THE EFFECTS OF BIOPTIC TELESCOPES

ON CONTRAST SENSITIVITY

by

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ABSTRACT

Background: Low vision devices are becoming more widely used in America. We expect this trend to continue as a large portion of the population ages and more people fall victim to sight-threatening diseases. Currently, bioptic telescopes provide visually impaired individuals with greater independence by enhancing their distance visual acuity. However, there is a lack of information available about how bioptic telescopes affect contrast sensitivity for the purpose of mobility and detail tasks. It is the intention of this project to address the issue of how bioptic telescopes influence contrast sensitivity. *Methods:* This study examines the effects of bioptic telescopes on contrast sensitivity by testing subjects' contrast sensitivity in each eye with the best corrected acuity by means of a Bailey-Lovie Acuity Chart at distance with and without a bioptic telescope. Our test population is normally sighted, near normally sighted, visually impaired, and legally blind subjects as defined by the American Optometric Association. *Results:* All groups demonstrated an average improvement in contrast sensitivity with the telescope. All groups except for the legally blind showed more improvement with the telescope while viewing the low contrast chart compared to viewing the high contrast chart. *Conclusions:* All of the data suggest that there is no adverse effect of the Galilean telescope when used for driving purposes. The contrast sensitivity of the driver seems to actually improve through the bioptic telescope. The results of this research support the continued use of bioptic telescopes by visually impaired drivers. More research needs to

be completed to gain a better understanding of how telescopes affect contrast sensitivity and other factors involved in driving.

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INTRODUCTION

According to the 2000 U.S. Census Bureau, there are 2.4 million Americans that are visually impaired with best corrected visual acuity being less than 20/40 in the better eye[1]. Additionally, the number of visually impaired Americans is expected to increase by seventy percent to 4.1 million individuals by the year 2020[1]. The rapid growth of the visually-impaired population will force American society to re-evaluate the laws and limitations in place for people with reduced vision. By the Fourteenth Amendment of the U.S. Constitution, all citizens are entitled to equal protection under the law[2], thus preventing discrimination against people based on personal traits or characteristics, including visual acuity. Currently, thirty-four U.S. states have held up this equal opportunity amendment and have allowed low vision patients to be eligible for a driver's license by allowing bioptic telescopes to be used by low vision patients to facilitate distance visual acuity[3]. Bioptic telescopes are used by patients to momentarily magnify distant objects while driving[1]. At this time, there are approximately 5,000 individuals who drive with a bioptic telescope[1].

A bioptic telescope produces a magnified image of the object being viewed at a distance. The telescope is mounted above the optical center of the spectacle lens[4]. The telescope is usually monocular and placed in front of the eye with the best corrected visual acuity; however, binocular telescopes are also available for low vision patients with similar visual acuity in each eye. There are two primary types of spectacle mounted bioptic telescopes that exist. One is the Keplerian telescope which consists of high plus ocular lens and a high plus objective lens in the telescope. This type of telescope offers the wearer a brighter image and wider field of view[4]. The disadvantage to this telescope is that it is consequently larger and heavier[4]. The other type of telescope consists of a high minus ocular lens and a high plus objective lens is called a Galilean telescope. This design offers the wearer a shorter and lighter telescope, but produces a dimmer image with a smaller field of view[4]. Whereas the 3x magnifying Keplerian telescope produces a field of view of approximately 13 degrees wide, the same magnification Galilean telescope has a field of view restricted to approximately 9 degrees[4]. Weight, magnification, comfort, and acuity are all variables that must be considered when selecting the style of bioptic telescope for each low vision patient.

