BINOCULARS: A LONG-IGNORED AID FOR THE PARTIALLY SIGHTED

PREPARED FOR THE DEPARTMENT OF HEALTH, EDUCATION AND WELFARE

S. M. GENENSKY

R-1402-HEW
NOVEMBER 1973

Rand
SANTA MONICA, CA. 90406
The work upon which this publication is based was performed pursuant to Grant No. 14-P-55846/9 with the Department of Health, Education and Welfare. Views or conclusions contained in this study should not be interpreted as representing the official opinion or policy of the Department of Health, Education and Welfare.
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Preface

This is the first of several reports that will contain the results of research carried on at The Rand Corporation under a grant (14-P-55846/9) from the Social and Rehabilitation Service of the U.S. Department of Health, Education, and Welfare to study the visual information transfer problems of the partially sighted.

This report is aimed primarily toward the partially sighted themselves and toward those who serve that population, including ophthalmologists and optometrists who throughout the report are referred to as clinicians. This work is meant to make them more aware of the invaluable help that binoculars can be to the partially sighted.
Summary

In the United States today, there are 1.77 million visually impaired people. Of this number, 1.64 million are **partially sighted** and **not** blind. Throughout the world, it is estimated that there are at least 30 million partially sighted. This population has been neglected or misguided by both public and private institutions, because many of these people could have been encouraged, taught, and trained to participate more fully in a sighted society.

One very important visual aid that has long been ignored by clinicians, and others who serve the partially sighted, are binoculars. They are simple to operate, easily obtainable, and relatively inexpensive. They can be used by the partially sighted in the home, in school, at work, while traveling, and while relaxing.

The author, who is himself partially sighted, has used binoculars in many ways **including** the following:

- To determine the status of a traffic light.
- To take notes on or copy from a chalkboard.
- To determine the number and destination of a bus.
- To ascertain a street address.
- To locate an article that has become visually misplaced.
- To watch a ball game.
- To determine the nature and price of merchandise.
- To watch a movie or television.
- To determine what friends and family really look like.

Some partially sighted people, and particularly those who are highly myopic, will find that they can use binoculars that magnify as much as twenty times without much difficulty. While seated in a moving automobile, they can use binoculars that magnify eight or ten times without experiencing any physiological discomfort. Some binoculars give the wearer the ability to see one or more faces of their prisms, and, even more interesting, foreign matter on the internal optical surfaces that completely eludes the normal eye.
Binoculars are often supplemented with specialized equipment that extends and improves their use for a larger number of purposes and for a greater variety of visual deficiencies. Some partially sighted people, such as the author, need to use a corrective lens over one or both binocular objectives to bring distant objects into sharp focus. (The need for this correction probably increases with age.) When the author compared binoculars with monoculars he found that the former were much easier to hold steady for long periods of time. Also of interest are zooming binoculars, controllable internal irises, and telescopic spectacles, but these are not without their disadvantages.

Although the author admits that his experience with binoculars may not be representative of all partially sighted people, he encourages clinicians to acquire a thorough knowledge of this aid and its potential for their partially sighted patients. If this is done, the visual horizons and capabilities of this population will be greatly expanded.
Acknowledgments

I thank my colleagues, Drs. Hubert L. Moshin and Harold E. Petersen, for suggesting and helping perform the experiments reported on in the appendices to this report and for their advice and encouragement throughout the preparation of this publication. I also thank Drs. Garry D. Brewer and Gene H. Fisher for reviewing a late draft of the report and, through their comments and suggestions, contributing significantly to the quality and readability of the final version.

Thanks are also due to Eleanor T. Gernert for editing the report and guiding it through the entire editorial process, to James Beavers for taking and preparing the photographs, and to Margaret Wray for typing the manuscript.
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I. Introduction

In the United States today, there are approximately 1.64 million partially sighted people. Of this population, 305,000 are considered legally blind and entitled to the benefits and exposed to the disadvantages of being so categorized. Tragically, the interpretation of the legal definition of blindness by many public and private institutions has led to inappropriate treatment of many partially sighted persons. Stereotyped views have contributed to the creation of “blind” people who could have been encouraged, taught, and trained to be functionally sighted.

This report is intended to encourage the partially sighted to enrich their visual experiences and to participate more fully in the sighted society.

I am myself partially sighted, having no visual acuity whatsoever in my left eye and approximately 20/750 in my right eye. If your visual acuity is as poor as mine, then at least 60 percent of the legally blind see better than you do. My loss of eyesight dates back to the first few days of my life, but this did not appreciably affect my participation in the sighted society, including the year I spent at a school for the blind at age thirteen. I was twelve years old when I discovered binoculars, and I have never been without them since—at school, in college, at work, at home, on vacation.

My adroitness in handling binoculars and discovering the many ways they could be valuable to me evolved over a period of years of experimentation, as well as from fortuitous meetings and conversations with persons better versed in optics and optical instruments than I. On this point I consider myself very fortunate. For even today most

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1 A person's visual acuity is said to be “m/n,” where m and n are positive integers, if at m feet the smallest symbols he can identify on an eye chart are the smallest symbols that a person with normal sight can identify on that chart at a distance of n feet. Thus, for example, if at 20 feet the smallest symbols he can identify on the chart are the smallest symbols a person with normal sight can identify on that chart at 750 feet, his visual acuity is said to be 20/750.
clinicians either do not know how valuable binoculars are to the partially sighted or, if they do, they rarely encourage their partially sighted patients to try them.

How can binoculars help the partially sighted? I will first carefully define a group of terms concerned with visual impairment, including "partially sighted." I will then examine the size of the partially sighted population and indicate how it has been unjustly treated. Next I will lead you through a demonstration—both in words and pictures—of what I have done with binoculars—from reading street signs, watching television, to viewing live ball games—not to mention the usefulness of such a visual aid in the classroom and in the working environment. Following the "when" and "how" of binoculars, I will introduce you to supplementary equipment that can increase the value of binoculars to the partially sighted. Finally, I will give you hints from my experience on various techniques for using binoculars and accessory equipment to their best advantage.

How much do binoculars cost? Currently, they range between about $20 and $350. However, reasonable quality binoculars that magnify between six and ten times can be purchased for between $30 and $50. These are of a high enough quality to meet the needs and financial capabilities of many partially sighted people.

In my opinion, more than half of the legally blind could benefit from the use of binoculars. In addition, many of the 1.33 million who are partially sighted but not legally blind and who have trouble seeing objects at a distance would also find binoculars of value. By "at a distance" I not only mean far away, but I may also mean as close as a few inches. To me, for example, at a distance means anything beyond 2 or 3 inches from my right eye. I readily concede that not all partially sighted people see the same way as I do, with or without binoculars, nor do they have the same interests and motivations that I have. Therefore, we can expect that many of them will prefer to use binoculars for a different set of purposes than I use mine, and that they will wish to adapt variations of the methods and techniques that I use and suggest in the course of this report. Nevertheless, I am convinced that if the partially sighted are willing to give themselves a fair chance to explore the ways binoculars can be of assistance to them, they will find that this sturdy and relatively simple visual aid can and will enlarge their visual horizons and capabilities, and as a consequence, increase their participation in and enjoyment of life in our sighted society.
II. The Population

I first consider definitional distinctions used to identify the "partially sighted" population and relate these to my best estimates of their number in the United States and the world. Next I examine the misapplication of the legal definition of blindness, as well as the failure to recognize the heterogeneity of the partially sighted population.

