With the exception of driving in rain, in bright sunlight, and at night, there was little difficulty with driving in a variety of situations, and levels of driving avoidance due to vision impairment were low (<10%).

Conclusions. The bioptic telescope met the (self-reported) driving needs of the majority of visually impaired drivers in this survey and was found to be a useful aid for tasks requiring resolution of detail. (*Invest Ophthalmol Vis Sci.* 2005;46:66–74) DOI:10.1167/iovs.04-0271

Thirty-four states in the United States currently permit visually impaired people with moderately reduced visual acuity to drive with the aid of a bioptic telescope.[1] The telescope provides the visually impaired driver with a magnified view of objects, such as the text or details of traffic signs, that otherwise could be resolved only at distances too short for a safe or timely response. Typically, the telescope is spectacle mounted at the top of the carrier lens[2,3] (Fig. 1). Most of the time, the driver views the road through the carrier lens (with a wide, uninterrupted field of view), looking intermittently through the telescope (achieved by a slight downward tilt of the head) to read road signs, determine the status of traffic lights, or scan ahead for road hazards.[4]

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Although driving with the aid of a bioptic telescope is not permitted in the European Union (EU), there is increasing interest in the possibility.[5] In determining whether to allow bioptic driving, various factors have to be considered including safety, driving performance, and the social and economic impact of bioptic driving on the life of the visually impaired person. Advocates of bioptic driving argue that, with appropriate training, the bioptic telescope can be a useful aid for drivers with reduced visual acuity[2,3,6–8]; however, some opponents of bioptic driving[9,10] are strongly of the opinion that visually impaired drivers obtain a bioptic telescope purely as a means to meet the static visual acuity requirement for driving licensure and do not use the device thereafter.

Therefore, it is important to establish the extent to which bioptic telescopes meet the driving needs of people with reduced visual acuity. We addressed this question through a survey of bioptic drivers in which we examined how much the bioptic telescope compensates for visual acuity impairment when driving (quantified by bioptic usage patterns) and how much it enables unrestricted driving (quantified by driving habits). Previous surveys (using postal questionnaires) have provided only limited data about bioptic usage patterns and driving habits of bioptic drivers and were restricted to drivers from a single state.[11–13] We included drivers from many states and used telephone interviews that provide greater opportunity for clarification of responses and control of questionnaire administration.[14]

Methods

Subjects

Visually impaired drivers with recent experience of driving with a bioptic telescope were recruited from across the United States to ensure a range of bioptic training and driving experience that was limited to neither one state nor one training program. The four sources selected were the Low Vision Clinic of one of the authors (EP) in a major urban area, the practice of a mobility instructor in a rural area, the participants in a bioptic driving training program (West Virginia Low Vision Driving Program), and a convenience sample of responders to an advertisement placed on the Bioptic Driving Network Web site (Table 1).

Fifty-eight subjects met the inclusion criteria, having driven with a bioptic for at least 3 months within the previous 3 years. Six subjects were not currently driving, but had driven within the past 3 years (five within the past year). All subjects provided informed consent, in accordance with institutional review board approval, and were assured of the confidentiality and anonymity of their individual responses. The study was conducted in accordance with the tenets of the Declaration of Helsinki.

For subjects recruited from the Low Vision Clinic and the West Virginia Program, most of the acuity, diagnosis, and telescope data were confirmed by review of clinical records. For the remaining subjects we primarily had to rely on their recall, although several of them referred us to their eye care practitioners who clarified missing or uncertain information.

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FIGURE 1. A bioptic telescope used for driving (3.0× Galilean, the type most commonly used by subjects in our survey). (**a**) The driver views below the telescope most of the time, (**b**) viewing only intermittently through the telescope by a downward tilt of the head.

Questionnaire

Previous surveys of bioptic[11–13] and nonbioptic drivers[16–19] were reviewed. Sets of questions relating to bioptic usage patterns and perceived visual difficulty of driving without a bioptic were then developed (Table 2). Driving habits were quantified using the Driving Habits Questionnaire (DHQ),[16] supplemented by a few questions specific to driving with a bioptic telescope (Table 2). To maintain the psychometric properties of the DHQ, the additional questions were treated separately from the original DHQ questions.[20] The questionnaire also included questions about background demographic factors, visual acuity and diagnosis, bioptic training received (in-office and on-road), and years of driving experience, with and without the bioptic. Responses were primarily sought in a yes/no format, a 5-point scale format (e.g., to grade level of difficulty or degree of helpfulness), or a short response. (The complete questionnaire is available at www.eri.harvard.edu/faculty/peli/shared/index.htm.)

