The Compensatory Effectiveness of the Quicktionary Reading Pen II on the Reading Comprehension of Students with Learning Disabilities

Eleanor L. Higgins
Marshall H. Raskind
The Frostig Center

The study investigated the compensatory effectiveness of the Quicktionary Reading Pen II (the Reading Pen), a portable device with miniaturized optical character recognition and speech synthesis capabilities. Thirty participants with reading disabilities aged 10-18 were trained on the operation of the technology and given two weeks to practice decoding single words and using various dictionary functions during independent silent reading in the classroom and other settings. Participants were then given a reading comprehension test under the following conditions: (a) reading passages silently using the Reading Pen, and (b) reading passages silently without assistance. Paired sample comparisons revealed significant differences under the two conditions in favor of using the pen ($p<.0001+$). Results are discussed in light of previous research on related technologies.

Over the last decade, the use of optical character recognition (OCR) systems combined with speech synthesis has become increasingly accepted as a means to compensate for reading disabilities. Several products have been developed (e.g., WYNN, Kurzweil 3000) and are now marketed internationally. These OCR systems, or reading machines which convert printed text to spoken language, are commonly found in assistive technology centers serving individuals with learning disabilities (LD) (Higgins & Raskind, 1997), frequently exhibited at LD conferences (Raskind, 1998), generally considered in assistive technology evaluations for students with LD (Bryant & Bryant, 2003; Raskind & Bryant, 2002; LD Online, 2003) and regularly discussed in publications on LD and assistive technology (Day & Edwards, 1997; Higgins & Boone, 1997; Raskind & Bryant, 2002; Raskind & Higgins, 1998a, 1998b). Fortunately, the acceptance of OCR as a viable assistive technology for LD is based on both a strong theoretical framework, as well as several studies directly investigating the technology's efficacy in compensating for the reading difficulties experienced by individuals with LD.

The idea that text-to-speech conversion may facilitate reading comprehension is suggested from research in reading disabilities. Numerous studies have indicated that students with reading disabilities have a particularly difficult time with word recognition, especially phonological decoding skills (Bruck, 1988, 1993; Holligan & Johnston, 1988; Lundberg, Frost & Petersen, 1988; Olson, 1985; Stanovich, 1988; Torgesen, 1994; Wagner & Torgesen, 1987). Several researchers (Daneman & Carpenter, 1980; Lundberg & Leong, 1986; Perfetti, 1975; Swanson, 1992) have suggested that the problems experienced by children with LD in phonological processing negatively impact reading comprehension by overtaxing the immediate cognitive processing mechanism with the decoding task, so that energies are not available to be used by other mental processes necessary for comprehension. Although phonological awareness may be impaired, there is also evidence that individuals with reading disabilities often exhibit no apparent deficit in understanding spoken language (Aaron & Phillips, 1986; Gough & Tunmer, 1986). Considering that persons with LD have difficulty with decoding print, yet may not have difficulty with oral language, it is not difficult to see how OCR systems that convert printed text to the spoken word might enhance reading comprehension.

Further support for the notion that OCR systems may improve comprehension comes from research using speech synthesis to remediate reading difficulties (Leong, 1992; Lundberg, 1995; Torgesen & Barker, 1995), spelling deficits (Wise & Olson, 1992), as well as to enhance writing performance (Meyers, 1992; Raskind & Higgins, 1995). Although the above literature supports the notion that OCR systems may be effective in compensating for reading difficulties, the strongest support comes from those studies that directly investigated the technology. For example, in a study of middle school students with dyslexia, Elkind, Cohen, and Murray (1993) found that most of the children enhanced their reading comprehension scores while using an OCR system. In a subsequent study of adults with reading disabilities, Elkind, Black, and Murray (1996) showed enhanced performance in reading speed and endurance when using OCR as compared to reading unaided. Similarly, Higgins and Raskind (1997) in a study of postsecondary students with LD found that severely disabled readers improved reading comprehension scores when using OCR. In addition, they found an inverse correlation between silent reading without assistance and reading with an OCR system such that the greater the severity of the reading disability the more the technology elevated reading comprehension scores.

