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Comparison of low-vision reading with spectacle-mounted magnifiers

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Abstract—Reading is the most common goal among persons with age-related macular degeneration and other retinal diseases that lead to macular loss, as well as the functional task most affected by the resulting central scotomas. This project determined whether reading ability is different when persons with macular loss read with a new hybrid-diffractive spectacle magnifier versus a refractive-aspheric spectacle magnifier and an aplanatic spectacle magnifier. After subjects completed a low-vision examination, we assigned them to groups that compared different types of spectacle magnifiers and assessed their reading acuity, speed, critical print size (print size large enough to provide a subject's best fluent reading), accuracy, and comprehension. Subjects completed visual analog scales to indicate their perceptions of satisfaction with reading, comfort with reading, and cosmesis (comfort with allowing others to see them read) and were asked which of the compared spectacle magnifiers they preferred for prescription. We subjected the data to paired *t*-tests to ascertain whether differences existed in subjects' reading ability and perceptions between the types of reading devices. Subjects' reading comprehension, perception of satisfaction, and perception of cosmesis were significantly better with the hybrid-diffractive lens than with the refractive-aspheric lens. Although subjects' critical print size was significantly better with the aplanatic lens than with the hybrid-diffractive lens, functional reading ability was not significantly different. More subjects preferred the hybrid-diffractive lenses for prescription. The hybrid-diffractive spectacle magnifiers are an important addition to the optical-device armamentarium for reading with low vision.

Key words: diffraction, literacy, low vision, magnifier, optical devices, optics, reading, refraction, spectacle, vision rehabilitation.

INTRODUCTION

Loss of the ability to read and manage finances and other literacy issues are the primary reason that older people give up independent living or attend rehabilitation programs [1–3]. Age-related visual impairment can lead to this loss of independent living; macular degeneration is the most common cause of visual impairment and is age-related. Most patients with macular degeneration eventually progress to bilateral vision loss, even though peripheral vision remains intact. The ability to read small print is the most commonly cited goal for rehabilitation among veterans with macular loss [3].

Abbreviations: *df* = degrees of freedom, GLE = grade-level equivalent, LVRCA = (Morgan) Low Vision Reading Comprehension Assessment, MNREAD = Minnesota Low Vision Reading Acuity Chart, VA = Department of Veterans Affairs.

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The onset of visual impairment among older veterans leads not only to the loss of literacy ability, but also to decreased mobility, loss of social support, decreased social activity, decreased safety in the home, vulnerability to depression, and increased burden of their caregivers. Vision rehabilitation services have been shown to ameliorate much of the disability of vision impairment, including literacy [4–7], activities of daily living and safe travel [6], and depression [8–9].

Patients with macular loss develop a strongly preferred retinal locus ("pseudofovea") [10] and are able to read again following the prescription of low-vision devices and therapy [11–12]. During the low-vision clinical evaluation in rehabilitation programs of the Department of Veterans Affairs (VA), the most commonly prescribed low-vision devices for reading were hand and stand magnifiers, spectacle-mounted magnifiers, and closed-circuit television systems [5]. Veterans' devices of choice for sustained reading ability (30 min or more) were spectacle magnifiers and closed-circuit television systems [5].

However, even after they are prescribed low-vision devices, patients with macular loss experience less reading ability than they experienced before the onset of their visual impairment. Although accuracy and comprehension of reading can remain within normal limits for patients following rehabilitation [11], the rate and duration of reading can remain depressed compared with that of normally sighted persons [13–15,12]. The decrease in the rate of reading for persons with macular loss is directly related to their field of view, contrast sensitivity function, and visual acuity [16]. Visual acuity can be enhanced with magnification, and contrast can be enhanced somewhat with filters, but few optical solutions have been developed for enhancing field of view for readers with low vision. Indeed, prescribing optical magnification to overcome loss of acuity creates more problems by further reducing field of view [17].

SPECTACLE MAGNIFIERS

Full-field spectacle magnifiers are characterized by three types of lenses that use refractive optics that are commonly prescribed in low-vision service-delivery systems: spherical, aspheric, and aplanatic. *Spherical* lenses have the same power in all meridians. As these lenses increase in power, oblique astigmatism and curvature of field begin to distort the image; therefore, this lens design is usually appropriate only in powers up to approximately +8 D. *Aspheric* lens design is used to minimize peripheral distortion; these lenses have ellipsoidal surfaces. The convexity of the lens is progressively reduced toward the periphery. The two types of aspheric lenses use full-diameter and lenticular designs. Full-diameter aspheric designs are used in powers from +10 D to +20 D. The aspheric lenticular design is an aspheric lens on a plano base. This design has the advantages of less weight and decreased thickness, with the disadvantage of smaller field of view. The aspheric lenticular lens generally has an optical zone diameter of 20 to 40 mm surrounded by the plano carrier lens. This lens is used in powers from +10 D to +48 D. *Aplanatic* or doublet spectacle magnifiers are designed with two convex lenses separated by an air space. The lenses may be glass or plastic and aspheric or spherical in design. The doublet design can provide high amounts of magnification with minimal spherical aberration, coma, oblique astigmatism, and curvature of field in the peripheral area of the lens. Doublet lenses can be found in magnifications ranging from +8 D to +80 D.

