The Efficacy of Computer-Based Supplementary Phonics Programs for Advancing Reading Skills in At-Risk Elementary Students*

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Abstract
In this study we examined the benefits of computer programs designed to supplement regular reading instruction in an urban public school system. The programs provide systematic exercises for mastering word-attack strategies. Our findings indicate that first graders who participated in the programs made significant reading gains over the school year. Their post-test scores were slightly (but not significantly) greater than the post-test scores of control children who received regular reading instruction without the programs. When analyses were restricted to low-performing children eligible for Title I services, significantly higher post-test scores were obtained by the treatment group compared to the control group. At post-test Title I children in the treatment group performed at levels similar to non-Title I students.

The process of reading involves two separate but interrelated abilities: word recognition and comprehension. Word recognition includes not only mastery of sound-symbol correspondences and phonic word-attack strategies, but also the ability to apply these skills quickly and effortlessly so that recognizing words becomes automatic. Difficulties in automatic word recognition negatively affect reading fluency and comprehension (Perfetti & Lesgold, 1979; Stanovich, 1980). Educators, reading specialists and psycholinguists have emphasized the importance of mastering word-attack strategies to advance automatic word recognition for decades. The National Research Council's report, *Preventing Reading Difficulties in Young Children* (Snow, Burns & Griffin, 1998) has concluded that explicit phonics instruction promotes reading development (see also Adams, 1990; Chall, 1983; Leong, 1991; McGuinness, 1997).

More specifically, it has been recognized that the development of phonological awareness is crucial for learning phonic word-attack strategies (Adams, 1990; Liberman & Shankweiler, 1985; Share & Stanovich, 1995; Wagner & Torgesen, 1987). Phonological awareness requires the ability to analyze the sound structure of spoken language. It includes the ability to segment words into sounds (phonemic analysis) and to blend these sounds back into words (phonemic synthesis). Current research suggests that instructional reading approaches that incorporate phonological awareness training in conjunction with explicit phonics instruction should be encouraged (e.g., Ehri, 2004; Hatcher, Hulme & Ellis, 1994). The *Report of the National Reading Panel* (National Institute of Child Health and Human Development [NICHD], 2000) included phonemic awareness and phonics instruction as two of the five components necessary for balanced reading instruction, equally important to vocabulary, fluency and comprehension. Although children typically begin to develop phonological awareness skills by the time they enter school, some fail to master these skills even after years of basic reading instruction. These children often experience significant difficulties learning to read. For them phonological awareness and phonics skills must be taught in a structured, systematic way (Bus & van Ijzendoorn, 1999; McGuinness, 1997).

In this report we discuss the findings of an intervention study aimed to facilitate the acquisition of word recognition skills in young

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readers. The intervention programs called *Phonics Based Reading* (PBR) and *Strategies for Older Students* (S.O.S.) (Lexia Learning Systems, 2001) are forms of computer assisted instruction (CAI) designed to supplement classroom instruction. The programs contain numerous activities that support learning and application of phonic word-attack strategies at the letter, word, sentence and paragraph levels to enhance automaticity in word recognition.

There have been a number of studies investigating the use of CAI to aid reading instruction (for reviews, see Blok, Oostdam, Otter & Overmaat, 2002; MacArthur, Ferretti, Okolo & Cavalier, 2001). In general, CAI is particularly well suited for providing supplementary instruction in reading. Computers are capable of presenting activities that are interesting and motivational -- using lively graphics, feedback and positive reinforcement. Students may work at their own pace and receive extensive practice to help build automaticity.

A common approach employed in early CAI was for the computer program to provide (synthetic) speech feedback when students encountered difficult words in reading text. The most extensive work in this area has been conducted by Wise and colleagues (e.g., Olson & Wise, 1992; Wise, Olson, Ring & Johnson, 1998). They found some gains in word identification skills for children exposed to speech feedback; however, they indicated that for children with significant reading problems, explicit training in phonological awareness (coupled with speech feedback) is more beneficial than providing speech feedback alone (Wise et al., 1998).