DEFINING THE POPULATION

Defining the partially sighted is a delicate and complex undertaking—one that has taken a good deal of time and professional attention [1,2,3]. However, as is the case with many complex tasks, I am still learning by reflecting long and hard on the operational significance of these definitions. Several of the many concepts related to partial sightedness and visual impairment, my operational definitions, and the explanations or rationales that I use to support these definitions are explained below. My use of these terms and concepts in this report conforms strictly to this list. Definitions include

1. Sighted
2. Legally blind
3. Corrective lenses
4. Visually impaired
5. Read and write as the literate sighted do
6. Identify visually familiar objects as the illiterate sighted do
7. Functionally blind
8. Functionally sighted
9. Functionally sighted with aided mobility
10. Functionally sighted with neither sighted literacy nor sighted illiteracy

Numbers in brackets refer to titles in the References section.
11. Partially sighted
12. Quasi-functionally sighted

1. A person is considered “sighted” or “normally sighted” if he is not visually impaired (see item 4).
2. A person is considered “legally blind” if the visual acuity (presumably measured at 20 feet) in his better eye with corrective lenses is no better than 20/200, or if the visual acuity in his better eye exceeds 20/200 with or without the aid of corrective lenses, but the diameter of his visual field in no direction exceeds 20 degrees.
3. “Corrective lenses” means prescription eyeglasses containing lenses found in a conventional ophthalmic and optometric lens kit, as well as microscopic spectacles used by persons with very poor visual acuity.
4. A person is considered “visually impaired” if the visual acuity in his better eye with corrective lenses does not exceed 20/70, or if the visual acuity in his better eye, with or without corrective lenses, does exceed 20/70, but his visual field is so restricted that he is unable to maneuver safely in an unfamiliar environment without the aid of a sighted person, a dog, or a cane. *
5. A visually impaired person is considered to be able to “read and write as the literate sighted do” if he is able, with or without the aid of optical or image enhancement devices, to use his eyes to read printed and handwritten material and to write with a pen or pencil without special tactile guides which assist him to maintain uniform letter size and to write on a straight line.
6. A visually impaired person is considered to be able to “identify visually familiar objects as the illiterate sighted do” if he is visually capable of reading and writing as the literate sighted do, but is unable to do so because he has not been taught or is incapable of being taught to read printed and handwritten material or to write with a pen or pencil. Yet he is able, in the course of an examination to determine his visual acuity, to identify visually familiar objects that sighted persons of the same age and approximate intelligence can recognize.
7. A person shall be considered to be “functionally blind” or “nonfunctionally sighted” if he is visually impaired and is

* Boldface words in these definitions represent significant departures from corresponding definitions given in Refs. 1, 2, and 3. Justifications for these departures are given immediately after this list of definitions.
unable to read and write as the literate sighted do, or to identify visually familiar objects as the illiterate sighted do, and is also unable to maneuver safely in an unfamiliar environment without the aid of a sighted person, a dog, or a cane.

8. A person shall be considered to be "functionally sighted" if he is visually impaired yet is able to read and write as the literate sighted do, or to identify visually familiar objects as the illiterate sighted do, and is also able to maneuver safely in an unfamiliar environment without the aid of a sighted person, a dog, or a cane.

9. A person shall be considered to be "functionally sighted with aided mobility" if he is visually impaired yet is able to read printed and handwritten material as the literate sighted do, or to identify visually familiar objects as the illiterate sighted do, but is unable to maneuver safely in an unfamiliar environment without the aid of a sighted person, a dog, or a cane.

10. A person shall be considered to be "functionally sighted with neither sighted literacy nor sighted illiteracy" if he is visually impaired and is unable to read and write as the literate sighted do, or to identify visually familiar objects as the illiterate sighted do, yet is able to maneuver safely in an unfamiliar environment without the aid of a sighted person, a dog, or a cane.

11. A person shall be considered to be "partially sighted" if he is visually impaired but is not functionally blind.

12. A person shall be considered to be "quasi-functionally sighted" if he is either functionally sighted with aided mobility, or functionally sighted with neither sighted literacy nor sighted illiteracy, but not both.

In the definition of the "visually impaired," which appeared in the publications noted above, I did not specify the visual acuity, which was to divide the visually impaired from the sighted, but I did suggest that it might be taken to be 20/100 or 20/70. Here I have specifically decided to use 20/70. Frankly, I am still uneasy about stating a specific visual acuity, which is to divide the visually impaired from the sighted, because, by doing so, there is always the chance that I may exclude from the ranks of the visually impaired people who need one or more of the services that are provided or should be provided to the partially sighted.

The new definition of the "visually impaired" differs from the old one in another respect: The original phrase "but the greatest diameter of his visual field does not exceed a" has been replaced by "but his visual field is so restricted that he is unable to maneuver safely in an unfamiliar environment without the aid of a sighted person, a dog, or
a cane." By making this change, I have avoided the difficult, if not impossible, task of trying to give meaningful quantitative measurements of field size and geometry. However, I believe I have provided a satisfactory alternative by introducing a functional definition of field restriction that should allow a clinician to determine whether a person should or should not be considered "visually impaired" when his visual acuity exceeds 20/70.

In the definition of "read and write as the literate sighted do," I have made a small but very important change. I have inserted the phrase "to use his eyes" right after the phrase "with or without the aid of optical or image enhancement devices." "The functionally sighted" and "the functionally sighted with aided mobility" are able to use their eyes to read printed and handwritten material and to write with a pen or pencil, while "the functionally blind" and "the functionally sighted with neither sighted literacy nor sighted illiteracy" are not. Persons in the latter two categories are able to use devices that (1) are equipped with a hand-operated electro-optical probe that they move letter by letter over printed material and that (2) in response produce either a series of musical tones (e.g., the VisiDian or Stereotone) or a tactile image of the scanned letters (e.g., the Optacon). Thus, after several months of practice, they are able to decode nonvisual images of ordinary printed material, although at speeds that are distinctly lower than those at which "the functionally sighted" and "the functionally sighted with aided mobility" can use their aided or unaided eyes to read the same materials.

SIZE OF THE POPULATION

According to a National Academy of Sciences report [4], in 1970 there were approximately 420,000 legally blind Americans and 1.28 million additional Americans who were unable to read newspaper column type even with the aid of corrective lenses. The population of the United States was 203.2 million in 1970 and 210.9 million at the end of June 1973. If we assume that the number of legally blind and of those unable to read newspaper column type increased at the same rate as the overall U.S. population during the period of 1970-1973, we estimate that at the end of June 1973 there were 436,000 legally blind Americans and 1.33 million Americans who could not read newspaper column type even with corrective lenses.

Our RANDSIGHT® research indicates that about 70 percent of the legally blind are partially sighted or about 305,000 of the 436,000

4 RANDSIGHT is the Certification Mark of The Rand Corporation. It is a closed-circuit TV (CCTV) system developed at Rand that enables many persons with severe-
legally blind are partially sighted and hence not functionally blind. The 1.33 million Americans who are not legally blind and who are unable to read newspaper column type even with corrective lenses are also partially sighted. The latter comprise the group whose best visual acuity even with corrective lenses is better than 20/200 but not better than 20/70, and whose visual field has a diameter that exceeds 20°. Not only is this group of people unable to read newspaper column type, but in most of the states in the Union, they are not permitted to drive.\(^5\)

Thus, if we assume that the partially sighted in America consist of the 305,000 legally blind who are not functionally blind as well as the 1.33 million who cannot read newspaper type with corrective lenses, we may conclude that as of June 1973 there were about 1.64 million Americans who are partially sighted.\(^6\)

In 1970 the world population was estimated to be 3.632 billion. If we assume that the world population is increasing at the rate of 2 percent per year, that population in mid-1973 was about 3.85 billion. If we further assume that the ratio of the U.S. population to that of the world equals the ratio of the partially sighted population of the United States to that of the world, we may conclude that in mid-1973 there were approximately 30 million partially sighted people in the world.

This estimate is probably conservative, because the incidence of partial sightedness is no doubt significantly lower in the United States and other developed countries than it is in the developing countries, which together contain the vast majority of the world's population.

HELP FOR THE POPULATION

It is a tragic fact that the legal definition of blindness has been interpreted by many public and private institutions as establishing the criteria by which they are obliged, or by which they have chosen,
to distinguish between those they should give service to and those they must turn away. This has led to unfair treatment of many visually impaired people who were not legally blind at the time they sought help.

The numerical values assigned to the visual acuity and the angular measure of field in the legal definition of blindness are not based on conclusions drawn from a carefully designed set of experiments aimed at determining those parameters, but probably represent the best estimates of a group of people who, at the time the definition was being considered for adoption, were looked upon as authorities on vision and the visually impaired. I am not convinced that “a carefully designed set of experiments” would have produced a better set of values, but I am convinced that the values that were chosen have proved to be too restrictive.

Many people who, with corrective lenses, have more than 20/200 and as much as 20/70 vision in their better eye and a large visual field are in need of help from public and private organizations which serve “the blind.” The same statement is probably true in the case of many people whose visual acuity in their better eye with corrective lenses exceeds 20/200 but whose visual field is such that its greatest diameter subtends an angle somewhat greater than 20 degrees. Many of these people need help while they are in school, and when they are preparing for an occupation or looking for a job, but find that they do not qualify for assistance because they do not fall within the scope of the legal definition of blindness. They were probably excluded from coverage by that definition, because the framers of the definition did not consider them to be “blind,” and by that term I believe they meant functionally blind. If the framers of the definition had chosen to adopt a definition that distinguished between visually impaired people who are functionally blind, functionally sighted, or quasi-functionally sighted, I conjecture that they might have been willing to adjust the parameters in their definition of blindness to allow more people to be covered by it. They might also have seen the wisdom of calling their definition “the legal definition of visual impairment” rather than “the legal definition of blindness.”