A new hybrid-diffractive lens has been developed for readers with low vision. At the time of this study, hybrid-diffractive spectacle magnifiers for low vision were available in powers of +12 D, +16 D, and +20 D, with a lens thickness of approximately 5 mm. (Later a +24 D lens was introduced.) In diffractive optics, all light rays within a single zone have the same optical path length. The difference of the path length from zone to zone is λ (by the 1.diffraction order). A constructive interference in the focal point is produced. Diffractive structures use concentric structures on the surface of a lens in various zones with different structure heights and intervals as small as 40 nm.

The front element of the hybrid-diffractive spectacle magnifier consists of a front surface with a modest aspheric curve and a rear surface with a multiorder diffractive surface. The second element consists of a front surface with a first-order refractive structure and a plano rear surface. Constructing the lens involves assembling these two elements so that the diffractive structures of each half are facing each other on the inside. When placed into eyewear, these lenses allow the use of +12 D, +16 D, or +20 D of equivalent power in a lens that is thinner and lighter than comparable magnifying lenses. **Figure 1** shows the hybrid-diffractive lenses.

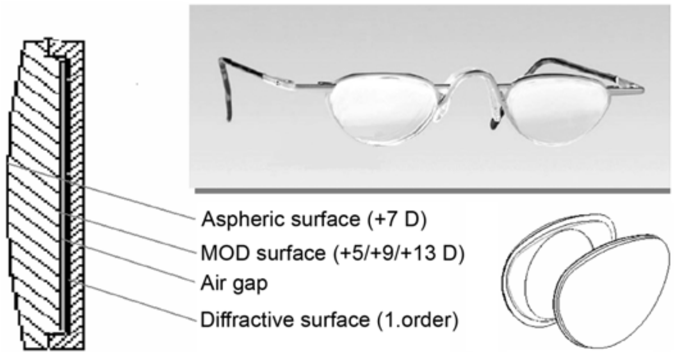

Figure 1.
Front element of hybrid-diffractive spectacle magnifier consists of front surface with modest aspheric curve and rear surface with multiorder diffractive (MOD) surface. Second element consists of front surface with first-order (1.order) refractive structure and plano rear surface. Lens is constructed with these two elements assembled so that diffractive structures of each half are facing each other on inside.

METHODS

We performed two experiments to compare the hybrid-diffractive spectacle magnifier with a refractive spectacle magnifier and an aplanatic spectacle magnifier. In the first experiment, we compared Eschenbach Optik Noves hybrid-diffractive spectacle magnifiers with American Optical Aolite refractive-aspheric spectacle magnifiers. The lenses were used in +12 D, +16 D, or +20 D as they were marked by the manufacturer. In the second experiment, we compared the Eschenbach Optik Noves hybrid-diffractive spectacle magnifiers with Designs for Vision, Inc. Clear Image2 aplanatic doublet spectacle magnifiers in +12 D, +16 D, or +20 D powers as they were marked by the manufacturer.

We measured dioptric power for the spectacle magnifiers. The hybrid-diffractive and aplanatic doublet lenses were within the ISO Standard (European Standard EN ISO 15253, Ophthalmic Optics and Instruments, Optical Devices for Enhancing Low Vision). However, the dioptric powers for the aspheric lenses were less accurate. Although labeled as +12 D, +16 D, and +20 D, the aspheric lens powers were +11.33 D, +14.6 D, and +17.5 D, respectively. We completed computerized ray-tracing analyses for the three sets of lenses, the results of which are shown in **Figure 2** and **Table 1**.

Experiment 1

In the first experiment, we selected 15 veteran subjects from the case records of the VICTORS (Visual Impairment Centers to Optimize Remaining Sight) Clinic of the Kansas City VA Medical Center. Power analyses indicated that this number would be sufficient to discriminate a critical effect size of 1.0 for reading measurements at an alpha level of 0.05 with a power of 0.85 The inclusion/exclusion criteria were as follows:

- Inclusion
  - Pathology: age-related macular degeneration, juvenile macular degeneration, or diabetic retinopathy
  - Visual acuity: 20/50 or less in the better-seeing eye
  - Visual fields: bilateral central scotoma or metamorphopsia
  - Goal for rehabilitation: ability to read continuous text such as newspapers, magazines, etc., and self-report previously read material at a grade-level equivalent (GLE) of 5 or more. (For example, "Dear Abby" in the local newspaper is usually a GLE of about 5; the front page of most newspapers is 8 to 10 GLE.)

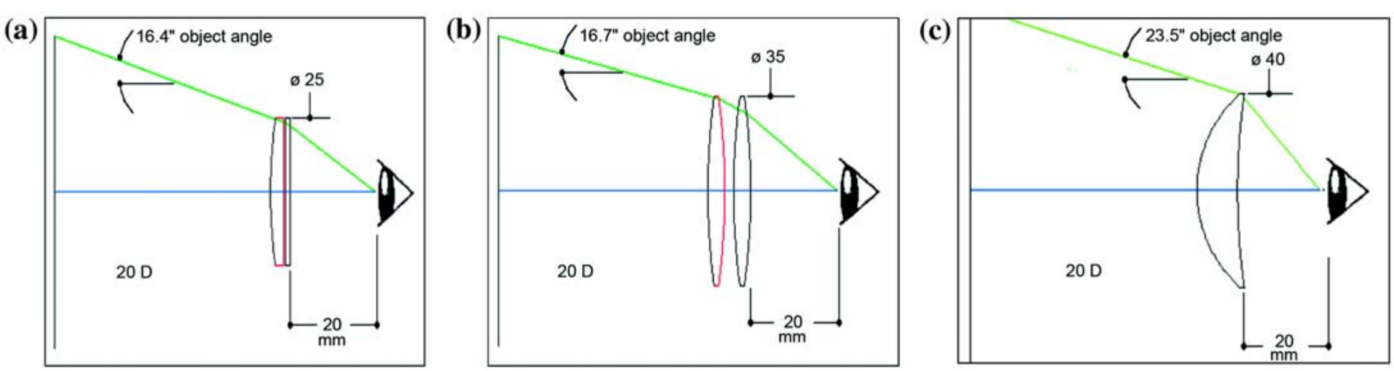

Figure 2.
Ray-tracing analyses indicate greater object field angle for **(b)** aspheric vs. **(a)** diffractive lenses, as well as greater object field angle for **(c)** aplanatic vs. **(a)** diffractive lenses. See **Table 1** for analysis data.

