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THE EFFICACY OF COMPUTER-ASSISTED INSTRUCTION FOR ADVANCING LITERACY SKILLS IN KINDERGARTEN CHILDREN

PAUL MACARUSO

Community College of Rhode Island, Lincoln, Rhode Island, USA

ADELAIDE WALKER

Harvard Graduate School of Education,
Cambridge, Massachusettes, USA

We examined the benefits of computer-assisted instruction (CAI) as a supplement to a phonics-based reading curriculum for kindergartners in an urban public school system. The CAI program provides systematic exercises in phonological awareness and letter–sound correspondences. Comparisons were made between children in classes receiving a sufficient amount of CAI support and children in matched classes taught by the same teacher but without CAI. The treatment and control groups did not differ on pretest measures of preliteracy skills. There were, however, significant differences between groups on posttest measures of phonological awareness skills particularly for students with the lowest pretest scores.

According to *The Nation's Report Card: Reading 2002* (Grigg, Daane, Jin, & Campbell, 2003), more than 50% of students in the United States today score below grade level on tests of reading (Sweet, 2004). To address this "literacy crisis," the National Reading Council report, *Preventing Reading Difficulties in Young Children* (Snow, Burns, & Griffin, 1998) strongly recommended that early reading instruction should be geared to the development of phonic word-attack strategies. A key component in building phonics skills is phonological awareness or the ability to analyze the sound structure of spoken language (Adams, 1990; Liberman & Shankweiler, 1985; Share & Stanovich, 1995; Wagner & Torgesen, 1987). In particular, it includes the ability to segment words into syllables and smaller sound units, as well as to blend these units back into words. Facility in processing sound units in spoken language

Address correspondence to Paul Macaruso, Department of Psychology, Community College of Rhode Island, 1762 Louisquisset Pike, Lincoln, RI 02865. E-mail: pmacaruso@ccri.edu

provides a foundation for mastery of letter–sound correspondence rules employed in identifying words in print. In many instances, typically developing children will readily acquire both phonological awareness and phonics skills in the context of regular classroom instruction; however, in the case of young struggling readers, a more intense effort to build these skills is necessary to prevent continued decline as the student ages (Torgesen, 2004).

Phonological Awareness Training

A number of researchers have investigated the efficacy of training phonological awareness on acquisition of literacy skills in children (for meta-analyses, see Bus & van Ijzendoorn, 1999; Ehri et al., 2001). The general finding is that training in phonological awareness can provide benefits in the acquisition of early literacy skills (Report of the National Reading Panel, 2000). For example, in a study with kindergartners, Torgesen, Morgan, and Davis (1992) divided their participants into three groups—one received practice in sound blending, a second received practice in sound segmenting and blending, and a third received no explicit phonological training. Improvements in the targeted phonological awareness skills were found in both training groups; in addition, participants in the segmenting and blending group learned to read a novel set of words at a faster rate than children in the no-training group (see also Brady, Fowler, & Stone, 1994; Lundberg, Frost, & Petersen, 1988).

From their meta-analysis, Bus and van Ijzendoorn (1999) concluded that phonological awareness training is particularly beneficial for young readers when combined with instruction in phonic word-attack strategies. For instance, Ball and Blachman (1991) provided instruction in phonological awareness (segmenting words into phonemes) and simple phonics (basic letter–sound correspondences) to a group of kindergartners. After instruction, these children performed significantly higher on a word reading test than kindergartners who worked on general language activities and phonics (without phonological awareness). Similar findings were obtained in a recent large-scale study with kindergartners (and pre-kindergartners) conducted by Hatcher, Hulme, and Snowling (2004). They reported significant benefits in reading words and non-words following classroom instruction in phoneme manipulation and phonics. Children receiving phoneme manipulation plus phonics outperformed children receiving phonics alone. Hatcher et al. (2004) noted, however, that the benefits of phonics plus phoneme manipulation occurred for low-performing children only. Average to above-average performers showed strong benefits from phonics alone.

Computer-Assisted Instruction

A number of researchers have studied the benefits of computer-assisted instruction (CAI) to support reading development in low performing children (for review, see MacArthur, Ferretti, Okolo, & Cavalier, 2001). In general, CAI is well suited as a supplementary aid to direct reading instruction. Computers are capable of presenting activities that are interesting and motivating to children—including the use of pictorial displays and positive feedback. Children can work at their own pace and receive enough practice to support word recognition skills and eventually fluent text reading.

