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Driving with Bioptic Telescopes: Organizing a Research Agenda

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Abstract

Being a licensed driver in the U. S. and many other countries facilitates health and well-being. Based on the vision standards in most states, individuals with worse than 20/40 visual acuity who desire licensure are denied through the usual licensure application process. However, over 40 states have bioptic telescope licensing programs where applicants can gain licensure contingent on meeting specific requirements. In spite of the existence of the bioptic telescope and these licensing programs since the 1970s, there has been little rigorous scientific study of this topic. Here I offer an organizing perspective for a research agenda on driving with bioptic telescopes, with the long term practical goal being to provide an evidence basis for licensure policies and training programs.

Keywords

vision impairment; driving; bioptic telescope; low vision

Driving is the primary mode of personal transportation in the United States and many other countries. It facilitates employment, social engagement, personal independence, access to healthcare, and for older adults, reduces the risk for depression and placement into long term care.^{1–7} Licensure to drive is regulated by governmental jurisdictions and is contingent upon the applicant meeting a “vision standard” (among other criteria such as age, “rules of the road” knowledge, on-road test). In virtually all jurisdictions the vision standard consists of a visual acuity screening test, and less commonly a visual field and/or color vision screening. The cut-point for passing the acuity screener differs among states in the US and various countries,^{8–10} however, 20/40 is the commonly used minimally acceptable level. A paradox is that there is little to no evidence that persons with visual acuity worse than 20/40 are at increased risk for motor vehicle collision (MVC) involvement.¹¹ Yet road signs in the US are designed based on sight-distances assuming that drivers have at least 20/30 binocular visual acuity,^{12,13} so from a human factors goal of reading signage, there is some validity to the standard.

It has been estimated that approximately 2.4 million Americans over 40 years old have best-corrected visual acuity worse than 20/40 but better than 20/200.¹⁴ Estimates for adults 40 years old are not available since population-based studies in the US have not focused on younger adults. Based on the vision standards in most states, individuals in this sizeable population who apply for licensure would be denied through the usual licensure application process. However, many states (currently 43) allow drivers with acuity in this range to

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obtain licenses if they demonstrate proficiency in the use of a bioptic telescope while driving as well as meeting other specific program requirements (which vary among the states).^{8,9} A bioptic telescope is an assistive device for persons with low vision, originally developed by Dr. William Feinbloom.^{15,16} The bioptic telescope is mounted in the superior portion of a regular spectacle lens (referred to as a “carrier lens”) or above the carrier lens affixed to the spectacle frame. The carrier lens consists of whatever lens is needed for distance refractive correction (or if no refractive correction is needed, the carrier lens is plano). In most cases the bioptic telescope is prescribed for one eye, although some drivers may prefer binocular telescopes depending on individual characteristics and preferences and the recommendations of the eye care provider. The most common telescope magnifications are between 2× and 4× and provide a field of view between 6° and 16°. While driving, the bioptic telescope user views the world through the carrier lens and then dips the head down very briefly (for about two seconds) to use the bioptic telescope to “spot”, i.e. view signs, traffic control devices, pedestrians, cyclists, and other potential obstacles. In 2004 Huss and Corn¹⁷ estimated that there were approximately 4,000–5,000 persons in the U.S. who were currently licensed bioptic drivers, based on their communications with states where bioptic driving is permitted. However, since that time there have been no reports of a formal or informal census of the number of drivers in the U.S. who are licensed through bioptic driving laws.

There is considerable variability among states in the specific criteria and provisions of laws that allow for bioptic licensing. For example, differences include the minimum acceptable level of visual acuity through the carrier lens, and whether it applies to each eye, both eyes, or binocular viewing; whether night driving is permitted; whether interstate or expressway driving is permitted; the extent of the horizontal visual field required; and the amount of magnification allowed in the telescope. In the absence of research supporting any of the criteria implemented in the various states, it is impossible to scientifically conclude which criteria, if any, are in the best interest of driver safety and performance.

