Using Computer-Based Readers to Improve Reading Comprehension of Students with Dyslexia

Jerome Elkind

The Lexia Institute and Xerox Palo Alto Research Center
Palo Alto, California

Karen Cohen

Massachusetts Institute of Technology
Cambridge, Massachusetts

Carol Murray

The Lexia Institute
Palo Alto, California

Twenty-eight middle school students, diagnosed as dyslexic and attending a school using the Slingerland approach to remediation of dyslexia, used a computer-based reading system for reading literature for about one-half hour a

Support for this study was provided by Xerox, the Principal Financial Group Foundation, the Luke B. Hancock Foundation, the Bothin Foundation, the Hills Foundation, Charles and Helen Schwab Foundation, and The Charles Armstrong School. The students and staff of the Armstrong School provided the environment in which the study could be undertaken, and we appreciate their willingness to participate and their many insightful comments. We especially want to thank Ginger Girvin, reading specialist at the Armstrong School, for providing the daily support to the students who participated in the study by helping them use the systems, preparing materials for them to read, and conducting the testing program.

Mailing address for correspondence and reprints: J Elkind, The Lexia Institute, 2040 Tasso Street, Palo Alto, CA 94301.

Annals of Dyslexia, Vol. 43, 1993.

ISSN 0736–9387

day for a semester. The system proved to be a strong compensatory aid, enabling 70 percent of the students to read with greater comprehension, approximately one grade level or more improvement, as measured by the Gray Oral Reading Test. For 40 percent of the students, the gains were large, from two to as much as five grade levels. However, not all students benefited. Fourteen percent showed lower comprehension scores when using the system, and there is some indication that this degradation is associated with kinesthetic-motor weakness. Some students reported gains in reading speed and exhibited increased span of attention for and endurance in reading when using the system. We did not find evidence that the computer-reader technology provided a positive remediation benefit incremental to that obtained from the school's intensive Slingerland remediation program. Our results indicate that computer-readers are important compensatory aids that can enable many people with dyslexia to perform more effectively in reading-related tasks associated with school and work.

Introduction

Many people with dyslexia never become proficient readers or even functional readers. They may not have received adequate remediation at an early enough age, or may have had reading disabilities that did not respond to remediation. Whatever the reason, these individuals are substantially disadvantaged by not being able to keep up with the reading required of them in school or at work, and they find that they cannot function effectively in these situations. They would benefit greatly from compensatory aids that enhance their ability to read at higher levels of comprehension and speed, that reduce the stress associated with reading, or that allow them to read independently without the aid of a tutor, friend, or relative.

There has been growing interest in the possibility that computer-based readers might provide these kinds of assistance. Computer-based readers employ a document scanner, optical character recognizer, speech synthesizer, and visual display to convert printed text into spoken text so that a user can simultaneously listen to the text and read it visually. The easily controlled and synchronized presentation of the material through both auditory and visual sensory channels distinguishes computer-based readers from audio tape transcriptions.

Often the aural language abilities of people identified as dyslexic are stronger than the visual abilities. Remediation programs for dyslexia, such as the multisensory approaches developed and adapted by Gillingham and Stillman (1960), Orton (1976), and Slingerland (1981) use the strengths of one modality to compensate for and overcome weaknesses in other modalities. Computer-based readers not only provide information through the (often stronger) auditory channel, but also provide redundant information through the two modalities.

This redundancy enables the auditory and visual channels to support each other in the reading process. Except for those individuals for whom the need to attend to multiple sources of information leads to degraded performance, the simultaneous auditory and visual presentation should help most dyslexic readers.

There has been considerable interest over the last ten years in the use of computer speech synthesis systems to aid reading. A recent special issue of *Reading and Writing: An Interdisciplinary Journal* (Leong (ed.) 1992) discusses work in this area. Most studies of speech synthesis for reading have addressed the use of this technology to help people develop reading skills (Hillinger 1992; Olson and Wise 1987; Wise, et al. 1989). Other studies have used computer speech synthesizers to provide pronunciation of requested or selected words and sentence structures to aid reading (Leong 1992; Wise and Olson 1992). These studies show that speech synthesis technology can serve as a helpful remedial reading tool in building reading skills. Speech synthesis has also been used to compensate for reading disabilities by allowing a reader to listen to the text while viewing it. Cohen et al. (1989) conducted a pilot study in which the Kurzweil Personal Reader (KPR), a computer reader developed for people with impaired vision, was used by a group of three dyslexic students to read assigned and personally selected literature. She observed improvements in reading comprehension test scores when the KPR was being used and gains in unaided reading test scores after several months use of the KPR. Her sample was small and there was no control or comparison group so her results can only be taken as suggestive of the value of using this technology as a compensatory aid. The work reported in this paper was conducted as a follow-up to this pilot study to determine whether these preliminary results could be confirmed in a statistically valid experiment.

Study Description

Scope

Our study was designed to answer three questions about computer-based readers when used for reading literature:

- Are computer readers an effective compensatory aid that enhances comprehension of material being read by dyslexics?
- Does their use for reading literature over an extended period provide a remediation benefit; that is, does it improve unaided reading ability?
- Do students have positive attitudes toward and see benefit from using computer readers?

Classes and Students

The study was conducted at The Charles Armstrong School in Belmont, California. It is a private day school dedicated to the remediation of students who are diagnosed as dyslexic. The instructional program is based upon the Slingerland adaptation for the classroom of the Orton-Gillingham remediation method that was developed for individual instruction.

We worked primarily with two middle school classes whose students had similar profiles and whose curricula and structure were similar. Class 1 had 13 students; Class 2, had 15 students. Seventy percent of the students of both classes were in sixth grade. The remainder of Class 1 were fifth graders; the remainder of Class 2 were seventh and eighth graders. The reading comprehension level of 70 percent of these students was more than one grade below their assigned grade as measured by the Gates-MacGinitie Reading Test (MacGinitie and MacGinitie 1989). Reading comprehension scores of these students ranged from the equivalent of grade 2 to the equivalent of grade 11.