It is an unfortunate but all too common fact that in our society, family, friends, and public and private organizations that provide educational, vocational, social, and other services to the visually impaired fail to recognize that they are dealing with a visually heterogeneous population. This results in their contributing to the creation of a large number of functionally blind people who could have been encouraged, taught, and trained to be functionally sighted (as well as others who could have been functionally sighted with aided mobility or functionally sighted with neither sighted literacy nor sighted illiteracy). What is even worse is the fact that many of
these groups and institutions have also developed stereotyped views of what “the blind” should be taught, what they are capable of learning, what jobs they should be prepared for, what jobs they can secure and hold, what hobbies they would enjoy, and what social activities would meet their needs. Rarely have “the blind” been consulted for their views on these important matters that affect their lives. I conjecture that many actions by a large number of personnel who believe they are serving “the blind” are based on preconceived and erroneous views regarding the interests and abilities of “the blind,” and as a consequence have led to inappropriate, unimaginative, inadequate, and unstimulating education and vocational guidance and training for all too many of the nation’s visually impaired.
III. Uses of Binoculars

In this section, which is the crux of the report, I draw on my many years of experience to demonstrate how binoculars can be used to expand the visual horizons of the partially sighted and to allow them to participate in the sighted society. I first explain why binoculars appear to help the partially sighted and describe general misconceptions about, or outright ignorance of, their value. Next, I proceed to a practical discussion of when and how the partially sighted can use this visual aid and its supplementary equipment. Hints for successful use are given in specific situations.

WHY BINOCULARS HELP THE PARTIALLY SIGHTED

Just why binoculars prove so effective for the partially sighted is very difficult to pinpoint. One important feature is the ability of binoculars to gather light with their large objective lenses and to concentrate that light into two relatively narrow but very bright beams. This is especially helpful to people suffering from such eye disorders as macular degeneration, in which the ability to see an object well enough to identify it tends to improve as the ambient illumination is increased. When this illumination is coupled with great magnification of an object, the pathological eye (which still has residual visual capability) is able to view a bright and enlarged image within which it can detect and resolve details, including color variations, that are completely absent when that eye is unaided or assisted with conventional eyeglasses.

WHY BINOCULARS ARE NOT USED MORE WIDELY

In the course of our research on electro-optical systems for the partially sighted, we at Rand have often asked our visually impaired
subjects whether they have ever tried to use binoculars (or a monocu-
lar) to assist them in viewing objects at a distance. Rarely do they
report that they have ever tried such a visual aid, and they frequently
comment that no one before has made such a suggestion. This is tragic,
because when the partially sighted do try to use binoculars, they very
often find that such an aid permits them to do many things that they
had never before been able to do, or had been unable to do since
suffering a visual loss.

I have frequently encountered clinicians who concede that binocu-
lars could be of great help to the partially sighted, but who claim that
most partially sighted people would not use them because of their
weight, bulk, and conspicuousness. I cannot help but think that what
the clinicians are really saying is that they themselves would not use
binoculars to accomplish the visual tasks that such an optical aid
permits the partially sighted to cope with, because they (the clinicians)
perceive binoculars to be too heavy, too large, and too conspicuous.

Whether or not this conjecture is valid, it is true that the sighted—
clinicians as well as others trying to help the partially sighted—find
it difficult to put themselves in the place of their patients and to
understand the actual visual experiences of the partially sighted and
how important a role binoculars can play in increasing the opportuni-
ties for them to participate more fully in the sighted society. If this
were not the case, I am convinced that clinicians would be more en-
thusiastic in urging their patients to try to use binoculars for one or
more of the purposes enumerated in the next section, and perhaps for
other purposes that do not appear in that list.

The clinicians' lack of knowledge about or little enthusiasm for
binoculars is partially explained by their professional training, which
either did not include the study of binoculars as a visual aid for the
partially sighted or did not place emphasis on their importance. It is
a well-known fact that we are products—or perhaps even victims—of
our training and experience, and clinicians are no exception.

WHEN TO USE BINOCULARS

Throughout the years, I have developed many uses for binoculars,
especially as circumstances presented themselves. Below I list a few
of the uses that have been most valuable to me. Additional uses will
occur to other partially sighted people as they gain experience and
become familiar with this aid.

- Reading street signs.
- Determining the address of a home or other building.
• Ascertaining the status of a traffic light.
• Determining the nature and price of merchandise.
• Viewing a chalkboard.
• Examining plants or animals while on a walk or hike.
• Viewing scenery while seated in a car, bus, train, boat, plane, or other moving vehicle.
• Watching television.
• Observing children at play.
• Watching a movie, play, ballet, or opera.
• Seeing a ball game or other sports event.
• Locating items that have fallen to the floor or have otherwise become "visually misplaced."
• Viewing a ceremony or ritual in a house of worship or at some other public gathering or meeting.
• Determining what members of the family or close friends really look like.

Figure 1a shows how I use my binoculars to look across a busy intersection to determine the status of a traffic light, and Fig. 1b shows how I use binoculars to view television. In Fig. 2a I am examining blooms on a flowering bush, and Fig. 2b illustrates how I can determine the price of merchandise in a store display. Figure 3 shows me viewing a wall-mounted print, and Fig. 4 points out how I can read the name of a street posted on an overhead sign. Finally, Fig. 5 indicates how I use binoculars to determine the route name and number posted on the front of a bus.

HOW TO USE BINOCULARS

Will the partially sighted have difficulty picking out an object or area of interest in the general field of view before they raise binoculars to their eyes? Also, will they have trouble locating and recognizing that object or area within the field of those binoculars after they have raised them to their eyes? These questions are reasonable ones to ask, particularly when one recognizes that the eyesight of many of the partially sighted is very limited and that, at least at magnifications greater than 5×, a pair of binoculars has a field of view that is quite small compared with the field of view of a normal eye.

In my experience, binocular field restriction, in general, has not turned out to be a serious problem, because the field of my right eye is almost perfectly normal, and with that unaided eye I am able to discern the rough shape and size of relatively large objects as well as their color or colors. With these cues I can easily locate and in some
Fig. 1—The author using binoculars (a) to determine the status of a traffic light across a busy intersection and (b) to view a home television receiver
Fig. 2—The author using binoculars (a) to view blooms on a flowering bush and (b) to determine the price of merchandise in a display window.
sense "see," at the usual distances one encounters them, such things as the stage of an indoor or outdoor theater, the chalkboard in a classroom or conference room, the show windows and showcases of a store, a large expanse of scenery, gross features of a house or other building, a writing tablet on a desk or table, the screen in a movie theater or of a home television receiver, or the playing field in a sports arena or stadium. When I want to view any of these things in detail, I bring my binoculars up to my eyes and almost instantly have a recognizable part of them in my field of view.

For those of you who have not had as much experience as I have had in using binoculars, I recommend that you first sight the object or area you wish to view along the upper edge of the center line of your
Fig. 4—The author using binoculars to determine the name of a street
binoculars or along the upper edge of one of its optical trains or paths; then, without moving your head, bring the binoculars up to your eyes. Usually this procedure guarantees that at least part of the object or area of interest will be in the field of view of the binoculars or very close to that field of view. In the latter case, a slight motion of the binoculars in one direction or another usually will bring the desired object or area into view.

When I wish to view objects or areas that are too small for me to discern with my unaided eye but which I can see with my binoculars, I am usually able to locate them with those binoculars, because previous experience with and without the aid of binoculars has taught me roughly where these objects are to be found in the general environment. Examples in this category include a traffic signal in daylight, an

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7 That is, along the upper edge of one of the two tubes that contain the lenses that gather light and present the eye with a magnified and erect image of what is to be observed.
approaching bus, a street sign, the address of a house or other building, a small article that has become visually misplaced, and my children at play. In all these cases, some searching with my binoculars of the areas in which these objects are expected to be found will usually reveal their presence or absence.

There are circumstances in which my binoculars cannot help me see everything I would like to view. For example, they cannot help me see objects that I cannot resolve even with their aid or objects that I cannot locate because of their large apparent motion. Thus even though at a baseball game I am able with my binoculars to see the field and the players, I am hard pressed to keep the baseball itself in view while it is in the air. I am obliged to rely on the report of a sighted person to tell me in which general direction the ball is traveling. Even then, I miss some of the important action, though I still find that I see enough of the ball game to make it intelligible and enjoyable.

Persons with very limited visual fields probably will experience more difficulty locating objects with binoculars than I do. Success may depend on the viewed object being at rest or undergoing little apparent motion. Patience and perseverance are the bywords.