Qualitative validation of the initial questionnaire was performed by a low-vision rehabilitation practitioner experienced in prescribing bioptic telescopes, two driving instructors with expertise with the visually impaired, and a bioptic driver, to assess the questions for ambiguities, readability, relevance, and face and content validity.[20,21] On the basis of this review, questions were selected and modified for inclusion in the questionnaire. The questionnaire was then tested on the first 10 subjects recruited into the study. Some extra demographic questions were added to the questionnaire at the end of the pilot testing, but the questions relating to bioptic usage, visual difficulty without the bioptic, and driving habits were not changed. Responses from the first 10 subjects were therefore included in the data analyses. The additional demographic questions were administered on a separate occasion to these subjects.

The questionnaire was administered by a telephone interview lasting 30 to 60 minutes. The majority (91%) of interviews were performed by one author (DHA), and the rest by another (ARB). Because of scheduling difficulties, three subjects completed a printed questionnaire.

Statistical Analyses

Statistical analyses were performed using the Statistical Package for the Social Sciences (ver. 11.5; SPSS Science, Chicago, IL). Descriptive statistics were used to characterize demographics and responses to questions relating to bioptic usage, visual difficulty without the bioptic, and driving habits. For all statistical evaluations, $\alpha = 0.05$ was used to define statistical significance. Differences in demographics between recruitment groups were analyzed using Kruskal-Wallis tests for rating scales and non-normal continuous variables, χ^2 tests for categorical variables, and one-factor ANOVAs for normally distributed continuous variables.

The relationship between potential independent predictor variables and dependent measures of (1) bioptic usage (mean bioptic helpfulness score and percentage of time viewing with the bioptic) and (2) driving habits (weekly mileage and mean driving difficulty) were analyzed using step-wise linear regression analyses (with probability to enter ≤ 0.05 and to exit ≥ 0.1). The independent predictor variables entered in regression analyses for the two bioptic usage measures were presence of central field loss, age, participation in bioptic driving program, years of bioptic driving, and mean visual-difficulty-without bioptic score. With the exception of mean visual-difficulty-without bioptic score, which was replaced by the variable living in a rural location, the same set of independent predictor variables was also used in multiple regression analyses for the two driving-habits measures.

Rasch analysis (MiniStep computer program, ver. 3.42[22,23]) was used to estimate interval scale measures[24] for the bioptic helpfulness scale and the visual-difficulty-without-bioptic scale. For both scales, the interval scale measure from the Rasch analysis and the mean rating correlated highly (bioptic helpfulness, $r = 0.98$, $P < 0.001$; visual difficulty without bioptic, $r = 0.97$, $P < 0.001$) and the outcomes of the statistical analyses were the same irrespective of which of these summary measures was used. We report only the results of the mean ratings.

Age, duration of visual impairment, mean bioptic helpfulness score, mean difficulty-without-bioptic score, mean driving difficulty, and weekly mileage were not significantly different from a normal distribution (Kolmogorov-Smirnov test $P > 0.1$); all other continuous variables were significantly different from a normal distribution ($P < 0.05$).

TABLE 1. Summary of Recruitment Sources

Recruitment Source	Number Included (Participation rate)	Type of Training	Geographic Location
Patients prescribed bioptic telescope at a Low Vision Clinic in Boston*	14 (100%)†	Limited in-office training in bioptic use (30–60 min); advised to arrange bioptic driving lessons with specialist instructor	Mainly Massachusetts
Clients of Certified Orientation and Mobility Specialist	9 (100%)‡	On-road bioptic driving program, including passenger-in-car, but no behind-the-wheel, training (~8 h)	New Hampshire
Graduates of the West Virginia Low Vision Driving program 1986–1998[15]	12 (42%)§	On-road bioptic driving program including classroom, passenger-in-car and behind-the-wheel training (≥100 hours)	West Virginia
Advertisement on Bioptic Driving Network Web site (www.biopticdriving.org)	23	Varied, from limited in-office to participation in on-road bioptic driving programs	Twelve of the United States; One province of Canada

* Vision Rehabilitation Service of author (EP).
† Sixteen met the inclusion criteria but 2 were excluded due to poor-quality responses.
‡ Contact details were available for nine clients, all of whom met the inclusion criteria.
§ Fourteen of 33 graduates agreed to participate, 1 did not meet the inclusion criteria, and 1 could not be reached.

