1040-5488/05/8202-0114/0 VOL. 82, NO. 2, PP. 114–127
OPTOMETRY AND VISION SCIENCE

ORIGINAL ARTICLE

Short-Term In-Office Practice Improves Reading Performance with Stand Magnifiers for People with AMD

ALLEN M.Y. CHEONG, PhD, BSc(Optom),
JAN E. LOVIE-KITCHIN, PhD, MScOptom, LOSc, Grad Dip Rehab Stud, FAAO,
ALEX R. BOWERS, PhD, MCOptom, and BRIAN BROWN, PhD, LOSc MApp Sc, BscOptom

Centre for Health Research, School of Optometry, Queensland University of Technology, Australia (AMYC, JELK, BB), and Schepens Eye Research Institute, Harvard Medical School, Boston, Massachusetts (ARB)

ABSTRACT: *Purpose.* People with low vision often use optical low vision aids to assist reading. There have been numerous training programs recommended to train people using magnifiers for reading. However, most of the programs are time consuming and labor intensive. In this study, we investigated the effects of home-based large print reading practice on reading performance when stand magnifiers (STM's) are first prescribed. *Methods.* Thirty-two subjects with age-related macular degeneration (AMD) and with minimal experience in using magnifiers for reading were recruited. They were divided into three groups: control, practice 1 (P1), and practice 2 (P2). Before the prescription of STM's, all the subjects were given the same amount of in-office practice with the STM (weeks 0 to 2). In addition, in these 2 weeks, P1 and P2 subjects were given large print books to read daily at home. P2 subjects were required to read the large print books through a reduced field of view. The control group subjects received no additional reading practice. Reading rates with and without STM's on passages of text were assessed for all the subjects regularly for 20 weeks. *Results.* There were no significant differences between the control, P1, and P2 groups in the increase in reading rate with STM ($p = 0.29$). At week 0, reading rate for small print with STM was significantly slower than reading rate on the equivalent-sized large print ($p = 0.004$); however, as time went on, reading rate with STM's increased significantly ($p = 0.02$). After 2 weeks of in-office magnifier practice and repeated measures of reading rate with STM, reading rate with STM had improved such that it was not significantly different from reading rate on large print ($p = 0.11$). *Conclusion.* Supervised, short-term, in-office practice with the magnifier was effective in improving magnifier reading performance to achieve maximum reading rate. Additional large print reading practice did not result in any greater improvement in reading rate than in-office magnifier practice alone. (Optom Vis Sci 2005;82:114–127)

Key Words: AMD, reading, stand magnifiers, reading rate, training

Although optical low vision aids (LVA's) allow people who are visually impaired to read smaller print, a magnifier introduces restrictions on reading that make the magnifier difficult to use at first. These limitations include the requirements to read under a decreased field of view and difficulties in controlling the magnifier when reading. Because of limited dimensions of the physical aperture of the magnifier, the number of magnified characters that can be seen through the lens (horizontal field of view) is restricted. In addition, difficulty manipulating magnifiers during reading has been suggested as one of the major problems encountered by magnifier users.[1–4] Therefore, it is perhaps not surprising that reading rate with magnifiers has often been reported to be significantly reduced compared with reading rate on large print.[1, 2, 4–7] However, other studies have found that reading with an LVA does not significantly reduce reading rate compared with that achieved without an LVA.[8–11] These conflicting findings are mainly because of the differences between studies in the levels of magnification provided with and without LVA's, characteristics of the participants, and the amount of experience of the subjects in reading with magnifiers.

The majority of previous studies have not used the same magnification to compare reading with and without LVA's (Table 1).[1, 4–7] Subjects in these studies were mostly normally sighted and could read small print without magnification. Often, the test ma-

TABLE 1.
Summary of previous studies on reading rates with and without LVAs on adults

Research Study	Sample	LVA	Training	Reading Tasks	Results	Comment on LVas Provided	Comparison of Magnification with and without LVA
Rumney and Leat[81]	27 LV 7 NV	Subjects' own LVAs	Subjects with LV were experienced	0.2 logMAR larger than near acuity (NV) and those with LVA (LV)	RR with LVA was significantly reduced by 55%	RR with LVA in LV people was compared with RR without LVA in NV people (unpaired sample)	Baseline RR for people with NV was faster than those with LV. The reduction of RR due to LVA for subjects with LV appeared to be more significant because it was compared to the RR for subjects with NV with no LVA.
Ahn and Legge[9]	40 LV	Subjects' own LVAs	Experienced	Text at N12 with LVA and at CPS without LVA	No significant difference		Retinal image sizes (level of magnification) with and without LVA were equivalent.
Ortiz *et al.*[82]	10 LV	Head-Mounted Video Magnifier (low-vision enhancement system)	Inexperienced	Range of different print sizes (sentence)	No significant difference	Maximum RR with and without LVA was compared.	The retinal image sizes with and without LVA were equivalent.
Bowers[6]	20 NV	HHM Spectacle-mounted	Inexperienced	N10	RR with LVA was significantly reduced by 35%		Retinal image sizes (level of magnification) with and without LVA were not equivalent.
Dickinson and Fotinakis[7]	12 NV	HHM	Inexperienced	N10 N18	RR with LVA was significantly reduced by 18% to 38%	Same EVD was used for each HHM	Retinal image sizes (level of magnification) with and without LVA were not equivalent.
Lovie-Kitchin *et al.*[10]	22 LV (MD)	Subjects' own LVAs	Experienced	Text at CPS	No significant difference		Retinal image sizes (level of magnification) with and without LVA were equivalent.

Subjects with low vision in the sample size mainly had mixed causes of low vision unless otherwise indicated.
NV, normal vision; LV, low vision; HHM, hand-held magnifier; STM, stand magnifier; LVA, low vision aid; RR, reading rate; EVD, equivalent viewing distance; CPS, critical print size.

terials used to measure the reading rates with and without the LVA were the same, such that the magnification (retinal image size) was much greater with the LVA than without.

Those studies that showed significant reductions in reading rate as a consequence of LVA use assessed subjects with normal vision rather than low vision.[1–6, 12] The maximum reading rate for people with normal vision is faster than that for subjects with low vision even when the print size is enlarged.[13–18] Introduction of a magnifier for people with faster reading rates is likely to result in more obvious reductions in reading rate compared with people with slower reading rates.

In addition, people with normal vision are likely to be inexperienced in reading with a restricted field of view and in manipulating LVA's for reading. Therefore, it is reasonable that their reading rates would decrease significantly when an LVA was introduced. In contrast, those studies that showed no significant difference in reading rates with and without LVA's assessed subjects with low vision who were experienced in using LVA's for reading.[9–11] Reading rate with an LVA in these studies was not significantly different from reading rate without an LVA, provided the magnification levels were equal for the two conditions. This suggests that training inexperienced magnifier users in the use of LVA's, in particular reading under a restricted field of view and/or training them to manipulate LVA's, would enable them to achieve their best possible reading performance.

Previous Training Programs in Low Vision

In the past 20 years, there have been numerous training programs proposed for improving the reading ability of people with low vision.[19–30] Many of these programs have focused on training eccentric viewing in people who have central visual field loss.[23, 28, 31, 32] Other programs emphasize that the training should include not only eccentric viewing but also techniques of manipulating magnifiers.[20, 21, 23, 25] However, most of these training programs have been time consuming and labor intensive; see Table 2 for a review of the studies reporting these training programs. Many of the previous studies to assess the effectiveness of training programs did not include a control group[19–21, 33] or did not measure baseline reading performance before training.[19, 29–31] Therefore, no comparison of reading performance could be made between subjects who received training and those who did not.

Training that can provide an easy less time-consuming way to improve reading performance for people with low vision would provide effective vision rehabilitation. Watson *et al.*[34] suggested that training or practice on reading was important to improve the reading performance of people with low vision. They recruited subjects with age-related macular degeneration (AMD) in three groups: control, practice, and training groups. The control group received no reading training or follow-up visits, whereas the practice group received unsupervised reading practice for 10 minutes daily (at home) and four biweekly follow-up visits. The training group received five biweekly reading sessions for 1 h each. Daily reading practice provided similar improvements in reading comprehension to that achieved by the training group,[34] suggesting that short-term reading practice is an effective rehabilitation technique. However, this study focused on reading comprehension for large print without magnifiers. Other studies have indicated that daily reading improves reading rate and comprehension.[35, 36] Again, these studies did not investigate the effect of reading practice on reading performance with LVA's.

The aim of this study was to investigate the effects of large print reading practice (home-based reading training), with and without reduced field of view, on reading performance with illuminated stand magnifiers (STM's) for subjects with AMD who were newly prescribed these LVA's. Before any reading practice, when an STM was first introduced, reading rate was expected to reduce (relative to the rate on large print without an STM) and then improve with practice. Therefore, reading rate was monitored over time. We expected that reading practice under restricted field of view would improve reading rates with STM more quickly than reading practice without restricted field of view.