Table 1.
Ray-tracing analyses data (**Figure 2**) (eye to lens distance = 20 mm).

Spectacle Magnifier	Magnification Diopter	Lens Diameter (mm)	Object Field Angle (°)
Diffractive	20	25	16.4
Aplanatic	20	35	16.7
Aspheric	20	40	23.5
Diffractive	16	25	18.8
Aplanatic	16	35	19.5
Aspheric	16	40	28.0
Diffractive	12	25	21.0
Aplanatic	12	35	22.6
Aspheric	12	40	32.0

- Exclusion
  - Cognition: scoring less than 26 on the Folstein Mini-Mental Health Examination
  - General health: having more than 10 sick days in bed in the last 6 months
  - Comorbidities: having illnesses that would affect stamina for reading, such as congestive heart failure, chronic obstructive pulmonary disorder, etc.

The study was conducted according to the Declaration of Helsinki and reviewed and approved by the Institutional Review Board of the Kansas City VA Medical Center. We read an informed-consent script to each subject that explained the nature and possible consequences of the study and informed subjects that their participation was voluntary and that information about them would be kept confidential. Subjects and the principal investigator signed the informed consent form; subjects' signatures were witnessed by a third party, who also signed the informed consent form.

Subjects' ages ranged from 45 to 89 years, with a mean age of 71 years. All subjects had received a low-vision examination and were using low-vision devices or were prescribed low-vision devices immediately before they participated in the research project. Using random assignment, we evaluated one-half the subjects first with the American Optical Aolite refractive-aspheric spectacle magnifier (n = 8) and the other half first with the Eschenbach Optik Noves hybrid-diffractive spectacle magnifier (n = 7). If using the lenses alone was not sufficient to provide the subject with his/her critical print size (the smallest print size at which print is still read with the best rate), we selected the reading tests in an appropriate critical print size.

The research project began when the patient was able to use a spectacle magnifier and demonstrate the ability to maintain the correct focal distance and appropriately scan for reading print. After subjects completed the testing with one device, we gave them a 1/2-hour break and then tested them with the other device (i.e., subjects who first used the hybrid-diffractive magnifier now used the aspheric magnifier and vice versa). Subjects read different forms of the reading tests in the two test conditions. All other aspects of testing, reading station ergonomics, lighting, and test print size were kept constant between the two test conditions. The examiner read the directions for the reading assessments from a script and carefully attempted to avoid biasing subjects' perceptions and preferences. If subjects asked questions during the examination that were not related to understanding what they were supposed to do, they were asked to wait for answers until all testing was finished.

We evaluated subjects with the Minnesota Low Vision Reading Acuity Chart (MNREAD) to measure their reading acuity, critical print size, and maximum reading rate [18]. We administered this test with the subjects' habitual near-Rx to obtain an unaided reading acuity, critical print size, and maximum reading rate. Habitual near-Rx refers to the prescriptive spectacles the subject would normally use for reading that correct refractive error and presbyopia, whether bifocals or a separate pair of reading glasses. **Table 2** provides subjects' performance on MNREAD with the habitual near-Rx.

Subjects completed the following three reading tests using both types of spectacle-mounted magnifiers. All three tests were developed for readers with low vision; the reliability and validity of the tests have been established with subjects who have low vision. **Table 3** provides subjects' performance on these measures.

- MNREAD, which measures reading acuity, critical print size, and maximum reading rate [18]. We administered this test to obtain a device-aided critical print size and maximum reading rate. We administered different but equivalent forms of the test in the two test conditions in which the spectacle magnifiers were compared.

Table 2.
Subjects' performance (mean ± standard deviation) with habitual near-Rx on Minnesota Low Vision Reading Acuity Chart.

Experiment (N = 15)	Reading Acuity LogMAR	Critical Print Size LogMAR	Maximum Reading Rate (wpm)
1	0.96 ± 0.37	1.18 ± 0.33	80.87 ± 47.54
2	0.97 ± 0.44	1.14 ± 0.46	105.00 ± 55.61

Table 3.
Subjects' reading performance (mean ± standard deviation) with spectacle magnifiers.