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

Section	Variables	Details
Visual difficulty without bioptic	Mean difficulty without bioptic score	Mean rating for seven items from the visual difficulty-without-bioptic scale (see Table A1, Appendix). Higher score represents less perceived difficulty.
Bioptic usage when driving	Mean bioptic helpfulness score	Mean rating for seven items from the bioptic helpfulness scale (see Table A1, Appendix). Higher score represents greater levels of bioptic helpfulness.
	Overall rating of bioptic helpfulness	Scale: 0 (no help) to 5 (extremely helpful); subjects' overall rating of bioptic helpfulness when driving.
	Percentage of time viewing with bioptic	Estimate between 0% and 100%.
	Percentage of time wearing bioptic	Scale: 0 (not worn) to 6 (worn all the time).
Driving habits*		
General	Speed relative to flow; quality of driving: confidence to drive with bioptic; quality of life	Self-ratings for each item on 5-point scale. Higher score represents higher self-rating. Items added: rating of confidence to drive with bioptic and extent to which driving with bioptic improved quality of life.
Driving exposure	Days per week; places per week; miles per week	Estimate of numbers of days, places, and miles driven in a typical week.
Driving space	Binary response for each location	Determines farthest distance driven from home. Binary (yes/no) response for each of six locations at increasing distances from home (DHQ items 29–34).
Driving difficulty	Mean driving difficulty score	Mean rating of driving difficulty for DHQ items 17–24. Higher score represents less perceived difficulty. Item added: rating of difficulty driving in bright sunlight.

* Driving Habits Questionnaire[16] (DHQ) to which a few items were added for the purpose of this survey.

RESULTS

Sample Characteristics

Demographics, visual status, and driving experience for the sample are summarized in Table 3. Subjects recruited from the Low Vision Clinic had a different demographic profile from those recruited from the other sources, where the demographics were more similar. Specifically, they were older (mean, 61 years; $F_{(3,54)} = 6.5$, $P = 0.001$) and had adult-onset eye disease (70% macular disease; $\chi^2_{(3)} = 23.4$, $P < 0.001$), a shorter duration of visual impairment (mean, 23 years; $F_{(3,54)} = 3.7$, $P = 0.02$), and greater total driving experience (median, 48 years; $\chi^2_{(3)} = 10.0$, $P = 0.02$).

Fifty percent of subjects had participated in a formal bioptic training program, either a full-scale program with behind-the-wheel training (31%) or a more limited program with passenger-in-car, but no behind-the-wheel training (19%). An additional 17% reported taking a few extra driving lessons or completing standard driver's education with the bioptic from an instructor who had some experience in teaching disabled drivers. Surprisingly, only 71% reported receiving in-office training. The majority used a monocular telescope (95%) of 3× (47%) or 4× (36%) magnification.

Properties of the Questionnaire

Psychometric properties relating to the two scales specifically designed for this survey are reported in this section (see the Appendix for properties of the rest of the questionnaire). Cronbach's α[25] measure of internal consistency for the seven items within the bioptic helpfulness scale was 0.75 and for the visual-difficulty-without-bioptic scale, 0.79. These values fall well within the recommended range of 0.70 to 0.90,[21] confirming that the scales were homogeneous (tapping different

TABLE 3. Demographics, Visual Status, and Driving Experience for the 58 Bioptic Drivers

Age (y), mean ± SD (range)	47 ± 17 (17–86)
Male, % (*n*)	62% (36)
Diagnosis, % (*n*)	
Albinism	38% (22)
Other congenital conditions	22% (13)
Age-related macular degeneration	12% (7)
Juvenile macular dystrophy	12% (7)
Other	16% (9)
Visual acuity without telescope, median (range)	20/100 (20/50–20/240)
Duration (y) visual impairment, mean ± SD (range)	34 ± 18 (2–81)
First license awarded with bioptic, % (*n*)	59% (34)
Years of bioptic driving, median (range)	8 (0.25–32)
Total years of driving, median (range)	16 (0.25–69)
Employment status, % (*n*)	
Employed	74% (43)
Unemployed	9% (5)
Retired	17% (10)
Education, % (*n*)	
Postgraduate	35% (20)
College	52% (30)
High school	14% (8)
Type of area, % (*n*)	
Rural	17% (10)
Small town	22% (13)
Medium town	26% (15)
Suburban	26% (15)
City	9% (5)
Public transportation within walking distance, % (*n*)	43% (25)

TABLE 4. Comments about Bioptic Telescopes (Open-Ended Questions)