Another aspect of the use of binoculars is that in many cases it is not possible to view all of an object or scene at one time. In general, I have not found this to be a serious problem. With practice, the viewer soon learns how to scan a scene to determine its more important details, how to concentrate on an important area or areas and to exclude the rest of the visual information, and how to cope with objects that appear to be in moderate or rapid motion.

For example, in movies most of the action is concentrated in those areas on the screen that are occupied by people who are speaking or by objects that are in motion, such as horses, cars, or planes. Thus the viewer need only concentrate on the important things and can neglect or occasionally shift his view to other objects and areas in the scene to assure himself that he is not missing anything. Occasionally, coverage of the whole screen is advisable, for example, when a large number of people are dancing in a musical or when broad expanses of scenery are being shown. In such cases, the viewer is advised to pan around the screen at a rate that is visually comfortable and visually intelligible; in this way, he will obtain at least a visual feeling of what is taking place.

Here, as elsewhere in this report, I emphasize and encourage the use of binoculars by the partially sighted to enrich their visual experiences and to help them become or remain an integral part of the sighted society.
SUPPLEMENTARY AND ALTERNATIVE EQUIPMENT

Binoculars are often supplemented with specialized equipment that extends and improves their use for a larger number of purposes and for a greater variety of visual deficiencies. We next consider supplementary lenses, zooming binoculars, and controllable internal irises, as well as the virtues and drawbacks of telescopic spectacles as an alternative visual aid.

Lenses and Lens Mounts

For many years I had a problem with binoculars—a problem that the normally sighted (even the clinicians) failed to comprehend. As I have grown older, I have found that most new binoculars, and almost all realigned binoculars, no longer permit me to focus sharply on very distant objects. Dr. Charles B. Margach of Pacific University was the first to come up with a solution to this problem. He pointed out that if my eye is able to focus clearly on objects an inch away from its cornea, it should be possible to place an appropriate negative corrective lens over the binocular eyepiece through which that eye is to view distant objects and as a result bring them into sharp focus. In my case, a minus 13 lens gave the needed correction.\(^8\)

It must be noted that not all partially sighted people need the help of corrective lenses to view objects at a distance with binoculars, but those who do should see a qualified low-vision specialist to have the job done properly. Also, for those who need such correction it is advisable to be able to remove the supplementary lens when using the binoculars to view objects that are relatively close for extended periods of time, for example, to watch television in the home or to examine paintings in a museum.

A more satisfactory solution to the focusing problem was found recently by my colleague Dr. Harold E. Petersen and myself while experimenting with various simple lenses placed over the objective\(^9\) of a pair of binoculars. We observed that with no supplementary lens over the right eyepiece of my 8 × 30 binoculars and with a minus 0.50 lens over its right objective, I saw an image of objects located more than 8 feet from my right eye equal in quality and sharpness to that produced by the same binoculars with no supplementary lens over the right objective but with a minus 13 lens over the right eyepiece. This was a very important finding, because it eliminated the necessity of

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\(^8\) This was determined by Dr. Frank A. Brazelton, Director of the Low Vision Clinic at the Southern California College of Optometry.

\(^9\) The objectives of a pair of binoculars are the large lenses that gather light and are located at the end of the binoculars opposite the binocular eyepieces.
putting corrective lenses onto or taking them off of the eyepieces of those binoculars. Putting supplementary lenses on or removing them from the objectives of a pair of binoculars is an operation that is much easier and more convenient than that involved in putting them on or taking them off the eyepieces of those binoculars. (See Fig. 12 on page 36.)

One of the most important features of supplementary lenses was brought to my attention in the mid-forties by Dr. Kenneth N. Ogil while I was visiting the Dartmouth Eye Institute in Hanover, New Hampshire. Dr. Ogil showed me that by placing a plus lens over a binocular objective, it is possible to view an object located a short distance away in sharp focus. This is done by viewing the object through the eyepiece that lies at the other end of the augmented optical train. Dr. Ogil pointed out that the shorter the focal length of the supplementary lens, the greater the magnification of the viewed object. Thus, it is possible to select a supplementary lens that will permit a pair of binoculars to be focused at any convenient distance or at virtually any magnification. For a given pair of binoculars, the choice of distance and the choice of magnification are not independent of one another. For example, if we need to be able to focus the binoculars at a given short distance, we can find a supplementary lens that will do the job, but we will have to accept the magnification that the binoculars and that lens provide.¹⁰

Using a pair of 8 × 30 Carl Zeiss binoculars (circa 1930s) with a plus 3.5 lens over the left objective, I can focus (the corresponding optical train) clearly on objects that are about 12.5 inches in front of my right cornea. Using such a lens over the left objective of those binoculars and no supplementary lenses over the right objective or eyepiece, I went to class, viewed the chalkboard, took notes on what

¹⁰ This is not strictly true, because almost all binoculars are equipped with a mechanism that permits the viewer to move either the eyepiece lenses or the objective lenses toward or away from the rest of the binoculars over a short distance, hence varying the focal length of the binoculars. This being the case for almost any specific pair of binoculars, it is possible to select supplementary lenses with focal lengths that lie within a restricted range that when placed over an objective of those binoculars will permit the corresponding optical train to be focused sharply on an object at a specified short distance. Thus, in general, for a given pair of binoculars, there exists a restricted range of magnifications at which an object at a specified short distance can be seen in sharp focus with the help of a supplementary lens. Table 1 of Appendix A of this report indicates that the greater the algebraic power of the supplementary lens, the smaller the working depth of field provided by that lens and the pair of binoculars to which it is attached and the closer such a combination must be brought to the viewed object to bring it into sharp focus. Therefore, the closer an object must be to an augmented pair of binoculars, the more restricted is the choice of supplementary lenses that will bring it into sharp focus and the greater the power or magnification of the lenses needed to do the job.
was displayed and on what my professors had to say throughout my entire college and graduate education.

As noted above, because I have only one eye with residual vision, namely, the right one, I chose to use the right optical system of my binoculars to view the chalkboard or demonstration table and the left optical system capped with a 3.5 add (i.e., lens) to view the notebook or writing pad. It must have been quite a sight to see me moving my binoculars from left to right to shift from viewing the chalkboard to viewing my notebook and from right to left to achieve the opposite transition. I recall that this was particularly dramatic when I was engaged in taking a fairly complex course in organic chemistry. But what is really important here is that this method of transferring words and symbols on a chalkboard into understandable notes really worked, and worked very well. Without it, I would have had to depend on others to obtain all or most of my notes, and very likely would not have been able to take an academic program in mathematics, physics, and chemistry.\textsuperscript{11}

Needless to say, many other partially sighted people can or could use this very effective method for achieving visual success in the classroom and at work. It is an undeniable fact that maneuvering binoculars rapidly to make the transition from distant to near objects and vice versa, particularly in the classroom, does draw the attention of the sighted. However, there is no reason for the partially sighted to feel self-conscious, because after the initial surprise and novelty have worn off and after the sighted have learned how valuable the technique is to the viewer, they almost invariably cease to notice the binoculars, and develop a greater respect for and feel more at ease with the visually impaired viewer.

\textbf{Zooming Binoculars}

What are the virtues and drawbacks of binoculars with zooming capability? A pair of binoculars that zooms over the range 8\x to 16\x or over the range 6\x to 18\x, for example, probably would be very valuable for many partially sighted people. However, at present it is impossible to obtain binoculars with such magnification ranges which, at the same time, are not too heavy or too bulky. Even if such binoculars were available, it might also be difficult to maintain image sharp-

\textsuperscript{11} I still use my binoculars to view a chalkboard and to take notes on what I see and hear, but now I am obliged to use a minus 0.25 diopter lens over the right objective of my 10 \times 40B binoculars to bring the material on the chalkboard into sharp focus. Thus, even acutely myopic people go through changes in their visual system that require the use of corrective lenses after they become 35 or 40 years old. (See footnote 20 on page 43 for the definition of diopter.)
ness over the entire zooming range without simultaneously altering the setting of the focusing ring. If the viewer is willing to settle for a 2 to 1 zooming range (of the order of $8 \times$ to $16 \times$) and to put up with a rather unwieldy unit, he currently can purchase a pair that has large pupillary openings and a large bright field.

It is recommended that those who are interested in purchasing zoom binoculars make sure that they invest in glasses whose zooming capability is governed by a gear train rather than by a pulley and belt arrangement. The former will operate smoothly and accurately for a much longer period of time than the latter.

