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A curriculum for training patients with peripheral visual field loss to use bioptic amorphic lenses

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Abstract—This article describes the experimental protocol used to instruct fifteen patients with peripheral visual field loss due to retinitis pigmentosa, choroideremia, or Usher's syndrome Type II how to effectively use bioptic amorphic lenses. The factors that contributed to the successful use of these lenses, as well as difficulties the patients encountered, are discussed. The results of the study (published in detail in Szlyk et al. Use of bioptic amorphic lenses to expand the visual field in patients with peripheral loss. Optom Vis Sci 1998;75:518–24) indicate that bioptic amorphic lenses, when combined with a comprehensive training program, can expand visual function in the areas of peripheral detection, recognition, scanning, tracking, visual memory, and mobility.

Key words: *bioptic amorphic lenses, driving, orientation and mobility, peripheral visual field loss.*

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INTRODUCTION

People with retinitis pigmentosa (RP) can slowly lose their peripheral vision until only a small central field remains. Two other diseases associated with this type of condition are Usher's syndrome and choroideremia. These patients usually first experience night blindness and eventually start to have difficulty detecting objects in their peripheral field of vision during the day. These patients experience problems in mobility, such as detecting people and obstacles and locating destinations. One of the greatest fears people have when they begin to lose their vision is that they will no longer be able to meet the state vision requirements to keep their driver's license.

There are several optical devices available that, while not legal for driving, expand the field of view for patients with peripheral vision loss. One such device is the amorphic lens. These lenses minify the image along the horizontal meridian while maintaining the same size along the vertical meridian (2). This minification enables the patients to view a wider field, which is necessary for safe navigation of the environment. The power of the minification ranges from $-1.2\times$ to $-2.0\times$.

A study by Hoeft, et al. (2) examined the use of amorphic lenses to improve general mobility for patients with RP. In that study, the lenses were designed as full-field lenses; that is, the subject looked continuously through the amorphic lens. The authors reported that 30 out of 69 subjects in their study immediately rejected the lens system with complaints of distortion, nausea, and dizziness caused by the horizontal minification of the lenses and off-axis rotation of the image. Of the 39 subjects who wore these lenses full time for two weeks, only 36 percent reported an increase in mobility. Subjects described several reasons for a lack of success of these lenses, including dizziness due to head movement (33 percent), distortion (28 percent), confusion caused by changes in the depth of field (13 percent), excessive weight (13 percent), and cosmetic factors (10 percent). None of these subjects was provided any type of instruction on use of the lenses.

After examining the study, we hypothesized two major reasons for the low rate of satisfaction and success among those participants who used the amorphic lenses: the use of the lenses as a full-field lens system rather than in a bioptic form, and the lack of training in their use for mobility and daily activities. The current study took special care to eliminate these problems. We configured the lenses in bioptic form, placing the amorphic lenses in the lower portion of both the left and right carrier lenses. Rather than looking continuously through the lenses, a subject was trained to use the amorphic lenses only as a spotting tool to obtain information that increased their effective field of view. We believe that the success of this bioptic amorphic lens system will depend on the employment of an appropriate curriculum to orient the patient to the lenses and on teaching the necessary skills for their effective use.

METHODS

Participants

Fifteen patients with peripheral vision loss due to either RP (13), choroideremia (1), or Usher's syndrome Type II (1) were included in this study. The participants ranged in age from 27 to 67 years. All the patients had valid driver's licenses and were currently driving. See **Table 1** for a description of patient characteristics including diagnosis, age, sex, lens power of the amorphic lens (Designs for Vision, Ronkonkoma, NY) prescribed, visual fields, visual acuity, and contrast sensitivity.

Table 1.
Patient characteristics.

No	Diag	Age	Sex	Lens	VF OD	VF OS	VA OD	VA OS	PR OD	PR OS
1	RP	28	F	-2.0	12	11	0.02	0.02	1.50	1.60
2	RP	40	F	-1.8	20	22	0.06	0.02	1.65	1.55
3	RP	38	F	-2.0	33	22	0.16	0.54	1.60	1.30
4	RP	37	F	-2.0	26	31	0.10	0.14	1.60	1.50
5	C	30	M	-2.0	18	14	0.44	0.06	1.40	1.55
6	RP	59	M	-1.6	18	21	0.62	0.12	0.60	1.55
7	RP	59	F	-1.8	19	22	0.48	1.40	0.80	0.05
8	RP	67	M	-2.0	17	16	0.54	1.30	0.85	0.10
9	RP	27	F	-1.8	17	16	0.04	0.02	1.65	1.65
10	RP	49	F	-2.0	35	37	0.20	0.10	1.65	1.35
11	RP	59	M	-2.0	38	26	0.06	0.12	1.65	1.60
12	US	42	M	-2.0	51	46	-0.06	-0.10	1.80	1.65
13	RP	60	M	-1.8	40	31	0.22	0.22	1.30	1.35
14	RP	51	M	-2.0	63	49	0.04	0.00	1.65	1.75

No=patient number; Diag-diagnosis (RP=retinitis pigmentosa; C-Choroideremia; US-Usher syndrome); Age in years; Lens=lens power; OD=right eye; OS=left eye; VF=visual field (Goldman III-4-e target), in degrees; VA=visual acuity (Lighthouse charts), in LogMAR; PR-Pelli-Robson contrast Sensitivity Charts, in Log CS.