Experiment (N = 15)	MNREAD: Aided CPS (M print size*)	MNREAD: Aided Rate (wpm)	Pepper Accuracy (% Correct)	Pepper Rate (wpm)	Morgan LVRCA (GLE)
Experiment 1					
Aspheric Lenses	1.17 ± 0.63	99.27 ± 58.60	89.73 ± 18.19	46.20 ± 26.95	11.13 ± 5.75
Diffractive Lenses	1.06 ± 0.57	98.33 ± 64.72	90.13 ± 17.94	43.47 ± 28.44	13.11 ± 5.18
Experiment 2					
Aplanatic Lenses	1.03 ± 0.77	109.67 ± 56.54	91.20 ± 10.97	42.47 ± 22.78	13.51 ± 4.73
Diffractive Lenses	1.22 ± 0.88	107.07 ± 59.64	91.00 ± 11.13	38.00 ± 18.11	12.75 ± 5.04

MNREAD = Minnesota Low Vision Reading Acuity Chart
CPS = critical print size
Pepper = Pepper Visual Skills for Reading Test
Morgan LVRCA = Morgan Low Vision Reading Comprehension Assessment
GLE = grade-level equivalent
*The reference for M print is printers' point designation; 1 point equals 1/72 of an inch (or 0.232 mm). An 8-point letter has a loop height such that it subtends 5° at the eye at viewing distance of 1 m and thus can be designated as 1 M print.

- Pepper Visual Skills for Reading Test, which measures text navigation ability and yields an accuracy percentage and a minimum reading rate score [13,19]. Different but equivalent forms of this test were administered in the two test conditions in which the spectacle magnifiers were compared.
- Morgan Low Vision Reading Comprehension Assessment (LVRCA), which measures reading comprehension ability in GLE measured via the cloze* technique [20]. The Morgan LVRCA is a standardized assessment instrument that is reliable and valid when it is used according to the directions for the screening of GLE for reading in persons with macular loss who were former readers. Different but equivalent forms of this test were administered in the two test conditions in which the spectacle magnifiers were compared.

We administered a visual analog scale of 125 mm length after the reading tests to record subjects' (1) satisfaction with reading, (2) comfort with reading, and (3) cosmesis (comfort with allowing others to see them read) with each device. The distance in millimeters of the index point from the left margin of the scale (denoting extreme dissatisfaction with reading) to the response mark on the scale line was used as the measure for each of these variables. Subjects were also asked their choice of the two types of magnifiers for prescription in response to the following question: "If you could, which of these two magnifiers would you choose for your daily reading?"

Experiment 2

For Experiment 2, we recruited 15 subjects and repeated the experiment exactly as described in Experiment 1, except that subjects were reading to compare the Eschenbach Noves hybrid-diffractive lenses with the Designs for Vision Clear Image2 aplanatic lenses (in the same powers as in Experiment 1, marked as +12 D, +16 D, and +20 D). These 15 subjects ranged in age from 59 to 90 years, with a mean age of 70 years. Subjects were randomly assigned to read first with the hybrid-diffractive lenses (n = 8) versus the aplanatic lenses (n = 7). We used paired t-tests to test for differences in objective reading performance (critical print size, maximum reading rate, minimum reading rate, accuracy, and comprehension), as well as subjects' perception of their reading performance (satisfaction with reading, comfort in reading, and cosmesis).

RESULTS

Experiment 1

Reading comprehension was significantly better when subjects used the diffractive lenses compared with the aspheric lenses. (Morgan LVRCA mean GLE for the diffractive lenses = 13.11, and mean GLE for the aspheric lenses = 11.13; t = 3.24, df = 14, and p = 0.006.) **Figure 3** shows individual subjects' comprehension data.

*In the cloze technique, one word is left blank in a sentence, and the reader indicates understanding by supplying a word that completes the meaning conveyed by the sentence.