METHODS

Subjects

Thirty-two subjects aged between 71 and 86 years (mean age, 80.3 ± 4.4 years) with low vision because of AMD were selected from the clinic database of the Queensland University of Technology (QUT) Vision Rehabilitation Centre and by referral from local ophthalmologists. Distance visual acuity in the better eye ranged from 0.22 logarithm of the minimum angle of resolution (logMAR; $20/30^{-1}$) to 1.08 logMAR ($20/250^{+1}$) (Table 3). The subjects had not used an STM previously and had little or no experience in using handheld magnifiers for daily reading. Before recruitment, participants received a preliminary vision examination to confirm that there were no other causes of low vision except AMD. Because of the physical limitation of the print size of large print material required for practice, only participants whose monocular near visual acuity in the better eye was equal to or better than N40 (5 M) at 25 cm (1.4 logMAR) were included. Subjects were generally in good health with no cognitive problems that might affect their compliance with home-training instructions (as determined from record cards, self-reports and clinical observations). All the subjects gave signed informed consent to their participation in this study, which was approved by the QUT Human Research Ethics Committee.

Because all the subjects had AMD, which is a progressive eye disease, it was expected that visual acuity would deteriorate if the disease progressed. Previous studies have shown that reading rate is highly correlated with visual acuity.[10, 14, 16, 19, 37–39] Therefore, any reduction in visual acuity would inevitably result in reduction in reading rate. To minimize the effect of vision deterioration on the change in magnifier reading rate across time, data from subjects whose distance visual acuity reduced by 0.2 logMAR or more during the study period (20 weeks) were excluded, resulting in data from only 25 subjects being included in the analyses (Tables 3 and 4). This criterion was based on previously reported repeatability of high contrast distance visual acuity in subjects with low vision.[40]

A simplified Neale analysis of reading ability[41] was used to confirm that all the subjects had reading ability of grade 6 or above to ensure that difficulties with comprehension would not affect reading rate. Four questions were asked of each subject after a short grade 6 story was read aloud by the experimenter. Any participant who could not answer three of four questions correctly was ex-

TABLE 2.
Summary of previous studies on training eccentric viewing and/or the use of LVAs

Research Study	Sample	Duration of Training	Type of Training	Total Length	Results	Remark	Comments
Goodrich *et al.*[19]	24 mixed LV	10 days (50 min/day)	Use of LVA (CCTV, optical LVA)	10 days	RR and reading duration significantly increased with CCTV and optical LVAs	The improvement in RR for the CCTV group was more apparent than that for the optical aid group	The 12 optical LVAs prescribed were only near additions, with no HHM and STM. There was no control group to compare people with no training.
Nilsson[20]	79 (DR)	6.75 sessions (1 hr/session)	Eccentric viewing (23% subjects received this training) Use of LVA	3.6 years	Significant improvement of distance and near VA with LVA, ability to read TV (64.6%) titles and newspaper text (86.1%)		There was no control group to compare people with no training
Nilsson and Nilsson[21]	120 (AMD)	7.5 visits (with 1 hr each)	Eccentric viewing Use of LVA (distance and near)	5 years	Significant improvement in distance and near VA with LVA, ability to read TV titles (49.2%) and newspaper text (80%)		The near LVAs were near additions and hyperocular lenses, not HHM or STM. There was no control group to compare people with no training
Nilsson[22]	96 mixed LV	No. of hours varied based on different LV causes	Eccentric viewing Use of LVA	3.6–6 years	Significant improvement in distance and near VA with LVA (>95%)	Due to the varied low vision causes, not many subjects required eccentric viewing training	No assessment regarding the reading on daily activities (e.g. newspaper text) as included in previous studies.
McMahon and Spigelman[2]	6 highly educated NV	Brief training	STM	2 weeks	Significant improvement of STM RR after 2 weeks of practice.		Working distance (between eye-to-lens) was not controlled which might result in different EVD in between visits. The improvement in RR might be due to the increase in magnification rather than by practice or training. Subjects recruited had normal vision, not low vision.
Nilsson[23]	40 AMD	4.8 Sessions (1 hr)	Eccentric viewing (50% subjects) Use of LVA	1 month	Significant improvement in ability to read TV titles and newspaper text and to write letters for the trained group. (100% for the trained group compared to 25% for the control group)	Control group with instruction given was included in the study	
Bowers[67]	3 NV	2 Days (3 sessions)	Brief instruction of STM used and in-office repeated measures	Short-term	Significant improvement in STM RR	Significant improvement of RR in first 2 sessions	Short-term practice effect was assessed in this study. Subjects recruited had normal vision, not low vision.
Goodrich *et al.*[29,30]	90 AMD	3 Training models*	Optical LVA CCTV	Not reported	Optical LVA needed 5 training sessions while training for CCTV required 7 sessions (Empirical model). RR and reading duration increased significantly by training across time.	Control group, which was named as "private sector" model with minimal training, was included and showed the improvement in RR and reading duration was less than that in training groups.	Baseline RR was measured after the 1st session of training rather than just after the provision of LVAs, so RR before any training was unknown. No direct comparison of RR could be made between control and training groups.

DR, diabetic retinopathy; AMD, age-related macular degeneration; NV, normal vision; LV, low vision; CCTV, closed circuit television; LVA, low vision aid.
* Three training models were used in this study: Traditional model used in the Department of Veteran Affairs (as per the program in 1977: 10 sessions of optical LVA training and 15 hours of CCTV training); Empirical model (five sessions of optical LVA training and five sessions of practice; and then with seven hours of CCTV training and 8 hours of practice); Private sector model (1 session of optical LVA training and 2 CCTV training sessions and three practice sessions).

TABLE 3.
Subjects' details

ID	Group[a]	Age	Visual Impairment (months)[b]	Type of AMD[c]	Distance VA (logMAR)	Near Word VA (M unit at 25 cm)	Threshold Print Size with STM (M unit)
1	P2	82	17	0	0.30	0.63	0.50
2[d]	P2	86	7	0	0.78	4.00	1.00
3	P2	76	18	0	0.24	0.63	0.40
4	P2	81	48	0	0.70	2.00	0.80
5	P2	73	24	0	0.54	1.25	0.80
6	P2	71	12	0	0.24	0.75	0.80
7[d]	P2	78	16	1	0.62	1.50	0.63
9	P2	84	16	1	0.32	0.75	0.50
10	P2	78	12	0	0.82	4.00	0.63
11	P2	84	12	0	0.92	4.00	1.00
12	P2	83	18	0	0.72	2.00	0.63
13[d]	N	79	36	0	0.58	1.25	0.50
14[d]	N	82	6	0	0.78	3.00	1.00
16	N	83	12	0	0.46	0.75	0.50
17	N	82	12	0	0.38	0.75	0.50
18	N	80	12	0	0.64	1.25	0.50
19	N	71	36	0	0.86	3.00	1.00
20[d]	N	82	12	1	0.64	1.25	0.50
21	N	79	1	1	0.56	0.75	0.50
22[d]	N	86	18	1	0.32	0.63	0.50
23	N	84	4	1	0.52	1.50	0.38
24	P1	86	12	0	0.22	0.75	0.50
25	P1	78	12	0	0.58	1.25	0.50
26	P1	84	6	0	1.08	3.00	1.00
27[d]	P1	82	12	0	0.60	2.00	0.80
28	P1	75	72	0	0.84	3.00	0.63
29	P1	79	12	0	0.50	1.25	0.63
30	P1	72	7	1	0.90	2.50	1.00
31	P1	81	11	0	0.72	1.25	0.80
32	P1	85	24	0	0.46	0.75	0.40
33	P1	78	4	1	0.60	0.75	0.50
34	P1	85	40	0	0.90	4.00	1.00

[a] Groups: N − Control group; P1 − Large print practice group; P2 − large print with reduced field of view practice group.
[b] The length of visual impairment was either reported by the subjects or recorded in the clinic database.
[c] Type of AMD 0 = dry AMD; 1 = wet AMD; VA = visual acuity; STM = Stand magnifier.
[d] Subjects whose distance visual acuity deteriorated by 0.2 log unit or more across the experimental period of 20 weeks.