Many of the CAI programs have targeted phonological awareness skills. Two of the more popular programs are *Daisy Quest* and *Daisy's Castle* (Foster, Erickson, Forster, Brinkman, & Torgesen, 1994). These programs provide activities in sound identification and segmentation of words into sounds. Foster et al. reported that preschoolers and kindergartners receiving CAI showed significant gains in phonological awareness skills compared to children not receiving CAI support. In a subsequent study, Torgesen and Barker (1995) found that practice with *Daisy Quest* and *Daisy's Castle* led to significant improvements in phonological awareness and word reading skills in first graders identified as lagging behind their peers in decoding abilities. More recently, Mitchell and Fox (2001) reported significant and comparable gains on phonological processing tasks in two groups of low-performing kindergartners and first graders, one group received teacher-delivered phonological awareness training and the second group used *Daisy Quest* and *Daisy's Castle.* Similar benefits of CAI as a tool for learning phonological awareness and letter–sound correspondences in support of reading instruction have been found for Dutch-speaking kindergartners (Reitsma & Wesseling, 1998; Segers & Verhoeven, 2005; van Daal & Reitsma, 2000) and for children learning to read Hebrew (Mioduser, Tur-Kaspa, & Leitner, 2000).

In a comprehensive study involving 200 elementary students identified as poor readers, Wise, Ring, and Olson (2000) contrasted two CAI programs for enhancing reading skills—"phonological-analysis," which included practice identifying sounds in non-words and manipulating sound/letter patterns, and "accurate-reading-in-context," which mainly focused on learning strategies for reading comprehension. Overall, Wise et al. found that "phonological-analysis" provided greater benefits in phonological awareness skills and untimed word reading than "accurate-reading-in-context," particularly for children who had the lowest initial reading levels.

Although most published studies report benefits of CAI for reading acquisition, a recent study by Paterson, Henry, O'Quin, Ceprano, and Blue (2003) failed to find support for CAI. Paterson et al. investigated the effectiveness of the Waterford Early Reading Program, Level 1 (WERP-1) in kindergarten classes from an urban public school system. WERP-1 provides practice in rhyming, sound segmenting and blending, alphabet skills, and concepts of print. Using data from an observational survey of early literacy skills, Paterson et al. reported no differences between students in treatment classes and students in control classes. Instead, variables measuring teacher performance such as "literacy facilitation" and "instructional time" were associated with differences in classroom performance (see also Weiner, 1994).

Unlike Paterson et al., other studies have reported significant benefits of WERP-1 in early elementary grades. Hecht and Close (2002) found that kindergartners in classes using WERP-1 obtained higher scores in phonological awareness and word reading than kindergartners in control classes. They noted wide variations among students in amount of time using the software and that benefits were restricted to students with strong use patterns. Like Hecht and Close, Cassady and Smith (2004) found significant benefits of WERP-1 in kindergarten classes. Most recently, Cassady and Smith (2005) reported benefits of WERP-1 for first graders. They found that gains in reading were the greatest when analyses were restricted to students with the lowest initial reading levels. According to Cassady and Smith (2005), benefits of using software programs hinge on whether the programs are properly integrated into classroom instruction.

In a recently completed study involving first graders, we examined the efficacy of two CAI programs *Phonics Based Reading* and *Strategies for Older Students* (Lexia Learning Systems, 2001) designed to supplement reading instruction by providing systematic exercises for mastering word-attack strategies (Macaruso, Hook, & McCabe, 2006). We found that students in both treatment classes receiving CAI and control classes benefited from receiving phonics-based reading instruction as part of their daily classroom curriculum. However, when analyses were restricted to "at-risk" low-performing students, significantly higher gains in reading were found in treatment classes compared to control classes.