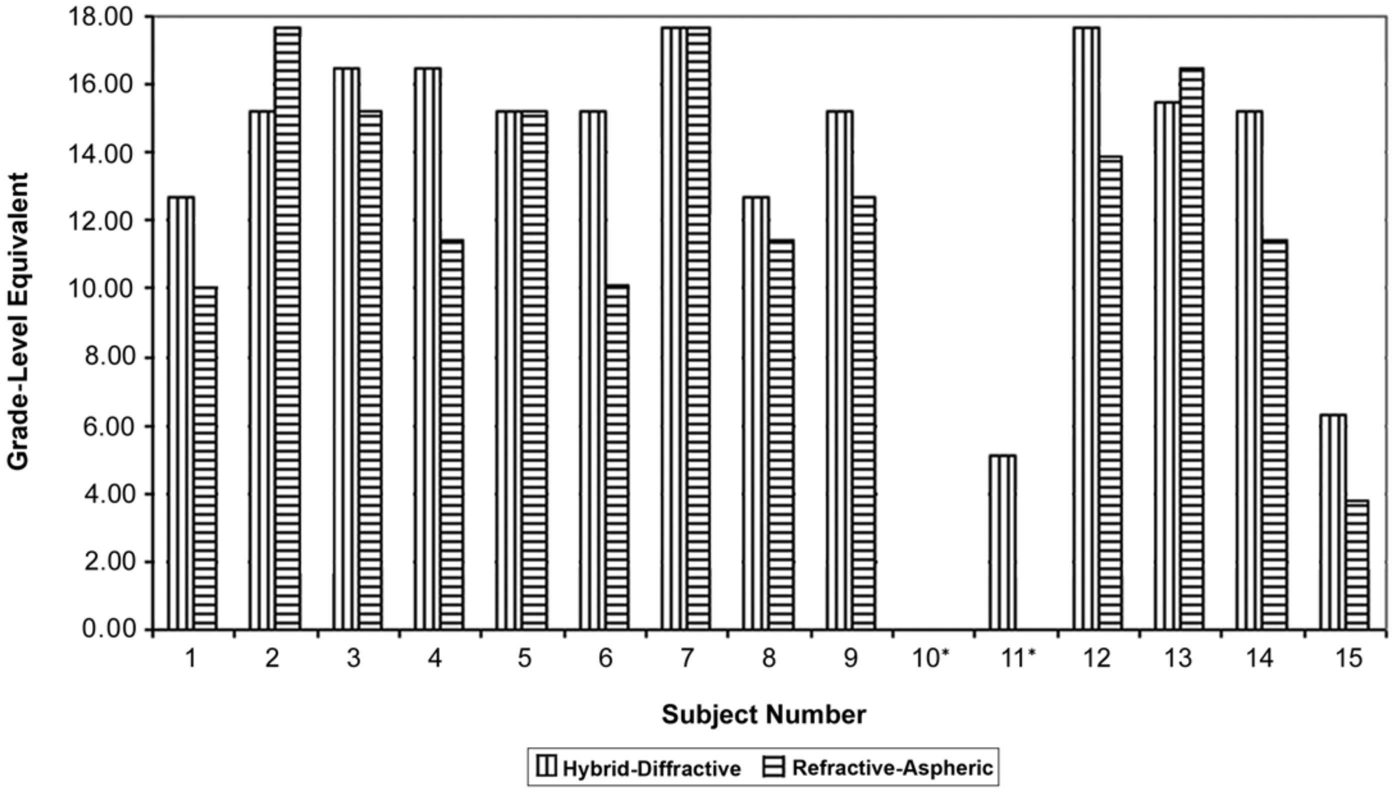

Figure 3.
Comparison of subjects' reading comprehension scores with diffractive vs. aspheric spectacle magnifiers; measured by Morgan Low Vision Reading Comprehension Assessment (LVRCA), reported by grade-level equivalent. Subjects' reading comprehension was significantly better when they read with diffractive lenses.*A subject may receive a score of zero on Morgan LVRCA if unable to provide correct answers for missing words in cloze sentences. This occasionally happens despite subject being able to read printed words of some sentences correctly. Comprehension requires reader to integrate and synthesize words into meaning; it requires more cognitive processing than merely recognizing words.

Subjects' perceived reading satisfaction was significantly higher with the diffractive lenses than with the aspheric lenses. (Visual analog scale is in millimeters, diffractive mean = 103.53, aspheric mean = 88.07; t = 2.47, df = 14, and p = 0.027.) **Figure 4** provides data on individual subjects' satisfaction as measured on the visual analog scale.

Subjects' perception of cosmesis was significantly improved with the diffractive lenses over the aspheric lenses. (Visual analog scale is in millimeters, diffractive mean = 110.73, aspheric mean = 96.80; t = 2.14, df = 14, and p = 0.050.) **Figure 5** shows individual subjects' cosmesis as measured on the visual analog scale.

As for subject's preference for prescription between the two devices, 12 subjects chose the diffractive lenses, 2 subjects chose the refractive-aspheric lenses, and 1 subject had no preference.

Experiment 2

Subjects' critical print size was significantly improved with the aplanatic lens over the hybrid-diffractive lens (device-aided MNREAD critical print size in M print size [21], diffractive mean = 1.22, aplanatic mean = 1.03, t = 3.303, df = 14, and p = 0.005). (The reference for M print is printers' point designation; 1 point equals 1/72 of an inch [or 0.232 mm]. An 8 point letter has a loop height such that it subtends 5° at the eye at a viewing distance of 1 m and thus can be designated as 1 M print.) **Figure 6** depicts data on subjects' device-aided critical print size. This comparison provided no other statistically significant results.

As for subject's preference for prescription between the two devices, seven subjects chose the diffractive lenses, five subjects chose the aplanatic lenses, and two subjects had no preference.