I am looking forward to the day when zoom binoculars will be available that (1) magnify between, say, $8 \times$ and $24 \times$; (2) remain in focus throughout their entire zooming range; (3) have large pupillary openings; and (4) are not excessively heavy or bulky. When and if such glasses come into being, I believe that they will constitute a very welcome addition to the storehouse of visual aids available to the partially sighted.

A Controllable Internal Iris

Although not currently available, a controllable internal iris placed in each of the binoculars' optical trains so that it does not image throughout its range of openings lies well within our current technological capability and might be very helpful to the partially sighted viewer. With its assistance, the viewer could control the brightness of the image. For example, he could view a brightly lighted scene at a level of illumination that is compatible with the nature and degree of his visual disorder, and that perhaps permits him to see details that would otherwise be obscured by an overabundance of incident light.

Telescopic Spectacles and Binoculars

Telescopic spectacles generally resemble and are worn like ordinary spectacles, but they are equipped with one or two compound lens systems that provide the wearer with additional magnification throughout all or part of the visual field available with the spectacles.\textsuperscript{12} Carl Zeiss, Designs for Vision, Keeler, and other optical companies manufacture telescopic spectacles that are available to the partially sighted, by prescription, through a qualified optometrist or ophthalmologist. These spectacles tend to be lightweight and have roughly the same dimensions as ordinary spectacles. Unfortunately, nearly

\textsuperscript{12} The reader is referred to N. Bier [7] and G. Fonda [8] for a detailed discussion of low-vision optical aids and, in particular, of telescopic spectacles. See especially Chapter 4 in Bier and Chapter 3 in Fonda.
all telescopic spectacles provide the wearer with a rather restricted visual field. Furthermore, to my knowledge, the highest magnification currently available with telescopic spectacles is $6 \times$, and with "wide angle" spectacles the upper limit is $2.2 \times$.\textsuperscript{13}

Positive adds are available for use with most telescopic spectacles. As in the case of positive lenses placed over one or both objectives of a pair of binoculars, they allow the wearer to resolve objects at short distances. They are usually chosen so as to allow the wearer to read printed material by holding that material at an appropriate distance in front of the augmented telescopic spectacles. The adds are usually mounted snugly over the objective of a telescopic unit. As in the case of adds used with binoculars, when the add is placed over the end of an optical train, that train or telescopic unit cannot be used for distant viewing while the add is in place.

Some telescopic spectacles are designed to present the wearer with a highly magnified image over a small portion of the field provided by the spectacles and a much less magnified or even a nonmagnified image over the rest of the field. In principle, the wearer of spectacles of this type is able to use the less magnifying or nonmagnifying portion of the visual field to move about from place to place, and to use the highly magnifying segment for viewing objects that need to be inspected in greater detail. Spectacles of this type have been prescribed for some partially sighted people so that they can qualify to drive a motor vehicle. [5,6].

Although some partially sighted people are able to use telescopic spectacles to drive, I believe the wisdom of doing so is open to question because of the very limited visual field provided by telescopic spectacles and because, even with corrective lenses, the wearer still has poor visual acuity. At least one other researcher appears to concur with this view [8], based mainly on the fact that telescopic spectacles, that is, the telescopic units themselves, provide the wearer with a visual field that is even smaller than that of a person considered legally blind in the United States. However, the fact that I believe that telescopic spectacles and binoculars should not be used when actually walking, running, or driving in no way detracts from their value as a viewing aid when performing many important tasks—tasks that can be carried out while sitting, standing, or riding as a passenger.

In my case, making a choice between telescopic spectacles and binoculars is simple and clear-cut. I have found that the magnification provided by most telescopic spectacles is too small to provide me with a clear and sharp image. Even though $6 \times$ telescopic spectacles provide enough magnification to make them of some value, they provide me

\textsuperscript{13} See Appendix B for a technical discussion of field measurements conducted with various types of telescopic spectacles and binoculars.
with such a tiny visual field that I find it difficult to bring a designated object into the field or to ascertain the nature of the object occupying the field. When I tried to use 6 × telescopic spectacles, I also found that the exposed lens in the eyepiece of the telescopic unit was so small that it occupied only a small fraction of my visual field even when its eyepiece was brought very close to my eye. When I brought the eyepiece close to my eye, I not only saw the lens opening clearly but I also saw a large expanse occupied by the glass or plastic housing that supports both the exposed eyepiece lens and the rest of the telescopic unit.

Telescopic spectacles are not inexpensive. When they are equipped with one telescopic unit, they cost between $250 and $350, and when they are equipped with two telescopic units they cost between $350 and $450. It should be noted, however, that the telescopic units referred to here are provided with eyepieces that incorporate a clinician’s prescription for the partially sighted patient.

SUGGESTIONS FOR SUCCESSFUL USE

Gaining experience with binoculars takes time and each individual’s experience will undoubtedly be somewhat different. However, there are several lessons that I have learned in using binoculars over the years, lessons that may be instructive for others as well.

Discussed in the succeeding sections are suggestions for maintaining image stability; observations on size, weight, and conspicuousness of binoculars; findings on magnification, image size, and light-gathering capability; and several lessons that I have learned through experience about different kinds of prisms and lenses in the presence of a highly myopic eye.

Maintaining Image Stability

I am frequently asked why I insist on using binoculars rather than a monocular—I see through only one eye, and one half of a pair of binoculars is lighter than a whole pair and probably less expensive. One answer to this question is quite mundane, but very practical: It is easier to balance a pair of binoculars for long periods of time than it is to hold a monocular. This is particularly true if one is able to use only one eye effectively, for then it is possible

1. To hold the binoculars with the hand that lies on the same side of the body as the poorer or nonfunctioning eye.
2. To use the better or functioning eye to look through the binoculars.
3. To rest the eyepiece corresponding to the poorer or nonfunctioning eye on that portion of the bridge of the nose that lies on the same side of the face as the poorer or nonfunctioning eye.

4. To rest the eyepiece corresponding to the better or functioning eye against the bone structure of that eye (in my case the bone structure above the eye and toward the nose; see Fig. 6).

Fig. 6—A close-up of the author using binoculars to view a distant object

If the arm that holds the binoculars is also provided with support in the vicinity of the elbow, the user is ready for hours of comfortable viewing (see Fig. 7). This degree of comfort cannot be achieved with a hand-held monocular because the monocular will have a tendency to rotate about the viewing eye (see Fig. 8). In the case of binoculars, this rotation is completely inhibited by the "eyepiece rest," namely, the bridge of the nose.\textsuperscript{14}

\textsuperscript{14} As this report was going to press, I received literature on a monocular called "Stede-Eye," which is equipped with a passive stabilizer. I was given an opportunity
Fig. 7—The author seated and viewing a distant object with his binoculars supported by his left arm: (a) the upper part of his arm rests on his binocular case, which in turn rests on the arm of the chair; and (b) his elbow rests on his binocular case, which in turn rests on the upper part of his left leg.
Fig. 8—The author seated and using two hands to hold a $20 \times 48$ monocular steady enough to view a distant object.
The foregoing remarks apply primarily to circumstances in which the viewer is called upon to observe a distant scene for a prolonged period of time, for example, a television program, a movie, a play, or a sports event. In situations in which he is obliged to look alternately at a distant scene and at a near one (for example, taking notes from a chalkboard), the technique must undergo some modification.

As was described, to take notes from a chalkboard, I move my binoculars from right to left to shift from viewing my writing pad with the left optical train (i.e., the left side of the binoculars) to viewing the chalkboard through the right optical train (i.e., the right side of the binoculars). This is done because I see through only the right eye, and because the left optical train is capped with a positive lens to permit me to focus on the writing pad while the right optical train is capped with a minus 0.25 diopter lens.\textsuperscript{15} Hence, the latter is prepared to bring distant objects into focus. It is clear that when I am viewing my writing pad (with my right eye looking through the left eyepiece of my binoculars), it is not possible for me to rest the left eyepiece on the left-hand side of the bridge of my nose. Image stability is achieved, however, by pressing the third quadrant of the rim of the left eyepiece against the right-hand side of the bridge of my nose.

Figure 9 shows me viewing a chalkboard with the help of binoculars, and Fig. 10 shows me using them to take notes on what I have read on the chalkboard.