Snellen/LogMAR
Some Snellen equivalents to LogMAR

LogMAR	Snellen
-0.10	20/16
0.00	20/20
0.10	20/25
0.20	20/32
0.30	20/40
0.40	20/50
0.50	20/63
1.00	20/200

Study Design

The subjects were divided into two groups, Group A and Group B. There was no significant difference between the mean age, mean visual acuity, mean horizontal field extent, and mean contrast sensitivity of the two groups. This study was completed in 6 months, with Group A receiving lenses and training during the first 3-month period, and Group B receiving lenses and training during the second 3-month period. An assessment battery was administered on three occasions (Test Days 1, 2, and 3). A baseline assessment of both groups was made without bioptic amorphic lenses and without training on Test Day 1. During the first 3-month period, Group A received lenses and training while Group B received nothing. At the end of this 3-month period both groups were given the assessment battery on Test Day 2. Group A completed the battery while wearing their lenses, and Group B completed the battery without any lenses. During the second 3-month period, Group B received lenses and training, while Group A kept their lenses and did not receive further training. At the end of the second 3-month period, both groups completed Test Day 3 while wearing their lenses.

This study structure allowed us to determine: 1) the effects of lenses and training: Group A—by comparing Test Day 1 to Test Day 2, and Group B—by comparing Test Day 2 to Test Day 3; 2) the test-retest reliability without lenses or training: Group B—by comparing Test Day 1 to Test Day 2; and 3) the sustained effects of lenses and training: Group A—by comparing Test Day 2 to Test Day 3.

Assessment Tools

The patients' use of, and performance with, the amorphic lenses was assessed and recorded in two main situations: 1) laboratory/mobility, which included driving on an interactive driving simulator, and 2) driving on an actual road course. This paper will focus on the laboratory and mobility training and assessment. A detailed description of the driving training and assessment is beyond the scope of this paper. However, interested readers can refer to Szlyk et al. (1) to learn more about the driving training component.

Visual behavioral performances were recorded and analyzed on both indoor and outdoor lab and mobility routes. The subjects' performance with the amorphic lenses was assessed in six main skill areas: peripheral detection, recognition, scanning, tracking, visual memory, and mobility. The assessment was conducted by a certified orientation and mobility specialist who coded performance on the mobility tests using the following scale: 1) not able to perform, 2) extreme difficulty, 3) moderate difficulty, 4) mild difficulty, or 5) no difficulty. For each task, performance, speed, or both were coded.

Progress was recorded on a weekly basis from observations by the instructor and from self-reports made by the patients regarding their experiences during the training period. With both types of data, the instructor was able to clearly monitor the accomplishments and difficulties each subject encountered. A driving instructor also evaluated the performance of each patient using the amorphic lens for driving before and after behind-the-wheel training. At the end of the study, each patient filled out an evaluation consisting of 23 questions of both components of the amorphic lens training program and provided their overall opinion of the lenses.

Procedures

The bioptic amorphic lens training program lasted twelve weeks, with the first four weeks focused on laboratory and mobility training, and the last eight weeks focused on driving. Each patient participated in the laboratory and mobility training once a week for two to three hours at a time. The training curriculum, presented here in detail, was developed and adapted by creating exercises using ideas that were generated by the present authors and from several sources (3–9). Six skill areas were taught: peripheral detection, recognition, scanning while stationary and moving, tracking while stationary and moving, visual memory, and mobility indoors and outdoors. The mastery of these skills was a prerequisite before the patients could begin driving instruction.

Before training began, the patients were familiarized with the lenses and instructed in some basic skills for using them. It was explained that head movement had to be limited to only vertical or horizontal movement, since angular head rotation can produce visual distortion. The patients practiced looking straight ahead into the carrier and then moving from the carrier to the amorphic lens by tilting their head slightly up and moving their eyes down. It was also explained that an image viewed through the amorphic lenses would tend to appear thinner than normal due to the minification along the horizontal axis of the image (**Figures 1a** and **1b**). The patients were alerted to the fact that the minification produces a reduction in acuity that may cause difficulty identifying an object or reading a sign, and that this is the primary reason the amorphic lenses should be used only as a spotting device.

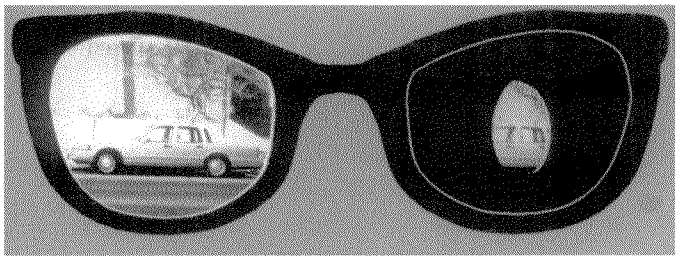

Figure 1a.
On the left side of the lenses is a view of a car from a person with full visual field extents. The right side of the lenses depicts a view of the car from a person who has peripheral visual field loss. Only a portion of the car can be seen.