Going back to the 1970s there has been sporadic discussion in the literature about various topics related to bioptic driving (for example, ^{17–31}), including descriptions of how to prescribe bioptic telescopes, training programs for bioptic drivers, various state laws governing bioptic driving, and the appropriateness of such laws. In spite of the attention this topic has received, there has been very little rigorous scientific research on bioptic driving. There are a myriad of questions that need to be addressed, ranging from the safety and on-road performance of bioptic drivers, to clinical and functional prognostic indices predictive of safe bioptic driving, to the most effective training programs to impart driving skills to visually impaired persons. Table 1 organizes a potential research agenda on this broad and multi-faceted area. Importantly, each topic should not be viewed as a separate, circumscribed area, but rather as a measurement domain for addressing research questions. A cross-cutting topic, not listed as a specific row in the table, is policy research, given that it involves all the other topics. For example, what is the most efficient way to teach visually impaired persons to drive using a bioptic telescope, in terms of licensure attainment and cost? This is a policy issue since in many jurisdictions, the state government (through its vocational rehabilitation agency), covers the cost of bioptic driver training programs. Another policy issue is how should a jurisdiction define the minimum best-corrected visual acuity through the carrier lens required in order to be eligible for bioptic licensure, should this apply to both eyes or only one eye, and what if any license restrictions are reasonable for bioptic drivers.

Motor Vehicle Collision Involvement

There have been a few attempts to evaluate the safety of bioptic drivers, i.e. whether they have an elevated MVC risk. It is difficult to make conclusions from this literature since

studies disagree and have methodological shortcomings. In addition, previous studies took place between 20–40 years ago^{18,32–36} (with one exception³⁷) and thus did not involve the latest technology and training programs for visually impaired drivers. A study of bioptic drivers in Massachusetts conducted 40 years ago indicated that bioptic drivers had lower crash rates than those in the general driving population.¹⁸ A California study found that bioptic drivers had a lower rate of traffic citations than the general driving population.³⁷ Yet several other studies reported that bioptic drivers had higher crash rates than control groups.^{32–37} Several of these studies used the general driving population as the control group for comparison, but it is not clear that this is the most relevant or fair comparison, from the standpoint of bioptic drivers. A study in Texas found that the crash rate for bioptic drivers was very similar to that for drivers with cardiovascular or neurological conditions,³⁵ conditions for which licensure is not often questioned. In studies that have found an elevated MVC risk for bioptic drivers, it is unknown what factor(s) specifically contributed to the increased risk. For example, was it the use of the bioptic telescope itself (e.g., dipping behavior to spot in the telescope which momentarily directs attention away from broader aspects of the roadway environment; ring scotoma created by the telescope), the driver's visual impairment itself (e.g., loss of spatial resolution, contrast sensitivity, scotomas in the visual field), the failure to use the bioptic when it was needed, or fundamental differences in driving exposure compared to normally sighted drivers (e.g., no or minimal night driving, avoidance of crowded traffic environments or unfamiliar routes). All these methodological and conceptual issues contribute to difficulty in drawing inferences from this literature.

The preponderance of studies on vision impairment and driving (not focused on bioptic use) suggest that drivers with visual acuity worse than 20/40 and ranging to 20/200 have similar safety records as those with 20/40 visual acuity or better.¹¹ In addition, closed road studies that simulated reduced visual acuity showed that even at levels of 20/200, drivers were able to navigate the roadways, and had gap judgments and maneuvering ability that were not different than that exhibited for 20/20 vision.³⁸ Thus, the results of these studies beg the question as to why are bioptic telescopes required for drivers with acuity between 20/40 and 20/100. The primary purpose of the bioptic telescope for visually impaired drivers is to assist them in recognizing signs, traffic lights, brake lights, and roadway obstacles at sight distances that allow them to respond appropriately. This benefit to the driver has not yet been clearly reflected in safety metrics, i.e. MVC rate. Barron²⁶ has argued that whether or not the bioptic telescope is prescribed for drivers with moderate visual acuity impairment should be considered on an individual basis, proposing that the telescope should not be mandatory to obtain a driver's license if visually impaired drivers can demonstrate driving fitness without a telescope. Because of the lack of evidence that drivers with visual acuity worse than 20/40 but better than 20/200 have an elevated collision risk, some states (e.g., Maryland, Iowa)^{39,40} have allowed for licensure of drivers with visual acuity as low as 20/100 to 20/200 (as long as other specific criteria are met), without the requirement they use bioptic telescopes when behind the wheel.