Comment	Percentage Who Made a Comment (*n*)*
Reasons for infrequent wear (*n* = 6, 10%)	
Difficulties using the bioptic	50% (3)
Only worn when driving in unfamiliar places or on the highway	33% (2)
Incorrect prescription bioptic (cannot afford correct one)	17% (1)
Other tasks for which a bioptic was reported to be useful when driving (*n* = 19, 33%)	
Finding correct toll lane, exit lane or travel lane on multi-lane roads	37% (7)
Spotting landmarks	11% (2)
Seeing hand signals (police/construction workers)	16% (3)
Navigating road detours	16% (3)
Looking past headlight glare	11% (2)
Miscellaneous	26% (5)
Problems encountered when using a bioptic for driving (*n* = 9, 16%)	
Weight of telescope	33% (3)
Solar glare (sunrise/sunset) through telescope	33% (3)
Bioptic limits visual field when looking through carrier lens (parallel parking)	22% (2)
Problems due to lack of training and experience	33% (3)

* In each section, some subjects made more than one comment.

aspects of the same attribute) without too high a level of item redundancy (indicated by high values of $\alpha > 0.90$). The two scales also had reasonable test–retest reliability over intervals ranging from 1 week to >1 year (intraclass correlation coefficient of 0.68 and 0.74 for the mean bioptic helpfulness score and mean visual-difficulty-without-bioptic scores, respectively). The mean bioptic helpfulness score was 2.4 ± 1.2 and the mean visual-difficulty-without-bioptic score was 3.4 ± 0.9. (The mean bioptic helpfulness score was calculated across all seven items in the scale and therefore reflects not only the degree of perceived help for those tasks [items] for which the telescope was used, but also the number of tasks for which the telescope was not used [recorded as helpfulness of 0]. When only those tasks for which the bioptic was used were included, the mean helpfulness score was 4.2 ± 0.9.)

Bioptic Use when Driving

Sixty-two percent of subjects reported wearing the telescope all the time when driving, whereas 10% wore it either rarely (<10% of driving time) or not at all (Table 4). The median estimate of the time spent viewing with the telescope was 5% of total driving time (range, 0%–70% [0% indicates subjects who did not wear the telescope]; interquartile range, 3%–10%). In the overall rating of bioptic helpfulness, 74% reported that the telescope was very helpful and 17% that it was moderately helpful. Furthermore, the large majority (90%) stated that they would still use the bioptic for driving, even if it were not required for driving licensure. The few (six) subjects who reported that they would not, mainly rated the bioptic telescope as useful only to obtain their driver's license, and half of these subjects reported wearing the bioptic either rarely or not at all.

All subjects used a telescope for reading road signs (the task that was perceived as visually most difficult without the bioptic), whereas fewer than 30% used a telescope for seeing brake/signal lights or judging the distance to the car in front of them (the tasks that were perceived as visually least difficult without the bioptic; Fig. 2). For each task, subjects who used a bioptic rated the task significantly more difficult visually than subjects who did not use it ($t_{(56)} > 3.8$, $P < 0.001$; mean differences, 1.1–3.0 rating points). Other driving tasks for which subjects reported using a bioptic are summarized in Table 4. We also asked about potential difficulties of using a bioptic telescope when driving, specifically difficulty (while viewing with the telescope) with awareness of traffic outside of the field of the telescope and difficulty lining up the telescope on the object of interest; however, the majority (85% and 86%, respectively) of subjects reported no difficulty with these tasks. Only 16% stated that there were any situations in which the telescope actually hindered their driving (Table 4).

Driving Habits

The majority (83%) of subjects preferred to drive themselves, rated their quality of driving above average (72%), and drove at the same speed as the general flow of traffic (84%). Confidence while driving with a bioptic was high; 88% were moderately or very confident. In a typical week they drove on a median of 6 days (range, 0–7) to four places (range, 0–7) and a mean of 222 ± 211 miles (range, 0–938; ranges include 0, as one subject drove only in emergencies and did not drive in a typical week). The main reasons for driving were to go shopping (83%) and to go to work (72%). Among those aged ≤65 years (*n* = 47), 40% had no public transportation in their areas, yet 90% were employed, and 85% drove to work. Of the total sample (*n* = 58), only 28% drove no farther than the neighboring town (i.e., had a restricted driving area[16]), whereas 60% drove outside their state, 33% outside their region of the United States, and 45% in a large city. Furthermore, the majority of subjects (79%) reported that driving with a bioptic telescope improved quality of life a lot, or moderately (12%), with only 3% stating that it did not improve quality of life at all.