TABLE 4.
The mean age, distance visual acuity and near visual acuity of the 25 subjects with stable vision who were included in data analyses

	Control Group (N) (n = 6)	Large Print Practice (P1) (n = 10)	Large Print with Reduced Field of View Practice (P2) (n = 9)	Significance Between Group Differences (p value)
Age (years)	80.80 ± 4.08	80.45 ± 4.50	79.64 ± 4.84	0.83
Distance VA (logMAR)	0.54 ± 0.18	0.68 ± 0.26	0.56 ± 0.30	0.46
Near VA (M unit at 25 cm)	1.33 ± 0.88	1.85 ± 1.117	1.78 ± 1.37	0.69

cluded. Subjects were assigned to one of three experimental groups according to age and near visual acuity to ensure that the distributions of these variables were not significantly different among groups. Subjects in the control group (N) received no reading practice at home, but repeated reading measures with and without STM's were taken in the laboratory at weeks 0, 1, and 2 before the STM's were supplied for home use. The subjects in the practice groups (P1 and P2) were instructed to do 10 min/day of large print reading practice at home. P2 subjects were additionally requested to read the large print through a restricted field of view (see below).

Repeated reading measures with and without STM's were taken in the laboratory at weeks 0, 1, and 2 before the STM's were supplied for home use. The STM's were supplied at week 2 to all the subjects for reading small print at home; at that point, large print reading practice ceased. Further reading measures with STM's were made at weeks 4, 8, and 20.

Materials for Home Practice

For reading practice at home, large print reading material selected from a storybook of fourth to sixth grade level was prepared in print sizes ranging from N64 (8 M) to N10 (1.25 M) in 0.1 log steps. Because many studies have shown that reading rate increases as print size increases from threshold,[14, 42–44] it was important to ensure that the print size of the reading material supplied for practice was large enough for fluent reading. Therefore, print size of the large print book provided for subjects in the two practice groups (P1 and P2) was the subject's critical print size (CPS), minimum print size for maximum reading rate,[14] determined by measuring reading rates for a range of print sizes (see below).

A device to simulate the reduced field of view of an STM, a "practice stand," was provided to P2 subjects for their large print reading practice at home (Fig. 1). This device was made of a small plastic transparent rectangular stand open at the top and bottom. A rigid gray card with a central rectangular aperture was attached to the bottom of the plastic stand. The aperture was used to narrow the field of view to about six characters horizontally and three lines vertically. Thus, the size of the aperture varied according to the print size of the reading material. The extended section of the card prevented the subject reading beyond the limit of the stand. Each side of the stand was covered by white paper with a central opening; this prevented subjects from reading through the sides but allowed sufficient illumination on the reading material.

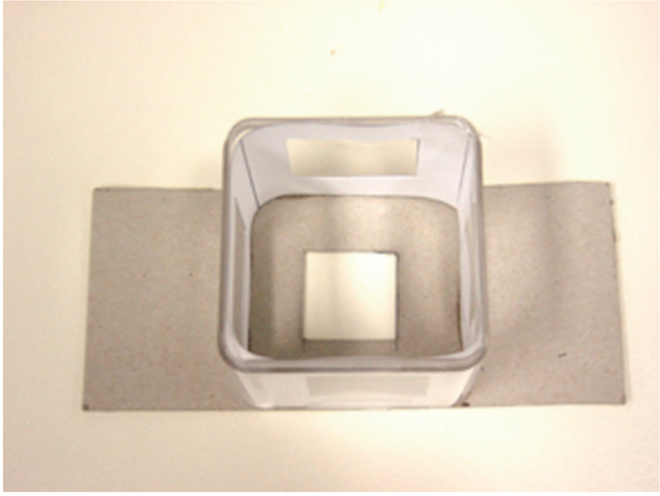

FIGURE 1.
Practice stand to simulate reduced field of view. The aperture of the practice stand narrowed the field of view to approximately six characters horizontally and three lines vertically. The size of the aperture varied according to print size of the reading material. Color version of this figure is available online only at www.optvissci.com.

Materials for In-Office Assessments

Two types of reading materials were used for in-office assessments of reading performance: Bailey-Lovie text reading charts[11] (single sentence at each print size) and passages of text (multiple, connected sentences for each print size). Reading performance on passages of text was the main outcome measure in this study because it reflected reading performance on habitual reading tasks (reading newspaper or mail) that were the reading goals of our subjects.

Bailey-Lovie text reading charts are similar to Minnesota Low-Vision Reading Test (MNRead) charts,[45, 46] with single sentences (selected from the MNRead Corpus[47]) at a range of print sizes (1.3 logMAR to −0.2 logMAR; 8 M to 0.25 M at 40 cm) in 0.1 log steps. At each print size, there is one sentence consisting of 60 characters (10 standard words[48]). However, there are differences in the formatting of the text between the two charts: MNRead charts use centrally aligned sentences printed over three lines, whereas Bailey-Lovie text reading charts use left-justified sentences, which better represent everyday printed materials, printed over two lines. Unlike MNRead charts, Bailey-Lovie text reading charts are small enough to sit easily on a reading stand for experimental measures of reading rate at controlled working distances and were therefore more suitable for our study. Twelve charts were produced so that no chart was used more than once at any visit; this compensated for any differences in text difficulty and reduced the likelihood of learning effects. Test-retest repeatability of reading rates found for the Bailey-Lovie text reading charts is high (84%)[49] and similar to that reported for the MNRead charts (87%).[50]

Passages of text were prepared in two series (of different word lengths) using materials of sixth grade level or below, analyzed by the Flesch-Kincaid Grading Level System (Microsoft Word 2000, Redmond, WA). The reading materials were selected from a range of sources: Sloan reading cards for low vision patients, Lighthouse reading cards, near vision text card from the University of Waterloo, and Maclure bar reading book for children. All the passages consisted of 8 lines of text, and 12 passages were produced at each print size for each series of passages. For the short passages (the first series), there was a mean of 263 ± 1.41 characters (43.8 standard words), and the number of characters per line was the same at all the print sizes, which ranged from N64 to N8 (8 M to 1.0 M) in 0.1 log steps. This series of passages was used to measure the reading rate without STM. For the assessments with STM, it was important to ensure that the navigation requirements (moving the magnifier across the page) were similar at all the print sizes. This was achieved by producing a second series of passages with constant line length in terms of physical distance for all the passages (each line was 15.6 cm long). The number of characters per passage in the second series increased as the print size decreased, with a mean of 617.1 ± 31.5 characters for the largest print size N16 (2 M) and 1661.7 ± 55.1 characters for the smallest print size N4 (0.5 M).

Procedures

A full optometric examination was conducted for each subject before the experiment to ensure that his or her distance spectacle prescription provided best vision.

Vision Assessment

Vision and reading were assessed monocularly for the eye with better near visual acuity or the eye with the smaller central visual field defect if near visual acuity was equal for each eye. Distance visual acuity was measured monocularly using a high contrast (93%) Bailey-Lovie (logMAR) letter chart[51] with the subject's current spectacle prescription. Near word visual acuity was measured monocularly with Bailey-Lovie word charts[52] at a working distance determined by the subject's near prescription. To control illumination and working distance, the reading charts were placed on a reading stand. The average illumination of the charts ranged from 320 to 380 lux (from the top to the bottom of the chart). Monocular visual field assessment and contrast sensitivity of the better eye were measured at 1 m using a Tangent (Bjerrum) screen[53] and the Pelli-Robson chart,[54] respectively. Central visual field loss was quantified in steradians as the solid angle subtended by the scotoma.[55, 56]

Reading Assessment without Stand Magnifiers

Reading rates, CPS, and text visual acuity were measured three times at each visit on sentences from the Bailey-Lovie text reading charts. Mean sentence reading rates, mean visual acuities, and median CPS were calculated for each subject and used in data analyses. In addition to assessing reading rate on sentences, reading measures were also conducted using the first series of text passages at median CPS. Passages of text at each subject's CPS were randomly selected at each visit to determine reading rate on large print, taken as the mean of three measurements.

Prescription of Stand Magnifiers

The necessary magnification level for each subject (and hence the equivalent power of the STM) was determined initially using the fixed acuity reserve (of 0.3 log unit) method,[11, 57, 58] which takes account of the subject's goal reading material (or target print size, which was newsprint) and his or her near visual acuity. Based on the equivalent power required and the near addition used by the subject, an appropriate STM from the 1550 series of Eschenbach illuminated STM's (Eschenbach [Germany] catalogue 2001/2002) was selected. Reading rate with the magnifier was measured using sentences from the Bailey-Lovie text reading charts. If the CPS achieved with the magnifier was larger than the target print size by >0.1 log unit, this indicated that the calculated magnification was insufficient to allow subjects to read their target print size fluently. When this was the case (only 2 of 32 subjects), magnification was recalculated using the individual acuity reserve method,[11, 59, 60] in which individual CPS and therefore individual acuity reserve were determined and the magnification adjusted accordingly. Illuminance of the reading materials with the STM (and two new alkaline batteries) ranged from 600 to 900 lux, depending on the size of the magnifier.