Computer Readers

The computer-based readers used in this study were a preliminary version of the *Bookwise* product developed by the Xerox Corporation. *Bookwise* is a PC-based system that scans a printed page of text, recognizes the characters and words on the page, and then speaks those words while displaying them on a computer screen. It includes a dictionary that provides the meaning of a selected word, that shows how a selected word is broken down into syllables, and how the syllables are pronounced and blended. The system provides a synchronized auditory and visual presentation of material that is to be "read." The sentence being vocalized is highlighted in contrasting color on the computer display. Users can select the colors used for display of text and for highlighting the text being read. They also can select the reading speed and the reading voice. Scanned material can be stored in computer files, and these files can be used as the source of text to be displayed and vocalized. This is important in classroom use since once a book has been scanned on one computer reader system, its text file can be used for reading on other systems. A picture of the display that is used during reading is shown in Figure 1.

Experimental Design

The study was conducted during the 1991/92 school year. Eight *Bookwise* systems were used. In the fall semester the eight systems were used by Class 2; in the spring semester they were used by Class 1. This design allowed us to compare the progress during each semester of the class using *Bookwise* with that of the class not using *Bookwise*. It

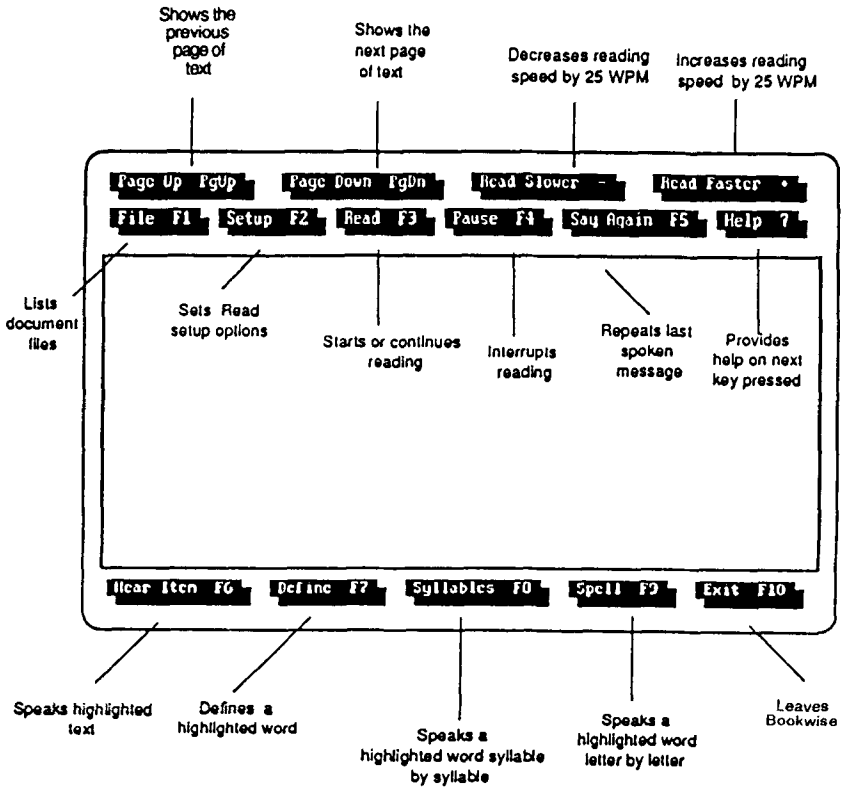

Figure 1. An illustration of the screen display used to control the reading part of the Bookwise *program. The user initiates the functions shown in the buttons at the top and the bottom of the screen by pointing at the buttons with the mouse cursor or by pressing the designated function or other keys. The text can also be scrolled up and down. Words are selected for look up in the dictionary or for pronunciation with the mouse.*

also allowed us to compare the progress of each class during the semester that it used *Bookwise* with its progress when it did not use the system.

Each class devoted an hour each day to reading and discussing literature. Each student in the *Bookwise* class used the system for approximately half of this reading period (30 minutes), four days a week during an entire semester, and accumulated about 20 to 25 hours of experience with the system during the semester. Students in the other class spent this period reading, discussing, and answering questions about their reading as they would normally. Reading selections as-

signed to the two classes were similar; both classes read many of the same books.[1]

Measurements

Tests were administered in September, January, and May. The September testing served as a pretest for both classes; the January testing was conducted after Class 2 completed their use of *Bookwise* (and before Class 1 began using it); and the May testing occurred after Class 1 completed their use of *Bookwise*.

Two different reading tests were administered in each testing period: the Gray Oral Reading Tests-Revised (GORT-R) (Wiederholt and Bryant 1986) and the Gates-MacGinitie Reading Tests, third edition (MacGinitie and MacGinitie 1989). The GORT-R was used to determine if *Bookwise* enhanced comprehension when it was being used as a compensatory aid. The test was administered first in the standard way and a second time in a non-standard application in which the student used the *Bookwise* to help read the test material. An improvement in performance associated with this use of *Bookwise* was taken as an indication of the comprehension benefit provided by *Bookwise*.

More specifically, in the standard administration of the GORT-R, the students read orally the set of paragraphs comprising the test. Successive paragraphs are of increasing difficulty. Associated with each paragraph is a set of five comprehension questions which the student attempts to answer. If three or more questions are answered correctly, the student proceeds to the next and more difficult paragraph. This continues until the student cannot answer at least three questions correctly. The student is then considered to have reached the "ceiling" level of comprehension and the test is terminated.

In the second and non-standard administration of the test, when the student reached the ceiling level, he or she went back to the paragraph prior to the one at which ceiling occurred. The student then reread this paragraph and subsequent ones using *Bookwise* as a reading aid until a new ceiling was established. In this second reading, the student saw the text on the computer screen and, through earphones, listened to it being read.

Thus, we obtained two scores from the GORT-R testing: one score representing comprehension when no reading aids were used, and a second score representing comprehension when *Bookwise* was used as an aid. The difference between these two is an indication of the benefit (or loss) attributable to the use of system.

Half the students used one form of the GORT-R and the other half

[1]The students read books such as *Animal Farm* (Orwell), *13 Clocks* (Thurber); and *The Lion, the Witch and the Wardrobe* (Lewis).

used the other form. In succeeding testing periods the forms used with each student were alternated so that students did not use the same form in successive periods. Students from both classes received about one hour of training in the use of *Bookwise* before GORT-R testing began. Students from Class 1 who had not used the system in the fall semester, received about one hour of retraining before the January testing.