Optical character reader systems are generally desktop computers combined with flatbed full-page scanners. Users scan printed documents (e.g., pages from books) in much the same way a copier is used. The printed text is converted to electronic text that is read aloud by an integrated speech synthesizer. The text is displayed on the computer monitor while the system reads the words aloud. As previously suggested, individuals with reading disabilities can bypass their phonological difficulties by hearing the printed word, which may be a more efficient way of comprehending text. These systems often include features that allow the user to customize the system for individual preferences including speech rate, pitch and volume, simultaneous highlighting of spoken text, font size/style, as well as background and text color. These systems may also include additional features such as study, writing, and Internet tools.

Over the last few years, another type of OCR device for persons with reading difficulties has been introduced into the marketplace that differs from the historical desktop systems. This device combines miniaturized OCR with synthetic speech and a liquid crystal display (LCD) in a battery-operated, handheld unit approximately 1" X 3/4" X 6." The device is called the Quicktionary Reading Pen II and is manufactured by WizCom Technologies, Ltd. The unit allows the user to scan printed text either a word or line at a time. Scanned words appear on the screen within 1-3 seconds and are read aloud by a built-in speech synthesizer. Similar to the larger desktop systems, speech rate, volume, and speed may be adjusted.

The introduction of this device offers some intriguing possibilities as a potential compensatory reading tool for persons with LD, particularly in light of the larger existing systems. First of all, the Reading Pen is completely portable (it weighs under 4 ounces) and easily transported from setting to setting (e.g., classroom to classroom, school to home) unlike the desktop units that are tied down to specific locations. The importance of portable technologies for individuals with LD who must function within multiple contexts has been repeatedly stressed (Raskind, 1994; Raskind & Bryant, 2002; Raskind & Scott, 1993). Secondly, at the writing of this paper, the cost of the Reading Pen was approximately $275, considerably lower than the desktop systems that ranged between approximately $1,000 - $2,000. Furthermore, because of its portability, the purchase of one unit is sufficient for multiple settings. Lower costs associated with the provision of assistive technology, is certainly a consideration in special education settings where financial resources are often limited. The importance of cost, and cost/benefit ratio, in the selection of assistive technology for persons with LD has also been emphasized in several publications (Raskind & Bryant, 2002; Raskind & Higgins, 1998(a); Raskind & Scott, 1993). Finally, this handheld technology offers the ability to scan words individually, on an as-needed basis, rather than requiring the scanning of entire portions of text (e.g., paragraph, page, chapter), which may require substantially more time. Furthermore, the desktop systems are designed to, and customarily used to, scan and read aloud connected text, rather than single words. As noted earlier, although research has indicated OCR systems may be helpful for some individuals with reading disabilities, it has also indicated that it may actually interfere with the reading comprehension of others. Higgins and Raskind (1997) found an inverse correlation between silent reading ability and the amount of improvement in reading comprehension scores. In other words, the greater the reading disability the more likely the technology was to help in elevating reading comprehension. This also meant that for less disabled readers the technology actually served to interfere with reading comprehension. The researchers speculated that the reading of every word aloud by means of the speech synthesizer may actually have interfered with comprehension by overly taxing working memory in those readers whose deficits were not as severe. Perhaps this interference effect could be avoided with the Reading Pen, which is primarily designed to read aloud single words, rather than connected text.

Considering that the Reading Pen utilizes the same basic principle of converting printed text to spoken language as the current desktop OCR systems, the authors were interested in determining whether this handheld device would also serve to compensate for the reading deficits of individuals with LD. Specifically, the question was asked as to whether reading comprehension scores would improve when using the technology as compared to reading without the technology. In the event that comprehension scores improved, the researchers were also interested in determining whether the interference effect, represented by the inverse correlation in previous studies, would be present, since this handheld unit would be used to read aloud only single words rather than connected text. It is important to emphasize that the present study was in no way intended as a comparison between desktop and handheld OCR. Clearly, depending on the specific task, individual, and context, one may be more appropriate than the other. (Please see Raskind and Bryant, 2002 for a complete discussion of selecting the appropriate assistive technology for persons with LD). Rather, this study was intended as a first look at the efficacy of a relatively new technology in compensating for the reading difficulties of individuals with LD.