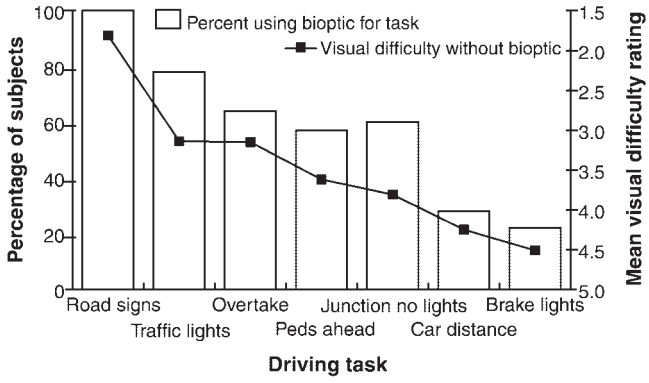

FIGURE 2. Percentage of subjects using a bioptic and mean perceived visual-difficulty-without bioptic for each of the eight visual driving tasks. As the degree of perceived visual difficulty without bioptic for each task decreased, the percentage of subjects using a bioptic also decreased. Mean visual difficulty is plotted so that visual difficulty increases up the *y*-axis (from 5 = no difficulty to 1 = extreme difficulty). Definitions of *x*-axis labels: Road signs, reading road/traffic signs; Traffic lights, identifying traffic light signals; Overtake, determining when safe to pass (overtake) another car on a two-lane road; Peds ahead, looking for pedestrians and other hazards on the road ahead; Junction no lights, determining when safe to move at an intersection without traffic lights; Car distance, judging the distance of cars in front; Brake lights, seeing brake lights/turn signals on vehicles ahead.

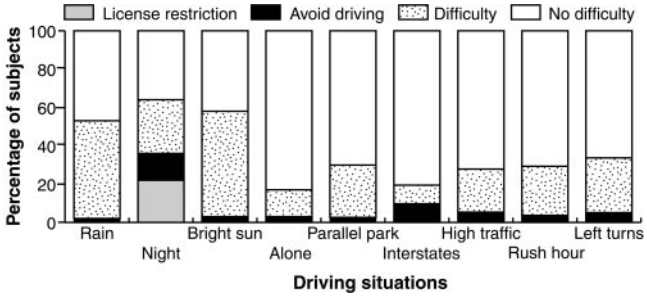

FIGURE 3. Percentage of bioptic drivers reporting driving difficulty and driving avoidance due to vision impairment in each of nine situations. With the exception of driving in rain and bright sunlight, only a low percentage of subjects reported driving difficulty. Avoidance levels were highest for driving at night, with 22% not driving at night due to a daytime-only license restriction.

In terms of driving dependency, 55% were usually the driver (when another driver was in the car), and 60% made occasional use of visual assistance from a normally sighted passenger for a variety of tasks—mainly, reading traffic signs (18 subjects, 51%), identifying the color of traffic lights (10 subjects, 29%), warning of hazards ahead (10 subjects, 29%), and helping with directions or navigation (8 subjects, 23%). Most subjects reported no crashes or citations; 12% reported one accident and 16% reported having being pulled over by the police once in the previous 12 months.

Overall levels of perceived visual difficulty with driving were low (the mean driving difficulty score was 4.4 ± 0.6) and fewer than 10% of subjects reported avoidance of driving because of vision impairment. The only situations for which 50% or more of bioptic drivers reported either difficulty or avoidance were driving in rain, in bright sunlight, and at night (Fig. 3). Twenty-two percent avoided driving at night because of a daytime-only license restriction; however, it is unknown to what extent they would have had difficulty driving at night (although four subjects who had reported a daytime-only license restriction, stated that they drove at night with little [two subjects] or no difficulty [two subjects]). Nevertheless, driving at night was the situation with the highest avoidance levels (Fig. 3). Higher levels of driving difficulty were weakly associated with other self-restricted driving habits, including low weekly mileage ($r = 0.35$, $P = 0.01$), driving on a low number of days per week ($r = 0.33$, $P = 0.01$), and driving no farther than neighboring towns ($r = 0.57$, $P < 0.001$).

Multiple Regression Analyses

Table 5 summarizes the independent variables and the outcomes of the multiple regression analyses for the two dependent bioptic usage measures (mean bioptic helpfulness score and percentage of time viewing with bioptic) and the two dependent driving habits measures (weekly mileage and mean driving difficulty). Mean visual-difficulty-without-bioptic was the only significant predictor of mean bioptic helpfulness score, whereas the presence of central field loss was weakly predictive of the estimated percentage of driving time spent viewing with the bioptic (Table 5). There were no significant predictors of driving difficulty, and the only independent variable selected for weekly mileage was age. Participation in a bioptic driving training program, living in a rural location, and years of bioptic driving were neither predictive of bioptic usage nor of the driving habits variables examined.