Since the GORT-R scores obtained with *Bookwise* confound the effects of using *Bookwise* with those of having a second try at reading the paragraphs, we also conducted a calibration experiment to determine the effects on comprehension scores of simply reading the paragraphs twice without the use of *Bookwise*. Thirteen students from a third middle school class (Class 3) at Armstrong School were tested using the GORT-R. When these students reached their ceiling, they repeated the last two paragraphs as did the experimental classes, but *did not* use *Bookwise* for the second reading. They simply read the paragraphs again unaided and continued to more difficult paragraphs until a second ceiling was reached. The difference in scores between the first and the second reading provides an indication or the effects of having two tries at reading the same material and was used to isolate the benefit attributable solely to *Bookwise* in the tests with the students of Classes 1 and 2.

The students in Class 3 were mostly seventh and eighth graders. Their reading comprehension levels as measured by the Gates-MacGinitie Test ranged from the equivalent of grade 2 to grade 12. The students in this class had more severe reading disabilities than those in Classes 1 and 2. Their reading comprehension levels averaged about three grade levels below their assigned grade, whereas the reading comprehension levels of the students in Classes 1 and 2 averaged about one grade level below their assigned grade.

The Gates-MacGinitie Tests (third edition) were administered in the standard manner. Form K of the tests was used in the September and May testing period and Form L was used in January. The test level was matched to the students' assigned grade level.

Interviews

Students were interviewed three times, in September, January, and May, while testing was being done. The September interviews focused on the students' initial attitude toward *Bookwise*, their expectations from using it, their experience with computers and computer games, the amount of reading they did at home and school, and the aids they used to help with reading (*e.g.* audio tapes). The interviews conducted in January and May, after students had used the systems, focused on changes in attitude toward reading and toward *Bookwise*,

the students' opinions about the benefits they and others could obtain from using the system, and difficulties that they encountered. Interviews were conducted in small groups of four to seven students outside their classes but during their regular reading periods. The size of each group was determined by the expediencies of completing the interviews, given the number in the classes to be seen and the brief time available. Answers to and comments on each question were elicited from each student in the group.

Results

Comprehension Benefit

Our most important findings relate to the improvement in comprehension test scores (as measured by the GORT-R test) that the students achieved when they used the *Bookwise* system. The average improvement was 1.2 grade level equivalents and is statistically significant ($p < .0001$). More than 70 percent of the students showed gains of at least one grade level; more than half of these, about 40 percent of the students, showed gains of more than two grade levels; and a small number of students, 11 percent, gained three to as much as five grade levels. Not all students benefited from the use of the system: 14 percent showed no improvement; another 14 percent actually had poorer comprehension scores when they used the system.

These results are shown in detail in Figures 2 through 5. Figure 2 shows the students' GORT-R reading comprehension standard scores[2] obtained when they used *Bookwise* as a reading aid plotted against their scores when they read unaided. The results for all the tests given to the students in both classes are shown in the figure. Points that lie above the line drawn in each plot represent tests in which the students had better comprehension scores when using *Bookwise* than they did when reading unaided. Most of the points are above the line indicating that in most of the tests *Bookwise* enhanced comprehension, but some of the points fall below indicating that in some of the tests it degraded comprehension. There are many instances shown in Figure 2 where the test scores increased by large amounts, from three to six units, one to two standard deviations and the equivalent of roughly 3.5 to 7 grade levels. It is interesting to note that students with high unaided comprehension scores benefited from the use of the system about as much as students with low comprehension scores.

Recall that our testing procedure required students to read para-

[2]The GORT-R is a normed test. The standard score indicates the standing of a student within his or her age group. The score has been scaled to have a normal distribution with a mean of 10 and a standard deviation of 3.

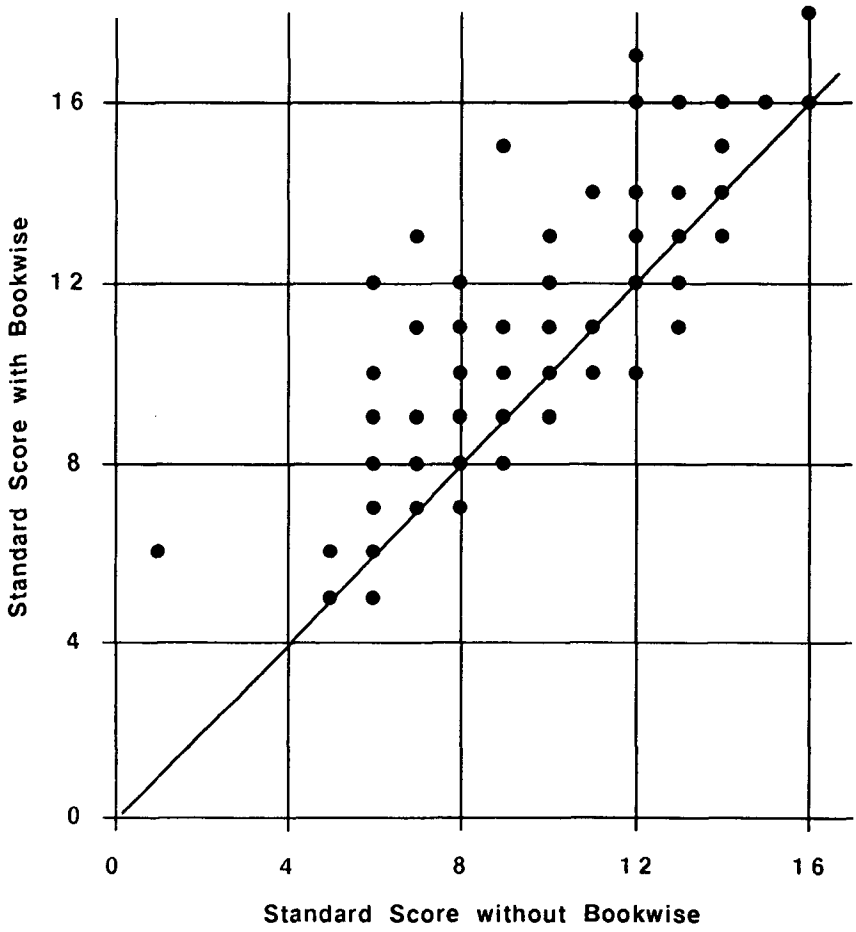

Figure 2. GORT-R Comprehension Test standard scores obtained when Bookwise *is used as a reading aid plotted against the standard scores obtained when reading normally without assistance of* Bookwise. *The results for all three administrations of the test to both Classes 1 and 2 are shown. The mean improvement in standard score with* Bookwise *is 1.2.*

graphs twice, first without *Bookwise* and then again using it. To test whether the comprehension improvements were a result of having a second opportunity to read the same material, we had students from Class 3 follow the same testing procedure except that on the second reading they did not use *Bookwise;* instead they read unaided. This test provides information about how much simply rereading the test material improves comprehension scores. Figure 3 shows the results. A few of the students had a one unit increase in score on the second reading,