A number of CAI programs have explicitly targeted phonological awareness skills. For instance, Foster, Erickson, Forster, Brinkman and Torgesen (1994) discuss the programs *Daisy Quest* and *Daisy's Castle*, which provide activities in which children practice identifying phonemes and segmenting words into phonemes. Foster et al. reported significant gains in phonological awareness skills in preschool children and kindergarteners following use of these programs. In a subsequent study by Torgesen and Barker (1995), practice with the *Daisy Quest* and *Daisy's Castle* programs were shown to lead to significant improvements in word reading skills in first graders. Results similar to Torgesen and Barker's were obtained in an earlier study by Roth and Beck (1987) using the *Hint and Hunt* and *Construct a Word* programs. These programs include both phonological awareness activities and practice learning sound-symbol correspondences. More recently, Mitchell and Fox (2001) reported significant gains in a variety of phonological processing skills (reading was not tested) in kindergarten and first grade children who participated in the *Daisy Quest* and *Daisy's Castle* programs.

One of the most comprehensive studies of CAI for reading was conducted by Wise, Ring and Olson (2000). They contrasted the benefits of two types of CAI programs in enhancing reading skills in 200 elementary grade students. Their "phonological-analysis" condition included practice manipulating sound/letter patterns, matching sounds to nonwords, and identifying articulatory gestures for speech sounds; various spelling exercises using words and nonwords were also provided. The second condition called "accurate-reading-in-context" mainly focused on providing strategies for reading comprehension. Children in both conditions received corrective speech feedback in the context of reading stories aloud. Wise et al. (2000) found that "phonological-analysis" was more beneficial than "accurate-reading-in-context," particularly when examining untimed reading of words and nonwords. They also found gains in reading to be a function of initial reading levels, with lower readers showing the most benefit from "phonological-analysis" training.

The present study examines the efficacy of CAI programs designed by Lexia Learning Systems to supplement reading instruction in an urban public school system. The PBR and S.O.S. programs were designed to provide intensive, structured and systematic practice in learning and applying word-attack strategies to improve word recognition skills. Phonological awareness was taught in conjunction with these phonic word attack strategies. The programs incorporate many

of the beneficial elements of CAI. The activities make use of visual graphics and are highly interactive, often requiring timed motor responses followed by immediate feedback. Students can work to improve their time through repetition of the same activity. The activities branch automatically based on the student's individual performance, reviewing when necessary and moving to more advanced items when easier ones have been mastered.

In this study we compared the reading performance of a large sample of first graders using the Lexia programs with control students receiving similar classroom instruction but without Lexia use. For this sample a separate set of analyses was conducted for low performing students eligible for Title I services. (Note: Title I services refer to additional academic support provided to low-achieving children.)

METHOD

Participants: Ten first grade classes were selected for participation in this experiment. The classes were located in five urban elementary schools in a greater Boston school district. One class in each school was assigned to the experimental (treatment) group and a second class to the control group. There were 92 students (52 male, 40 female) in the treatment group and 87 students (43 male, 44 female) in the control group. The mean age of students in the treatment group was 80.5 months (sd = 4.6), and the mean age for the control group was 80.2 months (sd = 4.3). The students came from diverse socio-cultural backgrounds. Twenty-one percent of the families in the school district were foreign born and 29% spoke a language other than English at home. Economic data reflect the city's relative lack of prosperity. The median household income of $37,000 was well below the median level in Massachusetts (approximately $50,000). Over 50 percent of students qualified for free or reduced lunch.

Nine students in the treatment group and three students in the control group were eligible for special education (SPED) services. Given the uneven number of SPED students in the two groups, these students were excluded from the sample. The remaining sample consisted of 83 students (46 male, 37 female) in the treatment group and 84 students (41 male, 43 female) in the control group. Fifteen students in each group were Title I eligible. These students were identified as "at risk" by their teachers given their performance on a number of classroom activities (e.g., picture/object vocabulary, recognizes letters). In addition, one student in each group was classified as an English as a Second Language (ESL) student.