Present Study

The main purpose of the present study was to build upon the findings of Macaruso et al. (2006) discussed above by exploring the benefits of a phonics-based CAI program for kindergartners. The program called *Early Reading* (Lexia Learning Systems, 2003) is designed to supplement classroom instruction in building a foundation for emerging literacy skills. The program contains nine activities involving sound identification, rhyming, segmenting and blending of sounds, and application of letter–sound correspondences for subsets of consonants and vowels. The activities make use of highly motivating visual graphics, including progress bars that fill up as a student successfully completes each unit within an activity. *Early Reading* employs an animated character, Lexie the Lion, to provide activity-specific instruction and scaffolded hints to support the student's progress. Illustrated in Figure 1 is a typical activity from *Early Reading* called the "Word Snip" segmentation task. On this task the student hears a word and is asked to pull down a ball for each syllable in the word. The activity begins with compound words (e.g., "pan-cake," as pictured) and progresses to individual sounds in words (e.g., "c," "o," "t" in "cot"). The box below the pull-down balls provides additional motivation; the character collects a balloon for each correct response and floats when the student completes the unit. *Early Reading* maximizes time-on-task for each activity by providing immediate feedback after each response without distraction or delay caused by superfluous elements. Automatic branching is also built into the program. The

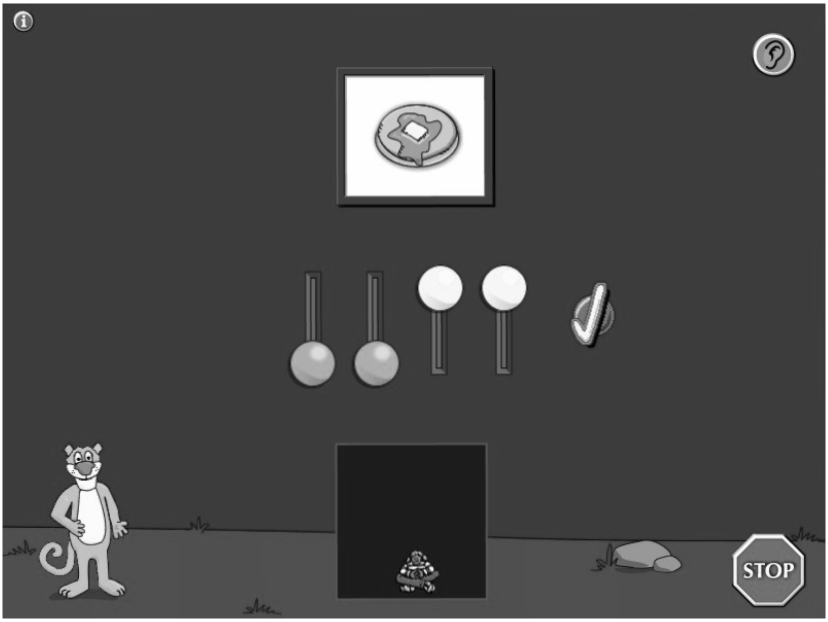

FIGURE 1 A screenshot of a sound segmenting activity ("Word Snip") from the *Early Reading* program.

student is allowed to progress to the next activity only when he has mastered current skills. In the case of repetitive mistakes within an activity, the program branches back to include hints and provide practice on the specific skills that pose a challenge. In this way the program offers individualized support to each student, which is especially valuable for low performers who may need significantly more practice to master a particular skill than can be provided in a group-instruction context.

Most studies that attempt to assess the benefits of CAI to supplement reading instruction do not include adequate controls for teacher and classroom variables, and these variables may have a significant impact on the academic performance of young children (e.g., Paterson et al., 2003; see Troia, 1999). We had an opportunity to evaluate *Early Reading* under conditions in which teacher, classroom, and instruction variables were held constant. Matched treatment and control classes were randomly selected from morning and afternoon classes taught by the same teacher in the same classroom.

A second purpose of this study was to address the benefits of CAI for kindergartners identified as low performers. There has been evidence indicating that CAI can be particularly effective for children at risk for learning problems (Cassady & Smith, 2005; MacArthur et al., 2001; Macaruso et al., 2006; Mitchell & Fox, 2001; Wise et al., 2000). To this end, separate analyses were conducted for the four lowest performers in each class.