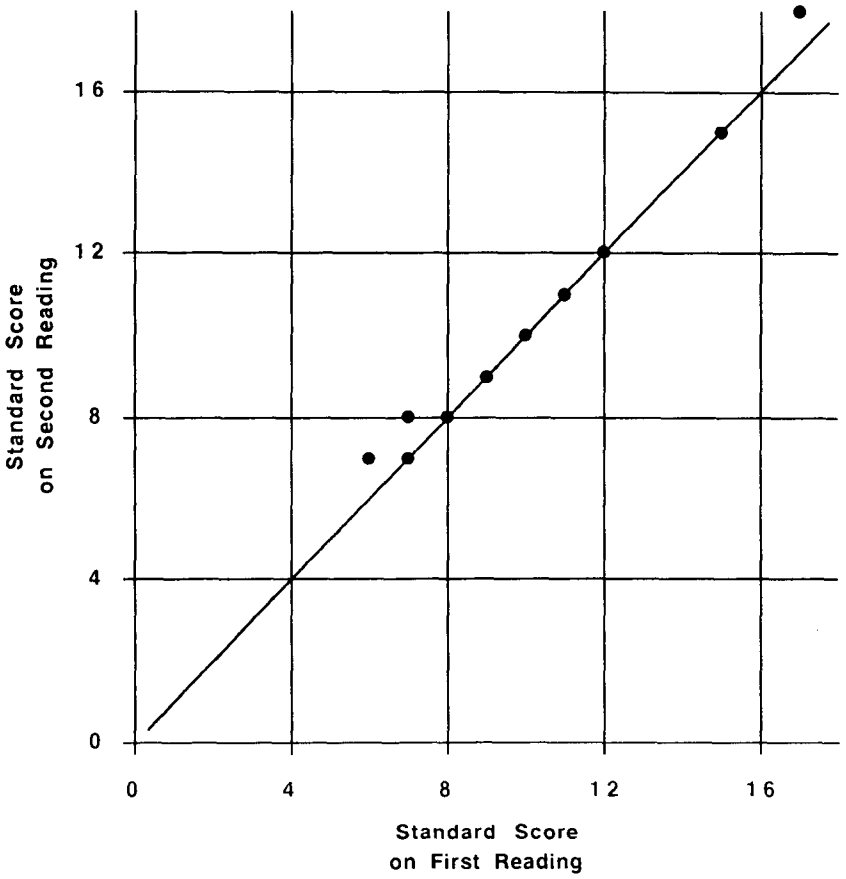

Figure 3. GORT-R Comprehension Test standard scores obtained when reading test material a second time plotted against the standard scores obtained on the first reading. Both readings were without the aid of Bookwise. *These results are from Class 3. Points above the line correspond to tests in which the student had higher comprehension on the second reading. The improvement in standard score has a mean of 0.23 unit which is not significant (t-test, p = .082).*

but for more than 75 percent their score did not change. None of the students in Class 3 showed improvement greater than one unit. The average improvement in standard score for this group was 0.23, which is not significant (p = .08). It is clear from the two histograms that the improvement obtained when Classes 1 and 2 used *Bookwise* is markedly different from that obtained when Class 3 read unaided twice. As a result, we attribute most of the enhancement shown in Figure 2 to the use of *Bookwise* with its synchronized auditory and visual display of text.

We see from Table I that the mean improvement in comprehension standard scores obtained in the combined group in Classes 1 and 2 when reading with *Bookwise* was 1.2 units. That obtained when Class 3 read twice unaided was only 0.2 units. The improvement in Classes 1 and 2, separately and combined, is significantly different from zero at the .0005 level or better (using the t-test) as can be seen from the last column; the improvement of Class 3 when reading twice was not significant ($p > 0.08$). The difference between the means of Classes 1 and 2 combined and Class 3 of 1.0 unit is significant at the .0001 level (not shown in the table).

There is considerable test-to-test variability in the scores of individual students over the three testing periods. We can obtain better estimates of the effect of *Bookwise* on individual students by computing an average score for each student. We can also correct for the effects of merely reading the test material twice by subtracting the mean improvement in score of Class 3 (0.23 units) from the average score of each of the students in the other two classes. The result of doing both of these operations is shown in Figure 4a, a plot of the corrected average comprehension standard scores obtained for each student with the aid of *Bookwise* against the average standard score obtained for each student for unaided reading.

Figure 4b is a histogram showing how the increases (and decreases) in average corrected comprehension scores are distributed over the students who participated in this study. In this figure we show the improvement in grade equivalent (GE) units, rather than standard score units. The mean corrected improvement of about 1.0 unit translates to 1.2 GE.

More than 70 percent of the students in Classes 1 and 2 showed average improvement in comprehension scores of 1 GE or more. More than 40 percent had gains of 2 GE equivalents or more. Three students,

Table I
Improvement in GORT-R Test Scores for Classes 1 and 2 Reading with *Bookwise* and Class 3 Reading Unaided

Class	Mean (st. score)	Standard Deviation (st. score)	t (t-test)	Degrees of freedom	Probability |Mean| > t
Class 1	1.08*	1.75	3.87	37	.0005*
Class 2	1.31*	1.83	4.80	44	<.0001*
Classes 1 and 2	1.20*	1.79	6.16	83	<.0001*
Class 3	0.23	0.44	1.90	12	.082

*Statistically significant at the .0005, .0001, and .0001 level for Class 1, 2, and 1 and 2, respectively, as shown in the last column.