Materials and Procedures: All treatment and control classes were engaged in daily reading instruction using some form of explicit phonics instruction based on *Scott Foresman Reading* (McFall, 2000) and/or *Bradley Reading and Language Arts* (Bradley, 1999). *Scott Foresman Reading* is a comprehensive reading program that includes activities in phonemic awareness, fluency, vocabulary and comprehension. It contains teaching resources, assessment handbooks, student storybooks, writing materials and manipulatives. *Bradley Reading and Language Arts* is a multi-sensory, systematic, explicit phonics program. Teachers for both treatment and control classes reported between 30 – 60 minutes per day of phonics instruction. Teachers for the treatment classes averaged 19 years of teaching experience (range: 1 – 35), and teachers in the control classes averaged 18 years of teaching experience (range: 1 – 33). Students eligible for Title I services received an additional 30 minutes per day of academic instruction with a Title I staff member.

The PBR and S.O.S. programs were installed on the networks in each school building and mapped to individual classroom and laboratory stations. Nearly all of the program use occurred in laboratory set-ups. Teachers in the treatment classes and computer lab staff members took part in orientation and training sessions for software implementation. The software is designed for regular weekly use (two to four weekly sessions of 20-30 minutes each). PBR has three levels, 17 skill activities, and 174 discrete units. Initial levels are selected by the teacher and then children work independently through the activities. Multi-sensory activities include

auditory/visual matching (e.g., natural speech sounds and letters) and tactile/kinesthetic (i.e., motor) responses. The activities are highly structured and systematic, building from the simplest concepts to more sophisticated strategies. The focus of each activity is on direct reinforcement of specific rules related to word-attack strategies (e.g., rules for closed syllables). The programs include activities in which word-attack strategies are applied to words in isolation as well as in contextual materials (sentences and paragraphs). Once the PBR activities were finished, children were introduced to S.O.S. activities. This advanced program contains five levels with 24 skill activities and 369 discrete units. Children in this study mainly worked on early levels of S.O.S., which build on their knowledge of phonics skills.

The treatment classes used Lexia software for approximately six months. The software tracks sessions and records skill units completed for each student. The mean number of sessions completed was 64, with a range: 37 – 91 sessions. Children took part in varying numbers of sessions mainly due to scheduling discrepancies across classrooms in the different schools. The mean number of skill units completed was 140 (range: 45 - 324). The vast majority of students worked on PBR activities exclusively. Only 14 of the 83 students in the treatment group moved on to S.O.S. activities. During the time when students in the treatment classes were participating in the Lexia programs, students in the control classes were receiving regular classroom instruction.

The *Gates-MacGinitie Reading Test, Level BR* (W. MacGinitie, R. MacGinitie, Maria, & Dreyer, 2000) was used to assess reading performance. Level BR contains four subtests – letter-sound correspondences for initial consonants and consonant clusters, letter-sound correspondences for final consonants and consonant clusters, letter-sound correspondences for vowels, and recognizing basic story words. Dependent measures included raw scores for each subtest and a normal curve equivalent (NCE) score based on the total raw score. (Note: NCE scores are on a 100 point scale with a mean of 50 and a standard deviation of 21.1.) Pretest scores were collected in November, 2001, prior to the onset of Lexia use in the treatment classrooms. The test was re-administered in June, 2002, following completion of Lexia use for the school year. The latter assessment served as a post-test.

RESULTS

Two sets of analyses were conducted. The first considered all students in the treatment and control groups. A second analysis was restricted to Title I students. A separate analysis was not conducted for ESL students (one in each group).

All students. Table 1 presents the mean pretest and post-test NCE scores for all students in the treatment and control groups. The treatment group had lower pretest scores than the control group, but the difference was not significant ($t(165) = 1.0$, $p = .34$). Students in both groups made significant gains from pretest to post-test (treatment: $t(82) = 10.2$, $p < .01$; control: $t(83) = 8.1$, $p < .01$). An analysis of covariance comparing post-test scores for the two groups using pretest scores as a covariate revealed no significant group difference, $F(1,176) = 2.3$, $p = .13$.