Low vision patients frequently perceive that they have functional impairment and loss of quality of life due to the limitations of their vision[5]. Studies show that low vision services, including the use of bioptic telescopes, improved subjective contentment in the lives of visually impaired individuals[5]. For example, bioptic telescopes improve facial recognition in low vision patients[6], thus allowing them to see the faces of friends and family once again. Additionally, there are thousands of visually impaired individuals that have gained independence and increased quality of life by obtaining a driver's license with the aid of a bioptic telescope[1]. These telescopes are used similar to rear-view mirrors that are glanced at while driving[2], and they should not be used for more than 10% of the time while driving[3]. The first bioptic driver's license was issued in California in 1971[1]. Since then, laws and legislation has helped to secure the rights of visually impaired people. The American Optometric Association and the American Academy of Ophthalmology passed policies in 1994 and 2001 for low vision drivers. Also in 2001, the Office of Civil Rights mandated that the National Highway Traffic Safety Administration accommodate low vision patients by addressing their needs and concerns[1]. Currently, 34 states in America have laws that allow low vision individuals to obtain a driver's license[2]. Most states require a minimal visual acuity through the bioptic telescope of 20/50 to obtain a driver's license[4]. The majority of bioptic drivers feel confident while driving and have never been in a motor vehicle accident nor had any driving citations[3]. One study reported that bioptic drivers with best corrected visual acuity of 20/80 - 20/200 through the carrier lens had 50% less accidents than those with vision of 20/50 – 20/70[1].

There are many ocular factors that can adversely impact driving. These factors include reduced visual acuity, loss of field of vision, abnormal color perception, lack of depth perception, glare, and reduced contrast sensitivity[7]. Of these various factors, only visual acuity and visual field are assessed for receiving a driver's license in the United States[7]. Research shows that spatial contrast sensitivity, or the ability to identify patterns or letters presented at various levels of contrast, may be a better predictor of driving competence than visual acuity[7]. The number of automobile accidents for individuals with good contrast sensitivity was significantly lower than for those with poor contrast sensitivity[7]. Those individuals involved in a motor vehicle accident were six times more likely to have reduced contrast sensitivity[2]. Poor contrast sensitivity has been shown to directly correlate to driving accidents, thus anything that reduces contrast sensitivity would consequently adversely affect driving capabilities. This research project examines the relationship between contrast sensitivity and bioptic telescopes and explores the implication of this relationship for the functional use of bioptic telescopes as driving aides for visually impaired individuals.

METHODS

In this study, patients were tested at either the Michigan College of Optometry in Big Rapids, MI or Walton & Becker Eye Care in Oxford, MI. The patient base was any consenting adult who was coming to the clinic for an eye exam. Patients were informed of the study, and they signed consent forms if they wished to participate (See Appendix A). In compliance with patient privacy, only gender, age, ocular disease, and visual acuity were recorded on data collection sheets. After finding a spectacle prescription that best corrected the vision, visual acuity was recorded at 20 feet with a direct projection Snellen acuity chart. This acuity was documented as the best acuity possible for the patient as measured with a standard acuity chart. Next, the eye with the poorer visual acuity was occluded for the duration of the testing. Visual acuity was measured monocularly in the best corrected eye with the Bailey-Lovie High and Low Contrast Acuity Chart (see Appendix B) through the manifest spectacle lens at 10 feet. Acuity was recorded as the lowest line visible to the patient multiplied by two over 20 to correct for the 10 foot working distance of the chart (see Appendix C). Letters missed on the lowest read line were subtracted from the visual acuity. High contrast visual acuity was measured and recorded first, then low contrast visual acuity was measured and recorded. After the acuity through the carrier lens was recorded, a 4x Galilean telescope was placed in the geometrical center of the lens that the patient was wearing. The initial spectacle lens acted as the carrier lens for the bioptic telescope in a trial lens frame. While the other eye still remained occluded, the patient was asked to again read the lowest line possible on the high contrast acuity chart and then the low contrast acuity chart. Acuity was recorded in the same manner as through the carrier lens. A copy of the data collection form can be found in Appendix D. Once Snellen visual acuity was ascertained, the minimal angle of resolution (MAR) could be calculated for each patient (see Appendix C), as well as the logMAR and the decimal acuity. This data then could be used to match up to other patient data in order to facilitate comparison and to highlight observable trends.

RESULTS

Data was collected from twenty-five patients: ten normally sighted, four near-normally sighted, six visually impaired, and five legally blind as defined by the American Optometric Association (See Appendix E). Baseline patient information is recorded in Table 1 below.