Instructions and In-Office Familiarization with Stand Magnifiers

Systematic instructions in the use of the STM were given to each subject by verbal communication, visual and/or tactile demonstration, and hands-on performance. First, specific instructions on the working distance between the eye and lens were given to ensure appropriate magnification and satisfactory focus (a clear and magnified image[61]) with the STM resting flat on the page. Second, handling technique for moving the magnifier along a line (forward movement) and back for a new line (retrace) was demonstrated. Each subject was encouraged to manipulate the STM until he or she became comfortable with the magnifier movement. At least two short passages were given to practice reading with the STM at each in-office session, and subjects were requested to report their comfort with the use of the STM before any experimental measures. Instructions for home use were given at week 2 when the magnifier was supplied for home use. Subjects were encouraged to use a reading stand or raise their reading material with piles of books or similar to ensure appropriate posture for reading with the STM. Previous studies[62, 63] have shown that reading rate improves with increasing illumination for the majority of people with AMD. Therefore, subjects were strongly encouraged to change batteries once the illumination started to dim. The first author, who had previous clinical experience of low vision training, gave all the instructions and training on the use of STM's.

Reading Practice (Home-Training) before the STM Prescription (P1 and P2)

Subjects from both practice groups (P1 and P2) were instructed to read their large print book at home for at least 10 min/day for 2 weeks. The results of Watson *et al.'s* study[34] had suggested that 10 minutes of daily reading practice was sufficient to produce significant improvements in reading performance. Subjects recorded on the large print book the number of pages read each day in an attempt to verify compliance with the reading practice (self-reported compliance). P2 subjects were additionally requested to read the large print with a restricted field of view (with the practice stand).

Reading Assessment with Stand Magnifiers

As described previously, subjects were given sufficient time to become familiar with the use of STM's before any measurements were taken. Similar to the reading assessment without magnifiers, reading rates, CPS, and text visual acuity with the STM were measured three times at each visit using Bailey-Lovie text reading charts. Median CPS achieved with the STM was determined, and reading rates on text passages from the second series at this CPS were then measured three times, and the mean rate was used in data analyses.

Because the object distance is less than the focal length of STM's, any change in the working distance (eye-lens distance) results in a change in magnification.[61] Therefore, the working distance was measured at each visit after the STM was supplied (at weeks 4 to 20) to ensure that subjects maintained a constant working distance and therefore magnification.

Reading Assessment with Reduced Field of View

At the last visit (week 20), reading rates on passages at CPS were measured with a restricted field of view simulated by the practice stand for all the subjects. This was used to examine any differences between groups in reading rates with full and restricted fields of view on large print. In addition, reading rates with the restricted field of view could be compared with the reading rates with STM's on passages at CPS, when the retinal image sizes for the two reading conditions were the same (same level of magnification).

Questionnaires

In addition to the objective measures of reading performance, subjective responses to reading with STM's were investigated. A short questionnaire, modified from the Manchester Low Vision Questionnaire[64] that assessed the frequency and duration of reading with STM's at home and the tasks that the subjects read with the magnifier, was administered verbally to subjects at weeks 4 to 20, after the STM was supplied. Most questions used five-point Likert scales for classification of the responses.

Data Analysis

The Statistical Package for the Social Sciences (SPSS, Chicago, IL) version 10 and GraphPad InStat version 3 (San Diego, CA) were used for all the analyses. Reading rates were transformed to log reading rates yielding frequency distributions that were not significantly different from normal distributions (Kolmogorov-Smirnov goodness of fit test, $p > 0.1$). Repeated measures analyses of variance (ANOVA's) were used to compare reading rates (with and without STM's) and vision measures across time. Multiple regression analyses were performed to investigate the relationship between reading rate and vision measures. A probability of <0.05 was taken to indicate statistical significance for all the analyses. Although multiple comparisons of log reading rates across time were conducted, Bonferroni adjustments to the probability level for significance to reduce the chance of type I errors were not considered necessary because this was a designed experimental study, and the analyses were planned to reflect this, not to develop a predictive model.[65]

RESULTS

Reading Rates with and without STM

Log reading rate with STM on passages at CPS improved significantly with time [$F(5,18) = 3.74$; $p = 0.02$; Fig. 2]. *Post hoc* analysis showed that the significant improvements were between weeks 1 and 2 ($p = 0.04$) before the provision of STM for home use, followed by a further small (but not significant) improvement until week 4. From week 4 onward, log reading rate with STM had reached a plateau ($p > 0.11$). The differences in log reading rates between groups at any visit were not significant [$F(2,22) = 0.37$; $p = 0.70$]. Although there appeared to be a tendency for the practice groups (P1 and P2) to show greater improvement than the control group in the reading rate with STM with time (Fig. 2), there was no significant interaction between groups [$F(10,36) = 1.25$; $p = 0.29$]. It could be argued that the small group sizes and the large variation among subjects in reading rates (Fig. 3) contributed to this lack of significant interaction, but the result indicated that short-term in-office practice with magnifiers before home use, with or without additional large print reading practice, was sufficient to

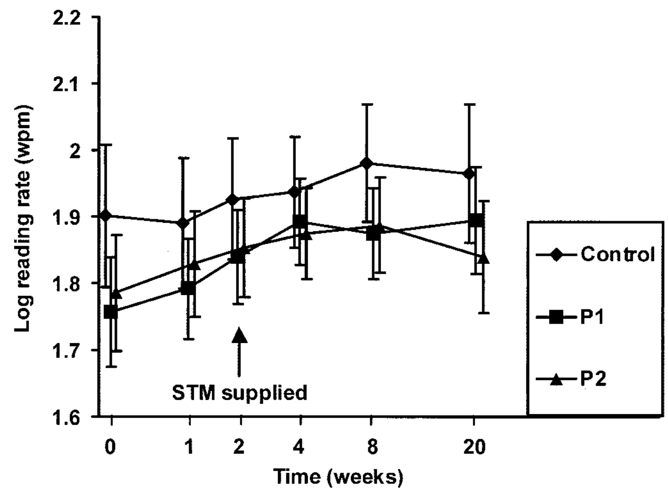

FIGURE 2.

Log reading rate with STM on passages at CPS across time (log scale) for each group. Log reading rate with STM improved at the first few visits and then was stable from weeks 4 to 20. However, there was no significant difference in log reading rate between groups. Error bars show 1 SEM.

give improvement in magnifier reading rate. This argument is further supported by the analysis of relative reading rate across time.

To account for the wide variation in baseline reading rates among persons, relative log reading rates (which were the difference between log reading rate at each visit and the log reading rate at week 0) were examined. There was a significant improvement in relative log reading rates from weeks 0 to 8 with no significant changes between weeks 8 and 20 [Fig. 4; $F(4,19) = 4.82$; $p = 0.007$]. The greatest improvement in relative log reading rate occurred between weeks 1 and 2 (*post hoc* analysis, $p = 0.004$), but again there was no significant interaction effect in the change in relative reading rate with time between groups [$F(8,38) = 1.02$; $p = 0.44$]. The improvement in relative log reading rate was found in all three groups. Although the magnitude of improvement appears greater for the practice groups (P1 and P2) than for the control group (Fig. 4), there were no statistically significant differences in relative log reading rate between groups at any visit [$F(2,22) = 0.69$; $p = 0.52$].

There were no significant differences in log reading rates without STM for passage reading for all the groups across time [$F(3,20) = 0.44$; $p = 0.72$; Fig. 5]. However, there was a significant interaction effect between groups [$F(6,40) = 3.03$; $p = 0.02$] with P1 and P2 showing a slight improvement in log reading rate at week 1, whereas the control group showed a small reduction in reading rate [*post hoc* analysis, $F(2,22) = 5.43$; $p = 0.01$]. However, when relative reading rates were analyzed, there were no significant differences in log reading rate across time [$F(2,21) = 0.69$; $p = 0.52$] and no significant interaction effect among groups [$F(4,42) = 1.44$; $p = 0.24$]. This indicates that the difference in reading rates between groups was confounded by the different baseline reading rates.