Table 1. Mean NCE scores on the *Gates-MacGinitie Reading Test* for all students.

	Treatment (N=83)		Control (N=84)	
	Mean	SD	Mean	SD
Pretest	46.6	16.8	49.0	15.9
Post-test	62.7	19.8	61.4	20.3

Title I students. A separate analysis was conducted for Title I students (see Table 2). The pretest scores for the treatment and control groups were not significantly different ($t(28) = .9$, $p = .38$). Both groups made significant gains from pretest to post-test (treatment: $t(14) = 7.8$, $p < .01$; control: $t(14) = 3.7$, $p < .01$). However, an analysis of covariance comparing post-test scores for the two groups (with pretest scores as a covariate) indicated a significant difference favoring the treatment group, $F(1,27) = 6.0$, $p = .02$.

Table 2. Mean NCE scores on the *Gates-MacGinitie Reading Test* for Title I students.

	Treatment (N=15)		Control (N=15)	
	Mean	SD	Mean	SD
Pretest	34.3	9.8	37.6	10.8
Post-test	59.8	17.4	52.0	21.2

A second set of analyses was conducted for Title I students examining performance on the four subtests of the *Gates-MacGinitie Reading Test* (see Table 3). Raw scores on the three subtests that assess knowledge of letter-sound correspondences (initial consonants and consonant clusters, final consonants and consonant clusters, vowels) were summed together in this analysis. There was no significant difference between treatment and control group on pretest scores for letter-sound correspondences, $t(28) = 0.5$, $p = .61$. However, an analysis of covariance comparing post-test scores (with pretest scores as a covariate) showed a significant difference favoring the treatment group, $F(1,27) = 6.1$, $p = .02$. For the basic story words subtest, there was no significant difference between groups on pretest scores, $t(28) = 1.2$, $p = .25$. An analysis of covariance showed no significant difference between groups at post-test, $F(1,27) = 1.9$, $p = .18$.

Table 3. Mean subtest raw scores on the *Gates-MacGinitie Reading Test* for Title I students.

Letter-Sound Correspondences (45 items)[a]	Treatment (N=15)		Control (N=15)	
	Mean	SD	Mean	SD
Pretest	18.7	4.7	19.7	5.9
Post-test	39.3	5.2	35.3	8.9
Basic Story Words (25 items)				
	Treatment (N=15)		Control (N=15)	
	Mean	SD	Mean	SD
Pretest	11.1	3.5	12.7	3.7
Post-test	22.8	3.6	21.9	4.4

a. Raw scores for letter-sound correspondences are summed scores for the three subtests – initial consonants and consonant clusters, final consonants and consonant clusters, and vowels.

Figure 1 presents comparisons of Title I students with students not eligible for Title I services (non-Title I students). Figure 1a compares the Title I treatment group with the non-Title I treatment group. An analysis of variance revealed a significant interaction between treatment group and pre- and post-test scores, $F(1,90) = 10.3$, $p < .01$. Post-hoc t-tests showed that at pretest, the Title I treatment group performed significantly below the non-Title I treatment group, $t(90) = 2.9$, $p < .01$. However, the post-test scores for the Title I treatment group did not differ from the post-test scores for the non-Title I treatment group, $t(90) = .1$, $p = 89$. A different pattern emerged when the Title I control group was compared to the non-Title I control group, as shown in Figure 1b. No significant interaction was found between control group and pre- and post-test scores, $F(1,85) = .1$, $p = .74$. The Title I control group performed significantly below the non-Title I control group both at pretest ($t(85) = 3.4$, $p < .01$) and at post-test ($t(85) = 2.3$, $p = .02$).