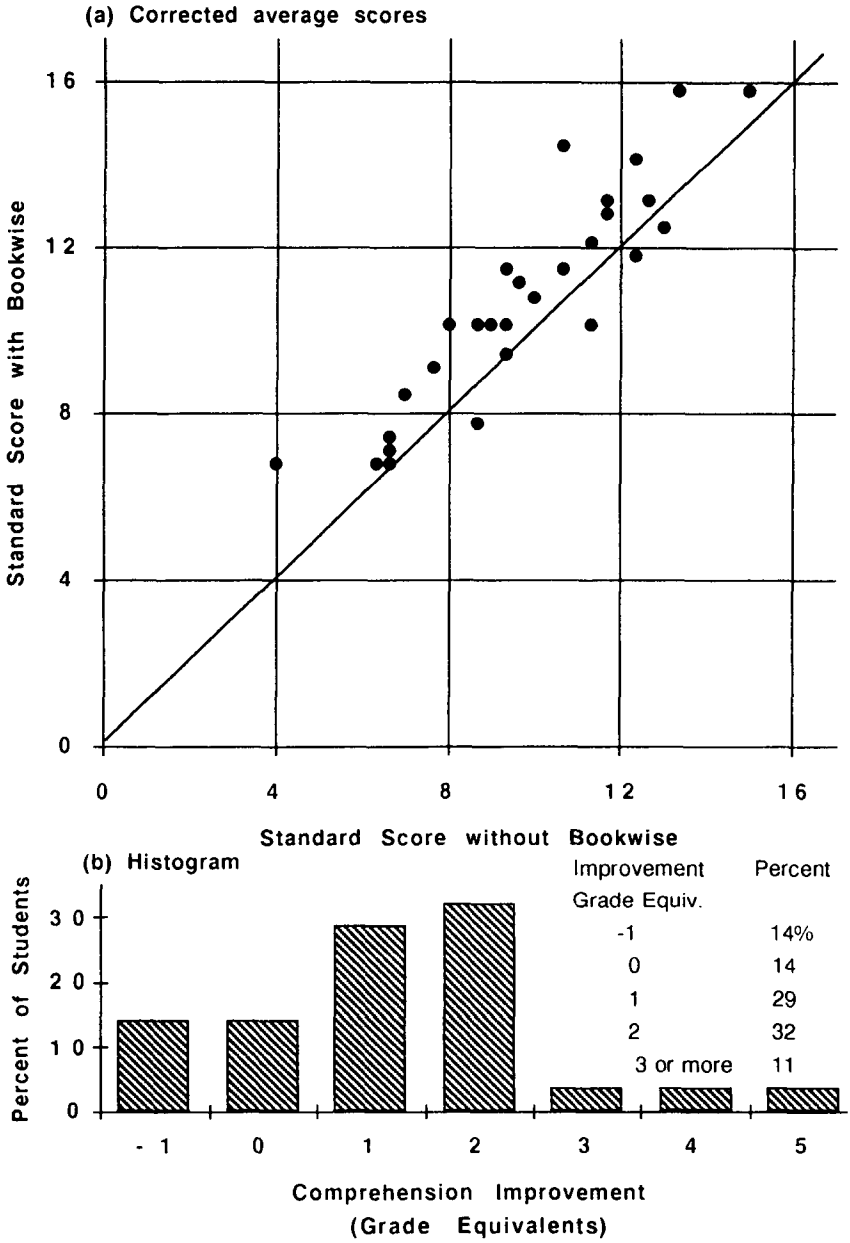

Figure 4. *Effect of* Bookwise *on the average GORT-R Comprehension Test standard scores of the students of Classes 1 and 2 corrected for the effects of reading test material twice. The correction was made by subtracting the mean improvement obtained by Class 3 from the average scores of each student in Classes 1 and 2. Figure 4a shows the average scores obtained when* Bookwise *was used plotted against the average scores for unaided reading. Figure 4b is a histogram of the corrected average scores. The table in Figure 4b summarizes the data in the histogram.*

11 percent, had gains of 3, 4, or 5 GE. The comprehension scores of 14 percent of the students did not change and the scores of another 14 percent were reduced by *Bookwise*. Although these gains are impressive, we must be cautious in extrapolating them to the dyslexic population at large. Our students were not selected to be a representative sample of the dyslexic population, although they were all diagnosed dyslexics with a wide range of reading-related disabilities. Therefore, we cannot claim that the gains obtained by our students will also be obtained in the larger population in the same magnitudes and percentages.

Given the different effect that *Bookwise* had on individual student test scores, it is interesting to look for correlates between student diagnostic profile and comprehension improvement. The students whose performance degraded when using *Bookwise* are particularly interesting. Two of these students reported difficulty in attending to information received simultaneously through the visual and auditory modalities. It is not surprising that they had difficulty when using the system.

We did not have consistent detailed diagnostic data on our students, but all students in our study (except one) were given one of two screening tests: the Slingerland Screening Test for Identifying Children with Specific Learning Disability (Slingerland 1970) or the Specific Learning Disability Test, Grade 6–8 (Malcomesius 1967). These tests do not give quantitative data on the strengths and weakness in different cognitive areas, but do provide examples of performance in specific language-related tasks (dictation, copying, comprehension). The results from the screening were evaluated by one of the authors (Murray) who is experienced in the identification of dyslexia, and she evaluated each student for strength or weakness in visual, auditory and kinesthetic-motor modalities.

We looked in some detail for consistent relationships between our limited diagnostic data and the observed changes in average comprehension standard scores associated with the use of *Bookwise*. We did not have a lot of success in finding such relations, but by looking at the extremes of the distribution of the change in standard scores, we found a hint of two interesting relationships. First, the three students who had the largest gains in comprehension had auditory strength and visual weakness. Second, the two students whose comprehension scores declined the most when using *Bookwise* had kinesthetic-motor weakness.