DISCUSSION

Sample Characteristics

The age and gender profile of the participants in our survey is similar to that reported for the total bioptic driving population in California[26] and for previous surveys of bioptic drivers that were limited to a single state.[11–13] The percentage of subjects

TABLE 5. Details of Multiple Regression Analyses for Two Bioptic Usage Measures and Two Driving-Habits Measures

Dependent Variable	Independent Variables	Predictors
Mean bioptic helpfulness score	Age Central field loss† Participation bioptic program‡ Years bioptic driving Mean difficulty-without-bioptic	Mean difficulty-without-bioptic Adjusted $r^2 = 0.58$, $F_{(1,54)} = 77.0$ $P < 0.001$ As visual difficulty without bioptic increased, mean rating of bioptic helpfulness increased.
Log_{10} percentage of time viewing with bioptic*	Same variables as mean bioptic helpfulness score	Central field loss Adjusted $r^2 = 0.22$, $F_{(1,54)} = 16.1$ $P < 0.001$ Those with central field loss gave a higher estimate of time looking through bioptic (12% cf. 5%).
Mean driving difficulty	Age Central field loss† Participation bioptic program‡ Years bioptic driving Live in rural location	No variables selected.
Miles per week	Same variables as mean bioptic helpfulness score	Age Adjusted $r^2 = 0.12$, $F_{(1,54)} = 8.2$ $P = 0.006$ As age increased, weekly mileage decreased.

* Converted to log_{10} percentage of time to achieve normal distribution for regression analysis.
† Subjects with diagnoses of macular disease and optic atrophy.
‡ Subjects who had participated in a formal bioptic driving training program.

with congenital ocular conditions (around 60%) was also similar to previous surveys,[11–13] but the proportion of our subjects with albinism was about four times higher. This may be due to the link on the NOAH (National Organization of Albinism and Hypopigmentation) Web site and newsletter to our recruitment advertisement on the Bioptic Drivers' Web site. Participation rates were very high (100%) for subjects recruited from the Low Vision Clinic and mobility specialist, whereas the rate (42%) for subjects recruited from the West Virginia Program was within the range reported in previous postal surveys (28%,[13] 44%,[11] and 73%[12]). Given that limited access to transportation is frequently an obstacle to employment for the visually impaired,[27] the high rate of employment in our sample was very notable. (By comparison, employment rates were lower for random-sample respondents aged 25 to 61 years who reported visual impairment [81% men, 53% women] and blindness [49% men, 30% women] in the USA National Health Interview Survey pooled across 1983–1996.[28])

Our sample of bioptic drivers was reasonably representative of the bioptic driving population in demographics, driving experience, and training received (from little formal bioptic training to participation in a comprehensive bioptic driving training program). However, the sample was limited in size, and it was a convenience sample. Drivers who did not use (or rarely used) their bioptic telescopes were probably underrepresented, especially in the group recruited via the advertisement on the Bioptic Drivers' Web site. Although many participants may have been strong proponents of bioptic driving, we are confident that the results of our survey have reasonable external validity and can be generalized to the wider population of bioptic drivers.

Bioptic Use when Driving

Most participants in our survey reported using the bioptic telescope when driving, found it very helpful, and would use it even if it were not required for licensure. Furthermore, they rarely found that the optical limitations of the bioptic caused difficulties or impeded driving (contrary to the opinions of Fonda[9] and Keeney[10]). In agreement with previous reports,[4,11] the main tasks for which the bioptic telescope was used were navigational tasks that required resolution of detail. The same tasks that were perceived by the subjects as requiring the greatest visual ability without a telescope. Our results suggest a strong association between bioptic usage and task-specific perceived visual difficulty.

In all states permitting bioptic driving, it is a mandatory requirement that the bioptic be worn whenever driving; however, only 62% of our subjects (similar to the 61% in the survey of bioptic drivers in Corn et al.[11]) reported wearing the bioptic all the time. As confidentiality was assured, these responses may indicate honest answers by our subjects (and are not likely to overstate the lack of usage). It appears that our bioptic drivers opt to wear the bioptic only when they feel that it will be useful and possibly do not realize that it should be worn at all times to comply with licensing regulations. Although not specifically questioned, some subjects commented anecdotally that they did not wear the bioptic when driving familiar routes.

Bioptic drivers are usually taught to view through the bioptic only intermittently when driving.[29–33] Jose and Ousley[8] suggest that the bioptic should be used no more than 10% of the driving time, even in the most demanding areas. Our finding of a median estimate of 5% of driving time spent viewing with the telescope falls well within this recommendation, but contrasts with the survey of bioptic drivers by Corn et al.,[11] in which the median estimate fell in the range of 16% to 20% of driving time and is at the lower end of the 5% to 20% range reported by Taylor.[12] It is possible that the higher estimates reported by Corn et al.[11] and Taylor[12] are a result of the respondent's having difficulty understanding the question (as these were mail rather than telephone surveys). Subjects with central field loss gave higher estimates of percentage of time viewing with the telescope than did subjects without central field loss, which may be related to difficulties of using a nonfoveal location for fixation.