Figure 1a. Mean NCE pretest and post-test scores for students in the treatment group (non-Title I, Title I)

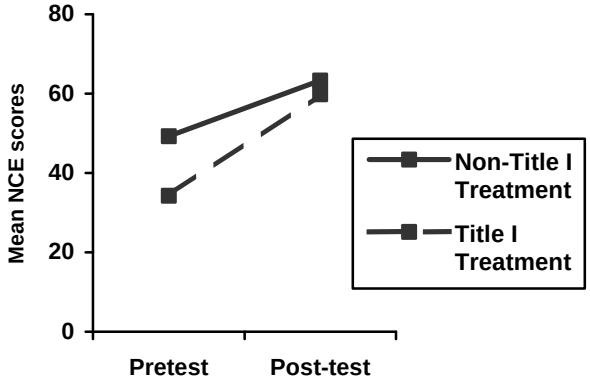
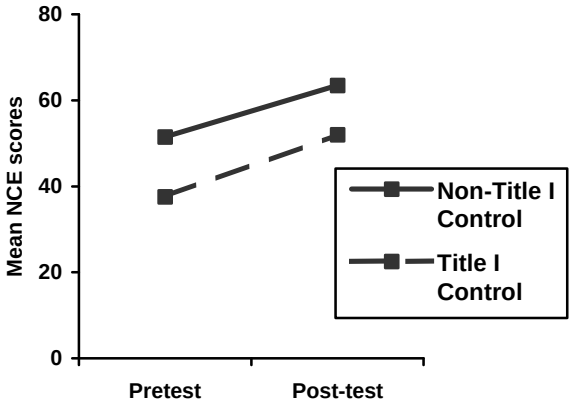
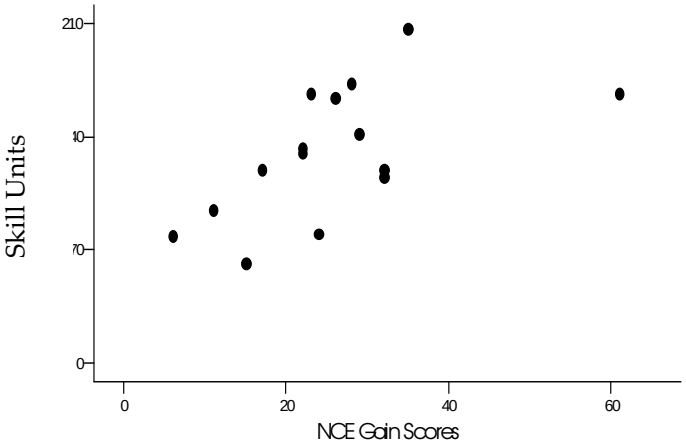


Figure 1b. Mean NCE pretest and post-test scores for students in the control group (non-Title I, Title I).



A correlation analysis was conducted to examine the relationship between NCE gain scores (post-test scores minus pretest scores) and completion of skill units for Title I students in the treatment group. The correlation is .60, p = .02 (see Figure 2). In other words, the Title I students who completed the most skill units showed the greatest gains in their reading performance.

Figure 2. Scatterplot showing the relationship between NCE gain scores and number of skill units completed by Title I students in the treatment group.



DISCUSSION

This study examined the benefits of two CAI programs designed to supplement regular classroom curriculum in an urban public school system. The programs provide systematic and structured exercises for mastering phonic word-attack strategies. Initial results showed that, overall, both treatment and control students in the first grade made significant gains in reading. The post-test scores of children in the treatment group were somewhat higher than the post-test scores of children in the control group but the difference between groups was not significant. Subsequent analyses revealed, however, that when students eligible for Title I services were examined separately, they showed particular benefits from participation in the treatment program. The post-test scores of Title I students in the treatment group were significantly greater than the post-test scores of Title I students in the control group. In fact, Title I students in the treatment group improved so much that they caught up to the non-Title I students at post-test. It was also determined that the degree of success in completing Lexia activities is related to reading gains in the Title I students. These results are consistent with the findings of Wise et al. (2000) showing that intensive phonics-based CAI can be quite beneficial to low performers in the early grades.

An examination of post-test performance on the *Gates-MacGinitie Reading Test* revealed a significant difference between Title I treatment and control groups on the subtests measuring knowledge of letter-sound correspondences (initial consonants and consonant clusters, final consonants and consonant clusters, vowels). Together, these subtests require children to match a target letter, letter cluster or printed word to a picture with a name that contains the sounds corresponding to the letter(s) or word. Gains in acquiring these skills are expected given the systematic emphasis on developing phonic word-attack strategies in the CAI programs.