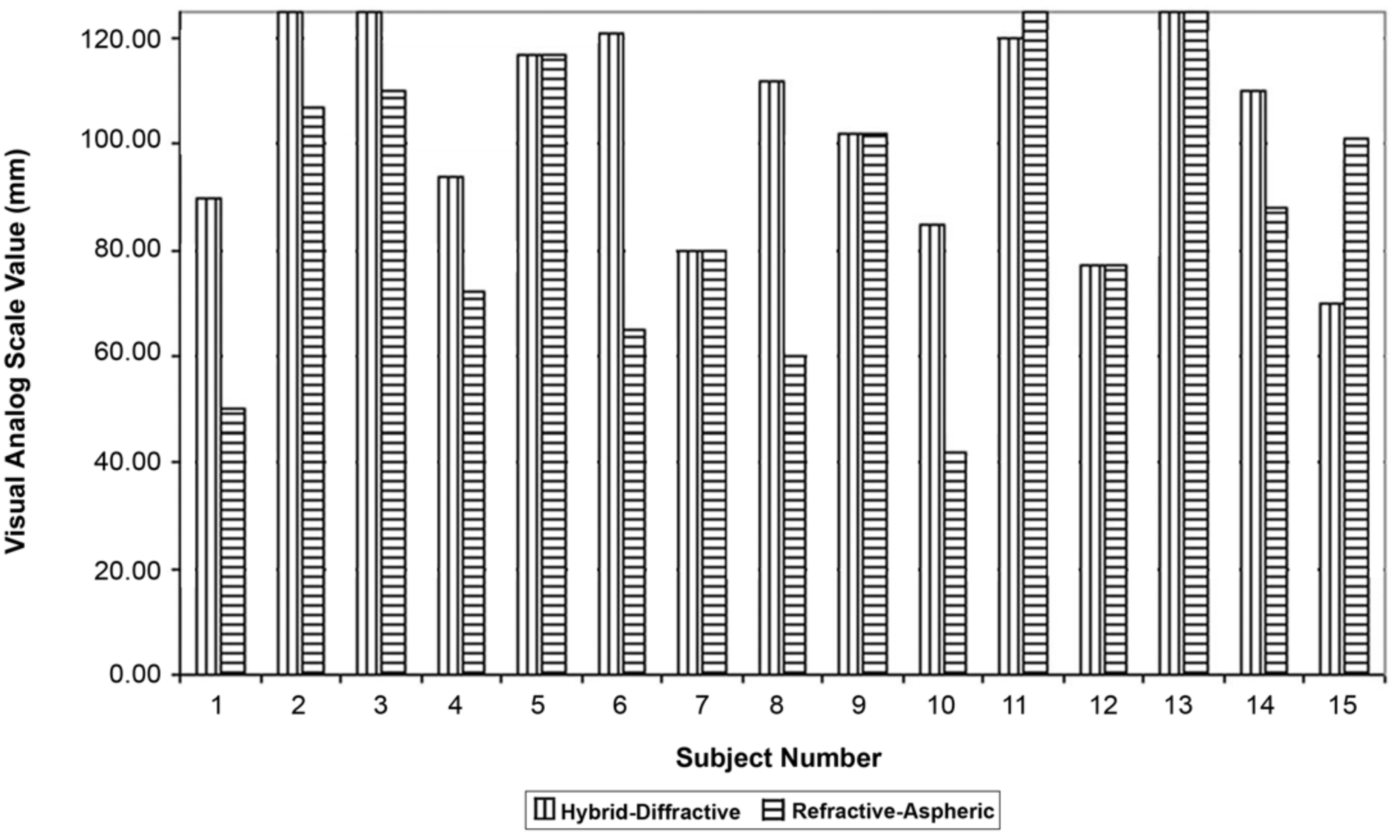

Figure 4.
Visual analog scale results for subjects' self-report of satisfaction with reading with diffractive vs. aspheric lenses. Visual analog scale was 125 mm long. Subjects' satisfaction with their reading ability was significantly better with diffractive lenses.

DISCUSSION

Experiment 1

The subjects' significant preference for the hybrid-diffractive lenses over the aspheric lenticular lenses for reading satisfaction and cosmesis as measured with the visual analog scale could be explained by the lighter and thinner nature of these diffractive lenses. The hybrid-diffractive lenses were cosmetically appealing to our subjects in that, except for the close focal distance, these lenses do not appear to be different from light-weight, half-eye glasses that are used by normally sighted older persons.

The intriguing nature of the comprehension results led us to a subsequent analysis to discover whether the improvement in reading comprehension might be explained by the order of reading; we were looking for fatigue effects (subjects becoming tired before finishing all reading) or practice effects (subjects' performance improving over the time that they were reading). However, no statistically significant effects were related to order of presentation, that is, using the hybrid-diffractive lens first versus using the refractive aspheric lens first. We also performed an exploratory data analysis to discover whether reading comprehension was related to any other measures of reading and found that (with both lens types) comprehension is significantly correlated with accuracy, although reading accuracy did not emerge as a statistically significant variable between the two lens types. **Table 4** shows these correlations. Further, no relationship existed between comprehension and reading rate or between comprehension and critical print size for subjects in Experiment 1.

Comprehension for readers with low vision has been studied less than other aspects of reading ability such as rate. Previous studies have shown that the slower rates of reading by persons with low vision are unrelated to comprehension abilities [14,11], indicating that some readers