Characteristics of Bioptic Drivers

Unfortunately there is no national database in the US for licensed bioptic drivers from states that have these programs. Analysis of such a resource would greatly assist in understanding this population's demographic characteristics, visual functional characteristics, and the etiology of their impairments. In addition, it could serve as a possible mechanism for surveying these individuals about their driver-training experiences, driving habits, and health-related quality of life, as well as facilitating a national population examination of MVC and moving violation rates. The utility of a national database is illustrated by an initiative undertaken by the Federal Motor Carrier Safety Administration (FMCSA) of the US Department of Transportation (DOT).⁴¹ In order to examine the safety of commercial

vehicle (CMV) drivers who did not meet the current visual acuity standard to obtain a CMV license, they created a national waiver program from 1992–1996 where drivers who did not meet the standard were granted commercial licenses. These drivers were followed over time through a database that tracked their collisions, so that FMCSA could evaluate the impact of the program on safety. A report from 1996 indicated that MVC rates of drivers in the waiver program as of 1995, adjusted for miles traveled, were not higher than a reference group of drivers of heavy trucks based on the General Estimates System of the National Highway Traffic Safety Administration, nor were their crashes more severe.⁴²

To my knowledge there have been three published surveys of bioptic drivers. The first conducted was based on drivers in Illinois and had a high response rate (73%) by survey research standards.⁴³ Survey results strongly highlighted the importance bioptic driving has for life satisfaction in persons with vision impairment. Subsequent surveys were based on drivers in Michigan,⁴⁴ and drivers from three different regions in the US as well as those responding to a web-based advertisement.⁴⁵ The generalizability of the findings from these latter two surveys is somewhat questionable since the Michigan survey⁴⁴ had a low response rate (28%) and the other survey⁴⁵ relied on a collection of convenience samples with unspecified participation rates with respect to the population. Respondents to all three surveys had wide ranging ages from teenagers to persons in their 80s, however, the vast majority were under age 60. This is interesting since on a population-basis, central vision impairment in the US is most prevalent among older adults, as compared to other age groups, especially due to age-related macular degeneration (AMD). Yet only a minority of the drivers were older adults and had AMD (most had early-lifespan onset or congenital conditions). It remains to be determined why persons with AMD do not become bioptic drivers. Possible reasons are that clinicians may not be presenting bioptic telescopes as an option for older drivers with AMD, or perhaps these older drivers are not interested in using bioptics to drive and/or they try them, but do not feel that they help. Many older adults have medical co-morbidities (e.g., cognitive impairment) that may make the training programs more challenging and less effective than for younger adults. Yet it is worth exploring the issue of AMD and bioptic driving further. With the availability of the anti-VEGF treatments for AMD, analyses have shown that the incidence of legal blindness (20/200 or worse) will be reduced in the US⁴⁶ and elsewhere.⁴⁷ Although early and intermediate forms of the disease are still present in the population, these individuals typically have better than 20/200 acuity, thus making them potential candidates for bioptic driving in many states. As discussed at the outset of this article, there are many health and quality of life benefits to being a driver, and thus, maintaining driving mobility through the use of a bioptic may be an attractive option for many adults with AMD.

How is the Bioptic Telescope Used During Driving?