Table 1
Patient Information

Age	BVA OD	BVA OS	Vision	Ocular Disease
26	20/20+2	20/20+1	Normal	None
57	20/20	20/20-2	Normal	None
49	20/20-2	20/20-1	Normal	None
45	20/20	20/20-2	Normal	None
60	20/20	20/20	Normal	None
36	20/20	20/20	Normal	None
33	20/20	20/20	Normal	None
36	20/15	20/15	Normal	None
28	20/20	20/20	Normal	None
27	20/20	20/20	Normal	None
80	20/50	20/50-1	Near Normal	ARMD
36	20/60-1	20/70	Near Normal	Refractive Amblyopia
24	20/40	20/40	Near Normal	Aniridia
76	20/150+1	20/30-2	Near Normal	ARMD
58	20/70-1	20/200	Visually Impaired	ARMD
80	20/100	20/80-1	Visually Impaired	Best's Disease
43	20/80	20/300	Visually Impaired	Degenerative Myopia
18	20/70	20/300	Visually Impaired	Optic Nerve Hypoplasia
86	20/120	20/1200	Visually Impaired	ARMD
55	20/150+2	20/200	Visually Impaired	Degenerative Myopia
19	20/200	20/1200	Legally Blind	Ret. Of Prematurity
85	20/400	20/200	Legally Blind	ARMD
18	20/320	20/240	Legally Blind	Degenerative Myopia
75	20/200	20/400	Legally Blind	ARMD
86	20/600	20/600	Legally Blind	ARMD

The patient population consisted of seven different ocular diseases with acuities ranging from 20/30 to 20/1200. Additionally, normal patients without ocular disease were included with acuities ranging from 20/15 to 20/20. Ages ranged from eighteen to eighty-six years old. Fifteen females and ten males were tested.

Visual acuity was recorded with the Bailey-Lovie high and low contrast acuity chart through the patient's best spectacle correction with and without the 4X Galilean telescope at ten feet. The data is recorded below in standard Snellen equivalent form (See Table 2).

Table 2
Bailey-Lovie High and Low Contrast Acuity With and without Bioptic Telescope

Age	Eye Tested	High Contrast	Low Contrast	High Contrast with Telescope	Low Contrast with Telescope
26	Right	20/16-2	20/20	20/12.5	20/12.5
57	Right	20/20-2	20/32	20/12.5	20/12.5-2
49	Left	20/20-2	20/32-2	20/12.5	20/16-2
45	Right	20/20	20/25	20/12.5	20/16-2
60	Right	20/20	20/32	20/63	20/12.5-1
36	Left	20/20-1	20/25-1	20/12.5	20/12.5-2
33	Right	20/20-1	20/25	20/12.5	20/12.5
36	Left	20/16	20/25	20/12.5	20/16
28	Left	20/16	20/20	20/12.5	20/12.5
27	Right	20/16-1	20/20	20/12.5	20/12.5-1
80	Right	20/80	20/200+1	20/40-2	20/63-2
36	Right	20/80+1	20/80-1	20/40+2	20/25-1
24	Left	20/40	20/63-1	20/25-2	20/20
76	Left	20/40	20/50	20/16	20/50
58	Right	20/125	20/40-2	20/200	20/80
80	Left	20/80	20/160-2	20/50	20/63
43	Right	20/63	20/200	20/63	20/100
18	Right	20/100	20/160	20/200	20/140
86	Right	20/160	20/320	20/50	20/320
55	Right	20/125	20/250	20/63	20/100
19	Right	20/200	20/250-2	20/63+2	20/250+2
85	Left	20/250-2	20/500-2	20/125	20/160
18	Left	20/200-2	20/250-2	20/100	20/160-2
75	Right	20/250	20/400	20/160	20/160
86	Right	20/800	20/2000	20/800	20/2000

Most of the normally sighted patients had acuities of 20/20 or better; however, patients with ocular disease had visual acuity ranging from 20/40 to 20/800 on the high contrast chart. Visual acuities on the low contrast chart showed a reduction in almost every patient. Through the telescope there was an overall improvement in acuity on both high and low contrast charts. Snellen acuity was then converted to LogMAR as shown in Table 3 below.