As predicted, log reading rate with STM at the first visit (week 0) was significantly lower than log reading rate without STM on large print [$F(1,22) = 10.52$; $p = 0.004$; Fig. 6]. Log reading rates with and without STM were not significantly different among groups

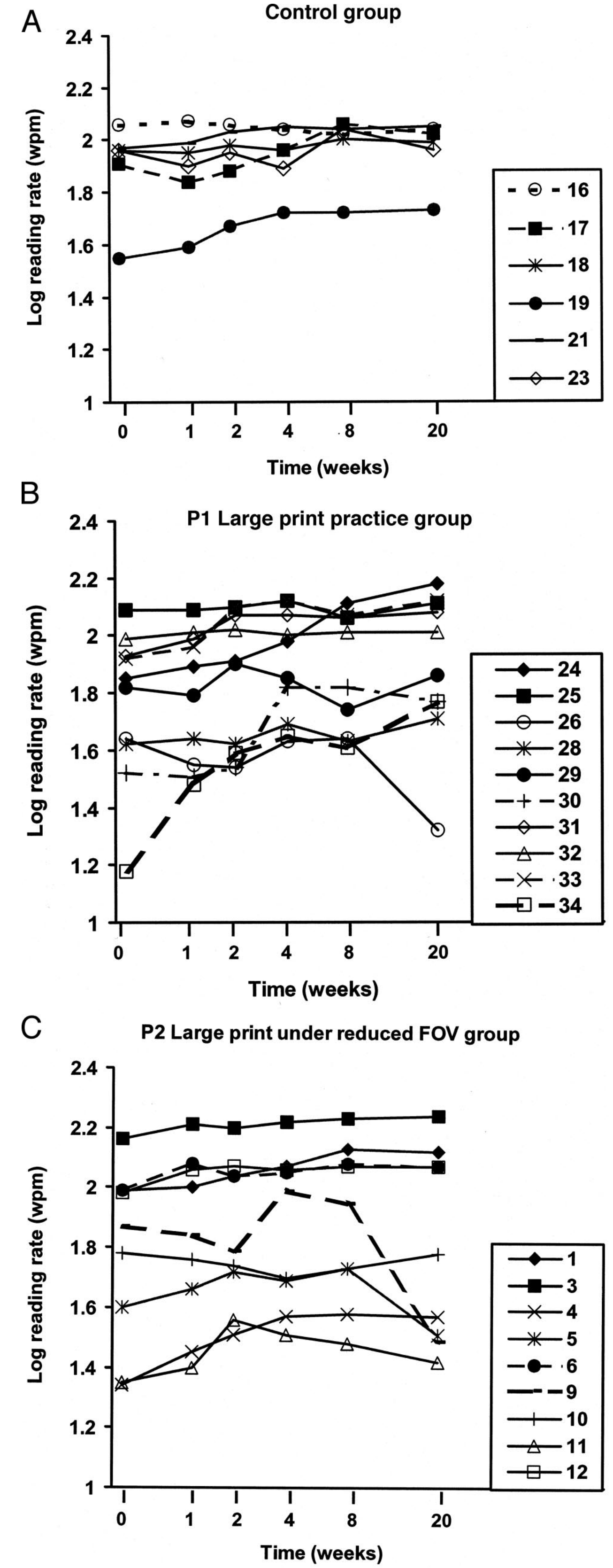

FIGURE 3.

Log reading rate with STM across time (log scale) for subjects from each group. The large variation among subjects in change in log reading rate with STM across time is illustrated. For this reason, no significant interaction effect among groups was found.

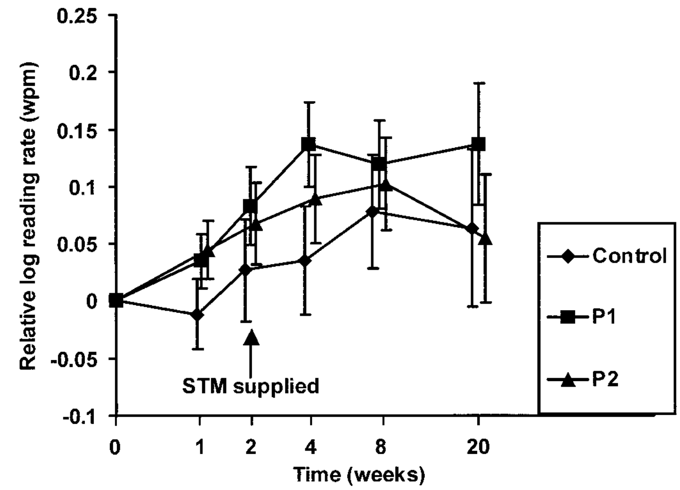

FIGURE 4.

Relative log reading rate with STM on passage across time (log scale) for each group. Relative reading rate with STM significantly improved from weeks 0 to 2 and stabilized at week 8. Although the increase in log reading rate in the practice groups (P1 and P2) appears to be larger than that in the control group, there was no significant interaction between groups. Error bars show 1 SEM.

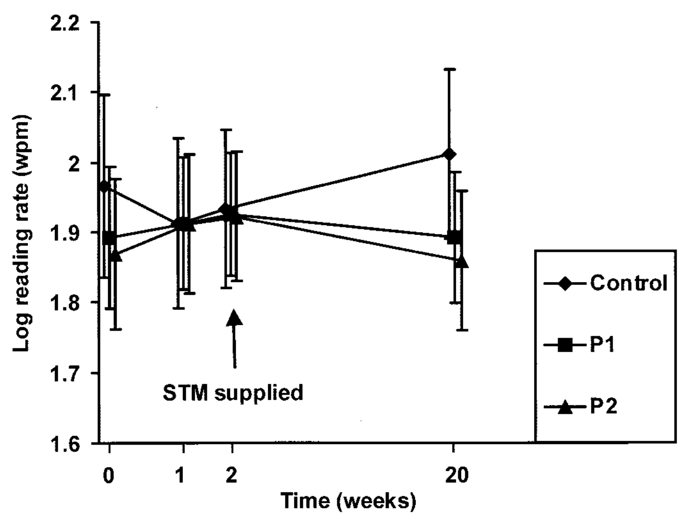

FIGURE 5.

Log reading rate without STM on passages across time (log scale) for each group. No significant change in log reading rate without STM was found across time. Log reading rate was not significantly different for subjects in the control and practice groups (P1 and P2) before the STM was prescribed (from weeks 0 to 2). Error bars show 1 SEM.

across visits from week 1 onward [$F(1,22) \geq 0.29$; $p \geq 0.11$]. These results indicate that for subjects with no experience in using magnifiers, reading rate with STM was reduced before any practice was given in reading large print or using STM but that it improved quickly.

At the last visit, there were no significant differences in log reading rate without STM with normal or restricted field of view compared with log reading rate with STM for all the subjects [$F(2,72) = 2.65$; $p = 0.08$], nor were there any significant differences between groups [$F(2,75) = 1.38$; $p = 0.26$].

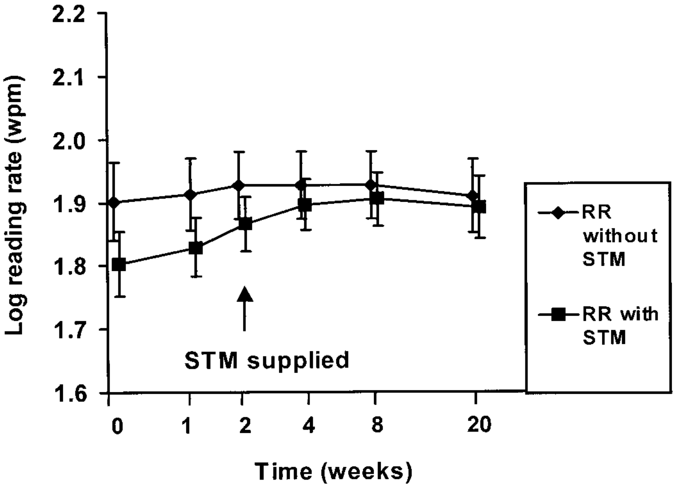

FIGURE 6.

Mean log reading rates with and without STM on passages across time (log scale) for all the subjects combined. At week 0, log reading rate with STM was significantly reduced compared with the log reading rate without STM. However, whereas the STM reading rate improved across time, the reading rate without STM did not change significantly. From week 1 onward, reading rate with STM was not significantly different from reading rate without STM. Error bars show 1 SEM.

Factors Predicting Log Reading Rate with STM

Because near visual acuities for word and text were highly correlated ($r = 0.96$), only text visual acuity was used in the multiple regression analyses. Of the vision measures at week 0 (distance visual acuity, near text visual acuity, contrast sensitivity, and visual field loss in steradians), text visual acuity was the only significant predictor of log reading rate without STM for passages (stepwise multiple regression, adjusted $R^2 = 0.67$; $p < 0.001$; Table 5).

Of the vision measures and log reading rate without STM, log passage reading rate without STM was the best predictor of log reading rate with STM for passages (adjusted $R^2 = 0.79$; $p < 0.001$; Table 5). The addition of contrast sensitivity improved the regression model with the two variables accounting for 85% of the variance in log reading rate with STM ($p < 0.001$). If log reading rate without STM was not included in the regression model, near text visual acuity was the only significant predictor of log reading rate with STM (adjusted $R^2 = 0.63$; $p < 0.001$; Table 5).