The percentage of time viewing with bioptic telescope was the bioptic-use question with the lowest test–retest reliability (see Table A3, Appendix). Conceptually, it was a more difficult question for subjects to answer than others in the bioptic use section of the questionnaire; therefore, the low reliability was not unexpected. Because our survey was administered on a single occasion, low test–retest reliability for this item was less of a concern than it would have been if it were an outcome measure in a study with repeated administrations. Nevertheless, objective measures are needed of bioptic usage patterns when driving, and we intend to evaluate such measures in future studies of bioptic driving.

Bioptic Driving Habits

Although there was some evidence of self-imposed restrictions, in many respects the driving habits of the participants in our survey were relatively unrestricted. The mean weekly mileage was very similar to that reported in a recent survey of adults[34] (222 and 203 miles, respectively). Little or no perceived visual difficulty was reported for a range of driving situations, and levels of driving avoidance due to vision impairment were lower than have been reported for some visually impaired, nonbioptic drivers.[17,35,36] Driving in rain, at night, and in bright sunlight (probably due to the high percentage of albinos in our sample) were the situations with the highest levels of perceived visual driving difficulty, situations in which aspects of the visual impairment not compensated for by the bioptic telescope would be likely to cause visual difficulty, and the bioptic might be of limited benefit. Although there was evidence that bioptic drivers self-restrict their driving to some extent (those reporting higher levels of visual driving difficulty also reported lower levels of driving exposure, as noted in nonbioptic drivers with early cataract[16]), the levels of driving avoidance in situations in which the bioptic telescope would be of limited benefit are possibly less than might otherwise be expected. This raises the question of whether a bioptic telescope might engender a false sense of confidence in the visually impaired driver with moderately reduced visual acuity. Although self-reports may overestimate levels of driving exposure and underestimate driving difficulty, measures of actual driving exposure and self-reports have been shown to be similar in older drivers.[37]

Conclusions

The results of this survey indicate that bioptic telescopes are used by and meet the needs of drivers with moderately reduced visual acuity. The telescope compensates for reduced visual acuity in driving tasks requiring resolution of fine detail and enables relatively unrestricted driving habits. However, further studies are necessary to obtain objective measures of bioptic usage (e.g., cameras placed in the vehicle) such that the true extent of bioptic usage can be determined, and training schemes can be designed appropriately, to encourage optimal usage of the bioptic. Furthermore, studies of driving performance (with and without bioptic telescopes) are

needed, to determine whether driving performance and safety are better when people with reduced visual acuity drive, with or without the aid of a telescope.

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APPENDIX

Properties of the Questionnaire

Internal Consistency of Items. Internal consistency of items within the bioptic helpfulness scale and visual-difficulty-without-bioptic scale (Table A1) were analyzed using item-total correlations[21] (correlation of an individual item with the scale total with that item omitted) and Cronbach's α.[25] Streiner and Norman[21] suggest that items with low item-total correlations (<0.20) should be excluded, as they are tapping different traits than the rest of the items. Item-total correlations were <0.20 for three of the 10 items in the bioptic helpfulness scale and for the same three items in the visual-difficulty-without-bioptic scale: reading street names, judging when it is safe to merge onto a freeway, and looking at the speedometer (Table A1). These three items were therefore excluded from each scale in all analyses. The minimum suggested value of Cronbach's α is 0.70.[21] After the three items were excluded, the Cronbach's α for each scale was: bioptic helpfulness 0.75 and visual difficulty without bioptic 0.79.

Merging on a freeway and checking the speedometer probably had low item-total correlations, as they are tasks for which a bioptic is not likely to be used (14% and 5% of subjects, respectively, reported using the bioptic for these tasks). However, it is less clear why the item-total correlation for reading street names was low. Although 76% rated the bioptic as very helpful for reading street names, it was a task performed only rarely and with difficulty. It was a task more likely to be performed when the car was almost stationary than when it was moving: anecdotal comments from eight (14%) subjects indicated that the car had to be slowed to "a crawl" or "stopped" to locate and then read a street name (as is frequently the case for drivers with normal sight).