Training programs teach visually impaired persons how to use the bioptic telescope to spot relevant targets in the roadway environment. However, we lack an understanding about how drivers routinely use the bioptic. No comprehensive investigations to date have video recorded bioptic drivers behind the wheel and then analyzed the video to determine for example, how frequently they “dip” the telescope, under what conditions, and what points in space they direct it towards. Measurement techniques have been described for video-recording bioptic drivers and for measuring telescope aiming,^{48,49} which may assist in addressing these types of questions in future research. There are some who have suggested that bioptic telescopes are not primarily used by visually impaired persons for on-road driving but are principally used to pass the visual acuity screening test when applying for licensure, and then are not used once the driver is licensed and on the road without a rehabilitation specialist in the vehicle monitoring his/her behavior.^{19,23} There is no evidence either to support or refute this contention. Bioptic telescopes create what is referred to as a

ring scotoma since the magnified view on the retina obstructs vision in a ring around central vision (which is normally available to the observer when not viewing through the telescope). There have been concerns raised that for binocular telescope users, the ring scotoma created by the magnified telescope view threatens driver safety, since it occludes potentially important features of the roadway environment.^{19,23} However, many bioptic drivers use monocular, not binocular, telescopes thus theoretically allowing the fellow, non-telescope eye an unimpeded view of that portion of the roadway. A recent study found that when target detection by the fellow eye was measured for monocular bioptic users, their detection rates were similar with and without the bioptic telescope.⁵⁰ Although the study was not performed in a driving environment but rather in a perimeter, it does highlight that concern about the ring scotoma from the telescope is likely exaggerated and perhaps entirely without merit. There are also some monocular bioptic telescopes mounted above the carrier lens that when the user dips to use the telescope, approximately 10° radius of the central field in the fellow eye is occluded. Although this dipping behavior is typically very brief (around 2 seconds) and very infrequent during driving, the impact of this occluded part of the fellow eye's visual field on visibility in the roadway environment remains to be determined.

Studies of on-road driving by bioptic drivers using an "instrumented vehicle" have not yet been reported in the literature, except for one pilot study on 2 drivers showing that it is in fact feasible.⁴⁸ This more objective measurement approach could be enormously useful in addressing questions about how the bioptic telescope is actually used, rather than self-reports of use that may not reflect actual behavior. Instrumented vehicles situations involve the installation of monitoring and recording devices in the vehicle (e.g., video camera, sensors for speed, global positioning systems) that when used in real on-road situations, can unobtrusively measure driver behavior, the roadway environment, as well as parameters of vehicle movement.^{48,51–53} In addition, instrumented vehicles can allow for the collection of data when a CDRS and/or study coordinator are not in the vehicle (often referred to as "naturalistic driving"), eliminating the possibility that their presence may be inadvertently biasing or influencing the driver's naturally motivated behaviors. These measurements not only provide information on how the telescopes are used, but also allow for the study of individual differences in their use and relationships to other driver characteristics (e.g., severity of impairment, etiology of impairment), telescope design, training experiences, and MVC involvement.

Efficacy of Training Strategies Poorly Understood

There have been several articles on bioptic driver training programs published in peer-review journals and textbooks, which are largely descriptions of different components of the process.^{17,18,20,21,28,29,31,54,55} However, none of these articles are formal outcome evaluations that address the efficacy or comparative effectiveness of bioptic driver training approaches (with one exception discussed below⁵⁶). Thus, even though the described programs sometimes report that they have led to "successes" (i.e., visually impaired drivers who become licensed), we know little about which approaches are cost-effective, are the most successful in terms of number of drivers eventually licensed, and facilitate the highest level of driver safety and performance. Table 2 provides an overview of some of the main steps involved in bioptic driver rehabilitation and training, the multi-disciplinary types of professionals involved in those steps, and some research questions that have not yet been adequately addressed with respect to training interventions. This is not meant to be an exhaustive list of all rehabilitation components, but rather an illustration of the multi-stage process involved in bioptic driver training, and the complexity of designing outcome evaluations for these training approaches. One study that evaluated a bioptic telescope training program studied clients with impaired visual acuity no worse than 20/100.⁵⁶ They compared task performance outcomes for a group of clients who completed a detailed three-