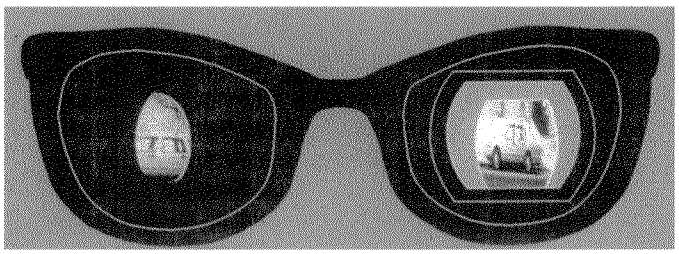

Figure 1b.
On the left side of the lenses is the same view of the car by a person who has a peripheral visual field loss. The right side of the lenses depicts the view of the same person looking through the amorphic lenses. The entire car can be seen, however, the image along the horizontal meridian is minimized causing the car to appear shorter in width.

Patients were made aware of the fact that an image viewed through the amorphic lenses will be displaced, appearing to be closer to the vertical meridian (spatial center) and further away in the distance. In order to demonstrate this, patients were asked to compare several images in the room when looking through the amorphic lenses to the same images when looking through the carrier lenses. This was done by pointing with one hand to where the detected object appeared to be, and with the other hand to where the patient thought the object actually was, all the while looking through the amorphic lenses. The patient then looked back into the carrier lenses and compared the two images. The patient was able to identify the object detected when looking through the carrier lenses.

To further demonstrate how the amorphic lenses displaced an image, the patients were instructed to continuously look through the amorphic lenses as opposed to the preferred method of spotting, and to walk as close to a positioned miniature street sign as possible without bumping into the sign. The sign was on a lightweight pole, which would not injure someone who might bump into it. On first trial, most patients walked into the sign because it appeared to be further away than it actually was. Patients were cautioned that the only time they should ever remain continuously focused in the amorphic lenses was for a supervised exercise such as this one.

Skill#1: Peripheral Detection

As described above, the patients were first instructed on the basic method of detecting an image in the amorphic lenses and then focusing on that image through the carrier lenses. The participants were involved in several training exercises in order to hone their skills of peripheral detection.

With the patient seated and looking through the amorphic lenses, the instructor stood behind the subject and moved objects, such as a pen, forward to the patient's right and left sides. The patient was instructed to continue looking through the amorphic lenses and grab the object as soon as it was detected in their periphery. In order to perform this task with accuracy, the patient had to remain aware that the object was actually closer than it appeared, and that this fact required reaching differently to grasp the object. The patient was reminded to always return his or her eyes back to the carrier to see where the object actually was.

In another peripheral detection exercise, using 35-mm slides designed by the authors, the patient sat 57 inches away from the screen and was instructed to stare through the carrier lens at the star located in the center of the screen (**Figures 2a** and **2b**). Due to the patient's constricted visual field and the close position to the screen, pictures and numbers projected along the edges of the screen could not be detected until the subject looked through the amorphic lenses. The patient was instructed to detect the image by looking through the amorphic lenses, then turning his or her head toward the object and identifying it more clearly through the carrier.

Skill#2: Recognition

To teach detection and recognition techniques simultaneously, miniature road signs (12 × 12 inches) standing four feet tall and ranging in visual angle from 5.5° to 29° were lined up along one side of a hallway. The patient began by looking straight down the hallway through the carrier lenses, at the furthest sign (80 feet), which was on the opposite side of the hallway. The patient was then asked to detect each sign by shifting his or her eyes into the amorphic lenses. Patients were

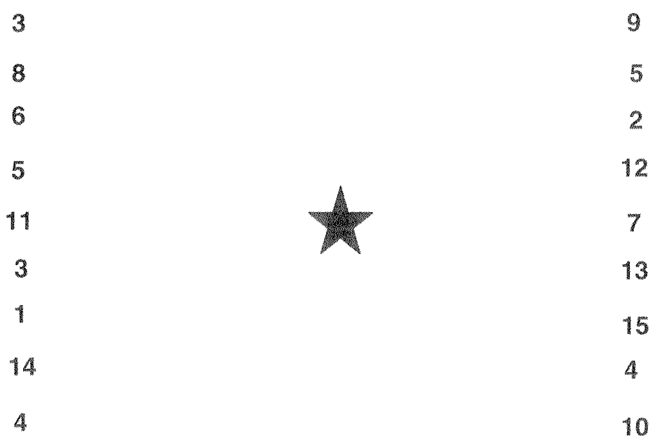

Figure 2a.
A training slide with numbers along the far left and right sides and a star in the center for fixation. When the patients fixated upon the star in the center of the screen, the numbers on the sides could not be detected until they glanced into the amorphic lenses.