Method

Participants

Six kindergarten classes were selected for participation in this experiment. The classes were located in two elementary schools in an urban community outside of Boston, Massachusetts. The six classes consisted of the morning class and the afternoon class for three teachers. One class for each teacher was randomly assigned to be a treatment class and the other class for that teacher was designated to be a control class. One morning class and two afternoon classes were treatment classes, and two morning classes and one afternoon class were control classes. There were 47 students (23 male, 24 female) in treatment classes and 47 students (22 male, 25 female) in control classes. The mean age of students in treatment classes was 67 months (sd = 3.9), and the mean age of students in control classes was 66 months (sd = 3.7). The students came from diverse sociocultural backgrounds. Twenty-one percent of the families in the school system were foreign born and 29% spoke a language other than English at home. The median household income of $37,000 in the school system was well below the median level in Massachusetts (approximately $50,000). Over 50% of students qualified for free or reduced lunch.

The treatment classes contained six students classified as English language learners (ELL) and three students classified as special education (SPED) students. There were no ELL students and two SPED students in the control classes. Given the uneven number of ELL/SPED students in the two groups, these students were excluded from the sample. The reduced sample consisted of 38 students (19 male, 19 female) in treatment classes and 45 students (20 male, 25 female) in control classes.

The treatment classes began using Lexia software in November 2003 and continued for approximately 6 months. The software is designed for regular weekly use (two or three weekly sessions of 15–20 minutes each). The software tracks sessions completed for each student. The mean number of sessions completed was 48, with a range of 30–62 sessions. Given evidence that sufficient use of CAI is needed to support gains in literacy (e.g., Hecht & Close, 2002; Segers & Verhoeven, 2005), we set a minimum criterion of more than 45 sessions completed (i.e., approximately two sessions per week or 15 hours over 6 months) for a student to be included in the treatment group. (Forty-five sessions is well below the mean number of sessions completed [64] in our first grade study [Macaruso et al., 2006] and reflects a bare minimum of use in which we might find benefits of CAI.) There were 26 students (out of 38 non-ELL/SPED students in the treatment classes) who met the criterion and were placed in the final treatment group. These students (12 males, 14 females) averaged 52 sessions completed. All analyses involving the treatment group included these 26 students only. The remaining 12 students who did not meet the criterion averaged 38 completed sessions.

Materials and Procedures

All treatment and control classes were engaged in daily reading instruction using 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 oral vocabulary, phonemic awareness, letter–sound recognition, and story comprehension. It contains teaching resources, assessment handbooks, student storybooks, writing materials, and manipulatives. *Bradley Reading and Language Arts* is a multisensory, systematic phonics program. Each teacher reported following the same scope and sequence of reading instruction for her treatment and control classes.

The *Early Reading* program was installed on the networks in each school building and mapped to individual classroom and laboratory stations. Nearly all of the program use occurred in computer laboratories. The kindergarten teachers and laboratory staff members took part in orientation and training sessions for software implementation. *Early Reading* has two levels. Level 1 contains four skill activities and 56 discrete units. The activities in Level 1 are designed to enhance phonological awareness skills, including recognition of initial and final sounds in words, rhyming words, segmenting words into syllables and sounds, and blending syllables and sounds into words. Level 2 contains five skill activities and 60 discrete units. Level 2 activities reinforce recognition of initial and final sounds and introduce letter–sound correspondences for consonants, vowels, and consonant digraphs. Both levels make use of matching tasks with auditory/visual stimuli (e.g., matching the sound /b/ or the letter *b* with a pictured object beginning with that sound or letter, such as *book*). The activities are highly structured and systematic, building from basic to more advanced skills. In the current study, each student was initially placed in Level 1 and allowed to work independently through the activities at his own pace. During the time when students in the treatment classes were participating in the Lexia programs, students in the control classes were engaged in language arts activities as part of regular classroom instruction.

The software program records skill units completed for each student. The mean number of skill units completed by the 26 students in the treatment group was 66 (range: 30–116). Sixteen of these students worked exclusively on Level 1 activities and 10 advanced to Level 2 activities.

To obtain pretest measures of preliteracy skills, we used results from the *Dynamic Indicators of Basic Early Literacy Skills*, 6th edition (*DIBELS*; Good & Kaminski, 2003) administered by the school system in September 2003. In accordance with test guidelines, the kindergartners were given two *DIBELS* subtests appropriate for the beginning of kindergarten: initial sound fluency (ISF) and letter naming fluency (LNF). The ISF subtest assesses phonological awareness skills. It requires children to point to a picture that begins with a sound produced by the tester or say the initial sound of an orally presented word that matches a picture. Scoring is based on the number of initial sounds identified or produced correctly in one minute. On the LNF subtest, children are asked to name aloud as many letters as possible in one minute. The letters are presented randomly in rows of ten, with uppercase and lowercase letters mixed in each row.