Table 3
LogMAR Acuity Conversion

Age	LogMAR High Contrast	LogMAR Low Contrast	LogMAR High Contrast With Telescope	LogMAR Low Contrast With Telescope	High Contrast VA Improvement	Low Contrast VA Improvement
26	-0.06	0	-0.2	-0.2	0.14	0.2
57	0.04	0.2	-0.2	-0.16	0.24	0.36
49	0.04	0.24	-0.2	-0.06	0.24	0.3
45	0	0.1	-0.2	-0.06	0.2	0.16
60	0	0.2	0.5	0.82	-0.5	-0.62
36	0.02	0.12	-0.2	-0.16	0.22	0.28
33	0.02	0.1	-0.2	-0.2	0.22	0.3
36	-0.1	0.1	-0.2	-0.1	0.1	0.2
28	-0.1	0	-0.2	-0.2	0.1	0.2
27	-0.08	0	-0.2	-0.18	0.12	0.18
Average of LogMAR Improvement for Normal Patients					0.108	0.156
80	0.6	0.98	0.34	0.54	0.26	0.44
36	0.58	0.62	0.26	0.12	0.32	0.5
24	0.3	0.52	0.14	0	0.16	0.52
76	0.3	0.4	-0.1	0.4	0.4	0
Average of LogMAR Improvement for Near-Normal Patients					0.285	0.365
58	0.8	0.34	1	0.6	-0.2	-0.26
80	0.6	0.9	0.4	0.5	0.2	0.4
43	0.5	1	0.5	0.7	0	0.3
18	0.7	0.9	1	0.84	-0.3	0.06
86	0.9	1.2	0.4	1.2	0.5	0
55	0.8	1.1	0.5	0.7	0.3	0.4
Average of LogMAR Improvement for Visually Impaired Patients					0.083	0.15
19	1	1.14	0.46	1.06	0.54	0.08
85	1.14	1.44	0.8	0.9	0.34	0.54
18	1.04	1.14	0.7	0.94	0.34	0.2
75	1.1	1.3	0.9	0.9	0.2	0.4
86	1.6	2	1.6	2	0	0
Average of LogMAR Improvement for Legally Blind Patients					0.284	0.244

All groups demonstrated an average improvement in contrast sensitivity with the telescope. Near-normally sighted patients showed the greatest improvement with the use of the telescope, while visually impaired patients showed the least improvement in contrast sensitivity with the telescope. All groups except for the legally blind showed more improvement with the telescope while viewing the low contrast chart compared to viewing the high contrast chart. Although the trend displayed a uniform improvement with the telescope, there were three patients that actually had a reduction in contrast sensitivity with the telescope.

DISCUSSION

The results indicate that the use of bioptic telescopes does not inhibit contrast sensitivity, but can actually improve it. Near-normally sighted patients gained the most benefit from the use of the telescope while visually impaired patients gained the least benefit. The nature of the ocular disease did not seem to predict the effect on contrast sensitivity in this study, as the acuity of some patients with the same disease improved while others worsened with the use of the telescope.

Three patients in the study had worse contrast sensitivity with the telescope. Reasons for this variation could include the patient's inability to maintain a stable posture and head movement while holding the telescope or the optical limitations of the Galilean telescope. Some patients were observed to have difficulty steadily fixating, and their tremors caused exaggerated movements of the image through the telescope. Additionally, the Galilean telescope, by design, has a smaller field of view and reduced illumination. These characteristics amplify any unwanted movements. The small field of view also complicates a patient's ability to fixate a target.

In summary, all of the data suggest that there is no adverse effect of the Galilean telescope when used for driving purposes. The contrast sensitivity of the driver seems to actually improve through the bioptic telescope. According to research, when contrast sensitivity is improved, overall driving ability is also improved[7]. Visually impaired patients most commonly use bioptic telescopes for driving, and this group showed the least amount of improvement in contrast sensitivity. However, the use of the telescope did indicate improvement in both high and low contrast situations. The results of this research support the continued use of bioptic telescopes by visually impaired drivers.

More research needs to be completed to gain a better understanding of how telescopes affect contrast sensitivity and other factors involved in driving.

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APPENDIX A

CONSENT FORM

CONSENT FORM

By signing below you are agreeing to participate in an educational study that will take approximately 5 minutes of your time. You will be asked to read an eye chart of letters of different contrast with and without the aid of a telescope. This data will be used to determine how the use of a telescope affects vision. Your participation in this study is strictly voluntary, and you may refuse to discontinue your participation at any time without penalty. There are no foreseeable risks or discomforts while participating in this study. The data gathered will remain confidential and anonymous. Your privacy will be protected to the maximum extent allowable by law. The results of the study will be available on May 1, 2007. You may contact Dr. Walter Betts at the Michigan College of Optometry at 231-591-2186 with any questions or concerns. You may also contact Connie Meinholt at Ferris State University at 231-591-2759 with any complaints regarding this educational study.