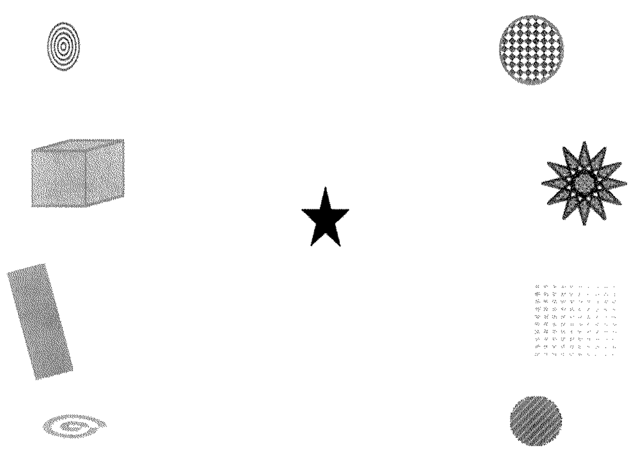

Figure 2b.
A training slide with different shapes along the far left and right sides and a star in the center for fixation. When the patients fixated upon the star in the middle of the screen, the shapes on the sides could not be detected until they glanced into the amorphic lenses.

reminded to return to the carrier in order to identify the signs they had just detected.

Skill #3: Scanning

Scanning While Stationary: Slides with multiple and single targets were projected onto a screen for the patients to practice scanning and finding (**Figure 3**). The instructor named a target and then the patient, using the amorphic lenses, scanned the screen in order to find that particular picture, number, or letter, and then returned to the carrier. In the university's student union, patients practiced locating stores, items on store shelves, and empty seats in the cafeteria.

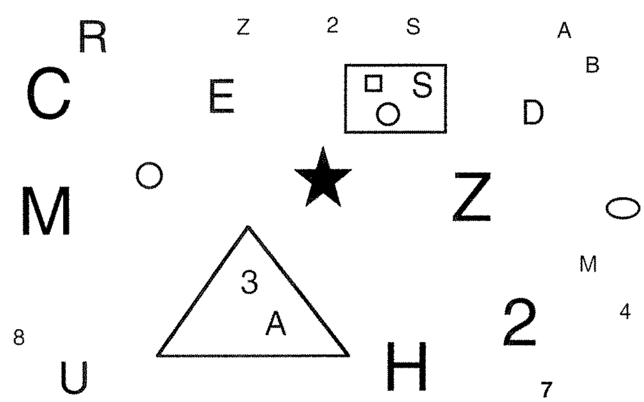

Figure 3.
A slide designed to teach systematic scanning techniques. The patient is asked to find specific items in this slide.

Scanning While Moving: A modified version of a scanning technique called "U" movement (3,9) was taught to the patients. While looking through the carrier lens and turning the head to the left, the patients quickly glanced through the amorphic lenses to gather as much information as possible about their left field of view before returning to the carrier lenses. The sequence was repeated for the right field of view. This technique was used to scan the left and right sides of hallways, sidewalks, and streets in order to locate addresses, bus stops, and cars while walking, riding as a passenger, or driving. The instructor provided opportunities to develop and sharpen scanning skills with walking trips to the university's student union and nearby stores. In the laboratory, slides and traffic signs were also used to teach this technique.

Skill #4: Tracking

Tracking While Stationary: While sitting or standing still, subjects were instructed to visually follow pictures and traffic signs that were moved by the instructor at a medium speed from five to twenty feet away. These pictures were to be detected by looking through the amorphic lenses and then quickly moving the eyes to the carrier lenses where the picture was identified and tracking resumed. Using a series of 35-mm slides made in our laboratory as well as slides from Bernell Corporation, (South Bend, Indiana) subjects practiced tracking. For example, subjects were instructed to visually track individual lines to their end points to determine their correct corresponding numbers (**Figure 4**). This eye movement is designed to simulate tracking a moving object (3). The subjects also tracked passing cars and practiced counting the number of passengers. Subjects were alerted to the fact that tracking through the amorphic lenses could cause nausea or dizziness, because of the frequent head tilting involved.

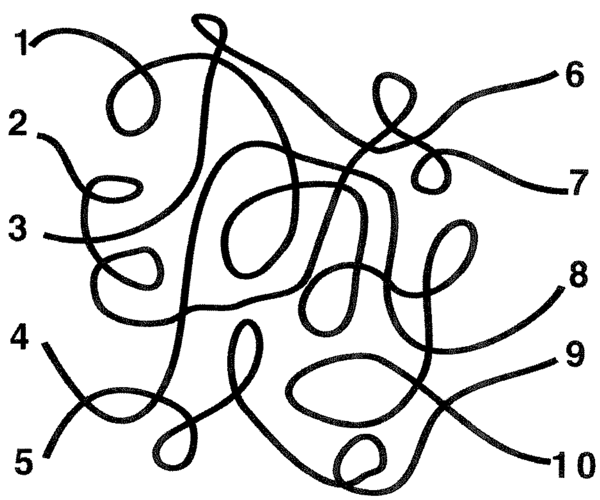

Figure 4.
A slide used to practice tracking. The patient starts by visually locating a number on the left-hand side and then visually follows the line to locate the number it is attached to on the right-hand side. This simulates tracking a moving object.

Tracking While Moving: As they walked and rode as passengers in a car, subjects watched and tracked moving cars and people.