These relationships are illustrated in Figure 5. In Figure 5a the shaded part of the histogram on the upper left of Average Change in Score identifies the three students who had the largest gain in standard score. These same students are identified by the shading in the histograms of Auditory and Visual Strength on the right side of this part of the figure. Note that these students had auditory strength and

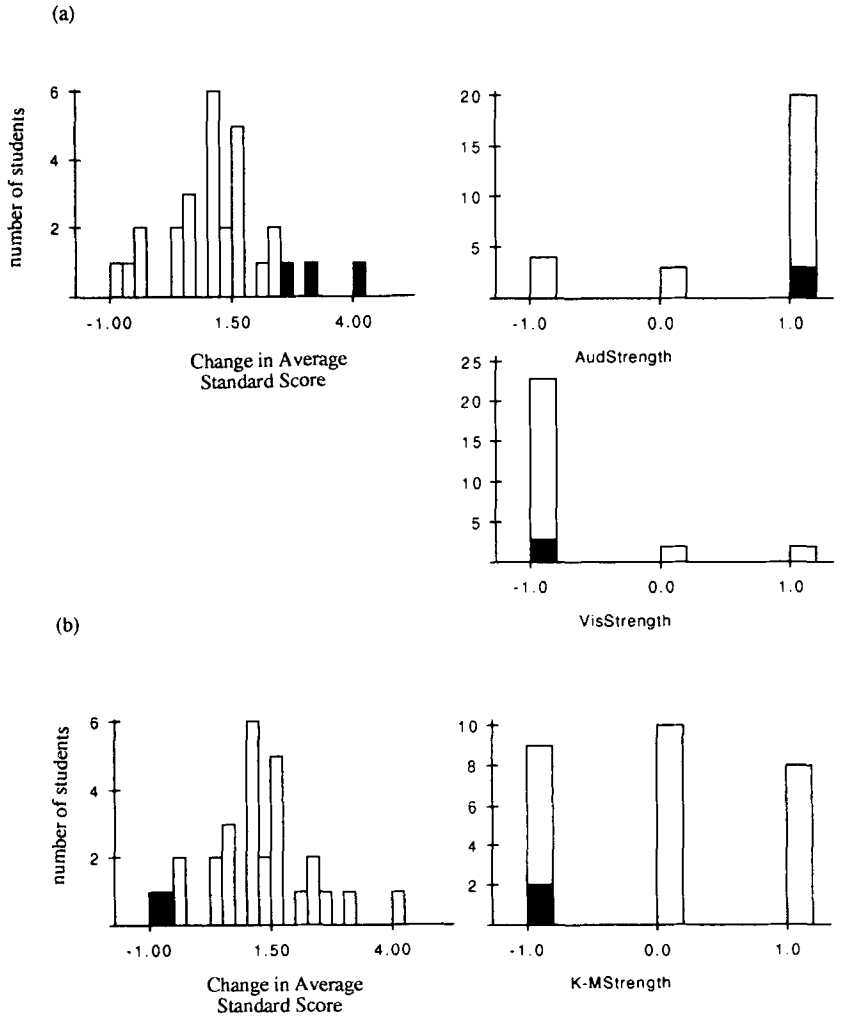

Figure 5. Possible diagnostic correlates between students who (a) showed greatest gain and (b) those who showed greatest loss in comprehension scores when using Bookwise. *Students whose average comprehension standard scores increased by more than 2.5 units (shaded area of Figure 5a) all had auditory strength and visual weakness. Students whose average comprehension standard scores decreased by more than 0.5 units (shaded area of Figure 5b) all had kinesthetic-motor weakness.*

visual weakness. The shading in the histograms of Figure 5b shows the two students with greatest loss in standard score and identifies these same students on the histogram of Kinesthetic-Motor Strength. Note that they exhibited kinesthetic-motor weakness.

The first result is not surprising since auditory presentation of text is the principal added value of the *Bookwise* system. However, we were surprised by the second result, the relationship to kinesthetic-motor weakness. It suggests that the task of using the system, which requires a small amount of motor activity for control and eye movements for reading, caused an interference with the primary reading task. The number of students who showed these traits was very small, too small to draw conclusions from the relationships that we have found. Clearly, more detailed and careful study of the diagnostic and other correlates of the changes in comprehension scores is required.

Remediation Benefit

The Gates-MacGinitie and GORT-R tests administered at the beginning and end of each semester provide information about the progress that the students made during each semester and during the year. We used these data to determine if use of the *Bookwise* system had a remediation benefit. We did not find a remediation benefit that could be attributed to the use of *Bookwise,* but we did find a significant gain in test scores that we attribute to the school's Slingerland remediation program.

In looking for a remediation benefit, we examined the vocabulary, comprehension and total normal curve equivalent (NCE) scores from the Gates-MacGinitie Tests, and the comprehension standard score and oral reading quotient from the GORT-R Tests. All of these scores are normed and have a normal distribution. They show the standing of the student within his or her grade cohort (Gates-MacGinitie) or age cohort (GORT-R).[3]

Table II shows the progress made by the two classes during the year in terms of the differences between the means of the test scores obtained for each class in May and those obtained in September. The results of t-tests to determine if the changes in test score means are statistically significant from zero are also shown in Table II. The September test scores are also shown to provide a reference level for each class on each test. Grade equivalents scores are also shown. Students in Class 2 made significant advances relative to their grade and age cohort during the year in all the tests that we examined. Students in Class 1 made smaller advances.

Table III shows how the use of *Bookwise* affected the test scores. It compares the improvements in test scores obtained when a class was using *Bookwise* with those obtained when the class was not using it.

[3]For the Gates-MacGinitie NCE scores, the mean is 50 and the standard deviation is 20. For the GORT-R comprehension standard score, the mean is 10 and the standard deviation is 3; for the oral reading quotient, the mean is 100 and the standard deviation 15.

Table II
Gains in Average Test Scores Made During the School Year

Class	Test	Fall Scores: Normal. Score	Fall Scores: Grade Equiv.	Year's Gain: Normal. Score	Year's Gain: Grade Equiv.	t-Test# Significance Level
1	G-M Vocab	42.5	5.3	4.8	0.8	p(12) >.05
1	G-M Comp	36.3	4.4	11.9*	2.2	p(12) <.01*
1	G-M Total	40	5.1	6.8*	1.4	p(12) <.01*
1	GORT Comp	9.5	5.6	0.77	1.6	p(12) >.05
1	GORT Quotient	91.9	5.3	6.0	1.2	p(12) >.05
2	G-M Vocab	41.5	5.7	8.4*	1.2	p(14) <.01*
2	G-M Comp	34.1	4.8	10.3*	1.6	p(14) <.01*
2	G-M Total	36.7	5.0	9.2*	1.8	p(14) <.001*
2	GORT Comp	8.9	5.7	1.67*	2.7	p(14) <.05*
2	GORT Quotient	91.4	6.0	9.2*	1.8	p(14) <.05*

*Significant at the level indicated

#The notation used for t-test results in this column indicates the degrees of freedom and the significance level for each of the average gains in normalized score (fifth column).