month training program in telescope use versus a group where telescopes were provided but with no training. Performance outcomes included tasks such as visual recognition, mobility, peripheral identification, and scanning. Some tasks involved driving simulator performance or on-road driving. Not surprisingly, those who were trained in telescope use for three months had greater improvements in task performance than those who had no training, although the results were not reported separately for the driving outcomes. Another study examined the speed with which novice users of bioptic telescopes learn to use them to recognize a peripherally presented letter or number.⁵⁷ They found that the skill is acquired very rapidly. However the study was done with normally sighted individuals with simulated visual acuity impairment. Thus it remains to be determined whether the skill is likewise rapidly learned by those with actual visual impairment who use it in the on-road driving context.

Which Driving Skills Are Most Challenging?

We know that several thousand visually impaired drivers in the US are behind the wheel because of bioptic telescope licensure programs, although as mentioned earlier, the exact size of this population is unknown. We do not objectively know which driving skills are most challenging for bioptic drivers to learn and then once licensed to execute on a routine basis. The vast majority of their driving takes place when they are not viewing through the bioptic, but rather when they are viewing through the carrier lens. Does their reduced visual acuity impact lane-keeping, steering steadiness, general awareness of the roadway environment through peripheral vision, and obstacle detection, and if so, how? How do other types of vision impairment in central vision, such as contrast sensitivity loss and areas of decreased light sensitivity, impact these on-road skills? What are the cues while viewing through the carrier lens that prompt the spotting of potential obstacles or signage through the bioptic telescope? This type of information would seem to be at the crux of training visually impaired persons on how to use the bioptic to enhance driving performance and safety. These issues generate much discussion among clinicians, researchers, and policy makers alike, but there has been little scientific research to date. Studies are needed to address these questions, yet are not in principle difficult to design given the availability of instrumented vehicle technologies discussed above. However, they can be costly because of the need for a specialized instrumented vehicle and the involvement of a multi-disciplinary research team (e.g., psychophysics, engineering, optometry, ophthalmology, human factors, occupational therapy, driving rehabilitation, driver education). A major challenge is the identification of eye movement recording methods that provide reliable and valid data in a roadway environment that has an ever-changing background luminance, also fraught with shadows, glare sources, and literally, bumps in the road. Some research groups have succeeded in doing eye movement recording during on-road driving in real-world situations (for example, ⁵⁸⁻⁶¹) but to our knowledge, there are no published on-road studies on eye movements conducted on visually impaired persons either with or without bioptic telescopes. Achieving valid and reliable eye movement recordings can be very challenging when drivers wear spectacles (which bioptic drivers do) and when participants are elderly (which many visually impaired persons are). In addition, sustaining high quality recordings and maintaining calibration over many participants (which is necessitated by study design concerns) is both challenging and expensive. These hurdles in recording eye movements during real-world on-road driving have prompted some researchers interested in vision impairment and driving to study eye movements in driving simulators or with film or video presentations where luminance and other visual characteristics can be controlled by design.^{62,63} Yet it is also important to understand the noteworthy limitations of driving simulators for understanding real-world driving performance.¹¹ For example, displays lack fidelity to the great complexity of the real on-road environment, and the events and obstacles

in the roadway as portrayed in the simulator are simplifications of those encountered during everyday driving.

Theoretically it seems that the speech-output of global positioning (GPS) navigational systems could be useful to bioptic drivers in route finding and processing other spatial aspects of the roadway (e.g., providing forewarning about turns at upcoming intersections). Research on bioptic drivers has not yet addressed the impact of these potential GPS cueing benefits or their potential drawbacks (e.g., divided attention demands); nor have well-designed surveys of bioptic drivers assessed the users' perspectives on GPS systems and whether and under what conditions they find them helpful. Although GPS systems can provide auditory information about upcoming street signs, they do not provide information about traffic control devices such as traffic lights and braking lights signifying that the vehicle ahead has stopped in the roadway.