Skill # 5: Visual Memory

In order to avoid nausea or dizziness, which may occur while looking through the amorphic lenses and thus compromise a person's ability to safely walk or drive, it is important to quickly glance into the lenses, gather as much visual information as possible, and return to the carrier lenses. Therefore, the subjects need to be able to accurately recall what was seen when they looked through the amorphic lenses. To practice visual memory, patients were asked to recall sequences of numbers, letters, or shapes, and critical features such as traffic signs and pedestrians from briefly presented 35-mm slides. Over the course of the training, presentation of the visual memory slides was decreased from 12 seconds to 3 seconds and finally to 1 second. To further emphasize the importance of visual memory skills, the instructor randomly asked the subject what he or she had just walked past during indoor and outdoor mobility lessons.

Skill #6: Mobility

It should be noted that mastery of all of the skills, peripheral detection, recognition, scanning, tracking, and visual memory is necessary for safe and independent travel. Throughout mobility exercises, the subjects were reminded to spend the majority of the time viewing through the carrier lenses and to periodically glance into the amorphic lenses to gather peripheral information. As well, subjects were cautioned that looking through the amorphic lenses while walking up and down stairs could prove to be very dangerous due to distortion and displacement factors. The subjects were instructed to either look through the carrier lenses above or below the amorphic lenses, or to simply remove the glasses from their face while navigating steps.

Mobility Indoors: While wearing the amorphic lenses, the subjects practiced walking down hallways and detecting stationary objects such as chairs, room numbers, pictures, and signs. The subjects also practiced detecting the traffic signs (described in skill #4) that were lined up in a hallway.

One exercise took place while both the subject and the target object were moving. As the subject walked down the hallway, the instructor approached the subject from the rear and passed him or her while holding a street sign. The subject was instructed to use the amorphic lenses to detect the passing sign.

Mobility Outdoors: While walking down a street with several stores and restaurants, the subjects used their amorphic lenses to scan the environment. They detected and identified landmarks and crossed streets at intersections with stop signs or traffic lights. The subjects were instructed to locate stores by address and/or name, enter the stores and locate specific items on the shelves, all the while using perfected scanning techniques. Visual memory was assessed as well, when the instructor asked subjects to name stores that they had walked past.

By the end of the training, subjects were able to judge when the amorphic lenses were helpful and when it was more appropriate to look through the carrier lenses. It should be noted that each skill builds upon the other skills and is continuously used once learned. **Table 2** lists, in detail, the skills that were taught during each day of training and the materials used during training.

Table 2.
Daily exercise and homework assignments.

Day 1	Day 2	Day 3	Day 4
1. Familiarization w/ lenses.	1. Tracking moving objects while patient is stationary.	1. Visual Memory	1. Visual Memory
-Learning to move from carrier lenses to amorphic lenses, back to carrier.	2. Visual Memory.	2. Detecting & Recognition	2. Detecting
-Understanding the displacement effect caused by the amorphic lenses.	3. Mobility - walking in an indoor environment.	3. Scanning & Finding	3. Scanning & Finding
2. Detecting, spotting, & recognizing stationary objects.	4. Scanning to locate stationary objects while patient is moving.	4. Tracking moving objects while patient is moving	4. Tracking
3. Scanning	5. Detecting stationary and moving objects on the sides while stationary and moving.	5. Modified "U" technique.	5. Modified "U" technique.
4. Finding		6. Mobility - walking in indoor environments.	6. Walking in an outdoor environment.
		7. Mobility - walking in outdoor environments.	7. Store travel.
		8. Store travel.	8. Scanning to locate: 1. Street signs. 2. Store signs. 3. Addresses. 4. Items in stores.
HOMEWORK	**HOMEWORK**	**HOMEWORK**	**HOMEWORK**
1. Practice moving from one lens to the other.	1. Walk around a neighborhood while wearing the amorphic lenses. Practice detecting, scanning, and tracking with the lenses.	1. Walk around a neighborhood while wearing the amorphic lenses.	1. Incorporate the amorphic lenses into your everyday life.
2. Spot items indoors and outdoors using the amorphic lenses.	2. Go shopping with the lenses on.	2. Ride in a car as a passenger and detect stationary and moving objects.	
	3. Ride in a car as a passenger and spot stationary objects.	3. Practice the modified "U" technique.	
		4. While the car is parked alongside the road, sit in the driver's seat and look in the rear and side mirrors.	
Materials Used	**Materials Used**	**Materials Used**	**Materials Used**
1. Objects in the room.	1. Slides	1. Slides	1. Slides
2. Slides	2. Pictures taped on sticks.	2. Traffic signs	
3. Traffic signs	3. Traffic signs		

Homework

After each training session, subjects were given exercises to practice at home and in their community. Their first assignment was to practice using the amorphic lens system to detect and recognize items in their homes and outdoor environment by moving their eyes from the carrier to the amorphic lens and back to the carrier lens as quickly as possible, kwith the goal being to decrease the amount of time spent viewing through the amorphic lenses. Subjects were then instructed to walk around their neighborhoods and shopping malls wearing the amorphic lenses to locate addresses, street and store signs, and specific merchandise on store shelves. They were also instructed to ride as a passenger in a car to practice spotting stationary objects such as signs, stores, and houses and to track moving objects such as pedestrians and bikers. Patients were instructed to sit in a parked car along the side of a road while wearing the amorphic lenses, and to examine the dashboard gauges and use the side and rearview mirrors to detect cars and pedestrians. The homework assignments for each day are also listed in **Table 2**.