METHOD

Participants

Thirty-four students at the Frostig Center, aged 10-18, participated in the research. The Frostig Center is a private institution in Pasadena, California, offering direct services (a 1st-12th school for students with LD, after-school tutoring for children in the community) and community education on LD, as well as conducting research on persons with LD. The participants, all students at the Frostig School, had been previously identified as having an LD by their public school district or through diagnostic assessment by professionals, and were further screened to meet the criteria agreed upon by the National Joint Committee on Learning Disabilities (1994). They were also identified as having a severe reading disability by scoring 2 years or more below expected grade level in reading comprehension as measured by the Woodcock Johnson Reading Mastery, passage comprehension subtest (Woodcock & Johnson, 1987). Four students decided not to participate in the study, leaving 30 students, who ranged from grades 4 through 12. Four participants had previously used the reading pen briefly, in conjunction with another study 2 years previously. A summary of demographics for the 30 students appears in Table 1. Complete demographics on individual participants appear in Appendix A.

Table 1.
Summary of Demographics

Category	Mean	S.D.	Range
Age	14.22	2.25	10.2-18.5
Full IQ	93.84	13.13	61.00-116.00
Standard Passage Comprehension	75.00	12.04	48.00-93.00

Gender: 10 female, 20 male
Ethnicity: 23 Caucasian, 5 African-American, 2 Hispanic
Socioeconomic Status: 1 Upper, 8 Upper-Middle, 19 Middle-Middle, 2 Lower-Middle

Equipment

The Quicktionary Reading Pen II, manufactured by Wizcom Technologies, Ltd., Version 2.0 was used. It is a portable, handheld scanning device with optical character recognition and speech synthesis capabilities. It is held much like a pen and is guided across printed text; it then converts the text to speech via speech synthesis. Scanned words are shown on a small LCD. It can read up to one full line of text, or can be set to read single words only. It reads text in 6-22 points in a variety of common fonts, colors, and background colors. It has a built in speaker but can also be used with an ear bud or ear phones. Speech rate, tone and volume can be adjusted to individual preferences. Dictionary functions can be employed that give primary and secondary definitions, which can be read silently from the display or aloud by means of speech synthesis. Single words can also be broken into syllables and displayed on the LCD.

Procedures

Training. Students were first trained to use the Reading Pen and then tested in three waves: elementary first, middle school next, and high school students last. Research staff met with 3 or 4 students at a time to complete the following tasks.

1. Customizing Reading Pens on such matters as right/left handed operation and ear bud or headphone volume settings. It was felt that using headphones or ear buds would be preferable to listening to the Reading Pen by moving it up to the ear. By using the ear bud or headphones, the students could see the displayed word and hear the word simultaneously. Although research on the efficacy of multisensory literacy approaches is equivocal (Myers & Hammill, 1982), these approaches have a long history in the field as a strategy for improving the academic difficulties of students with LD (Fernald, 1943; Gillingham & Stillman, 1968; Heckelman, 1969).
2. Training on scanning, obtaining a dictionary definition, and accessing the syllabication feature. Although the researchers did not plan to assess the efficacy of use of the latter features, it was thought that children might find these features useful when using the Reading Pen for independent reading. Training continued until each child could successfully scan 3 single words without error, and could locate and use the dictionary and syllabication features without prompting.
3. Obtaining a signed contract from each child to care for and return the Pens without damage. In all but one case, training was completed in 25 to 30 minutes.

Practice period. Children were then instructed to practice over the following two weeks, using the pens when they did independent reading in class or in the library. It was during this practice period that a 30-minute classroom observation was made in each of the eight classes.

Classroom observation. A member of the research staff visited classes during the language arts period to observe participants in the study, usually 3 or 4 students per class. The researcher was positioned close enough to participants to be able to observe the use of specific features of the device, as well as to record more general classroom behaviors. A Classroom Observation Behavior Checklist form was employed to record the number of times the pen was used, which features were used, and how often, time spent reading, and requests for assistance. The form appears in Appendix B. The research staff also kept anecdotal records of incidents occurring during the training, observation, and testing periods.

Testing. After 2 weeks of practice, children were tested twice using the Formal Reading Inventory (FRI) (Wiederholt, 1986), a test of passage comprehension. This standardized test consists of 13 short reading selections, increasing approximately one grade level per selection in difficulty, with 5 multiple choice comprehension questions for each selection. The nature of the printed format allowed students to refer back to the paragraph or questions at any time. Stories ranged in grade level from 1.3 to 12.0 using the Flesch-Kincaid Grade Level routine available on Microsoft Word 2000. Students progress through the easiest selection and continue until 3 of the 5 questions are incorrect.