Research Priorities

It is obvious from the above discussion that the research field on bioptic driving is in its infancy. As research in this area moves forward, there are some aspects of the research agenda that seem particularly salient for stimulating progress in research and for facilitating the best possible driving options for persons with moderate central vision impairment. First, development of a national database or registry of licensed bioptic drivers in the US would be an invaluable tool for research on bioptic driving since it forms a sizeable population to study, most likely thousands of individuals. There are undoubtedly regulatory, administrative, and financial obstacles involved in creating such a database, but they do not seem insurmountable if we are guided by the experiences of other investigators who have successfully implemented research disease-based registries in medical science. The US DOT has already set a precedent in this general area through their creation of the previously mentioned database of commercial truck drivers enrolled in the vision waiver program. It may be possible to enlist the interest of DOT's National Highway Traffic Safety Administration in facilitating an effort to create a bioptic driver database since it could improve both the safety and mobility of drivers with moderate visual impairment, while also enhancing the safety of other road users. Second, on-road driving performance using an instrumented vehicle (either in the present of a CDRS or under naturalistic driving conditions) is the most appropriate methodology for understanding both the process of learning to use a bioptic on the road, and the driving performance by visually impaired persons who use bioptics. It allows for direct measurement of behavior and roadway environment, and it is increasingly accessible to researchers given the advances in vehicle instrumentation technologies. A challenge for future research in naturalistic driving in particular however is the development of analysis techniques to extract relevant parameters from the continuous recording streams of behavior and environment as the person drives in an instrumented vehicle. There has been some work in this area but these methodologies are not yet widely used for the study of visually impaired drivers. Third, states vary considerably in their minimum visual criteria for bioptic driving. Perhaps in this wide array of state laws, there is enough similarity among certain groups of states to compare and contrast the safety profiles of bioptic drivers in states with different types of laws, through the use of ecologic study designs. Finally, perhaps the most nagging question of all is whether persons with moderate visual acuity impairment (in the range of 20/40 to 20/200) actually should be required to wear bioptic telescopes on the road. Does the spotting behavior and identification of distant targets that the bioptic enables (if used) make them safer drivers? Answers to these questions are needed in order to inform policies on vision standards for driving that are evidence-based and thus fair for visually impaired persons who seek licensure.

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Table 1

Possible research agenda for bioptic driving.

Topic	Description	Example research questions
Driver characteristics	Demographics; etiology of vision impairment; visual functional characteristics; years of experience as driver; age at bioptic licensure; whether person was previously licensed through standard process.	Are persons with certain kinds of eye conditions causing central vision impairment more likely to become licensed bioptic drivers? Is degree of visual acuity impairment related to licensure success? To on-road performance? To driver safety?
Driving exposure	How much driving (e.g., miles/week, days/week, trips/week); day driving; night driving; avoidance of or difficulties with challenging driving situations (e.g., rush-hour traffic, inclement weather); whether drives alone.	How does the on-road driving exposure of bioptic drivers compare to similar-age drivers who are licensed through the standard process? Are bioptic drivers more likely to drive with a front-seat passenger who verbally assists in navigation and obstacle avoidance?
Bioptic telescope characteristics	Bioptic telescope design (e.g., magnification, field size, position on carrier spectacles), monocular versus binocular	Is a wider field size in the telescope associated with spotting behavior (e.g., higher correct detection rate of signage)? Do binocular telescopes offer any measurable on-road advantages or disadvantages over monocular telescopes?
Training process	Various steps and elements of training process, beginning with prescribing telescope, training in use of telescope in general (outside of driving), training in use of telescope while driving, for novice drivers, training to drive; various types of professionals involved in training process and their roles.	Are certain elements of training (e.g., mandatory minimum number of hours of on-road training versus training to performance criterion) associated with greater likelihood of success at licensure? Better pedestrian detection? Better safety record?
On-road driving skills	Lane position, steering steadiness, obstacle and pedestrian detection in roadway environment, road sign and traffic control device identification, braking, speed, gap distance	Is the performance of on-road driving skills associated with visual acuity and other aspects of visual function? To what extent is the frequency of dipping into the bioptic related to on-road skills such as road sign and traffic control device identification?
Driver safety	Rate of motor vehicle collisions (MVC) or moving violations over person-years or person-time of driving	Do licensed bioptic drivers have an elevated risk for at-fault MVC involvement as compared to age-similar drivers? How do MVC rates among bioptic drivers vary with different state bioptic licensing criteria?
Quality of life	Impact of bioptic licensure on visually impaired person in terms of employment, psychological well-being, social engagement, access to healthcare, health-related quality of life	Are persons with irreversible visual acuity impairment between 20/40 and 20/200 who are licensed bioptic drivers less likely to be depressed compared to those who are not licensed? More likely to be employed?