Driving Training

The subjects were involved in a driving training program during the remaining eight weeks of the program. They drove in a car with dual brakes on the enclosed grounds of a Veterans Administration Medical Center and rode as passengers in residential and business areas with the driving instructor. As mentioned previously, it is currently illegal for the bioptic amorphic lenses to be used while driving. We cautioned the study subjects against using their lenses illegally to drive. In addition to our verbal warnings, all subjects signed a consent form and initialed the section stating: "I agree not to drive with any prescribed lens system except when driving with the kinesiotherapist on the controlled experimental course in the car with dual controls."

Because the subjects all had previous driving experience, they did not need to learn basic driving skills, but instead were helped to incorporate the techniques they had just been taught with driving. They used the amorphic lenses to apply the skills of peripheral detection, recognition, scanning, tracking, visual memory, and mobility. Specific activities included detecting and recognizing signs, addresses, and potential hazards, pulling out of driveways to enter the traffic flow, initiating turns at intersections, using proper scanning techniques including the modified "U" technique, using the car's side and rearview mirrors, as well as navigating complex environments as a passenger.

RESULTS

All of the assessments, including the laboratory, mobility, and driving assessments, were categorized into six areas: peripheral detection, recognition, scanning, tracking, visual memory, and mobility. These were all analyzed for improvement before training and after training. The results of this study described by Szlyk et al. (1) showed a 37 percent overall task improvement in these areas.

Results of Observation by Instructor

During the training sessions, the instructor observed the progress of each patient, including the accomplishments and difficulties each was having adjusting to the amorphic lens system and mastering the six skills. Overall the patients progressed quickly in learning the six skill areas of peripheral detection, recognition, scanning, tracking, visual memory, and mobility. The lenses allowed patients to scan faster indoors and outdoors, and were especially helpful at intersections. The instructor noted that patients navigated more smoothly through crowded areas and were better able to avoid obstacles. At the beginning of training, the patients tended to look through the amorphic lenses far too long. As a result, they were missing the detail and clarity needed to recognize and identify objects, and also experienced some queasiness due to the displacement effects. It soon became evident that all of the patients needed practice moving quickly from the carrier lenses into the amorphic lenses and back again.

The amorphic lenses were not useful for recognizing individual items on the store shelves, because labels could not be read. Some of the patients had difficulty mastering the technique of systematic scanning, which made it difficult to locate individual items. This also applied to finding street signs and addresses. The patients needed to work on their visual memory skills. Initially after walking down a street with several stores, most of the patients were unable to name even one of the stores they had passed.

Results of Self-Reports from the Patients

Patients would report back on how well they did on their homework assignments. Their reports provided clear feedback about their experiences at home and in their neighborhoods for each particular skill. They expressed amazement at the capability of the amorphic lenses to bring the periphery into their field of view. Stationary and moving objects were detected in their periphery more quickly and with greater ease than without the lenses, and some patients reported noticing houses and buildings they never even knew existed. One patient located his newspaper on the lawn by looking through the amorphic lenses. Another patient reported being able to monitor her children while they played in the backyard. The amorphic lenses enabled patients to avoid bumping into kitchen table chairs left askew, check to see if venetian blinds were even, find misplaced items, and view a room in its entirety. Using the amorphic lenses when canoeing enabled one patient to see a panoramic view of the river, and when mowing the lawn, tree branches were avoided. Each patient who rode as a passenger in a car reported how easily signs, trees, people and cars merging from crossroads were detected when they used the amorphic lens system. Unlike the Hoeft et al. study (2) in which 43 percent of the patients could not use the amorphic lens system because of dizziness and nausea, none of our patients reported experiencing these symptoms (beyond the negligible queasiness/disorientation experienced during the initial adjustment to the lenses).

In stores, the amorphic lenses were beneficial for detecting displays and promotional items in the aisles, thus preventing one from walking into them. Although the majority of self reports were positive, some patients thought the amorphic lenses were not helpful for navigating familiar stores, and in fact made things more confusing because the lenses caused the aisles to look very narrow. Other complaints had to do with the design of the lens system itself. The black casing around the amorphic lenses was reported to be bothersome to some of the patients because it obstructed the lower field when looking through the carrier lenses, which made it difficult to detect curbs and steps when walking. Some patients felt the lens system was somewhat cumbersome, and a few of the patients felt self-conscious wearing the lenses in public, which prevented them from practicing the skills outdoors and in stores.

Results of Amorphic Lenses Evaluation by Patients

Overall, 86 percent of the patients were satisfied to extremely satisfied with the amorphic lenses (1). Complete results of the evaluation are listed in Table 3. They were very satisfied with the training program and agreed the laboratory and mobility training was useful in learning how to efficiently use the amorphic lenses. Patients reported an improvement in their scanning and visual memory skills, and commented that they gained a better understanding of their vision as well as the purpose of amorphic lenses. Patients felt the slides and the traffic signs used to teach detecting, scanning, and visual memory were beneficial and agreed the outdoors routes to nearby stores were helpful to incorporate the use of the amorphic lenses with more realistic settings. The homework exercises were beneficial for the same reasons.