Another approach to handling the problem of alternately viewing distant and near objects with one eye is to cap the objective of the optical train, corresponding to the functioning or better eye, with an appropriate plus lens that can be easily swung into and out of view as needed. (See Figs. 11a, 11b, and 11c.) This would permit the viewer to see both distant and near objects with only one optical train by merely flipping the positive lens out of or into view with, say, the little finger of the hand that helps support the binoculars. Thus, it would no longer be necessary to shift the binoculars from left to right or vice versa to change viewing distances. This technique would also permit the portion of the bridge of the nose that lies on the same side of the face as

to examine an $8 \times$ version and was able to view an object—and to keep that object in view—even when someone bumped my elbow or shook my arm. I did find, however, that when I shifted my view rapidly from one object to another, the various objects in the visual field appeared to float from place to place. This I found to be disconcerting. Still I feel that passively stabilized monoculars deserve careful examination to determine whether or not they offer visual assistance to the partially sighted in circumstances in which current binoculars prove less than satisfactory, for example, when a viewer cannot hold his hands very steady for one reason or another—such as when he is viewing objects from a rocking boat or a fast-moving motor vehicle.

\textsuperscript{15} See footnote 11, page 21.
the nonfunctioning or poorer eye to be used as an eyepiece rest when carrying out both near and distant viewing.

If the viewer needs a corrective lens over the objective of his binoculars to focus on objects at a distance as well as one to focus on nearby objects, it should be possible to design a lens mount that would support the corrective lens needed for distant viewing in a static position directly over the objective while permitting an appropriate positive lens to be swung into or out of view. Here, of course, the positive lens used for viewing nearby objects must be chosen to provide a sharp image in the presence of both the distant viewing corrective lens and the lenses that make up the binoculars’ regular optical train.

If the viewer is able to use both eyes with binoculars, then, in principle, handling the problem of alternately viewing distant and nearby objects can be solved by (1) constructing lens mounts, as described above, to be placed over both binocular objectives; and (2) providing a mechanism that permits the simultaneous removal from or insertion into the fields of view of the corrective lenses needed for viewing nearby objects. The mechanism probably could be operated by the little finger of the nonwriting hand.
Fig. 10—The author using binoculars to take notes on, to copy, or to sketch what he has seen on the chalkboard
Weight, Size, and Conspicuousness

While I do not believe that binocular weight, size, and conspicuousness should inhibit partially sighted people from using this aid, I readily concede that there is no need for the partially sighted, or for that matter anyone else, to use a pair of binoculars that is any heavier or bulkier than necessary. However, if magnifications of at least 6× are needed and a large pupillary opening and visual field are required, it is not possible to obtain binoculars that are so small, say, that they can fit in the palm of one hand. For example, if a relatively compact 10 × 40 pair of binoculars meets the visual needs of a partially sighted person, it should be recommended over a larger and perhaps heavier pair of 10 × 50 binoculars. In this example, the increase in field (approximately 56 percent) and the increase in pupillary opening (from 4 millimeters to 5 millimeters) is implicitly assumed to be outweighed by the additional weight and bulk of the 10 × 50 binoculars.

Magnification, Image Size, and Light-Gathering Capability

My colleagues and I have found that for many purposes 6×, 7×, 8×, or 10× binoculars are adequate for most partially sighted people. However, for viewing objects at great distances—for example, performers from the balcony of a theater or athletes from almost any seat in a stadium—even larger magnifications may be needed. Generally speaking, for persons whose eyes focus best for reading at normal distances (of the order of 14 to 16 inches), it becomes very difficult to hold a pair of binoculars steady for long periods of time—that is, anywhere from about 15 minutes to several hours—if they magnify more than 8 or 10 times. However, it is “visually” possible for those whose eyes focus best for reading at very short distances (of the order of, say, 1, 2, or 3 inches), to hold 12×, 15×, or even 20× binoculars steady enough to concentrate on a small area in the distance for long periods of time without having to put the binoculars down to rest their eyes.

This is a very important but rarely understood point, because most people with normal sight immediately assume that since they cannot successfully cope with hand-held binoculars that magnify 8 or 10 times for long periods of time, it follows that the partially sighted will also not be able to work with hand-held instruments that magnify that many or more times for comparable periods. One reason that some partially sighted people, especially those who are highly myopic, are able to successfully use very high-powered binoculars is that the image that such a device produces on their retinas is less magnified than it is on the retinas of persons with normal sight. Hence, the image
Fig. 11—A metal supplementary lens mount that fits snugly over a binocular objective and that permits the supplementary lens to be easily swung into or out of view: (a) the lens mount detached from the binocular objective housing, (b) the lens mount attached to that housing, with the supplementary lens swung into the line of sight, and (c—opposite page) the lens mount attached to the housing with the supplementary lens swung out of the line of sight.
appears to undergo less apparent motion when viewed by a short focal length eye than when viewed by a normal eye.

I, for example, can read newspaper column type that is located an inch from my right eye. But I can only read the 20/80 line on a Snellen chart at 20 feet when I use my $8 \times 30$ binoculars, equipped with a minus 13 lens over the right eyepiece, and the 20/40 line with my $10 \times 40$ binoculars, equipped with a minus 0.25 add placed over the right objective. Yet I am able to use either of these binoculars continuously while riding in a moving automobile without experiencing any visual, visceral, or other discomfort. I am rarely ever aware of any annoying image motion generated by the movement of the vehicle. Persons with normal sight who have tried to use my binoculars under similar conditions find that they become dizzy, nauseated, or otherwise physically upset.\footnote{The $8 \times 30$ binoculars are at least 30 years old and have no coated lenses (coating is intended to reduce internal reflections), and the $10 \times 40$ binoculars are less than a year old and are equipped with coated lenses. Both binoculars were manufactured by Carl Zeiss and the newer pair was donated to me by that company for use in our Randsight research.}

Our experience also indicates that the partially sighted perform
better with binoculars that have a large exit pupil\textsuperscript{17} and good light-gathering capability. These people find it easier to have their eye(s) wander over an image whose diameter appears to be comparable with or larger than their pupillary opening. They appear to be able to locate and look at a binocular image of this magnitude more rapidly and for longer periods of time than they can when confronted with images that appear to be distinctly smaller than their pupillary opening(s). Persons with pronounced nystagmus\textsuperscript{18} have a particularly difficult time locating an image that occupies only a small portion of their visual field, and many other partially sighted people find it uncomfortable and somewhat disconcerting to look through binoculars and see (or be conscious of seeing) a small image embedded in an opaque or translucent field. The latter probably constitutes a greater problem for highly myopic persons, that is, those whose eyes permit them to focus on an object located 1 to 3 inches from their corneas. When using binoculars, these people see the edge of the exit pupil quite clearly, and hence are acutely conscious of its presence and extent.

Good light-gathering capability is particularly important if the binoculars are to be used under reduced lighting conditions, for example, in the home or outdoors at twilight or at night. The light-gathering capability of binoculars is a function of the size of the objective lenses, the size of the exit pupils, and the type, nature, and degree of coating that is applied to the lenses. I have found that some manufacturers apply coating to their lenses that absorbs an appreciable fraction of the incident light. Thus, although such coatings may reduce internal reflections to acceptable levels, the viewer is confronted with an image that is quite dim and, in some cases, permeated with a cast of discernible color. For example, with some binoculars whose lenses are amber-coated, white objects appear pale green, and the image generated is distinctly dimmer than that produced by other binoculars of like power and quality.

**Binocular Prisms and the Highly Myopic Eye**

In general one would not expect the usefulness of a pair of binoculars to a partially sighted person to depend on the physical properties

\textsuperscript{17} An exit pupil of a pair of binoculars is the optically created limiting aperture (or opening) through which all light rays leaving one side, or optical train, of the binoculars must pass. The exit pupils can be seen by holding the binoculars a foot or more in front of the face in the direction of a relatively large and uniformly illuminated surface, such as a sunless portion of the sky in daylight, so that the eyepieces of the binoculars are directly facing the observer. Each exit pupil will then appear as an illuminated circle roughly in the center of the eyepiece. The diameter of an exit pupil is equal to the diameter of an objective of the binoculars divided by the power of the binoculars.

\textsuperscript{18} A rapid and involuntary repetitious motion of one or both eyeballs.
of its prisms. However, I have found that some partially sighted people are able to bring at least one set of prismatic surfaces into focus when the prisms are made of barium crown glass (index of refraction of about 1.5), and that this does not occur when they are made of heavy flint glass (index of refraction greater than 1.7). When these people look through an eyepiece of a pair of binoculars with barium crown prisms, they actually see a diamond- or rhombic-shaped area containing a highly illuminated image embedded in a circular field, the rest of which is a distinctly dimmer continuation of that contained within the diamond-shaped area. Partially sighted people who can see this phenomenon are usually highly myopic and hence are able to focus clearly on objects that are placed an inch or two from their eyes.