Table III
Comparison of Test Score Gains for Semester When *Bookwise* Was Used and the Semester When It Was Not

Class	Test	Gain with *Bookwise* Normalized Score	Gain without *Bookwise* Normalized Score	t-test Significance Level*
1	G-M Vocab	1.5	3.3	p(24) >.05
1	G-M Comp	6.9	5.0	p(24) >.05
1	G-M Total	1.9	4.8	p(24) >.05
1	GORT Comp	0.62	0.15	p(24) >.05
1	GORT Quotient	4.2	1.8	p(24) >.05
2	G-M Vocab	5.5	2.7	p(26) >.05
2	G-M Comp	7.4	1.8	p(26) >.05
2	G-M Total	6.3	2	p(26) >.05
2	GORT Comp	0.73	1.0	p(28) >.05
2	GORT Quotient	3.4	5.0	p(28) >.05

*There were no significant gains in unaided reading that can be attributed to the use of *Bookwise*.

The average gain in test scores that occurred during each semester and the results of t-tests to determine if there is significant difference between gains made when *Bookwise* is used and when it is not are shown in this table. We found no significant differences between the changes in test scores obtained in the semester in which *Bookwise* was used and the semester in which it was not used.

Thus we find that whereas these students at the Armstrong School advanced relative to their age or grade cohort, none of this improvement can be attributed to the use of *Bookwise*. We attribute the student gains to the intensive Slingerland remediation program at their school. The total amount of time the students spent on *Bookwise* was small, only 20 to 25 hours. This is far less than the amount of direct instruction that they received. So the lack of an incremental remediation effect from *Bookwise* should not be surprising. Our study does not address the question of whether *Bookwise* would provide a remediation effect in a school that was not otherwise providing a remediation program. Results obtained by Wise et al. (1989) in such a setting indicate that a remediation benefit is obtained when synthetic speech is used in a structured reading program.

Student Interviews and Attitudes Toward Use of The System

In addition to the standardized testing administered to the students of Classes 1 and 2, the students were also interviewed in small groups at the three times that testing was being done. All students

were interviewed, and each was encouraged and expected to respond to every query. There was some "echoing" of responses, *i.e.* students following the first respondent and repeating the same or similar answers, but this in no case was universal, and a range of opinion was present in each group interview. This section lists the questions asked of the students (Table IV) and then summarizes the general student responses for the questions involved. Although data were recorded and can be analyzed in detail for each individual and each group and class, an examination of the results revealed no likely trends and the potential for obfuscation. All interviews were conducted by the same interviewer, one of the authors (Cohen), who was external to the school. Students were promised confidentiality in their responses and appeared to be quite frank and open.

It is important to note here that although there were no major changes or differences in student attitudes during the year, and few should be expected from an intervention such as this experiment, there were some interesting reactions and suggestions which are presented below. There were also major differences in the atmosphere and behavior of the groups being interviewed from Class 1 and Class 2. The students from Class 2 were consistently well-behaved, focused and generally positive. The students from Class 1 were difficult to handle, fought among themselves, and were often unresponsive or belligerent.

Students in all groups, from the start, were quite positive about

Table IV
Interview Topics

Attitude toward reading
Problems with reading
Experience with the *Bookwise* system (omitted prior to use)
Attitude toward the *Bookwise* system
Attitude toward using *Bookwise* (omitted prior to use)
Experience with computers
Other aids they have used and/or are using to help in reading
Time/day or week spent with TV or computer games such as Nintendo; watching TV programs
Time spent reading outside school
How will *Bookwise* help others?
How did *Bookwise* help (third interview only with little response): reading, spelling, pronouncing, definitions, homework, understanding words, reading more, reading faster, anything else
If the reader is to be used with other students, what is the best way to make use of it? Who will it help, what kind of readers (third interview only)
When you read on your own, do you hear any voice(s)? If so what? (third interview only)
Suggestions, reactions, other comments

their attitudes toward reading, and this did not change during the year of the experiment. Students, similarly, were hard-pressed to identify problems they themselves had with reading, for the most part stating "none." The only negative problem that emerged in one group after they had used *Bookwise* for a semester was that they didn't read fast enough. Basically, students felt and stated that they were good readers, at times had difficulty with pronouncing big words, but their attitudes toward reading were positive throughout.[4] Questions aimed at finding out how much time they spend outside school with computers, video games, and reading indicated that the majority spent about an hour a day reading outside of school. There may have been a slight increase in the time spent reading during the school year, but attributing it to *Bookwise* is probably not appropriate. Time spent with computers and video games probably did not change during the year, although student participants elected to combine the two questions (knowing from initial interviews what they would be), and any attempt to differentiate between these two activities would not be meaningful.

When asked how *Bookwise* would help others, the major responses (after the students had experience using the system) were in reading hard words and reading faster. The types of people for whom they felt the reader would be best, in descending order of frequency, were: dyslexics, blind people, people who cannot read at all, children learning to read, rich people (students were aware that the system cost several thousand dollars), people who are not deaf, and individuals with severe disabilities. The students clearly saw some use for the system, but not necessarily for themselves. There was negativism on the part of many male students who had initially been told that the system was developed for blind people. They felt they were being classified as handicapped, using a crutch, and, as a result, less "macho"—the word of one student—if they used the system. The students in this experiment were already in a school devoted to helping them with their dyslexic problems. Consequently, they probably didn't want or need reminding of those problems since most of them felt they were doing very well in school.

Informal Observations

In the course of this study we had extensive opportunity to observe students using *Bookwise* and to develop insights about the strengths and weaknesses of the system and its impact on the stu-

[4]It is not unusual to find that middle school students attending a special school for dyslexia have a low awareness of their reading difficulty. They do not realize yet to what extent their poorer reading skills will impede their progress in high school and at work. They are in a sheltered, supportive environment with peers who have a similar difficulty. As a result, they do not have much opportunity to see how their reading performance differs from peers who are not dyslexic.

dents. On the positive side we observed that for many students, especially those in Class 2, the system allowed them to read with pleasure for extended periods of time, much longer than they were able to without its assistance. They were obviously relaxed and enjoying their books. It was as if the stress associated with all their prior reading had been eliminated. Several students, who were experiencing attention difficulty when attempting to read their assignments, were able to read with *Bookwise* successfully for extended periods. It seemed that the combination of the computer generated display and the auditory input was able to focus their attention or block out diversionary stimuli.