The patients reported being pleased with the driving training and felt their overall driving ability improved. While they all would have liked some driving experience outside the limits of the Veterans Administration, the patients found the amorphic lenses especially beneficial for specific aspects of driving, including the navigation of intersections.

DISCUSSION

Szlyk et al. (1) provides the quantitative analysis to evaluate the training program described here. That study reported that subjects improved 37.3 percent overall in the skill areas that were measured (1). Patients showed a 39-percent improvement in tasks involving peripheral detection, a 40.5-percent improvement in recognition tasks, 27-percentimprovement in scanning tasks, 44-percent improvement in tracking tasks, 36-percent improvement in visual memory tasks, and 46.4-percent improvement in mobility tasks.

The reason for improvement in the skill area of peripheral detection appears to be directly related to the use of the amorphic lenses. Patients would immediately detect something in their periphery simply by glancing into the amorphic lenses. Their awareness of their surroundings both indoors and outdoors was increased. During observation of the patients, some potential serious incidents, such as bumping into obstacles while walking and hitting a pedestrian crossing the street while driving, were prevented when the patient looked into the amorphic lenses. Glancing into the amorphic lenses more frequently may have further increased the number of items the patients detected, resulting in a higher percentage of improvement.

Improvement in the area of recognition appears to be directly related to peripheral detection. A greater num-

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Table 3.
Results of patient evaluation of the training program.

RT	Very B	B	Somewhat B	A Little B	Not B	NR
1. Slide Presentations	5	7	3	--	--	--
2. Traffic signs on poles exercise	5	6	2	--	1	1
3. Outdoor lessons	11	2	1	1	--	--
4. Homework	9	4	1	1	--	--
5. Driving Training	11	2	--	--	--	2
	Just Right	**Too Short**	**Too Long**	**Not Sure**	**--**	**NR**
6. Length of each lesson of the lab and outdoor training	13	--	1	1	--	--
7. Length of the lab and outdoor training	12	1	1	--	--	1
8. Length of each lesson of the driving training	10	2	1	--	--	2
9. Length of the driving training	10	2	1	--	--	2
	Stay the Same (4 wks)	**Change to 6 wks**	**Change to 8 wks**	**--**	**--**	**NR**
10. The # of weeks for training	12	1	1	--	--	1
	Stay the same (8 wks)	**Change to 9-10 wks**	**Change to 6 wks**	**Change to 4 wks**	**--**	**NR**
11. The # of weeks for driving training	9	1	1	2	--	2
	Extremely S	**Very S**	**S**	**A Little S**	**Not S**	**NR**
12. Satisfaction with Amorphic Lenses	1	3	9	1	1	--
	Will In-corporate	**Sometimes**	**Maybe**	**Never**	**--**	**NR**
13. Whether the Amorphic Lenses will be incorporated in everyday life	4	6	1	1	--	3
	Yes	**Probably**	**Maybe**	**No**	**--**	**NR**
14. If Amorphic Lenses become legal for driving, would you drive with them?	12	--	--	2	--	1

Uses of the Amorphic Lens

Everyday	Driving
1. Scanning	1. Picking up "information" from the sides
2. Finding things both indoors and outdoors	2. Driving along curved roads
3. Bike riding	3. Detecting people crossing streets
4. Viewing television	4. Detecting hazardous drivers from crossroads
5. Checking to see whether venetian blinds are straight	5. Detecting other moving objects
6. Shopping, including at malls	6. Scanning an intersection
7. Walking, especially in unfamiliar and crowded areas such as downtown, train station, etc.	7. Detecting landmarks
8. Cleaning	8. Providing added reaction time to movement of vehicles and other moving objects detected through the amorphic lenses
9. Redecorating	9. Detecting signs close and off in the distance
10. Mowing the lawn	10. Detecting drivers pulling out from crossroads
11. Boating	11. Approaching and entering intersections
12. Driving	12. Scanning ahead for potential hazards
13. Watching sports	13. Detecting hazardous situations in parking lots
14. While riding as a passenger in a car	
15. To see a large group of people all at once	
16. For looking around and scanning	

RT=Rehabilitation Training-Lab/O&M; B=beneficial; NR=no response; S=satisfied.

ber of items detected expanded the opportunity to recognize more items, resulting in a noticeable amount of improvement in this skill area. Some subjects had difficulty returning quickly from the amorphic lenses back to the carrier, consequently missing the details necessary for identifying an object. Further practice may have increased improvement in this area.

Scanning was one skill area that did not show as much improvement as the other skill areas. Improvement, which did occur, was likely a result of the instructor teaching systematic scanning techniques to those patients who were having difficulty locating and finding items. Instruction using the amorphic lenses to scan large areas in the environment and incorporate the modified "U" technique expanded their opportunity to improve in this skill. In addition, subjects who had already developed good scanning techniques prior to the study may not have shown a significant amount of improvement in this skill area.