The ability to bring one or more prismatic surfaces into focus has at least one other interesting consequence, namely, that dust and other translucent or opaque particles resting on the sharply focused prismatic surfaces are also seen in sharp focus. The normal eye, when looking through binoculars that have dust or other particles on one or more prismatic surfaces, would only observe at worst a general degradation in the overall image quality.

The ability to observe this phenomenon sometimes leads to amusing and at the same time frustrating experiences. I once took my binoculars to a reputable firm to be cleaned and aligned. When the binoculars were returned to me, I saw dark specks in the visual field and complained to the shopkeeper. He looked through the glasses and stated that he saw no specks. He asked other normally sighted people in the shop to look through the binoculars, and they reported that they too did not see any dark specks. Usually, the customer will disengage at this point and resign himself to use the binoculars in their unclean state or to find someone else to clean them. I took a more aggressive approach. I insisted that the shopkeeper take the binoculars apart and look directly at the prisms in the absence of an intervening train of lenses. When he did so, he had no trouble seeing the offending particles. As a consequence, he took great care to remove all the particles he could find, including many that even I would not have been able to see, and when the binoculars were reassembled and returned to me, both the shopkeeper and I were fully satisfied.

Dust or other translucent or opaque material can also be seen in sharp focus on nonprismatic optical surfaces. For example, when looking through my assembled binoculars, I have observed offending particles on interior lens surfaces that completely escape the notice of persons with normal sight.
Experience with Supplementary Lenses

Figure 12 shows a supplementary lens in a flexible plastic mounting being placed over the left objective of a pair of binoculars. The supplementary lens is not bonded to its lens mount, but fits snugly into it. In addition, when the mount is placed over a binocular objective, its walls and lip hold the lens against the end of the housing containing the objective. However, although this type of lens mount is simple and convenient to use, I have found that it is not without its problems.

All too often, I have observed that when its inner wall becomes covered with oil and other lubricants from my hands and those of other people, the lens mount tends to slip if the binoculars happen to

Fig. 12—A supplementary lens in a flexible plastic mount being placed over the left objective of a pair of binoculars
rub against my clothing while I'm walking or otherwise in motion. This, of course, can lead to a minor disaster if the supplementary lens falls and is damaged or broken.

There are several ways of avoiding this problem: One technique that I have used in conjunction with my 8 × 30 binoculars, and that to my recollection has led to the loss of only one lens in about twenty years, is to use a supplementary lens mount that is made of brass or another easily machined metal. The mount must be machined so as to fit snugly over either of the objective housings of the binoculars. Since the rubbing of metal against metal will soon remove most or all of the paint from the outer wall of an objective housing, and hence make the binoculars rather unsightly, it is advisable to design the supplementary lens mount so as to be able to bond a piece of felt to its inner wall, still permitting the augmented lens mount to fit snugly over the outer wall of the objective housing.

Probably the surest way to solve this problem, but admittedly neither the cheapest nor the most convenient way, is to make the supplementary lens mount of metal, machine threading on the appropriate walls of the lens mount and the objective housings, and then thread the mount to the appropriate objective housing to hold it and its lens firmly and tightly against that housing. Since machining accurate threading is an operation requiring great skill and accuracy, this approach would probably only be practical if binocular manufacturers were to provide threading on the inner or outer wall of the ends of the objective housings, and were also to manufacture and sell supplementary lens mounts that thread easily onto the objective housings.

We would still have to face the fact, however, that it is much easier and quicker to put on or take off a supplementary lens mount that slips on or off of a binocular objective housing than to work with a lens mount that must be threaded. At this point of time, I tend to favor supplementary lens mounts that slip over and fit snugly against an objective housing to those that must be threaded.

**Experience with a Polarizing Lens**

At the suggestion of Dr. Petersen, our colleague Raymond W. Clewett placed a polarizing lens in a mount that fits snugly over the right objective of my 8 × 30 binoculars. With the polarizing lens, I am able to change the relative contrast between sky and foreground when the sky is blue and contains relatively little light-scattering material such as haze or dust. I am also able to reduce or eliminate light reflected from such highly polished surfaces as glass, metal, or wood. However, the polarizing lens absorbs a great deal of light, and hence, except when used in daylight, it tends to suppress or mask details in a scene.
that may be of importance to the viewer. Even when I used it in bright daylight, I did not find that it revealed any important details that I could not observe with the same binoculars but without the addition of the polarizer.

I conclude that although a polarizer can produce dramatic scenes in the presence of a bright clear blue sky and can remove glare from a highly polished surface, it does not contribute enough to my visual needs or enjoyment to compensate for the significant reduction it causes in overall image illumination. Even so, I encourage clinicians and the partially sighted to experiment further with a polarizer, as they may find that it has redeeming virtues that I may have overlooked.

IN CONCLUSION

I readily admit that not all partially sighted people see the same way as I do. For example, the vast majority, perhaps as many as 96 or 97 percent, have better visual acuity than I, but very few of that population can read J-1 type with their unaided eyes as I can with my functioning eye.¹⁹ Therefore, the reader is advised not to assume that my experience with binoculars or other visual aids is necessarily representative of what one can expect from all or even most other partially sighted people.

In view of this, I recommend that those who serve the partially sighted should acquire a thorough knowledge of binoculars, telescopic spectacles, and other visual aids, including a clear understanding of the advantages and disadvantages of each kind. They must be willing to ascertain the perceived as well as the actual visual needs of their partially sighted patients. At first glance, worrying about the difference between “perceived” and “actual” needs may appear to be rather esoteric. However, as pointed out earlier in this report, clinicians and others who serve the partially sighted frequently are not aware of how well these people can see with their limited eyesight and how well they could perform with various aids and under circumstances that would prove at best extremely uncomfortable for the normally sighted. Thus, those who serve the partially sighted must be willing to listen to what the latter have to say, to observe what they can actually do, to give them every opportunity to prove themselves, and to make a concerted effort to put themselves in their place before passing judgment on their capabilities or limitations.

¹⁹ J-1 or Jaeger 1 type is approximately equal in size to 4-point type. J-1 lowercase letters are about 0.03 inches (0.7 millimeters) high.
I am confident that if this procedure is followed, the advantages of binoculars will become better known and appreciated, and hence clinicians will have a greater tendency to prescribe or recommend them to their partially sighted patients. Further, the visual horizons and capabilities of those patients will be greatly expanded, and their participation in and enjoyment of life in our sighted society will be vastly improved.
References


Appendix A

Technical Measurements with Supplementary Lenses

Table 1 gives my visual range or “working” depth of field with my 10 × 40B Carl Zeiss binoculars. The right objective of these binoculars is capped with various supplementary lenses, ranging in strength from −0.25 to +6.00 dipters. I am viewing the test object, namely, a Lighthouse Near Acuity Test Card, through the right side of the binoculars with my right eye.20

For each supplementary lens, at least one measurement was made of the distance from my right eye at which I considered the letters on the test card to be in sharp focus when the binocular optics were (1) contracted and (2) extended as far as possible.21 When the optics were contracted as far as possible, a measurement of the “near point” was made; and when they were extended as much as possible, a measurement of the “far point” was made. It turned out that making an accurate measurement when the right objective was capped with a −0.25 dipter lens or when it was covered by no lens at all proved to be very difficult, because under those circumstances I was no closer than 6 feet from the test card when I reported that the letters on the card appeared to be in focus. I have to say “appeared” because with

20 In this report the measure of the strength of a lens is defined to be its power in diopters. The larger the absolute value of the power of a lens, the greater is its strength. An x-diopter lens is one whose focal length is one meter divided by x. When x is positive the lens is said to be a converging lens, and when x is negative it is said to be a diverging lens.