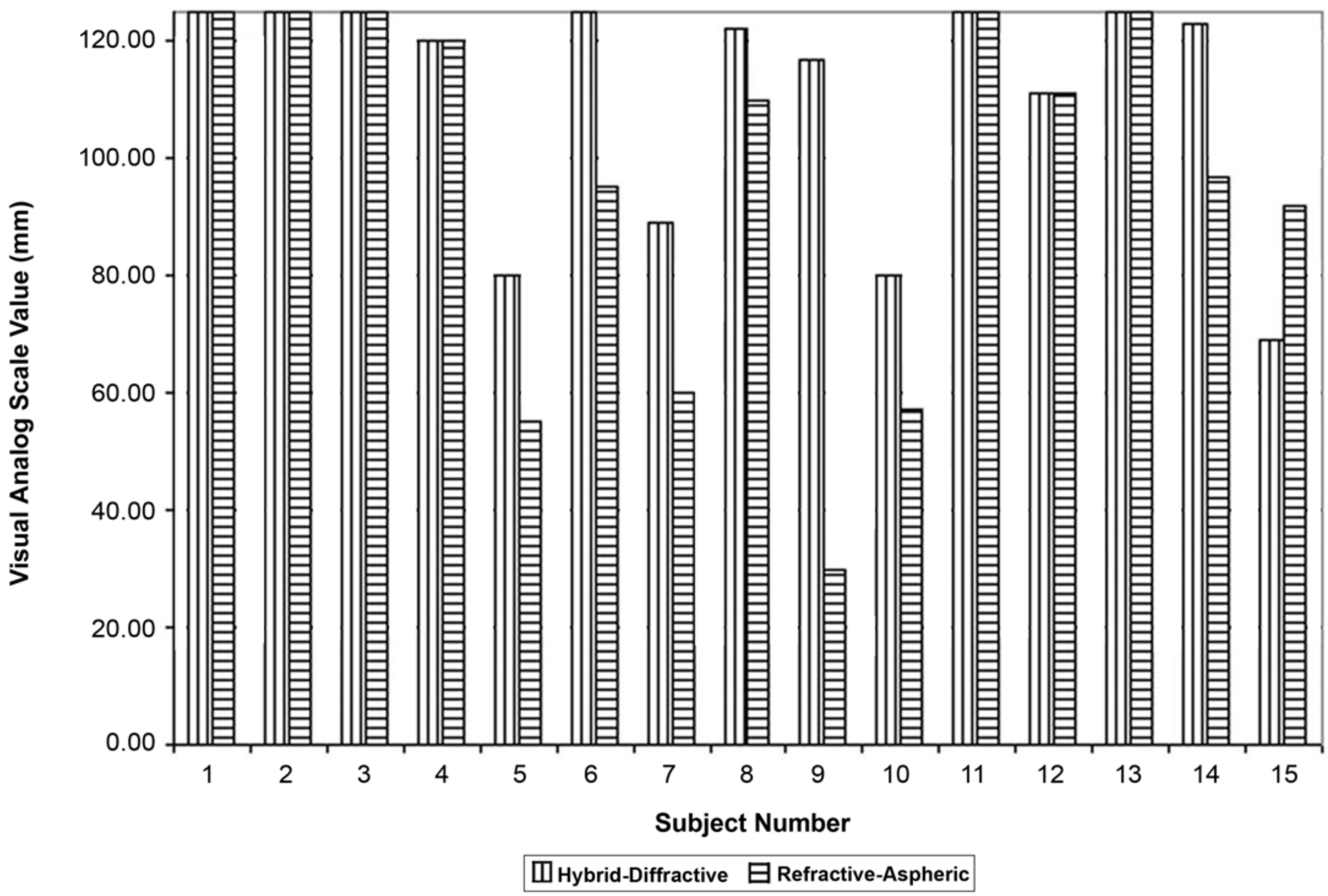

Figure 5.
Visual analog scale results for subjects' self-report of comfort with letting others see them reading with lenses (cosmesis) when they compared diffractive with aspheric lenses. Visual analog scale was 125 mm long. Subjects reported significantly more comfort with letting others see them when they used diffractive lenses.

with low vision have few problems with the mental juggling act of decoding and understanding print despite their slow rates. Although readers with macular loss are limited in rate by a variety of visual factors such as acuity, contrast, and scotoma [16], following rehabilitation, they appear to be able to attain comprehension abilities that are comparable to normally sighted peers [11].

Research has been inconsistent regarding the issue of whether degraded visual input (i.e., visual impairment) causes more context reliance in reading. Fine and Peli found no difference in context gain between participants with macular loss and normally sighted readers [22]; however, Bullimore and Bailey found relatively larger context gains for readers with macular loss than for normally sighted readers [23]. One might argue that readers with macular loss might depend on contextual information more because this information reduces the need to see every word. On the other hand, readers with macular loss might be less able to make use of contextual information because the task of decoding already burdens processing capacities.

The reading comprehension measure chosen for this task uses the "cloze" technique. This type of reading evaluation is a very good measure of syntactic processing in reading [24]. Syntactic processing, a higher order skill than semantic processing, is related to the amount of mental working capacity [25–26]. Readers with macular loss may be required to allocate more of their processing capacity to the decoding process and need to keep the elements of a sentence in working memory for a longer period because of their slower rates of reading.