Each student was tested once using the Reading Pen to decode unknown words or use the dictionary and syllabication features, and once not using the pen, on successive days. Order of testing conditions (i.e., using the Pen first or last) was randomly assigned. Each test was administered using a different form (A, B, C, D) of the FRI, also randomly assigned. Raw scores were then analyzed using SPSS 8.0 Comparison of Means, Paired Samples routine. Additionally, descriptive statistics were obtained for classroom behavioral observations.

Results

Results of the paired sample test of comparisons of the with—and without—Reading Pen conditions appear in Table 2.

Means of raw score paired differences between the two conditions were statistically significant at the $p < .0001+$ level, and means of standard score paired differences were also significant ($p<.002$). Students obtained on average 7 more correct items using the pen, and jumped 5 standard points. There were no significant correlations between difference scores for age (.123, p=.518), ethnicity (.180, p=.340), gender (.300, p=.107), or teacher (.149, p=.432). In previous research with postsecondary students on the use of OCR and speech synthesis (SS) in reading comprehension of connected text conducted by the authors (Higgins & Raskind, 1997) a significant inverse correlation was found between silent reading comprehension scores without using the assistive technology and amount of difference between scores on the with- and without-technology conditions. Students with low scores on unassisted reading comprehension scores showed the most growth when using assistance while those with relatively high unassisted reading scores showed no growth, or poorer performance when using the speech synthesis. Elkind, Cohen, and Murray (1993) found a similar pattern with the same technology. In the current study an inverse correlation existed but it was not significant (-.338, p=.067).

Table 2.
Results of Paired Sample t-tests

Condition	Raw Scores				Standard Score			
	Mean	Paired Sample *S.D.*	Paired Sample *t-value*	*Sig.*	*Mean*	Paired Sample *S.D.*	Paired Sample *t-value*	*Sig.*
With Reading Pen	23.38	11.4			85.93	9.21		
Without Reading Pen	15.80	10.4	4.487	<.0001+*	80.93	9.97	3.391	002**

*p<.0001+
**p<.005

Results of the eight classroom behavioral observations are listed in Table 3.

Table 3.
Results of Classroom Behavioral Observations

Measure	Mean	Standard Deviation	Range
Minutes of Observation	33.125	3.48	30-40
Number of students with pens	3.75	1.83	1-6
Times scanning a word	16.125	8.74	8-34
Times using dictionary	3.25	2.38	1-8
Times using syllabication	1.5	1.60	0-5
Times needing help scanning	.125	.35	0-1
Times needing trouble-shooting	.25	.46	0-1
Times needing other help from teacher/aide	1.00	1.77	0-5
Times pen interfered with other classroom activities	.125	.35	0-1

The children were, in fact, using the Reading Pen to decode words frequently and to a lesser degree the two features they had been trained to use, the dictionary and syllabication features. According to the data, the use of the Reading Pen did not appear to create distractions for other students, and very little assistance appeared to be necessary from teachers/aides when the pens were in use.

A perusal of anecdotal records taken during training, monitoring, and testing students revealed that most students responded well to the technology, with some being quite enthusiastic. Two students related they had ordered a Reading Pen for themselves to use at home as well as at school. Only one of the 30 participants had any difficulty mastering the technique of scanning and required additional time to reach proficiency. By the time testing began, all students reported they had used the Reading Pen during reading period and across several settings throughout the day for independent reading assignments in the library, and in science and social studies classes. During the classroom observations, several students were motivated to investigate and experiment with the new vocabulary they were seeing/hearing for the first time and engaged in word play, such as rhyming, breaking words into prefixes, roots and suffixes, and relating the word to semantically and phonologically similar words in various ways.

Discussion

The study investigated the compensatory effectiveness of the Reading Pen on students with LD, and specifically with reading disabilities. The statistical analysis revealed significant increases in correct responses to reading comprehension questions. Students not only read the easier selections on the test more accurately, but were able to move on to read more difficult passages with good comprehension. Each selection increased approximately one grade level in difficulty as the child proceeded through each one. On average, the children obtained scores 7 points higher, more than a grade level higher when using the pen.