The finding that Title I students in the treatment group outperformed Title I students in the control group is rather striking given that all first grade children were receiving highly systematic, phonics-based reading instruction as part of their general curriculum. The success of the school district's curriculum is evident in the significant improvements in post-test scores made by

children in both groups. Given that the reading scores are based on standardized norms, significantly higher post-test scores compared to pretest scores indicates that students in both groups were progressing faster than expected based on the norms. Students in these schools were receiving appropriate instructional programs allowing them to show substantial advancements in reading over the school year. However, participation in the supplementary CAI programs provided an additional advantage for the Title I children, allowing them to catch up to the non-Title I children while the Title I control group did not. This finding highlights the fact that well-structured CAI programs can deliver the kind of systematic, intensive practice required for low performers to learn word-attack strategies. The opportunity for extensive review through self-paced activities, tailored to the individual student with immediate feedback, allows struggling readers to progress further than children not given this opportunity.

Researchers have often noted that non-CAI supplementary reading programs often fail to produce significant gains when performance of the most severely impaired readers is examined. For instance, Torgesen, Wagner and Rashotte (1997) reported that their phonological awareness and phonics-based training programs were largely ineffective in improving the reading skills of the lowest performing kindergarten children following 88 hours of one-on-one treatment extended over a two and one-half year period. The authors concluded that extremely low performing children require more intensive instruction in order to make progress in reading. In later studies, Torgesen and his colleagues were able to demonstrate significant gains in low-performers when they were provided with highly intensive, individualized phonics-based instruction (see Torgesen, 2004). Additional research is needed to determine if CAI programs like Lexia's can be adapted to provide the intensive practice necessary for even the lowest performing children to make strides in reading.

To gain a sense of the teachers' perceptions about the effectiveness of CAI, we administered an informal survey to four of the five teachers in the treatment group. Given the importance of motivation in effective learning, we included six items addressing motivation (e.g., *The software program holds student attention and keeps him/her on task*). Based on a 10-point rating scale, a mean rating of 8.5 was obtained for these items. As pointed out by Malone (1980) and Lundberg (1985), game-like activities and the interactive nature of CAI provide motivational tools for learning. It appears that motivational factors helped support skill acquisition, thus contributing to the success of CAI in this study. Remaining items on the survey addressed four areas: instructional content, instructional design, ease of use, and management of the programs. The ratings in these areas were uniformly high (mean ratings of 8.8, 8.8, 9.0, and 8.4, respectively). As one teacher wrote, "I would give the Lexia program a favorable rating. The class enjoyed coming. They knew how to use the program independently and it allowed each child to progress at his/her own ability level." In summary, teachers reported high levels of satisfaction with the CAI programs.

At the present time we are in the process of extending this research project in the same public school system, as well as in Boston and Chicago public schools. The programs are being implemented with children from kindergarten to grade 4 covering approximately 35 classrooms and over 700 students. The effectiveness of the programs will be investigated for children of diverse backgrounds and ability levels, and exposed to a wide range of reading curricula.

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Robert McCabe is the Director of Research and Product Management at Lexia Learning Systems, which published the software used in this intervention study. Pamela Hook served as consultant in the design of the Lexia programs, and Paul Macaruso served as a consultant for data analysis and manuscript development.

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Paul Macaruso is an assistant professor of psychology at the Community College of Rhode Island. He is also a research scientist affiliated with Haskins Laboratories, New Haven, CT, and an adjunct faculty member in the Communication Sciences and Disorders program at the MGH Institute of Health Professions. He has published numerous research articles in the areas of developmental and acquired disorders of reading, writing and number processing.

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Robert McCabe is Director of Research for Lexia Learning Systems, Inc. He is responsible for the coordination of the company's research efforts including site selection, training, implementation, data collection, and analyses. He has led school-based community service, training and research programs for the past 14 years.

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