There were several instances where students used the system to start a book and after a few chapters became interested and motivated enough to voluntarily take the book home and read it independently. These events are especially notable because they occurred with students who had never or rarely ever read independently unless forced to do so. Many students, especially in Class 2, would choose to use the system to answer assigned questions about the stories they were reading rather than look them up in the printed text. They found it attractive to scan through the text on the screen and listen to the sections addressed in their assigned questions. They stated that they could do so more quickly.

On the negative side, there were students who disliked to use the system. Two of these turned out to be students who had weak kinesthetic-motor modality. There also were ones who said they had difficulty attending simultaneously to both the auditory and the visual presentations. Several students did not like the computer synthesized speech and objected when it mispronounced words. Others felt that the system was reading for them and reducing their opportunity to improve their independent reading skills or was unnecessary since they felt that they could read well by themselves. Most of the students who were negative toward the system were in Class 1, which as mentioned earlier was a difficult class.

We found the task of scanning material more troublesome than we had expected. Not all books could be scanned successfully. In some the print was of poor quality, in others the inner margins were too narrow. Scanned material usually had to be edited after scanning to correct errors. We found that it was not a good use of students' time to have them scan their own material unless it was only a few pages. As more school material becomes available in digital as well as print form, the need for scanning will decline.

Discussion

It is clear from the results obtained in this study that computer-based readers can be a valuable reading aid for many people with dys-

lexia. The system used in our study, *Bookwise*, enabled more than half of the students in our sample to read with greater comprehension (at least one grade level higher) than they could read unaided. For about 40 percent of the students, the gains were large, the equivalent of two to as much as five grade levels. For dyslexic students, who have not or cannot develop adequate reading skills, improvements in reading comprehension of this magnitude and improvements in speed of reading can make a big difference in their ability to keep up with the reading requirements of school and to be successful in their academic work.

Not everyone benefited from the system. The reading comprehension scores for some students showed no improvement, and others had lower comprehension scores when using the system. Some students reported that the system interfered with their reading, and others did not like to use it. Clearly, it is important to be selective in the application of the technology, and it would be useful to be able to predict from diagnostic information who will benefit from the use of the technology. Our study provides some hints about correlates between diagnostic profile and effects of the technology on reading comprehension, but more work is required to understand this issue better.

We did not find that the computer-reader provided a remediation benefit incremental to the benefit obtained from the intensive remediation program that the students were already receiving at the Armstrong School. The program at the school is a strongly focused multisensory remediation program that uses the Slingerland approach, and students made significant gains in test scores during the year. Those in Class 2 progressed more than those in Class 1. It is important to note that we did not attempt to use the computer-reader to provide direct instruction to build decoding, word recognition, or other reading skills. Others (for example, Wise et al. 1989) have found that the use of computer reader technology in this mode led to improvements in reading skills that exceeded those of dyslexic students who were not receiving special remediation.

It is important that the reading problems of dyslexic children be identified early and that every effort be made to help them find good strategies for reading. It is also important to recognize that many dyslexic children will not become proficient readers either because they do not respond adequately to the remediation programs they receive or, as is often the case, adequate programs are not provided in their early years, if ever. For many of these students it appears that computer-reader technology could make the difference between academic success and failure and enable them to develop realistic aspirations for careers that require higher reading skills. As computer technology continues to advance, the size and cost of computer-based readers will decline, and they will become ever more convenient and affordable for

use by individuals at school and work. As more material becomes available in computer formats, one of the barriers to the easy use of computer-readers, scanning of printed documents, will be reduced. Thus the technology is certain to become more attractive, and it is important that today's students become aware of its potential as they develop their career goals.

References

Cohen, K., Bean, G., Liberman, M., Axelrod, J., and Romberg, R. 1989. *A Pilot Study to Evaluate the Impacts of the Xerox/Kurzweil Personal Reader with Dyslexic Children.* Cambridge, MA: Kurzweil Computer Co.

Gillingham, A. and Stillman, B. 1960. *Remedial Training for Children with Specific Disability in Reading, Spelling and Penmanship.* Cambridge, MA: Educators Publishing Service.

Hillinger, M. L. 1992. Computer speech and responsive text: Hypermedia support for reading instruction. *Reading and Writing: An interdisciplinary journal* 4:219–229.

Leong, C. K. (ed.). 1992. Special issue on the use of text-to-speech computer systems. *Reading and Writing: An interdisciplinary journal* 4.

Leong, C. K. 1992. Enhancing reading comprehension with test-to-speech (DECtalk) computer system. *Reading and Writing: An interdisciplinary journal* 4:205–217.

MacGinitie, W. and MacGinitie, R. 1989. *Gates-MacGinitie Reading Tests,* third edition. Chicago, IL: Riverside Press.

Malcomesius, N. 1967. *Specific Learning Disability Test, Grade 6–8.* Cambridge, MA: Educators Publishing Service.

Olson, R. and Wise, B. 1987. Reading instruction and remediation with the aid of computer speech. *In* D. Reinking (ed.). *Computers and Reading: Issues for theory and practice,* New York: Teachers College Press, Columbia University.

Orton, J. L. 1976. *A Guide to Teaching Phonics.* Cambridge, MA: Educators Publishing Service.

Slingerland, B. 1970. *Slingerland Screening Test for Identifying Children with Specific Learning Disability.* Cambridge, MA: Educators Publishing Service.

Slingerland, B. 1981. *A Multisensory Approach to Language Arts for Specific Language Disability Children.* Cambridge, MA: Educators Publishing Service.

Wiederholt, J. and Bryant, B. 1986. *Gray Oral Reading Tests Revised.* Austin, TX: Pro-ed.

Wise, B., Olson, R., Anstett, M., Andrews, L., Terjak, M., Schneider, V., Kostuch, J., and Kriho, L. 1989. Implementing a long-term computerized remedial reading program with synthetic speech feedback: Hardware, software and real-world issues. *Behavior Research Methods, Instruments, and Computers* 21:173–180.

Wise, B. and Olson, R. 1992. How poor readers and spellers use interactive speech in a computerized spelling program. *Reading and Writing: An interdisciplinary journal* 4:145–163.