These results are consistent with other research in assistive technology that demonstrates the positive compensatory effects of certain related technologies such as speech synthesis with OCR (SS/OCR). Higgins and Raskind (1997), as well as Elkind, Cohen, and Murray (1993) have shown that speech synthesis, in combination with optical character recognition, improved comprehension of college students with severe reading deficits. Both studies also found that there was a significant inverse correlation between silent reading score without assistance and amount of improvement in scores when using SS/OCR. Although there was a tendency for the poorer readers to benefit more from technological assistance than proficient readers, the trend did not reach significance as it had in the above two studies. Inspection of scatterplots of difference scores revealed that the performance of the more able readers did not decline as had been found in the earlier desktop SS/OCR study (Higgins & Raskind, 1997).

As mentioned previously, there are differences in the two technologies, and these may well explain the weaker correlation. The participants in the current study were using the equipment to decode single words rather than all of the text as was the case in the above studies. Higgins and Raskind suggested in their study that the continuous auditory input may have interfered with comprehension in able readers. Early research on sub vocalization has indicated that phonological processes are implicated in silent reading comprehension of syntactic structures. Hardyck and Petrinovich (1969, 1970) were able to train subjects to inhibit sub vocalizations, and interestingly, they found that suppression of these sub vocalization muscle movements disrupted the comprehension of difficult, but not simple sentences. Crowder (1982) has suggested that this is evidence that phonological coding may also act as a short-term memory buffer for syntactic processing. Perhaps the brief and occasional auditory interference when using the Reading Pen may have disrupted the comprehension process of the more able readers less than had continuous auditory input.

Finally, as mentioned earlier, several studies suggest that speech synthesis support may be helpful in the remediation of reading (Elkind, Cohen & Murphy, 1993; Leong, 1992; Lundberg, 1995; Torgesen & Barker, 1995) and spelling difficulties in children (Wise & Olson, 1992), as well as enhancing writing performance (Higgins & Raskind, 1995; Meyers, 1992; Raskind & Higgins, 1995). Although the study did not address the remedial effects of use of the Pen, there was anecdotal evidence that long-term effects on reading skills might occur. For example, several times during training and during observations children would engage the researchers in conversations about a new word, and would demonstrate assimilation of it into their vocabulary (e.g., using it spontaneously in a sentence, making up a joke using the word, or relating it to other words they already knew). Over time, the constant exposure to new vocabulary that stimulates this exploratory, analytic behavior could conceivably result in significant improvements in reading vocabulary and affect comprehension positively. Results suggest a longer term research project to measure possible remedial effects may well reveal positive long-term benefits.

In summary, The Quicktionary Reading Pen II was effective in compensating for deficits in the reading comprehension of students with LD, aged 10-18. Students were quickly and easily trained to use the pen, liked using the equipment, and because of its portability, used it across various school settings (e.g., classroom, library, subject matter courses, homework completion). Children used the pens in their classrooms independently with very little adult support or interference with other classroom activities.

Limitations

The study concentrated on upper elementary through high school population of LD students with reading difficulties. The reader is cautioned to avoid generalizing the efficacy values reported here to other chronological ages and grade levels, or to other populations of disabled and non-disabled readers. Further, the demographics of the population in the study may not be typical of other groups. For example, socio-economic status and ethnicity are skewed when compared to the larger Southern California community. The setting in which these participants are taught (i.e., special day class) is also not reflective of what occurs in public school settings in California. The fact that the participants were in class with LD students only may have influenced their inclination to use the device (i.e., they may have been more reluctant to use it in an integrated setting). In addition, since the Frostig Center actively promotes the use of assistive technology by students, the population has had much more experience with using related compensatory devices such as speech synthesis, voice recognition, and word prediction than might be true of students with LD in other settings. This fact may have predisposed participants to readily adopt the

Reading Pen as an additional compensatory technology, whereas another population of students with LD may be more reticent to employ the device. Further, the participants' prior experience with related technologies may have influenced the ease with which they were trained on the device, while students with less experience may have more difficulty.

The findings suggest that the effectiveness of the technology may differ across individuals, which implies that careful assessment of efficacy on an individual level should be conducted and the results clearly communicated to participants and parents so that informed decisions can made about the use and purchase of the technology (Raskind & Bryant, 2002). Further, differences in the effectiveness of a particular technology across tasks have been found in the assistive technology literature. For example, speech synthesis/screen review systems have been applied to the task of proofreading as well as reading comprehension (Raskind & Higgins, 1995). With this study it was found that the technology was equally effective for almost all subjects, not just below average readers or proofreaders. This fact points out that the efficacy of any assistive technology is not only specific to individuals but task specific as well, further underscoring the need for careful, individual assessment across a variety of tasks. Finally, considering the small sample size in the study, readers are cautioned to generalize findings judiciously.