To obtain posttest measures of preliteracy skills following the treatment program, we used results from the *DIBELS* administered by the school system at the end of the school year (May–June 2004). Following test guidelines, the kindergartners were given two *DIBELS* subtests appropriate for the end of kindergarten: letter naming fluency (LNF) and phoneme segmentation fluency (PSF). The LNF subtest is described above. The PSF subtest assesses phonological awareness skills. Children hear a word (e.g., "sat") and are asked to say aloud the individual phonemes in the word (e.g., "/s/," "/a/," /t/"). Scoring is based on the number of phonemes produced correctly in one minute.

To further assess preliteracy skills following the treatment program, we administered the *Gates-MacGinitie Reading Test, Level PR (Pre-Reading)* (MacGinitie, MacGinitie, Maria, & Dreyer, 2000) at the end of the school year (June 2004). The *Gates-MacGinitie Reading Test* is a standardized assessment tool that allows us to compare children's scores with established norms. (Note that the *Gates-MacGinitie Reading Test* does not have an assessment tool for children at the beginning of kindergarten.) It contains four subtests—literacy concepts, oral language concepts, letters and letter–sound correspondences, and listening (story) comprehension. The literacy concepts subtest assesses basic knowledge of printed text (e.g., finding the first letter in a word). The oral language concepts subtest assesses phonological awareness skills. It requires children to identify pictures with names that begin or end with the same sound or identify pictures that have rhyming names. The letters and letter–sound correspondences subtest requires children to identify when two letters match and to match letters with pictures that begin with sounds corresponding to the letters. The listening comprehension subtest asks children to listen to a passage and select a picture that most closely reflects the meaning of the passage. Dependent measures on the *Gates-MacGinitie Reading Test* 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.)

Results

All Students

Table 1 presents mean pretest and posttest scores on the *DIBELS* for all students in the treatment and control groups. There were no

TABLE 1 Mean Pretest and Posttest Raw Scores on the *DIBELS* for All Students and Students Identified as Low Performers

	All Students							
	Pretest				Posttest			
	Treatment (N = 26)		Control (N = 45)		Treatment (N = 26)		Control (N = 45)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
ISF	7.1	5.1	8.9	7.1	—	—	—	—
LNF	14.2	14.0	12.0	13.5	38.3	16.9	38.5	17.0
PSF	—	—	—	—	28.0	13.3	30.9	19.1
	Low Performers							
	Pretest				Posttest			
	Treatment (N = 12)		Control (N = 12)		Treatment (N = 12)		Control (N = 12)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
ISF	3.1	2.8	2.3	3.3	—	—	—	—
LNF	12.2	11.5	10.8	10.4	39.2	12.4	38.4	12.7
PSF	—	—	—	—	29.0	11.0	28.0	21.2

Notes. ISF: Initial Sound Fluency; LNF: Letter Naming Fluency; PSF: Phoneme Segmentation Fluency.

significant differences between groups on the two pretest scores: ISF ($t(69) = 1.13, p = .26$) and LNF ($t(69) = 0.63, p = .53$). The two groups showed comparable levels of phonological awareness and letter-naming skills prior to initiation of the CAI program. Analyses of covariance were used to compare posttest *DIBELS* scores for the two groups with *DIBELS* pretest scores serving as covariates. There was no significant difference between groups at posttest on the LNF subtest ($F(1,67) = 0.48, p = .49$) or on the PSF subtest ($F(1,67) = 0.14, p = .71$). Given that the CAI program emphasizes phonological awareness activities, it might be expected that students in the treatment group would outperform students in the control group on the PSF subtest, but no group difference was found.