Signed: ______________________________ Date: ____________________

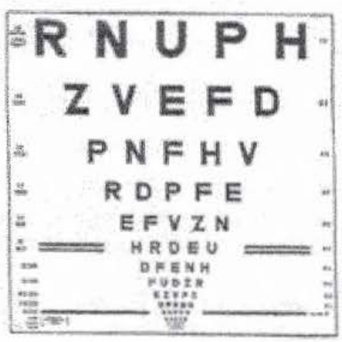
APPENDIX B

BAILEY-LOVIE HIGH & LOW CONTRAST ACUITY CHARTS

BAILEY-LOVIE HIGH & LOW CONTRAST ACUITY CHARTS

There are many advantages to the Bailey-Lovie chart. To start, there are five letters in each row which helps maintain equal contour interactions throughout the chart. Also, the letter spacing within each line in equal to width of the letter, and the spacing between lines is equal to the height of the letters below. This again controls contour interactions. The letter size follows a logarithmic progression, increasing in 0.1 logMAR steps. The logarithmic change of letter sizes is justified because it has been shown that the minimal just noticeable difference within a person's visual acuity is approximately equal across the range of letter sizes if a logarithmic scale is used. Another advantage to the Bailey-Lovie chart is that it allows for maximal visual acuity scoring within the chart. If a patient reads all the letters on one line and half of the letters on the next, a score can be assigned that is half way between these two letter sizes.

The high contrast side of the chart has a percent contrast of 100% through black letters on white background. However, the low contrast chart maintains a contrast percentage of 10% throughout the chart owing to the gray letters on the white chart. The difference between the two infers a relationship to the contrast sensitivity function.



(Thompson D. Visual acuity testing in optometric practice. Clinical. 6 May 2005: 22-24.)

APPENDIX C

VISUAL ACUITY EQUIVALENCY CHART

VISUAL ACUITY EQUIVALENCY CHART

Snellen Notation (Metric)	**Snellen Notation** (10 feet)	**Snellen Notation** (Standard)	**MAR**	**logMAR**	**Decimal**
6/48	10/80	20/160	8.0	0.9	0.13
6/38	10/62.5	20/125	6.3	0.8	0.16
6/30	10/50	20/100	5.0	0.7	0.20
6/24	10/40	20/80	4.0	0.6	0.25
6/19	10/30	20/60	3.2	0.5	0.32
6/15	10/25	20/50	2.5	0.4	0.40
6/12	10/20	20/40	2.0	0.3	0.50
6/9.5	10/15	20/30	1.6	0.2	0.63
6/7.5	10/12.5	20/25	1.25	0.1	0.80
6/6	10/10	20/20	1.00	0.0	1.00
6/4.8	10/8	20/16	0.80	-0.1	1.25
6/3.8	10/6.25	20/12.5	0.63	-0.2	1.58
6/3.0	10/5	20/10	0.50	-0.3	2.00

LogMAR is an acronym for Log10 of the Minimum Angle of Resolution (MAR). The MAR is taken as the stroke width of the letters, which is one fifth of their vertical angular subtense. Thus a 20/20 letter which subtends 5 minutes of arc, equates to a MAR of one minute and a logMAR of 0 (Log10(1)=0).

APPENDIX D

DATA COLLECTION FORM

DATA COLLECTION FORM

Contrast Sensitivity Testing
Circle Site: MCO, Dr. B

Patient Gender: M, F Age:___________ Date:____________________

Visual Acuity: (c,s) @ distance O.D._________ O.S.__________

Normally Sighted / Near Normally Sighted / Visually Impaired / Legally Blind

Ocular Disease(s):____________________________________

Bailey Lovie Chart	**Right or Left Eye**	
	High Contrast	**Low Contrast**
Contrast Sensitivity @ 10 feet		
Contrast Sensitivity w/ 4X Bioptic @ 10 feet		

Signed By: ____

APPENDIX E

AOA CLASSIFICATION OF VISUAL IMPAIRMENT

AOA CLASSIFICATION OF VISUAL IMPAIRMENT

Classification	Levels of Visual Impairment
Normally Sighted	20/10 – 20/25
Near-Normally Sighted	20/28 – 20/60
Visually Impaired	20/70 – 20/160
Legally Blind	20/200 or worse