References

Aaron, P.G., & Phillips, S. (1986). A decade of research with dyslexic college students: A summary of findings. *Annals of Dyslexia, 36,* 44-65.

Bruck, M. (1988). The word recognition and spelling of dyslexic children. *Reading Research Quarterly, 23*, 51-69.

Bruck, M. (1993). Component spelling skills of college students with childhood diagnoses of dyslexia. *Learning Disability Quarterly, 16,* 171-185.

Bryant, D.P., & Bryant, B.R. (2003). *Assistive technology for people with disabilities.* Boston, MA: Allyn and Bacon.

Crowder, R.G. (1982). *The psychology of reading: An introduction*. New York: Oxford University Press.

Daneman, M., & Carpenter, P.A. (1980). Individual differences in working memory and reading. *Journal of Experimental Psychology: Human Perception and Performance, 2,* 280-385.

Day, S.L., & Edwards, B.J. (1997). *Assistive technology for postsecondary students with learning disabilities.* In K. Higgins and R. Boone (Eds.), Technology for students with learning disabilities (pp. 191-204). Austin, TX: PRO-ED.

Elkind, J., Black, M.S., & Murray, C. (1996). Computer-based compensation of adult reading disabilities. *Annals of Dyslexia, 46,* 159-186.

Elkind, J., Cohen, K., & Murray, C. (1993). Using computer-based readers to improve reading comprehension of students with dyslexia. *Annals of Dyslexia, 43*, 238-259.

Fernald, G. (1943). Remedial techniques in basic school subjects. New York: McGraw-Hill.

Gillingham, A., & Stillman, B. (1968). *Remedial training for children with specific disability in reading, spelling and penmanship.* Cambridge, MA: Educators Publishing Service.

Gough, P.B., & Tunmer, W.E. (1986). Decoding reading and reading disability. *Remedial and Special Education, 7,* 6-10.

Hardyck, C.D , & Petrinovich, L.F. (1969). Treatment of sub vocal speech during reading. *Journal of Reading, 1*, 1-11.

Hardyck, C.D , & Petrinovich, L.F. (1970). Sub vocal speech and comprehension level as a function of the difficulty level of material. *Journal of Verbal Learning and Verbal Behavior, 9*, 647-652.

Heckelman, R.C. (1969). A neurological impress method of remedial reading. *Academic Therapy, 4*, 277-282.

Higgins, K., & Boone, R. (Eds.) (1997). *Technology for students with learning disabilities.* Austin, TX: PRO-ED, Inc.

Higgins, E.L., & Raskind, M.H. (1995). An investigation of the compensatory effectiveness of speech recognition on the written composition performance of postsecondary students with learning disabilities. *Learning Disability Quarterly, 18*, 159-174.

Higgins, E.L., & Raskind, M.H. (1997). The compensatory effectiveness of optical character recognition/speech synthesis on the reading comprehension of postsecondary students with learning disabilities. *Learning Disabilities: A Multidisciplinary Journal, 8,* 75-87.

Holligan, C., & Johnston, R. (1988). The use of phonological information by good and poor readers in memory and reading tasks. *Memory and Cognition, 6,* 522-532.

Kurzweil 3000® [Computer software]. (1997). Waltham, MA: Kurzweil Educational Systems, Inc.

LD Online. (2003) Retrieved from www.ldonline.org/ld_indepth/techology/technology.html#techeval.

Leong, C.K. (1992). Enhancing reading comprehension with text-to-speech (DECtalk) computer system. *Reading and Writing: An Interdisciplinary Journal, 4,* 205-217.

Lundberg, I. (1995). The computer as a tool for remediation in the special education of reading disabled students: A theory-based approach. *Learning Disability Quarterly, 18,* 89-100.

Lundberg, I., Frost, J., & Petersen, O.P. (1988). Effects of an extensive program for stimulating phonological awareness in preschool children. *Reading Research Quarterly, 23*, 263-284.

Lundberg, I., & Leong, C.K. (1986). Compensation in reading disabilities. In E. Kjelmquist & L. Nilsson (Eds.), P*sychological Compensation and Technical Aids* (pp. 171-190). Piorth-Holland: Elsevier Science Publishers B.V.