In an attempt to investigate the variable(s) affecting the improvement in magnifier reading rate, the change (slope) in log reading rate with STM from weeks 0 to 2, which was the period when significant improvement in magnifier reading rate was found, was determined for each subject. This was the dependent variable in the regression analysis, which showed that log passage reading rate without STM (at week 0) significantly predicted the improvement in log reading rate with STM (adjusted $R^2 = 0.28$; $p = 0.004$; Table 5). Subjects with faster baseline large print reading rates showed smaller improvements in magnifier reading rates (i.e., fast readers are likely to show less change in reading rate than slow readers). However, this variable explained only 28% of the variance in the change in log reading rate with STM (Table 5). This indicates that although large print reading rate to some extent predicts the likely change in reading rate with STM, there are other factors involved, such as motor function (e.g., eye-hand coordination) and perhaps psychological acceptance of the eye disease and of using an STM.[66] It is unlikely that frequency or duration of STM use had any significant effect on the improvement in reading rate for the subjects in this study. First, subjects from all the groups received the same amount

TABLE 5.
Summary of the multiple regression analyses

Dependent Variable	Independent Variables	Predictors	Adjusted R^2	p Value
Log reading rate without STM	Distance visual acuity Near text visual acuity Contrast sensitivity Visual field loss (steradians)	Near text visual acuity	0.67	<0.001
Log reading rate with STM	Distance visual acuity Near text visual acuity Log reading rate without STM Contrast sensitivity Visual field loss (steradians)	Log reading rate without STM and Contrast sensitivity	0.79 Additional factor improved R^2 to 0.85	<0.001
	Distance visual acuity Near text visual acuity Contrast sensitivity Visual field loss (steradians)	Near text visual acuity	0.63	<0.001
Change in log reading rate with STM (slope)	Distance visual acuity Near text visual acuity Log reading rate without STM Contrast sensitivity Visual field loss (steradians) Group[a]	Log reading rate without STM	0.28	0.004

[a] Each group was coded by a binominal variable as either 1 (practice) or 0 (control).

of in-office practice with magnifiers in weeks 0 to 2 before prescription of STM. Second, after the magnifier was prescribed, results of the questionnaire administered at weeks 4, 8, and 20 (Fig. 7) showed that the use of the STM at home was not significantly different among groups (frequency and duration, Kruskal-Wallis test, $\propto^2 = 0.11$; $p > 0.44$).

DISCUSSION

Reading Rates with and without STM

Previous studies have shown that reading rate reduces significantly when magnifiers are introduced for reading.[1, 2, 4–7] Participants in these studies had normal vision[1, 4–7] rather than "real" low vision. The current study recruited people with low vision who had no experience in using STM's for reading; our findings confirm that reading rate reduces when STM's are first used by people with low vision (AMD). As predicted, magnifier reading rate then improved, with most improvement achieved by week 2 and no further improvement beyond week 4 (Fig. 2). This is in agreement with previous studies that found greatest improvement in magnifier reading rate in the initial period of training[19] or with repeated measures of reading rate within a short period,[67] although in some studies[19, 68] the initial improvement was then followed by a continued gradual but significant increase in reading rate over a longer period.[19, 68]

The results of this study suggest that short-term in-office practice with STM (without any further training interventions) was sufficient to achieve maximum reading rate (equivalent to reading rate at CPS on large print without magnifier). The in-office STM practice in this study comprised familiarization with magnifier (reading up to two passages) and then the repeated assessment of STM reading rate (three text charts and three passages) at three sessions within a 2-week period. This amount of in-office practice was more than the practice usually given in the QUT Vision Rehabilitation Centre before a magnifier is prescribed and is likely to be more than typically given at many low vision centers with limited resources.

Results of previous studies[19–23, 30, 68, 69] have suggested that a longer period of training (or practice) with the magnifier is necessary to achieve maximum reading rate. This may simply be because of lower levels of magnification being prescribed (smaller acuity reserve) for subjects in earlier studies compared with this study. In the past 10 to 15 years, there has been a marked change in the prescription guidelines for magnification as a result of the research studies by Legge *et al.*[14, 59, 60] and Whittaker and Lovie-Kitchin.[58, 70] In the past, practitioners were advised to prescribe minimum magnification for reading with low vision so as to maximize the field of view available.[71, 72] In contrast, higher magnification for reading fluency has been recommended to clinicians in recent years.[58, 59, 70] Previous studies did not clearly describe the procedure for prescribing magnification for the participants of their training programs. It is likely that the magnification prescribed did not provide sufficient acuity reserve for fluent reading. As a consequence, participants needed more intensive and longer training to achieve maximum reading performance. In addition, most previous training programs included eccentric viewing training before the training with LVA's (refer to Table 2). The subjects who participated in our study did not need training in eccentric viewing; the majority (22 of 25) had developed eccentric fixation. Although this study involved only subjects with AMD and moderate visual impairment, it is likely that the findings would also apply to subjects with other causes of low vision with a wider range of vision loss.

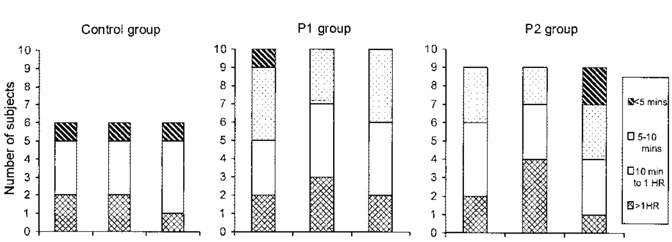

FIGURE 7.

Duration of STM use across time after the provision of STM for home use. The majority of subjects used their STM's for 10 to 60 minutes. There were no statistically significant differences in the duration of STM use across time or among groups.

Although large print reading practice with or without a practice stand (P1 and P2) did not further improve reading rates beyond that achieved with short-term in-office STM practice, we cannot conclude that large print reading practice *per se* is of no benefit in reading rehabilitation. Watson et al.[34] found significant improvements in reading comprehension for reading without magnifiers using a similar regimen of unsupervised home-based large print reading practice. However, because comprehension was not formally assessed in this study, we do not know whether comprehension for magnifier-aided reading improved with the large print reading practice in this study.

Previous literature has stated that reduced field of view and navigational problems are the major difficulties that people with low vision encounter when they use STM's for reading.[2, 17, 67, 73, 74] The "practice stand" introduced these impediments to reading—reduced field of view, the requirement for manipulation of a stand, and navigation across the text during reading—and thus simulated reading with an STM but without the optical limitations such as aberrations. Therefore, it was surprising that our results did not support the hypothesis that large print reading practice with the stand would provide a faster improvement in STM reading rate than large print practice without the stand. However, it should be noted that our results were based on a relatively small sample size. Given the wide intersubject variability in reading rates found in this study, a sample of 62 subjects for each group would have been required to detect a minimum difference of 0.15 log words/min in reading rates for statistical significance ($\alpha = 0.05$; $\beta = 0.95$). Such subject numbers were not available for our study. In addition, although we are confident that subjects complied, there was no objective confirmation that P1 and P2 subjects followed their instructions on home reading practice without and with the practice stand, respectively. Reading rate was significantly reduced when the P2 subjects first used the practice stand (restricted field) at week 0, just as it was when an STM was introduced. This was presumably because of inexperience in reading with a restricted field of view or manipulating the practice stand while reading.

Reading with STM or large print reading practice had no significant impact on reading rate without STM. Large print reading rate (at CPS) did not significantly change across time. This finding supports the suggestion by Ahn and Legge[9] that reading rate on large print (at or above CPS) reflects a person's maximum reading rate with magnifiers. Because of its repeatability, maximum reading rate on large print could be one of the parameters, in addition to vision measures, used to monitor the progression of the ocular disease. Elliott *et al.*[75] recommended that practitioners measure a patient's optimal reading rate before cataract removal because it could be a useful parameter to predict potential visual function after the cataract surgery.

Lovie-Kitchin *et al.*[10] suggested that the difference between reading rates with and without magnifiers reflected the extent to which the reading rate with the magnifier could be improved. The results of the current study support this suggestion, indicating that after in-office practice and repeated assessment of reading with the magnifier, reading rate with STM improved to the point that it was not significantly different from reading rate on large print. This is in line with previous studies,[9–11] which concluded that magnifiers do not significantly reduce reading rate compared with large print, provided that magnifications are the same and some form of practice with STM is given.

Interestingly, the result of this study showed that reading rate with reduced field of view (either using STM or practice stand) was not significantly different from reading rate with a full field once subjects became experienced in reading with the restricted field. This agrees with the argument that a reduced field of view is not a significant limiting factor on reading rate for experienced low vision readers, provided that optimal magnification is prescribed.[76, 77]

Predictors of Reading Rate with and without Magnifiers

Near text visual acuity was the only significant predictor of reading rate without an STM for the subjects with AMD, accounting for 67% of the variance in reading rate. This finding agrees with the results of previous studies in which near visual acuity was a strong predictor of reading rate for subjects with macular degeneration.[10, 16] As in previous studies,[9, 10] near visual acuity was also a strong predictor of STM reading rate when large print (maximum) reading rate (without STM) was not included in the regression analysis. In clinical consultations, when maximum reading rate without the magnifier may not always be assessed, near visual acuity can give a good indication of the potential magnifier reading rate.