Further analyses of covariance were conducted to compare posttest scores from the *Gates-MacGinitie Reading Test* using the

TABLE 2 Mean Posttest Raw Scores on Subtests from the *Gates-MacGinitie Reading Test* for All Students and Students Identified as Low Performers

	All Students			
	Treatment (N = 26)		Control (N = 45)	
	Mean	SD	Mean	SD
Oral Language Concepts (20 items)	14.8	4.0	12.8	3.5
Letters and Letter-Sound Correspondences (30 items)	24.7	4.5	23.7	5.4
Literacy Concepts (20 items)	16.8	2.8	15.7	3.0
Listening Comprehension (20 items)	13.6	3.8	12.6	3.5
	Low Performers			
	Treatment (N = 12)		Control (N = 12)	
	Mean	SD	Mean	SD
Oral Language Concepts (20 items)	16.0	2.2	12.4	3.6
Letters and Letter-Sound Correspondences (30 items)	25.6	2.6	22.3	5.4
Literacy Concepts (20 items)	17.1	2.5	15.3	2.9
Listening Comprehension (20 items)	13.4	4.1	11.5	3.6

DIBELS pretest scores as covariates. A significant group difference was obtained for overall NCE scores, $F(1,67) = 4.80$, $p = .03$. The mean NCE score was significantly higher for the treatment group (54.2) than the control group (46.4).

Posttest scores for the two groups on the four subtests of the *Gates-MacGinitie* are shown in Table 2. A significant difference between groups was found on the oral language concepts (phonological awareness) subtest, F(1,67) = 4.78, p = .03. The mean score was significantly higher for the treatment group (14.8) than the control group (12.8). We also found that the treatment group produced higher scores than the control group on the remaining subtests (literacy concepts, letters and letter–sound correspondences, listening comprehension); however, group differences were not significant. It should be noted that although the CAI program includes practice in learning letter–sound correspondences, these activities occur in Level 2 of the program. Only 10 of the 26 children in the treatment group progressed to Level 2, and only six completed more than half of the 60 units in Level 2. This suggests that students in the treatment classes did not receive enough practice in letter–sound correspondences to support a group difference. A significant correlation was obtained between number of units completed and scores on the letters and letter–sound correspondences subtest (r = .40, p = .04).

Low Performers

To determine whether *Early Reading* might be particularly beneficial for low-performing students, a subanalysis was conducted with children in the two groups who demonstrated the lowest scores on the *DIBELS* ISF pretest (i.e., the bottom four scorers in each of the three treatment classes and the bottom four scorers in each of the three control classes). These students were selected because they showed signs of weak phonological awareness skills and thus could be expected to benefit greatly from participating in the CAI program. Mean scores on the ISF subtest for these groups fall in the "at risk" category according to *DIBELS* benchmark goals.

Shown in Table 1 are the mean pretest and posttest scores on the *DIBELS* for the two groups of low performers. The groups did not differ on pretest scores: ISF (t(22) = 0.60, p = .55) and LNF (t(22) = 0.30, p = .77). Analyses of covariance were used to compare posttest *DIBELS* scores for the two groups with *DIBELS* pretest scores serving as covariates. There was no significant difference between groups at posttest on the LNF subtest (F(1,20) = 0.03, p = .87) or on the PSF subtest (F(1,20) = 0.01, p = .98). Like the results for all students, an expected difference between groups on the PSF subtest was not found.

Further covariate analyses were used to compare the two groups of low performers on posttest scores from the *Gates-MacGinitie Reading Test* using the *DIBELS* pretest scores as covariates. A significant group difference was obtained for overall NCE scores, $F(1,20) = 11.00$, $p < .01$. The mean NCE score was significantly higher for the treatment group (55.8) than the control group (41.6). Posttest scores for the low performers on the four subtests of the *Gates-MacGinitie* are shown in Table 2. A significant group difference was found on the oral language concepts (phonological awareness) subtest, $F(1,20) = 7.95$, $p = .01$. Low performers in the treatment group (16.0) obtained significantly higher scores than low performers in the control group (12.4). Differences favoring the treatment group were also seen on the remaining subtests (literacy concepts, letters and letter-sound correspondences, listening comprehension); however, these differences failed to reach significance.

Overall, when considering significant group differences on the *Gates-MacGinitie*, effect sizes for low performers were strong (1.56 for NCE scores, 1.24 for oral language concepts). By comparison, effect sizes for all students were in the moderate range (.48 for NCE scores, .53 for oral language concepts). These findings indicate that differences favoring the treatment group were greater for low performers than for all students. In fact, an examination of individual students' NCE scores revealed that 8 of the 12 low performers in the treatment group scored above the normed average (50) compared to only 1 of the 12 low performers in the control group.