21 The 10 × 40B binoculars are “dialyt” binoculars. Unlike other binoculars, turning the focal rings on dialyt binoculars causes their objective lenses to move forward or backward rather than bringing about similar motions with respect to their eyepiece assemblies. One of the two adjustment rings on the 10 × 40B binoculars causes both objective lenses to move over a total distance of 3/8 inch, while the other causes the right objective lens to move over an additional 1/8 inch.
Table 1

THE AUTHOR'S VISUAL RANGE WITH 10 × 40B CARL ZEISS BINOCULARS

| (1) Power of Supplementary Lens (in diopters) | (2) Far Point (in inches) | (3) Near Point (in inches) | (4) Lighthouse Acuity (at 16 inches) | (5) Author's Adjusted Acuity
<table>
<thead>
<tr>
<th></th>
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<tr>
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<td>∞</td>
<td>110</td>
<td>20/400</td>
<td>20/58</td>
</tr>
<tr>
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<td>106</td>
<td>107.5</td>
<td>20/400</td>
<td>20/60</td>
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<td>20/300</td>
<td>20/41</td>
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<td></td>
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<td>None</td>
<td></td>
<td>76</td>
<td>20/200</td>
<td>20/42</td>
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<td>88</td>
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<td>20/250</td>
<td>20/45</td>
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<tr>
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<td>75</td>
<td></td>
<td>20/250</td>
<td>20/53</td>
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<tr>
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<td></td>
<td>20/250</td>
<td>20/51</td>
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<tr>
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<td>55</td>
<td>20/150</td>
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<td></td>
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<td>16</td>
<td></td>
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<td>20/50</td>
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<td>20/41</td>
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<td></td>
<td>20/25</td>
<td>20/32</td>
</tr>
<tr>
<td>+6.00</td>
<td>12.5</td>
<td></td>
<td>20/25</td>
<td>20/32</td>
</tr>
</tbody>
</table>
Notes to Table 1

a The acuities reported in this column are those obtained when the author viewed a Lighthouse Near Acuity Test Card with his 10 × 40B Carl Zeiss binoculars equipped with the supplementary lenses indicated in column 1 and at the distances stated in either column 2 or 3.

b Each entry in this column is the author’s measured visual acuity adjusted to the measured distance appearing in either column 2 or 3 of this table (in the same row as the entry in this column). The second number in each ordered pair in this column is the result of multiplying the second number of the corresponding ordered pair in column 4 by 16, dividing that product by the corresponding entry in either column 2 or 3, and rounding the result of that division to the nearest positive integer. Thus, with a +3.00 supplementary lens, the measured near point distance was 17.5 inches and the measured Lighthouse acuity was 20/40. Multiplying 40 by 16 and dividing by 17.5 yields approximately 36.57, which upon rounding to the nearest integer becomes 37. Hence, the adjusted acuity in column 5 is 20/37.

my meager visual acuity, even with the aid of the binoculars, it was not possible for me to be sure that the card was really in sharp focus at those distances. This explains why we decided to make more measurements when I was using the binoculars equipped with supplementary lenses weaker than 0.75 dipters.

Almost all the measurements reported here were made in our RANDSIGHT test facility, which at that time was 20 × 14 feet and was illuminated from the ceiling by four 8-foot fluorescent units, each equipped with four 75-watt “cool white” fluorescent tubes. This lighting system delivered about 150 foot-candles at the height above the floor where measurements were made. My ability to focus the binoculars at great distances with a –0.25 lens over the right objective was determined outdoors on a clear sunny day, and my “near point” with that supplementary lens was also measured outdoors. The test card and the observer were located under an open-roofed passage that allowed daylight to enter freely from the sides, but completely shaded the observer and the card from direct sunlight.

Even a cursory examination of Table 1 will reveal that visual range or working depth of field decreases as the algebraic power of the supplementary lens increases. In like manner, the distance between the viewer and the viewed object also decreases as the algebraic power of the supplementary lens increases.

Table 1 also gives, for each near or far point measurement, my visual acuity using the 10 × 40B binoculars equipped with the indicated supplementary lenses. Column 4 gives the measured Lighthouse
Acuity at 16 inches, but since the Lighthouse Test Card was viewed at distances at which the card was in sharp focus, using the augmented binoculars, rather than at 16 inches, it was meaningful to adjust the measured acuities in column 4 to account for the fact that all but one of the acuity measurements were actually made at distances other than 16 inches. This was done by multiplying the second member of each ordered pair in column 4 by 16, dividing the resulting product by the corresponding entry in column 2 or 3, rounding the result of this division to the nearest positive integer, and entering that integer in column 5, as the second element in an ordered pair whose first element is 20. The acuities in column 5 are comparable and may be looked upon as measurements of my actual visual acuity when I am using my 10 × 40B binoculars.

Since I was able to report with confidence that the letters I viewed were in sharp focus when my binoculars were augmented with supplementary lenses stronger than +0.50 diopters, the adjusted acuities corresponding to measurements made with those lenses are probably more accurate than those made with weaker supplementary lenses. If this conjecture is correct, then, from the data, my acuity using my 10 × 40B binoculars lies between 20/50 and 20/30 and probably is very close to 20/40.

Expressing visual acuity as "m/n," where m and n are positive integers, does not imply that m is divided by n, but rather that m is the first element in an ordered pair with n as the second element. I have been very careful to respect this interpretation throughout this report.
Appendix B

Telescopc Spectacles and Binoculars

My colleague Dr. Hubert L. Moshin and I measured the field that I was able to obtain with various telescopic spectacle assemblies, that is, with various telescopic units that were not mounted in either a test frame or in an ordinary eyeglass frame.\(^23\) The eyepieces of these units or assemblies were brought as close to my right eye as was possible and comfortable in order to maximize the visual field obtained with each of the assemblies.\(^24\) Similar measurements were made with one of the telescopic units using normally sighted subjects, who in this experiment used only one eye. In addition, measurements were made with a partially sighted subject other than myself using another telescopic unit. A summary of those measurements is given in Table 2.

It will be seen that with a 2.2× wide-angle Feinbloom telescopic unit,\(^25\) on the average the normally sighted subjects obtained a larger field than I did, though neither they nor I found the field to be greater than 21.5° during any individual measurement. The fields obtained with the Feinbloom 2.2× full-diameter telescopic unit and with the corresponding Kollmorgen unit appear to be larger than that obtained

\(^23\) Recall that I have no vision in my left eye and the visual acuity in my right eye in 20/750. However, I am able to read J-1 type by bringing it to within an inch of my unaided right eye. In addition, the visual field of that eye appears to be normal, and no scotomas have ever been detected within that field. It is possible, however, that my very poor distant acuity, combined with the nystagmus that is present in my right eye, may act to mask any small scotomas that might be present. (A scotoma is an area in the visual field throughout which either no vision is present or the vision that is present is distinctly depressed when compared with that in immediately adjacent areas.)

\(^24\) Since eyeglasses composed of lenses from a conventional ophthalmic lens kit have no appreciable effect on the quality or quantity of my eyesight, no corrective lens or lenses were placed between my right eye and the telescopic assemblies during these measurements.

\(^25\) Feinbloom telescopic units are named after their designer Dr. William Feinbloom and are manufactured by Designs for Vision.
### Table 2

**SUMMARY OF FIELD MEASUREMENT WITH TELESCOPIC SPECTACLES AND BINOCULARS**

<table>
<thead>
<tr>
<th>Type of Unit</th>
<th>Averaged Measured Field</th>
<th>Subject</th>
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<tbody>
<tr>
<td>F 2.2× WA FD TS</td>
<td>17.5°</td>
<td>A</td>
</tr>
<tr>
<td>F 2.2× WA FD TS</td>
<td>19°</td>
<td>B</td>
</tr>
<tr>
<td>F 2.2× WA FD TS</td>
<td>19.5°</td>
<td>C</td>
</tr>
<tr>
<td>F 2.2× WA FD TS</td>
<td>19°</td>
<td>D</td>
</tr>
<tr>
<td>F 2.2× FD TS</td>
<td>19°</td>
<td>A</td>
</tr>
<tr>
<td>K 2.2× FD TS</td>
<td>18.5°</td>
<td>A</td>
</tr>
<tr>
<td>K 2.2× FD TS</td>
<td>17.5°</td>
<td>E</td>
</tr>
<tr>
<td>F 4× TS</td>
<td>6°</td>
<td>A</td>
</tr>
<tr>
<td>CZ 10 × 40B</td>
<td>6.5°</td>
<td>A</td>
</tr>
</tbody>
</table>

---

*a* In every case reported here, the telescopic unit was not in a test or spectacle frame while the field measurement was being made; rather it was held as close to the eye as was possible and comfortable.

*b* The following abbreviations have been used in this column: F = Feinbloom, WA = wide angle, FD = full diameter, TS = telescopic system, K = Kollmorgen, CZ = Carl Zeiss.

*c* Field size has been rounded to the nearest half-degree.

*d* In this column, “A” represents the author and “E” represents the other partially sighted subject. All other letters represent the normally sighted subjects.

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with the Feinbloom 2.2× wide-angle unit; however, this may not be significant, because the dispersion in the measurements with the latter unit was quite large (12.5° to 21.5°), and this was not the case with respect to the other units. The field observed with the 4× Feinbloom telescopic unit was only 6°, and the dispersion between individual measurements was almost negligible. The field obtained with the Carl Zeiss 10 × 40B binoculars was 6.5°, and although this field may also appear to be small, it should be observed that a 6.5° field with 10× binoculars is equivalent to a 16.25° field with a 4× telescopic unit or a 29.5° field with a 2.2× telescopic unit.