However, in agreement with earlier studies,[9, 10] large print reading rate without STM was the strongest predictor of reading rate with STM, accounting for 79% of the variance in this study. Furthermore, large print reading rate at week 0 was the only significant predictor of the improvement in STM reading rate. These results suggest that large print reading rate, rather than near visual acuity, should be used as the criterion for allocating subjects to groups in future studies of interventions to improve magnifier reading performance.

There were many variables not assessed in this study that could affect subjects' reading performance with STM, such as subjects' physical (e.g., health and hand-eye coordination) and psychological status (e.g., motivation and acceptance of using an STM as their reading aid). People with visual impairment who have been prescribed handheld or STM's have to manipulate the magnifiers during reading. A person's motor function may have an impact on reading performance with the magnifiers and the improvement in reading rate as they learn to use a magnifier. Further research to address the role of motor function in reading with magnifiers is being conducted.[78–80]

Clinical Recommendations

For clinical purposes, low vision practitioners should ensure that appropriate magnification is prescribed to provide sufficient acuity reserve (at least 0.3 log units, or three lines) for fluent reading. Supervised in-office instructions (on working distance between the eye and lens and handling technique of magnifier manipulation) and practice with the magnifier (two or three sessions reading short text passages) should be given to each patient before the magnifier is prescribed to ensure maximum reading rates. In addition to routine vision measures (visual acuity and contrast sensitivity), reading rates with and without magnifiers should be assessed as the baseline reading measures at the time of magnifier prescription. A follow-up visit is recommended after a 1- to 2-week trial with the magnifier to enable assessment of the improvement in magnifier reading rate or any difficulty in using the magnifier for reading. If the reading rate with the magnifier shows no improvement compared with the reading rate at the previous visit or the reading rate with the magnifier is still significantly slower than the reading rate without the magnifier, further investigations, such as reassessment of vision, recalculation of magnification, or training in the technique of manipulating the magnifier for reading, are indicated.

CONCLUSIONS

Supervised, short-term, in-office practice with the STM (three sessions within 2 weeks) was found to be effective in quickly returning reading rates to maximum after an STM was first prescribed for subjects with moderate visual impairment (AMD). Contrary to our expectations, additional home-based large print reading practice did not improve reading rates beyond that achieved with short-term in-office STM practice. Further clinical trials with a larger sample size, including subjects with a wider range of visual acuities, without repeated measurements of STM reading rate before prescription of the magnifier, and with assessment of comprehension are required before we can confirm whether large print reading practice (with or without restricted field of view) is of any additional benefit in reading rehabilitation.

ACKNOWLEDGMENTS

We thank European Eyewear (Australia) and Eschenbach Optik (Germany) for supplying the Eschenbach internally illuminated stand magnifiers for the subjects who participated in this study. Supported by a QUT International Postgraduate Research Scholarship.

Received February 27, 2004; accepted November 17, 2004.

REFERENCES

1. Mancil GL, Nowakowski R. Evaluation of reading speed with four low vision aids. Am J Optom Physiol Opt 1986;63:708–13.
2. McMahon TT, Spigelman V. Reading with a stand magnifier: 1. Effect of text configuration and experience on normal subjects. J Visual Rehab 1989;3:19–23.
3. Neve JJ. Reading with hand-held magnifiers. J Med Eng Technol 1989;13:68–75.
4. Cohen JM, Waiss B. Reading speed through different equivalent power low vision devices with identical field of view. Optom Vis Sci 1991;68:795–7.
5. Cohen JM, Waiss B. Comparison of reading speed in normal observers through different forms of equivalent power low vision devices. Optom Vis Sci 1991;68:127–31.
6. Bowers AR. Eye movements and reading with plus-lens magnifiers. Optom Vis Sci 2000;77:25–33.
7. Dickinson CM, Fotinakis V. The limitations imposed on reading by low vision aids. Optom Vis Sci 2000;77:364–72.
8. Koenig AJ, Layton CA, Ross DB. The relative effectiveness of reading in large print and with low vision devices for students with low vision. J Visual Impair Blin 1992;86:48–53.
9. Ahn SJ, Legge GE. Psychophysics of reading. XIII. Predictors of magnifier-aided reading speed in low vision. Vision Res 1995;35: 1931–8.
10. Lovie-Kitchin JE, Bowers AR, Woods RL. Oral and silent reading performance with macular degeneration. Ophthalmic Physiol Opt 2000;20:360–70.
11. Cheong AM, Lovie-Kitchin JE, Bowers AR. Determining magnification for reading with low vision. Clin Exp Optom 2002;85:229–37.
12. Neve JJ. On the use of hand-held magnifiers during reading. Optom Vis Sci 1989;66:440–9.
13. Legge GE, Pelli DG, Rubin GS, Schleske MM. Psychophysics of reading. I. Normal vision. Vision Res 1985;25:239–52.
14. Legge GE, Rubin GS, Pelli DG, Schleske MM. Psychophysics of reading. II. Low vision. Vision Res 1985;25:253–65.
15. Fine EM, Peli E. Scrolled and rapid serial visual presentation texts are read at similar rates by the visually impaired. J Opt Soc Am A Opt Image Sci Vis 1995;12:2286–92.
16. Bullimore MA, Bailey IL. Reading and eye movements in age-related maculopathy. Optom Vis Sci 1995;72:125–38.
17. Beckmann PJ, Legge GE. Psychophysics of reading. XIV. The page navigation problem in using magnifiers. Vision Res 1996;36: 3723–33.
18. Legge GE, Ahn SJ, Klitz TS, Luebker A. Psychophysics of reading. XVI. The visual span in normal and low vision. Vision Res 1997;37: 1999–2010.
19. Goodrich GL, Mehr EB, Quillman RD, Shaw HK, Wiley JK. Training and practice effects in performance with low-vision aids: a preliminary study. Am J Optom Physiol Opt 1977;54:312–8.
20. Nilsson UL. Visual rehabilitation of patients with advanced diabetic retinopathy. A follow-up study at the Low Vision Clinic, Department of Ophthalmology, University of Linkoping. Doc Ophthalmol 1986; 62:369–82.
21. Nilsson UL, Nilsson SE. Rehabilitation of the visually handicapped with advanced macular degeneration. A follow-up study at the Low Vision Clinic, Department of Ophthalmology, University of Linkoping. Doc Ophthalmol 1986;62:345–67.
22. Nilsson UL. Visual rehabilitation of patients with advanced stages of glaucoma, optic atrophy, myopia or retinitis pigmentosa. Doc Ophthalmol 1988;70:363–83.
23. Nilsson UL. Visual rehabilitation with and without educational training in the use of optical aids and residual vision. A prospective study of patients with advanced ARMD. Clin Vision Sci 1990;6:3–10.
24. Langmann A, Lindner S, Kollegger E. [Low-vision training for better usage of magnifying visual aids]. Ophthalmologica 1994;208:92–4.
25. Nilsson SE, Nilsson UL. Educational training in the use of aids and residual vision is essential in rehabilitation of patients with severe ARMD. In: Kooijman AC, ed. Low Vision: Research and New Developments in Rehabilitation. Amsterdam: IOS Press, 1994:147–54.
26. Stoll S, Sarma S, Hoeft WW. Low vision aids training in the home. J Am Optom Assoc 1995;66:32–8.
27. Freeman PB, Jose RT. The Art and Practice of Low Vision, 2nd ed. Boston: Butterworth-Heinemann, 1997.
28. Nilsson UL, Frennesson C, Nilsson SE. Location and stability of a newly established eccentric retinal locus suitable for reading, achieved through training of patients with a dense central scotoma. Optom Vis Sci 1998;75:873–8.
29. Goodrich GL, Kirby J, Keswick C, Oros T, Wagstaff P, Donald B, et al. Training the patient with low vision to read: does it significantly improve function? In: Stuen C, Arditi A, Horowitz, Lang MA, Rosenthal B, Seidman K, eds. Vision Rehabilitation: Assessment, Intervention and Outcomes. Lisse, The Netherlands: Swets & Zeitlinger, 2000:230–6.
30. Goodrich GL, Kirby J. Low vision training for reading: a Goldilocks effect? Optom Vis Sci 2001;78(suppl):292.
31. Goodrich GL, Mehr EB. Eccentric viewing training and low vision aids: current practice and implications of peripheral retinal research. Am J Optom Physiol Opt 1986;63:119–26.
32. Graessley D, Kirby J. Literature review of current programs for training eccentric viewing. J Vis Rehab 1996;10:19–21.
33. Goodrich GL, Quillman RD. Training eccentric viewing. J Visual Impair Blin 1977;71:377–81.
34. Watson GR, Wright V, De l'Aune W. The efficacy of comprehension training and reading practice for print readers with macular loss. J Visual Impair Blin 1992;86:37–43.
35. Samuels SJ. The method of repeated readings. The Reading Teacher 1979;33:403–8.
36. Layton CA, Koenig AJ. Increasing reading fluency in elementary students with low vision through repeated readings. J Visual Impair Blin 1998;92:276–92.
37. McMahon TT, Hansen M, Viana M. Fixation characteristics in macular disease. Relationship between saccadic frequency, sequencing, and reading rate. Invest Ophthalmol Vis Sci 1991;32:567–74.
38. Leat SJ, Woodhouse JM. Reading performance with low vision aids: relationship with contrast sensitivity. Ophthalmic Physiol Opt 1993; 13:9–16.
39. Bowers AR. Reading performance in ARMD: The relationship between intelligence and comprehension. In: Vision '96, Book I, Proceedings of the International Conference on Low Vision 1996. Madrid: Organización Nacional de Ciegos Españoles, 1998:217–22.
40. Woods RL, Lovie-Kitchin JE. The reliability of visual performance measures in low vision. Vision Science and Its Applications, Vol. 1. 1995 OSA Technical Digest Series. Washington, DC: Optical Society of America, 1995:246–9.
41. Neale MD, McKay MF, Barnard J. Neale Analysis of Reading Ability, 3rd Australian Ed. Camberwell, VIC: Australian Council for Educational Research, 1999.
42. Lovie-Kitchin JE, Woo GC. Effect of magnification and field of view on reading speed using a CCTV. Ophthalmic Physiol Opt 1988;8: 139–45.
43. Rubin GS, Turano K. Low vision reading with sequential word presentation. Vision Res 1994;34:1723–33.
44. Plass R, Yager D. Presentation of video-based text to low vision