Case Studies

Given the large discrepancy in the number of low-performing treatment students and low-performing control students who scored above average at posttest, we decided in this section to examine the characteristics of a few of these low performers. From the treatment group we selected GL, one of the lowest performers at pretest, and KD, one of the top scorers at posttest. The third case, FD, was the only low performer from the control group who scored above average at posttest. The first treatment student, GL, obtained pretest scores of only 2 and 0 on the ISF and LNF subtests from the *DIBELS*, respectively. However, following CAI use, she obtained a *Gates-MacGinitie* NCE score of 45, which falls within the average range. In fact, GL's score of 25 out of 30 on letters and letter–sound correspondences fell above the mean for all students in the treatment and control groups. GL's teacher reported that Lexia use helped "her practice and develop her early reading skills." The second treatment student, KD, also obtained low scores at pretest on the *DIBELS* (3 and 7 on the ISF and LNF subtests, respectively). However, after CAI use, her posttest scores were uniformly high. Her scores on the PSF and LNF subtests from the *DIBELS* were 46 and 49, respectively, and she obtained a *Gates-MacGinitie* NCE score of 72. She did particularly well in the area of phonological awareness, scoring 19 out of 20 on the oral language concepts subtest. According to her teacher, KD was "one of my top students by the end of the year." As these two cases illustrate, low performers in the treatment group by and large showed average to above-average performance in literacy skills subsequent to CAI use. Our final case, FD, was the only low performer in the control group who obtained a posttest *Gates-MacGinitie* NCE score above 50. She did particularly well on the literacy concepts subtest, scoring 19 out of 20. Of course, FD's success cannot be attributed to CAI use. Instead, her teacher recalls that FD actively participated in the classroom and she had supportive parents who "played an active role in her progress and performance." These cases illustrate that, while CAI is a key contributor to reading gains in low performing kindergartners, other factors can play an important role as well.

Discussion

This study examined the benefits of a CAI program designed to supplement regular classroom instruction in an urban public school system. The program provides systematic and structured exercises for developing phonological awareness and basic letter–sound correspondences in kindergarten children. Comparisons were made between treatment classes receiving the supplemental CAI program and control classes receiving the same phonics-based reading curriculum without CAI support. There were no differences between treatment and control groups on pretest measures of preliteracy skills. However, at posttest the treatment group significantly outperformed the control group on the *Gates-MacGinitie*

Reading Test. Group differences were most pronounced for children with the lowest pretest scores. A closer look at posttest performance on the *Gates-MacGinitie* revealed that the greatest discrepancy between groups was on the oral language concepts subtest, which measures phonological awareness skills. Higher scores for students in the treatment group on this subtest indicate that these students (particularly the lowest performers) benefited from an intensive, systematic emphasis on developing phonological awareness through the CAI program. It has been well established that phonological awareness is a key prerequisite for later reading success (Report of the National Reading Panel, 2000).

Phonics-Based Curriculum

The public school system we studied employed highly systematic, phonics-based reading instruction as part of its literacy curriculum. This conforms to the National Reading Panel's (2000) recommendation that early (and struggling) readers benefit from a systematic, explicit approach to reading instruction. Provided with this curriculum, students in both treatment and control classes produced mean NCE scores on the *Gates-MacGinitie Reading Test* within the average range by the end of the school year, reflecting adequate progress in a low-SES school system. However, even within the context of this strong curriculum, we were able to demonstrate that participation in the supplementary CAI program provided a significant boost, particularly for the low performers in the treatment group. This finding highlights the fact that well-structured CAI programs can deliver the kind of intensive practice required for struggling readers to develop their literacy skills (see Wise et al., 2000).

Matched Classes

The kindergarten classes available for this study provided an exceptional opportunity to investigate the benefits of the CAI program in closely matched treatment and control groups. Each group contained either the morning class or the afternoon class taught by the same teacher. One class for each teacher was randomly assigned to the treatment group and the other class to the control group. Each teacher reported using the same curriculum and following the same daily routine for her two classes. The only difference was that while treatment classes went to computer laboratory, control classes spent extra time engaged in language-related classroom activities. This type of design eliminates many potential threats to internal validity related to teacher and classroom variables, which are often seen in field studies assessing the effectiveness of supplementary reading programs (see Troia, 1999). The use of matched classes enhances the likelihood that significant group differences were due to the use of CAI in the treatment classes.

