Journal of Computer Assisted Learning (2000) **16**, 54-63

The learning value of computer-based instruction of early reading skills

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Abstract This study examined the unique contribution of computer-based instruction when compared with more conventional modes of instruction (i.e. teacher instruction with textbooks) to early reading skills acquisition, as well as the effects of specific features of computer technology on early reading skills performance. Forty-six pre-school children (aged 5–6), at high risk for learning disabilities, participated in the study. They were assigned to one of three study groups that received different treatments. Three dependent variables were defined, i.e. children's phonological awareness, word recognition and letter recognition skills measured prior and after the treatment. Results clearly indicated that children at high risk who received the reading intervention program with computer materials significantly improved their phonological awareness, word recognition, and letter naming skills relative to their peers who received a reading intervention program with only printed materials and those who received no formal reading intervention program. The results are discussed in detail, with reference to the features of the computer-based materials that contributed to the acquisition of critical early reading skills.

Keywords: Computer; Control group; Instruction; Literacy; Pre-school; Reading; Special education

Introduction

The development of reading competency is a complex process which is based on both natural development and formal acquisition of a large set of abilities and skills. Reported research stresses the importance of the relationship between pre-reading or early reading skills (e.g. phonological processing, letter recognition) and reading competency (Bentin & Leshem, 1993; Mann, 1993; Steven & Bruce, 1994). There is no consensus, however, about the directionality of this relationship, and it has been suggested that:

- early reading skills are a result of reading competency (Hamer *et al*., 1992);
- they are a *prerequisite* for reading competency (Lundberg *et al*., 1988);

Accepted: 1 August 1999

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- these two sets of skills are closely interrelated and affect each other mutually (Yopp, 1992).

On any of these views however, a significant correlation was found between at-risk children's low level mastery of early reading skills and their reading competency (Ehri, 1989; Cornwall, 1992). Research has indicated that children with reading disabilities (RD) exhibit difficulties in performing tasks involving skills such as phonological awareness, encoding and retrieval of phonological information stored in long-term memory (Felton, 1993), word decoding (Spear-Swerling & Sternberg, 1994), and letter naming and letter/sound knowledge (Tunmer *et al*., 1988).

In light of these difficulties, a major goal in the field of learning disabilities is that of developing effective intervention programs for children who are at-risk for RD. Researchers have shown that training in early reading skills improved those learners' reading performance (Lundberg *et al*., 1988; Lovett *et al*., 1990) and even produced long-range effect over several schooling years as reported in longitudinal studies (MacDonald & Cornwall, 1995; Steg *et al*., 1994).

Current early reading training programs, like many areas of educational practice, make wide use of advanced computer technology. Sophisticated features that are potentially relevant to the instruction of reading skills (e.g. high-quality sound and visual capabilities, interactive mechanisms, speech synthesis and recognition) are today available in low-cost computers located in homes and schools. Of particular interest are features that could offer specific support to the learning needs of children with RD, such as:

- *digitised speech* which enables immediate association between graphemes (letter forms) and phonemes (sounds) (Foster *et al*., 1994);
- *touch-screens* allowing the learner to trigger the uttering of a letter or word by touching it (CET, 1996);
- *drill generation and adaptation algorithms* supporting automation of skills (Hannaford, 1983);
- *individualisation of instructional sequence* and feedback according to the child's pace of learning, motivation and developing self-confidence (Speziale & La-France, 1992).

These unique features of computer technology invite a revision of basic issues regarding the training process of early reading skills for at-risk children. This study examined two main questions:

> Is there 'added learning value' in the use of computer based materials for training early reading skills of pre-school children who are at-risk for RD?
>
> Which specific/relevant features of the computer technology are most related to specific outcomes regarding children's acquisition of early reading skills?

In other words, this study focused on a broad examination of the unique contribution of computer-based instruction. It compared that with more conventional modes (i.e. teacher instruction with textbooks) of children's acquisition of early reading skills, as well as on the effects of specific features of the computer technology on children's performance on specific early reading skills.

Method

Forty-six children aged 5–6 attending six special-education kindergartens in the central region of Israel participated in the study. The kindergartens serve children from average socio-economic status families. The participants were assessed through a comprehensive psycho-educational assessment and had been identified by the regional Psychological Services as children at high risk for learning disabilities. The participants were also identified as children at high risk for reading disabilities (having scored 55 points or below out of 122 possible points on the Phonological Awareness Test (Lapidot *et al*., 1995).

All children had normal vision and hearing; they had no gross neurological abnormalities, or severe emotional disturbances or behaviour disorders, as indicated by their records. Children's IQ scores were not available as they are confidential under Israeli law, but children were reported to function within the average level of intelligence. All children received the regular special education program for special kindergartens. None of the selected children had received formal instruction in reading nor did they know how to read.

The participants were randomly assigned to one of three study groups (each group comprised participants from two kindergartens) which received different treatments:

- *Group 1* (n = 16) received instruction in reading with a special reading program which included both printed and computer-based materials;
- *Group 2* (n = 15) learned only with the printed materials of the special reading program;
- *Group 3* (n = 15) served as control group and was given only the regular special education program without specific reading training.