readers: rapid serial visual presentation vs. full-page reading. Invest Ophthalmol Vis Sci 1995;36:S671.
45. Mansfield JS, Legge GE, Leubker A, Cunningham K. MNRead Acuity Charts. New York: Lighthouse Low Vision Products Inc., 1994.
46. Legge GE, Ross JA, Luebker A, LaMay JM. Psychophysics of reading. VIII. The Minnesota Low-Vision Reading Test. Optom Vis Sci 1989;66:843–53.
47. MNREAD 2000 project. Available at: http://gandalf.psych.umn.edu/~gellab/MNREAD/MNREAD2000/. Accessed November 18, 2004.
48. Carver RP. Reading Rate: A Review of Research and Theory. San Diego: Academic Press, 1990.
49. Cheong AMY. Reading performance with stand magnifiers in ARMD. PhD thesis. Queensland University of Technology, Brisbane, Australia, 2003.
50. Ahn SJ, Legge GE, Luebker A. Reading speed and serial/parallel processing in vision. Invest Ophthalmol Vis Sci 1991;32(suppl):1041.
51. Bailey IL, Lovie JE. New design principles for visual acuity letter charts. Am J Optom Physiol Opt 1976;53:740–5.
52. Bailey IL, Lovie JE. The design and use of a new near-vision chart. Am J Optom Physiol Opt 1980;57:378–87.
53. Henson DB. Visual Fields. New York: Oxford University Press, 1993.
54. Pelli DG, Robson JG, Wilkins AJ. The design of a new letter chart for measuring contrast sensitivity. Clin Vis Sci 1988;2:187–99.
55. Weleber RG, Tobler WR. Computerized quantitative analysis of kinetic visual fields. Am J Ophthalmol 1986;101:461–8.
56. Lovie-Kitchin J, Mainstone J, Robinson J, Brown B. What areas of the visual field are important for mobility in low vision patients? Clin Vis Sci 1990;4:249–63.
57. Lovie-Kitchin JE, Whittaker SG. Prescribing near magnification for low vision patients. Clin Exp Optom 1999;82:214–24.
58. Lovie-Kitchin JE, Whittaker SG. Prescribing magnification for reading with low vision: what are the criteria? In: Stuen C, Arditi A, Horowitz, Lang MA, Rosenthal B, Seidman K, eds. Vision Rehabilitation: Assessment, Intervention and Outcomes. Lisse, The Netherlands: Swets & Zeitlinger, 2000:314–8.
59. Legge GE, Ross JA, Isenberg LN, LaMay JM. Psychophysics of reading. Clinical predictors of low-vision reading speed. Invest Ophthalmol Vis Sci 1992;33:677–87.
60. Ahn SJ, Legge GE, Luebker A. Printed cards for measuring low-vision reading speed. Vision Res 1995;35:1939–44.
61. Bailey IL, Bullimore MA, Greer RB, Mattingly WB. Low vision magnifiers—their optical parameters and methods for prescribing. Optom Vis Sci 1994;71:689–98.
62. Bowers AR, Meek C, Steward N. Illumination and reading performance in ARMD. Clin Exp Optom 2001;84:139–47.
63. Eldred KB. Optimal illumination for reading in patients with age-related maculopathy. Optom Vis Sci 1992;69:46–50.
64. Harper R, Doorduyn K, Reeves B, Slater L. Evaluating the outcomes of low vision rehabilitation. Ophthalmic Physiol Opt 1999;19:3–11.
65. Rothman KJ. No adjustments are needed for multiple comparisons. Epidemiology 1990;1:43–6.
66. Dickinson C. Low Vision: Principles and Practice. Boston: Butterworth-Heinemann, 1998.
67. Bowers AR. Stand magnifiers: page navigation and short-term practice effects. In: Stuen C, Arditi A, Horowitz, Lang MA, Rosenthal B, Seidman K, eds. Vision Rehabilitation: Assessment, Intervention and Outcomes. Lisse, The Netherlands: Swets & Zeitlinger, 2000:319–23.
68. Goodrich GL, Mehr EB, Darling NC. Parameters in the use of CCTV's and optical aids. Am J Optom Physiol Opt 1980;57:881–92.
69. Goodrich GL, Kirby J. A comparison of low vision reading performance with hand-held and stand-mounted CCTV. Optom Vis Sci 2000;77(suppl):125.
70. Whittaker SG, Lovie-Kitchin J. Visual requirements for reading. Optom Vis Sci 1993;70:54–65.
71. Mehr EB, Freid AN. Low Vision Care. Chicago: Professional Press, 1975.
72. Lovie-Kitchin JE, Bowman KJ. Senile Macular Degeneration: Management and Rehabilitation. Boston: Butterworths, 1985.
73. Spitzberg L, Jose RT, Kuether C. A new ergonomically designed prism stand magnifier. J Vis Rehab 1989;3:47–51.
74. Fine EM, Kirschen MP, Peli E. The necessary field of view to read with an optimal stand magnifier. J Am Optom Assoc 1996;67:382–9.
75. Elliott DB, Patel B, Whitaker D. Development of a reading speed test for potential-vision measurements. Invest Ophthalmol Vis Sci 2001;42:1945–9.
76. Lovie-Kitchin JE, Whittaker SG. Low vision assessment for reading rehabilitation: Indications for visual field assessment. In: Vision '96, Book I, Proceedings of the International Conference on Low Vision 1996. Madrid: Organización Nacional de Ciegos Españoles, 1998:268–75.
77. Lovie-Kitchin JE, Whittaker SG. Interaction between acuity reserve and window size for scrolled reading rates in adults with normal and low vision. Invest Ophthalmol Vis Sci 1999;40:S34.
78. Bowers AR, Lovie-Kitchin JE, Cheong AMY. The effect of passage width on page navigation with optical magnifiers. Invest Ophthalmol Vis Sci 2002;43:ARVO E-Abstract 4786.
79. Bowers AR, Lovie-Kitchin JE, Cheong AMY. Factors affecting page navigation with optical magnifiers. International Society for Low Vision Res and Rehabilitation. Abstracts for Vision 2002. Available at: http://www.islrr.org/Vision02/247.html. Accessed November 18, 2004.
80. Cheong AMY, Bowers AR, Lovie-Kitchin JE, Brown B. Does a line guide improve reading performance with stand magnifiers? Invest Ophthalmol Vis Sci 2004;45:ARVO E-Abstract 5446.
81. Rumney NJ, Leat SJ. Why do low vision patients still read slowly with a low vision aid? In: Kooijman AC, ed. Low Vision: Research and New Developments in Rehabilitation. Amsterdam: IOS Press, 1994:269–74.
82. Ortiz A, Chung ST, Legge GE, Jobling JT. Reading with a head-mounted video magnifier. Optom Vis Sci 1999;76:755–63.

Allen Ming Yan Cheong
Department of Psychology
University of Minnesota
N218 Elliott Hall
75 East River Road
Minneapolis, MN 55455
e-mail: cheon015@umn.edu