Pretest/Posttest Measures

In most situations one would use the same assessment tool to collect pre- and posttest measures. However, given substantial and qualitative changes in preliteracy skills during the kindergarten year, assessment tools like *DIBELS* use different subtests for the beginning and end of the school year. The *Gates-MacGinitie Reading Test* does not consider its *Pre-Reading* battery appropriate for kindergartners at the beginning of the school year. With these limiting protocols we found it necessary to employ a different battery at pre- and posttesting to assess phonological awareness and other preliteracy skills.

Although the treatment group significantly outperformed the control group on the *Gates-MacGinitie* measure of phonological awareness, group differences were not found on other *Gates-MacGinitie* subtests. Two of the subtests, literacy concepts and listening comprehension, assess preliteracy skills that are tangential to skills practiced in the CAI program. The letters and letter-sound correspondences subtest does assess skills practiced in the CAI program; however, most students did not work extensively on this part of the program. Group differences were also not found on two *DIBELS* posttests, letter naming fluency and phoneme segmentation fluency. The CAI program does not include letter-naming practice, though it does include phoneme segmentation activities. It is not entirely clear why group differences were not found on the phoneme segmentation fluency subtest. One possibility is that in addition to phonological awareness skills (as practiced in the CAI program), further processes need to become proficient in order to show marked differences on timed tests like the *DIBELS*. According to *DIBELS* benchmarks, students in both groups were in the "some risk" category in phoneme segmentation fluency at the end of the school year.

Given that we were unable to pretest the kindergartners with the *Gates-MacGinitie Reading Test*, it could be argued that significant group differences favoring the treatment group on the oral language concepts (phonological awareness) subtest could stem from uneven ability levels prior to the onset of the CAI program. However, pretest results from the *DIBELS* initial sound fluency subtest strongly suggest that the groups did not differ in phonological awareness skills prior to the onset of the CAI program. Mean scores on the initial sound fluency subtest were uniformly low and quite similar for the treatment and control groups. It should be noted that the phonological awareness skills tested on the initial sound fluency subtest overlap with the skills assessed on the oral language concepts subtest. Both subtests require students to identify sounds that occur in the names of pictured items. However, while the *DIBELS* subtest is designed to be a fluency measure, the low scores for both groups at pretest indicate that the students were struggling with identifying sounds in addition to speed of processing.

Typical Students

It should be noted that participation in CAI could be beneficial not only for struggling readers but also for typically developing children. CAI provides an engaging format for all children to practice skills and progress independently at their own rate. In conjunction with CAI programs designed for first graders (see Macaruso et al., 2006), typically developing kindergartners could advance beyond *Early Reading* and systematically acquire higher level skills. We are currently conducting research to examine this possibility. In addition, utilizing CAI with typically developing children as part of flexible groupings and center activities would allow teachers to spend extra time with children who may need more individualized support.

Regular Classroom Practice

In conclusion, the public school system we studied had embraced CAI as part of its literacy curriculum. Therefore, we had an opportunity to investigate the efficacy of CAI as an integrated component of typical classroom practice—giving rise to a high level of ecological validity (Cassady & Smith, 2005; Paterson et al., 2003). However, by studying CAI in the midst of typical classroom activities, we sacrificed some degree of control over implementation. As a result, we found inconsistent use patterns and needed to exclude children from the treatment group who did not complete a sufficient number of sessions. In our first-grade study, strong gains were found when students averaged 64 sessions of CAI use (Macaruso et al., 2006). Here we set as a bare minimum 45 sessions of CAI use and had to eliminate 32% of the students in the treatment classes because they failed to meet the minimum. Despite these limitations, we were able to demonstrate significant benefits of CAI, particularly for those who started out as low performers. However, it is likely that we would have revealed even greater benefits if students were able to maintain stronger CAI use patterns throughout the year. Others have reported a relationship between amount of CAI time and reading gains (e.g., Hecht & Close, 2002; Segers & Verhoeven, 2005). Concerns about time on task as it relates to reading gains have also been discussed with regard to non-CAI treatment studies (Ehri et al., 2001), particularly as it applies to low performers (Torgesen, Wagner, & Rashotte, 1997). Issues regarding the role of implementation in CAI efficacy studies and factors that contribute to stronger or weaker use patterns will be addressed in our future studies.

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