The patients showed improvement in the area of tracking. Again, as a result of improved performance in the area of peripheral detection, an increased number of moving targets was first detected through the amorphic lenses. The patients then had an ample amount of moving targets to practice tracking while stationary, walking, and driving.

Visual memory showed significant improvement. Patients realized the importance of exiting the amorphic lenses as quickly as possible and the necessity to remember what was just seen through them. Visual memory is an essential skill for the execution of many driving maneuvers such as changing lanes. Many exercises during the training sessions gave the patients several opportunities to improve in this area.

The greatest area of improvement was in the area of mobility. The amorphic lenses helped increase the patients' ability to navigate their environment safely and independently, and helped them gain confidence during driving training sessions.

The curriculum began with simple skills in each area and expanded to more complex skills and exercises. This contributed to the success of the program and helped the subjects gain confidence when using the amorphic lenses in their everyday life and during driving training. Encouragement from both the orientation and mobility and driving instructors motivated the subjects to use the amorphic lenses independently in the home environment. Further research is required to investigate to what extent the patients continue to use the amorphic lenses for everyday activities beyond the study period.

The weight of the amorphic lens system, however, made it uncomfortable for the subjects to wear them for long periods of time. More attractive and lighter lenses could extend the time patients can wear them, and thus further enhance the patients' quality of life. We hope that this study and other studies to follow will encourage the manufacturer to change the design of the lenses.

Eighty-six percent of patients stated that, if it were legal to do so, they would definitely use the amorphic lenses for driving. The purpose of our study was not to lobby for the legal use of amorphic lenses while driving. Rather, our goals were: 1) to test the success of a bioptic amorphic lens configuration and training program in improving general orientation and mobility, and 2) to collect scientific data on the use of these lenses while driving that can be used by the general public and government when examining the legalization issue. Before promoting the legal use of these lenses, large-scale safety studies should be conducted to protect both the patient and the general public. While driving was very important to most of our study patients, we would like to stress that these study patients also found the lenses and training to be beneficial for everyday non-driving uses, as seen in **Table 3**.

This study was designed to determine the effectiveness of bioptic amorphic lenses for improving mobility and driving skills. The only previously published study on amorphic lenses used a full-field form that failed to increase the mobility of the majority of the study subjects (2). Inspired by the success of bioptic telescopes for driving, we developed a bioptic form of the amorphic lens that was used effectively in this study. Our research site is the only location that has used the bioptic amorphic lens configuration and the curriculum described here.

Although the number of participants in this study was 15, we do not feel that this number of subjects compromises the study's generalizability. This is because our subjects had a spectrum of visual field loss, which has been found to be a critical variable in predicting improved mobility with the lens system (1). In the previously published report of this study (1), we highlighted data demonstrating that the patients with smaller visual fields showed significantly greater improvement on peripheral detection and scanning tasks, suggesting that these patients benefit the most from the bioptic amorphic lens system. In addition to the wide range of visual field extents represented by our 15 subjects, we collected an extensive amount of data on each subject to reach our conclusions. During each of the 3 testing batteries, the patients performed 203 individual assessments composed of clinical, psychophysical, laboratory, orientation and mobility, and driving tests. During each driving simulator test alone, approximately 14,000 data points were collected per subject (a constellation of simulator performance indexes are measured approximately two times per second during testing).

Further large-scale studies need to be conducted before bioptic amorphic lenses and the orientation and mobility training program are used in non-research settings as a standard curriculum. Our analysis done on the improvement scores in the Szlyk et al. study showed no differences in improvement based on age or gender (1). We included equivalent numbers of males and females. However, our sample was relatively young with a range of ages from 27 to 67 years. To investigate the effects of age more fully, a study sample encompassing a larger range would be required. We did not include patients with other disabilities in this study. This is also left as a question for future research. After completion of further research, practical issues such as cost to benefit ratio, insurance coverage, and the possible shortage of trained staff such as orientation and mobility specialists need to be addressed. The 8-week driving component could be omitted from non-research training programs unless there is a change in current legislation.

The bioptic amorphic lens system and the training program reported here has the potential to help a large number of people with peripheral vision loss. The Foundation Fighting Blindness estimates that 100,000 people in the United States have RP (10). In addition to RP patients, a subset of individuals suffering from diabetic retinopathy and glaucoma have peripheral vision loss that could potentially be helped by this program. According to the World Health Organization, diabetic retinopathy is the leading cause of adult blindness in developed countries, and glaucoma affects 67 million people worldwide (11). Additionally, the training curriculum described in this paper may be applied to other field-enhancing lens systems, such as the Gottlieb Visual Field Awareness Systems (Rekindle, Stone Mountain, Georgia) or the bilaterally-placed Fresnel prisms (Press-On, 3M Health Care, St. Paul, Minnesota), that are yet to be investigated.

Given the complexity of all of these adaptive systems, we can only speculate that patient success will be due to rigorous training programs. A recent study completed in our laboratory with central vision loss patients using relatively more straightforward magnifying systems, that is, bioptic telescopes, showed greater success in the patients who received telescopes and training, compared to a group of patients receiving only telescopes without training (12). Further research is needed to define standards and evaluation measures for training curricula.

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