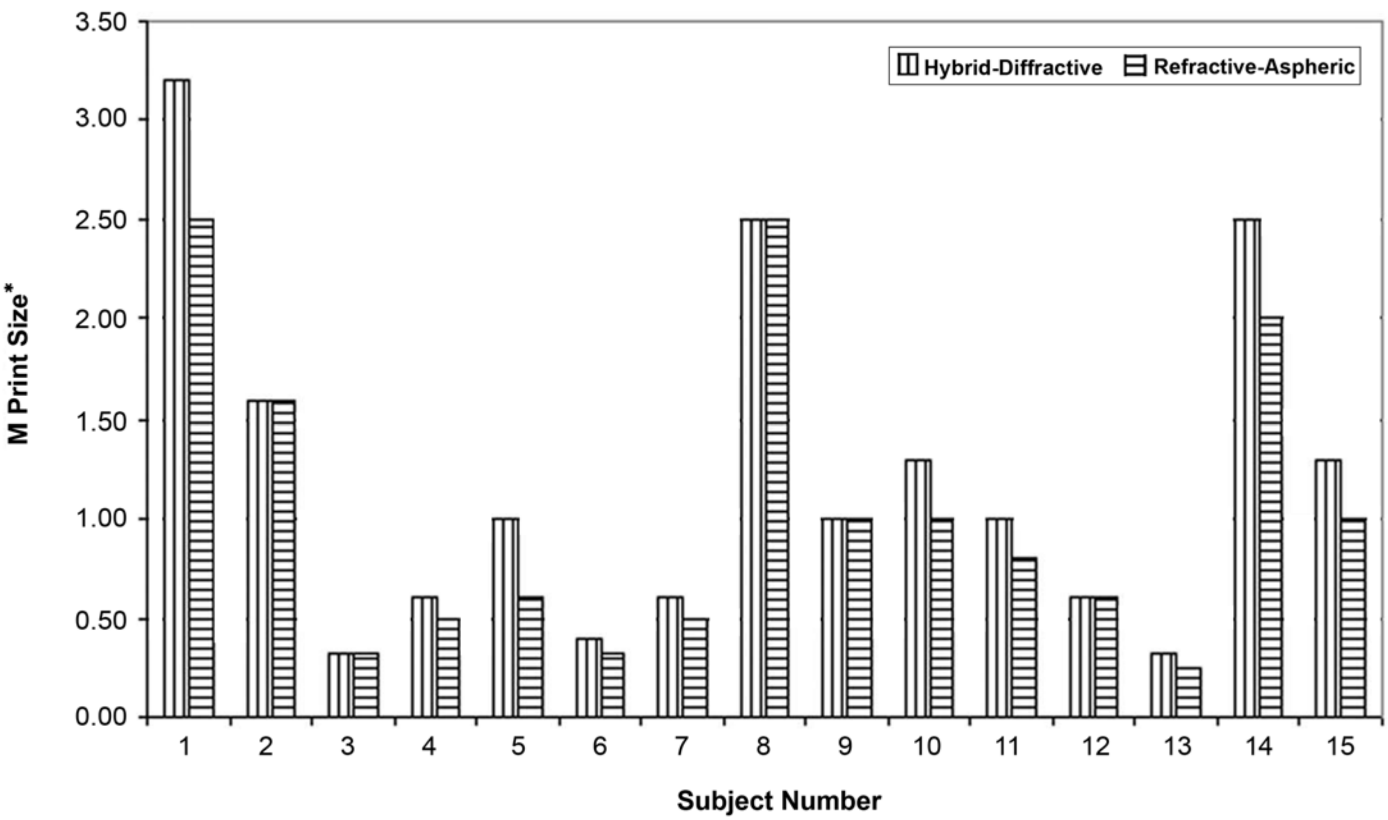

Figure 6.
MNREAD results in M notation comparing subjects' device-aided critical print size for diffractive vs. aplanatic lenses. Subjects' critical print size was significantly smaller with aplanatic lenses. *Reference for M print is printers' point designation; 1 point equals 1/72 of an inch (or 0.232 mm). An 8 point letter has a loop height such that it subtends 5° at the eye at a viewing distance of 1 m and thus can be designated as 1 M print.

Table 4.
Relationship of comprehension scores to accuracy scores.

Comprehension with Lens	Accuracy with Lens	Correlation of Comprehension to Accuracy
Hybrid-Diffractive	Hybrid-Diffractive	$r = 0.754$, $p = 0.001$
Hybrid-Diffractive	Refractive-Aspheric	$r = 0.746$, $p = 0.001$
Refractive-Aspheric	Refractive-Aspheric	$r = 0.578$, $p = 0.024$
Refractive-Aspheric	Hybrid-Diffractive	$r = 0.622$, $p = 0.013$

r = Pearson correlation coefficient.

Several possible hypotheses exist for the improved comprehension ability obtained with the hybrid-diffractive lenses:

1. The results may be spurious or an artifact and are not reproducible.
2. Subjects' comprehension abilities may be related to their former reading ability, intelligence, time since the onset of visual impairment, or some other aspect of cognition, attention, or vision that was not measured.
3. The difference in dioptric power between the lenses possibly could have been responsible for the improved comprehension of subjects using the hybrid-diffractive spectacle magnifier since the aspheric lenses labeled +20 D actually was more than 2 D lower in power than

the +20 D diffractive lens. However, no significant difference resulted in device-aided critical print size obtained by subjects.

4. The results could be related to the distortion in the field of view of the "barrel effect" of the aspheric lenses, which creates difficulty with perceptual span despite the wider field of view of that lens. Evidence exists in the literature that letter crowding reduces reading rate in the periphery [27], but the effect of "bowed" letters or the difference in spacing cased by aspheric lenses has not been studied.
5. Some aspect of the optics of the hybrid-diffractive lenses may have allowed readers to decode more rapidly and/or to decode wider spans of information and free more of the working memory for syntactic processing.
6. Some psychological boost may have affected reading comprehension related to the subjects' perception of improved cosmesis and satisfaction in reading. However, any psychological boosts or optical advantage of the hybrid-diffractive lenses did not appear to affect accuracy, rate of reading, or the critical print size for achieving fluent reading. Therefore, we are left to speculate what aspects may have freed working memory for the syntactic comprehension task and allowed our readers to significantly improve their comprehension when they used the hybrid-diffractive lenses.

Experiment 2

The results of Experiment 2 indicated that readers gained a better critical print size with the refractive aplanatic lenses than with the hybrid-diffractive lenses, but this gain did not significantly improve functional reading ability (accuracy, rate, or comprehension) for the group. However, the ability to achieve a smaller critical print size may give readers an advantage over a longer duration of reading, which we did not measure. Although some subjects voiced the opinion that print was more "clear" or that they felt that the field of view was wider with the aplanatic lenses, when asked their preference for prescription, more of them still preferred the smaller, lighter diffractive lenses.

CONCLUSION

Although the sample size for our experiments was small, we were able to achieve statistically significant results and are able to arrive at some conclusions about the comparisons of these lenses. Readers with macular loss have improved performance in reading comprehension with and increased preferences for the smaller and lighter hybrid-diffractive lenses compared with the refractive-aspheric lenses. Although the aplanatic lenses gave a better critical print size, no differences existed in functional aspects of reading ability or in the perceptions of comfort, satisfaction, or cosmesis when subjects were reading. When given a choice, more readers preferred the diffractive lenses over the aplanatic lenses, citing the small and lightweight lens design.

A research project of this type is helpful in evaluating the usefulness of new devices arriving on the market. Understanding the impact of device design on functional performance and subject preference will help to balance prescriptive decision making that is usually based on acuity, cost of devices, and optical quality.

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