Meyers, L.F. (1992). Teach me my language: Teaching children with learning disabilities to link meaning with speech and text. *Writing Notebook: Creative Word Processing In the Classroom, 9*, 44-46.

Microsoft Word 2000©. (2000). Redmond, WA: Microsoft Corporation.

Myers, P.I., & Hammill, D.D. (1982). *Learning disabilities: Basic concepts, assessment practices and instructional strategies.* Austin TX: Pro-Ed.

National Joint Committee on Learning Disabilities (1994). *Collective Perspectives on Issues Affecting Learning Disabilities.* Austin, TX: PRO-ED.

Olson, R.K., (1985). *Disabled reading processes and cognitive profiles.* In D. Gray & J. Kavanagh (Eds.) Biobehavioral measures of dyslexia, (pp. 215-244). Parkton, MD: York Press.

Perfetti, C.A. (1975). Language comprehension and fast decoding: Some psycholinguistic prerequisites for skilled reading comprehension. Paper presented to the Development of Reading Comprehension Seminar of the International Reading Association, Newark, Delaware, July, 1975.

Quicktionary Reading Pen II®. WIZCOM Technologies, LTD. www.wizcomtech.com.

Raskind, M.H. (1994). Assistive technology for adults with learning disabilities: A rationale for use. In P. Gerber & H. Reiff (Eds.) *Learning disabilities in adulthood: Persisting problems and evolving issues* (pp. 152-163). Boston, MA: Andover Medical Publishers.

Raskind, M.H. (1998). Literacy for adults with learning disabilities through assistive technology. In S.A. Vogel and S. Reder (Eds.) *Learning disabilities, literacy and adult education.* Baltimore MD: Brookes.

Raskind, M.H., & Bryant, B.R. (2002). *Functional evaluation for assistive technology: Manual*. Austin, TX: Psycho-Educational Services.

Raskind, M.H., & Higgins, E.L. (1995). The effects of speech synthesis on proofreading efficiency of postsecondary students with learning disabilities. *Learning Disabilities Quarterly. 18*, 141-158.

Raskind, M.H., & Higgins, E.L. (1998a). Technology and learning disabilities: What do we know and where should we go? *Perspectives, 24* (2), 1.

Raskind, M.H., & Higgins, E.L. (1998b). Assistive technology for postsecondary students with learning disabilities: An overview. *Journal of Learning Disabilities, 31,* 27-40.

Raskind, M.H., & Scott, N. (1993). Technology for postsecondary students with learning disabilities. In S.A. Vogel & P.B. Adelman (Eds.), *Success for postsecondary students with learning disabilities* (pp. 240-279). New York: Springer-Verlag.

Stanovich, K.E. (1988). Explaining the differences between the dyslexic and garden-variety poor readers: The phonological-covariable-difference model. *Journal of Learning Disabilities, 21*, 590-612.

Swanson, H.L. (1992). Generality and modifiability of working memory among skilled and less skilled readers. *Journal of Education Psychology, 84*, 473-488.

Torgesen, J.K. (1994). A longitudinal study of early intervention in phonological awareness. *Journal of Learning Disabilities, 27*, 276-286.

Torgesen, J.K., & Barker, T.A. (1995). Computers as aids in the prevention and remediation of reading disabilities. *Learning Disability Quarterly, 18*,

Wagner, R., & Torgesen, J.K. (1987). The nature of phonological processing and its causal role in the acquisition of reading skills. *Psychological Review, 101*, 192-212.

Wiederholt, J.L. (1986). *Formal Reading Inventory.* Austin, TX: PRO-ED.

Wise, B.W., & Olson, R.K. (1992). How poor readers and spellers use interactive speech in a computerized spelling program. *Reading and Writing: An Interdisciplinary Journal, 4*, 145-163.

Woodcock, R.W., & Johnson, M.B. (1987). *Woodcock Johnson reading mastery test-revised.* Circle Pines, MN: American Guidance Service

WYNN® [Computer software]. (1998). Sunnyvale, CA: Arkenstone, Inc.

Eleanor L. Higgins is Associate Director of Research at the Frostig Center. Marshall H. Raskind is Director of Research at the Frostig Center. Address correspondence to Eleanor Higgins, Frostig Center, 971 N. Altadena Drive, Pasadena, CA, 91107. Email to Higgins@frostig.org.