Table 2

Bioptic Driver Rehabilitation and Training Programs: Topics in need of research¹.

Element	Professionals likely involved	Potential issues for evaluation
Determination of a client's eligibility for bioptic driving in his/her state of residence based on visual characteristics	Optometrist or Ophthalmologist	How do visual eligibility criteria differ among states that permit bioptic driving and what is the evidence supporting one type of vision standard over another in terms of driver safety and performance?
Prescribing and fitting bioptic telescope	Optometrist or Ophthalmologist	What is the efficacy of different telescope designs and styles, monocular versus binocular, for driver safety and performance?
Basic training in using the bioptic telescope (outside of driving environment) such as dipping, aligning, spotting; practice exercises facilitating learning of these skills	Vision rehabilitation specialists; occupational therapist; certified low vision specialist	What are the training curricula that are most efficacious for learning telescope skills and also the most time efficient strategies of learning? Do these differ by etiology of impairment, severity of impairment, or age of client?
Training and practice spotting targets of interest in the vehicle in a roadway environment, first as sitting in the passenger seat	Certified driving rehabilitation specialist (CDRS), particularly with specialized training in bioptic driving	What are the training curricula that are most efficacious for learning telescope skills and also the most time efficient strategies of learning? Do these differ by etiology of impairment, severity of impairment, or age of client?
For novice drivers: on-road driver training coupled with training in using the bioptic while driving, and the extended practice that goes along acquiring driving skills for the first time. For experienced drivers who have experienced vision loss after standard licensure that requires them to become bioptic drivers: on-road driver training coupled with training in using the bioptic while driving, and reinforcement of driving skills now that have experienced more significant vision impairment	CDRS, particularly with specialized training in bioptic driving; driver educator	What are the most effective training strategies for signage and traffic control device spotting and recognition? For maintaining lane position and steering steadiness? For spotting obstacles in or near the roadway such as pedestrians, parked vehicles, rear brake lights for vehicle ahead? How much practice is optimal (e.g., practice to criterion level of performance, or minimum number of hours practice) and over what calendar time?
Determination that client has acquired sufficient driving skill and use of bioptic to apply for bioptic licensure	CDRS	What criteria does the CDRS use to determine that the client is ready to take the licensure examination, and how does this decision tree relate to success versus failure at licensure?
Evaluation for licensure by the state	State agency in charge of licensure	How safe are the drivers that are licensed in the bioptic driver program? What is the relevant comparison group?

¹Not appearing in this Table, but very often involved in the bioptic driver training process are vocational rehabilitation counselors who work at a state's rehabilitation agency; they often make the initial referral to bioptic training programs since driver licensure can facilitate employment. In many cases these agencies pay for part or all of the cost of bioptic driver training.