Test–Retest Reliability. To evaluate test–retest reliability, we administered the questionnaire a second time by telephone to 12 subjects who had participated in the original survey (median period between surveys, 1.3 years; range 1.1–1.4). Only subjects with no reported change in visual status were included. Two subjects, however, reported a change in employment that resulted in driving shorter distances. These two subjects were excluded from analyses of driving exposure and driving space. The questionnaire was also administered on two occasions by telephone to five subjects who had replied to the advertisement on the Bioptic Driving Network Web site, but were too late to be included in the original round of data collection (median period between surveys, 7 days; range, 6–9). Demographic and driving experience data of the 17

TABLE A1. Summary of Bioptic Helpfulness and Visual Difficulty-without-Bioptic Scales

Scale	Items	Scoring
Bioptic helpfulness	Reading road/traffic signs; Identifying traffic light signals; Seeing brake lights/turn signals on vehicles ahead; Judging the distance to cars in front; Looking for pedestrians/other hazards on road ahead; Judging when safe to pass another car on 2-lane road; Judging when safe to move at an intersection without traffic lights; Reading street name signs*; Judging when safe to merge on a freeway*; Checking the speedometer*	Rating of bioptic helpfulness for each item (task) for which a bioptic was used Scale: 1, not helpful, to 5, very helpful. 0 recorded if bioptic telescope not used.
Visual difficulty without bioptic	Same items as bioptic helpfulness scale	Rating of the degree of perceived (visual) difficulty without bioptic telescope for each item. Scale: 1, extreme difficulty, to 5, no difficulty.

* Items excluded from each scale for all analyses.

TABLE A2. Demographics and Driving Experience for 17 Subjects Included in Test–Retest Analyses

Age (y), mean ± SD (range)	46 ± 12 (31–72)
Male, % (*n*)	65% (11)
Diagnosis, % (*n*)	
Albinism	35% (6)
Other congenital conditions	29% (5)
Age-related macular degeneration	6% (1)
Juvenile macular dystrophy	12% (2)
Other	18% (3)
Visual acuity without telescope, median (range)	20/100 (20/60–20/300)
Duration (y) visual impairment, mean ± SD (range)	38 ± 17 (10–62)
First license awarded with bioptic, % (*n*)	71% (12)
Years of bioptic driving, median (range)	12 (2–32)
Total years of driving, median (range)	21 (6–56)
Participation in bioptic driving training program	47%

TABLE A3. Intraclass Correlation Coefficients for Test–Retest Reliability for Items in Each Section of the Questionnaire*

Section	Details	All Subjects (n = 17)	Subjects with >1 Year Test Interval (n = 12)	Subjects with 1-Week Test Interval (n = 5)
Background	Demographics, training, years driving with and without bioptic, mean (range)	0.88 (0.46–1.00)†	0.86 (0.51–1.00)	0.89 (0.40–1.00)
Visual difficulty without bioptic	Seven items on difficulty without bioptic scale, mean (range)	0.60 (0.46–0.85)	0.50 (0.40–0.97)	0.66 (0.43–1.00)
	Mean difficulty without bioptic score	0.74	0.54	0.97
Bioptic usage when driving	Seven items on bioptic helpfulness scale, mean (range)	0.61 (0.48–0.76)	0.56 (0.41–1.00)	0.74 (0.34–1.00)
	Mean bioptic helpfulness score	0.68	0.58	0.85
	Overall rating of bioptic helpfulness	1.00	1.00	1.00
	Percentage of time viewing with bioptic	0.58	0.24	0.87
	Percentage of time wearing bioptic	0.90	0.84	1.00
Driving habits	General, mean (range)	0.71 (0.60–0.86)	0.72 (0.49–0.81)	0.84 (0.80–0.88)
	Driving exposure, mean (range)	0.79 (0.58–0.94)	0.81 (0.64–0.93)	0.53 (0.50–0.95)
	Driving space, mean (range)	0.88 (0.77–1.00)	0.83 (0.64–1.00)	1.00
	Driving difficulty, mean (range)	0.74 (0.56–0.98)	0.66 (0.40–0.98)	0.88 (0.80–0.96)
	Questions added specific for this survey, mean (range)	0.74 (0.62–1.00)	0.72 (0.49–1.00)	0.82 (0.40–1.00)

* Mean coefficient and range are given for sections of the questionnaire containing more than one item.
† Mean coefficient for demographic items alone was 0.95.

subjects are given in Table A2. The majority (88%) used a monocular telescope of 3× (47%) or 4× (29%) magnification.

Test–retest reliability was assessed using intraclass correlation coefficients.[20,21,38] Results are summarized in Table A3. Reliability coefficients for the questions from the DHQ were within the range reported by Owsley et al.[16] for a sample of older drivers (mean, 71 years) with a 2-week interval between each telephone DHQ administration. As might be expected, there was a trend toward the reliability coefficients being higher for the five subjects with the 1-week interval between questionnaire administrations than the 12 subjects with more than a year between administrations; however, any such comparisons are limited by small sample size.

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