Appendix A
Demographics for Individual Participants

Participant	Gender	Age	Ethnicity	Socioeconomic Status	Full Scale IQ	Overall Academic Achievement (grade equiv.)	Specific Academic Achievement (grade equiv.) Reading	Math	Grade Level
1	female	11.6	Caucasian	upper	93	2.2	2.0	2.5	5
2	female	10.3	Caucasian	middle	116	5.2			5
3	male	11.4	Caucasian	middle	94	1.9	<1.0	3.1	5
4	male	10.2	Caucasian	upper middle	104	4.4	3.4	5.4	4
5	female	11.7	Af-American	lower middle	"avg range"	3.4	3.4	3.2	5
6	male	12.6	Hispanic	middle	"avg range"				6
7	male	12.6	Caucasian	middle	96	3.3	3.0	3.6	7
8	male	12.6	Caucasian	middle	88	4.8	5.6	4.8	6
9	male	12.9	Caucasian	upper middle	87	3.1	3.4	3.1	5
10	male	13.9	Caucasian	middle	90	4.5	5.2	4.8	8
11	male	15.3	Caucasian	middle	89	4.9	6.5	4.9	8
12	male	14.9	Caucasian	middle	93	4.0	6.5	7.1	8
13	male	13.2	Caucasian	middle	98	5.3	5.1	4.2	7
14	female	13.5	Caucasian	middle	88	5.0	4.0	6.8	7
15	male	13.5	Caucasian	middle	103	4.0	4.0	4.9	7
16	male	13.3	Caucasian	upper middle	105	2.8	2.6	2.9	7
17	male	14.0	Caucasian	upper middle	100	4.5	4.3	6.3	8
18	male	14.2	Caucasian	middle	79	3.1	4.7	2.5	9
19	female	13.7	Caucasian	upper middle	"avg range"				7
20	female	13.3	Caucasian	middle	"avg range"	3.4	3.5	3.4	8
21	female	15.0	Caucasian	middle	"avg range"				8
22	female	16.2	Caucasian	upper middle	110	4.1	5.1	3.3	10
23	female	16.0	Hispanic	middle	"low avg range"	5.9	5.8	8.3	10
24	female	17.9	Af-American	middle	"avg range"				11
25	male	17.2	Caucasian	upper middle	"avg range"	3.2	3.3	3.7	11
26	male	14.8	Af-American	lower middle	84	7.3	5.7	7.7	9
27	male	18.5	Caucasian	middle	104	4.3	3.7	4.5	11
28	male	16.7	Af-American	middle	"low avg range"	5.8	6.0	7.4	11
29	male	17.4	Caucasian	upper middle	101	4.3	5.2	5.0	11
30	male	17.2	Af-American	middle	61	5.1	3.7	6.8	11

Appendix A (continued)
Demographics for Individual Participants

Participant	Level of Special Ed. Placement	Time in Special Ed. (years)	Geographic Location
1	Special Day Class		Southern California
2	Special Day Class	2	Southern California
3	Special Day Class	3	Southern California
4	Special Day Class	.5	Southern California
5	Special Day Class	1	Southern California
6	Special Day Class	2	Southern California
7	Special Day Class	1	Northern California
8	Special Day Class	2	Southern California
9	Special Day Class	2	Southern California
10	Special Day Class	.5	Southern California
11	Special Day Class	1	Southern California
12	Special Day Class	4	Southern California
13	Special Day Class	3	Southern California
14	Special Day Class	1	Southern California
15	Special Day Class	4	Southern California
16	Special Day Class	2	Southern California
17	Dual Enrolled	.5	Southern California
18	Special Day Class	2	Southern California
19	Special Day Class	1	Southern California
20	Special Day Class	2	Southern California
21	Special Day Class	2	Southern California
22	Special Day Class	.5	Southern California
23	Dual Enrolled	8	Southern California
24	Special Day Class	6	Southern California
25	Special Day Class	5	Southern California
26	Special Day Class	1	Southern California
27	Special Day Class	4	Southern California
28	Special Day Class	2	Southern California
29	Special Day Class	4	Southern California
30	Special Day Class	8	Southern California

Appendix B
Classroom Observation Behavioral Checklist

Date________

Minutes of Observation____

Number of students with pens ____

Times scanning a word ____

Times using dictionary____

Times using syllabication____

Times needing help scanning ____

Times needing trouble-shooting ____

Times needing other help from teacher/aide ____