The usual kindergarten teachers, who received the usual training in reading instruction, administered all treatments. For the rest of this paper the groups will be referred to as the *computer*, *printed-only*, and *control* groups.

The independent variable in this study was the treatment. Three dependent variables were defined regarding children's phonological awareness, word recognition and letter recognition skills measured prior to and after the treatment.

The instructional materials (the reading program) and four tests served as the instruments. The reading program administered (to groups 1 and 2) was '*I have a secret – I can read*', a curriculum for early reading acquisition developed for special education (CET, 1996). The program consists of booklets for individual work and computer materials. The hardware environment includes a touch screen, speakers and headphones. The child works with the computer, assisted by the teacher when needed, and interacting with the software by means of the touch screen (the keyboard is reserved for teacher's use).

The first stage of the instruction focused on reading readiness, e.g. letter recognition, auditory perception, visual discrimination. The second stage took the form of a detailed progression of reading training activities. The activities were organised in blocks, with each block comprising four tutorial sessions followed by practice sessions. The computer version of the practice was in the shape of four game-like templates. For each session the teacher selected the appropriate level of difficulty for the child and the skills to be practised. The child selected from among the four game templates the one she wanted to work with at any given session. In this program the printed and computer materials complement and reinforce each other in support of the instructional process. The four tests administered were:

- *Phonological awareness test* (Lapidot *et al*., 1995), focusing on 11 specific skills, e.g. phoneme recognition at the beginning or end of a word; new-word composition out of known-word phonemes; rhyme recognition and formation.
- *Word recognition test* comprising sets of general-content words as well as kindergarten-topics related words.
- *Letter naming test* which test required subjects to name all 22 uppercase letters of the Hebrew language. Letters were printed on a white page and were presented to the children in a single random order. Subjects were encouraged to take a guess if they did not know the answer. The maximum score on this test was 22.
- *Peabody Picture Vocabulary Test – Revised (PPVT-R)* (Dunn & Dunn, 1981) was administered in order to measure the children's vocabulary level prior to instruction.

It was hypothesised that Group 1's improvement in performance for all measured skills would be significantly higher as a result of treatment (training including computer materials) than that of Groups 2 (training including printed-only materials without computer materials) and 3 (control group).

Results

No significant group differences were found (prior to instruction) on participants' performance in the *phonological awareness* (total score), *word recognition* and *letter naming tests*. There was no difference between the groups for the initial vocabulary level as measured by the *PPVT-R:*

$$F_{2,42} = 1.1745,\ p = 0.138$$

In order to facilitate direct comparison of the three independent variables on the 11 phonological tasks, scores were turned into improvement proportions (i.e. the percentage of improvement scores from pre-to post-intervention). Group differences on the overall extent of improvement in performance as a result of treatment on phonological awareness, on word recognition and on letter naming measures were analysed using a MANOVA. Means, standard deviations and *F*-scores of the univariate analysis are presented in Table 1. The analysis showed significant mean improvement for group membership, and a significant interaction for group by test:

$$\text{Hotteling's } T^2 = 5.523;\ F(26,546) = 3.89,\ p < 0.001$$

Significant group differences were observed for the percentage of increase in performance on all three tests. The extent of improvement on the three tests was significantly higher in the computer group than in the printed-only and the control groups. A more detailed analysis of the extent of improvement in performance on the 11 tasks in the phonological awareness test is presented in Table 2.

Table 1. Mean, SD,% improvement and *F*-values for the three groups in the tests

	printed + computer ($n = 16$)		printed without computer ($n = 15$)		control group ($n = 15$)			
	increase mean/(*sd*)	**%**	**increase mean/(*sd*)**	**%**	**increase mean/(*sd*)**	**%**	***F***	**between groups**
Letter naming	5.75 (2.67)	26.1	2.93 (1.91)	13.3	0.50 (0.94)	2.3	25.67 **	1 > 2 > 3
Word recognition	3.94 (1.24)	32.8	2.73 (1.94)	22.8	0.36 (1.55)	3.0	18.85 **	1 > 2 > 3
Phonological awareness	28.31 (8.25)	23.2	17.07 (4.82)	14.0	5.86 (4.47)	4.8	49.30 **	1 > 2 > 3

** $p < 0.001$

As can be seen in Table 2, the improvement of the computer group was significantly higher than that of the other two groups on six out of the 11 tasks (i.e. *Initial* phoneme recognition, *Final* phoneme recognition, *Identical initial* phoneme recognition in two words, *Identical final* phoneme recognition in two words, *Rhythmical* rhyme identification, *Unrhythmical* rhyme identification). In two tasks (Phoneme isolation at the end of a word and Rhyme formation) the two groups who received reading training (with or without computer) outperformed the control group, while no significant differences were found between the computer and the printed-only groups' percentage of improvement. No significant differences were observed for the percentage of increase in performance between the three groups in two tasks (Initial phoneme deletion, Final phoneme deletion)

Discussion

The aim of this study was to examine the contribution of the computer module of the reading program *I have a secret – I can read* for the acquisition of early reading skills in kindergarten children at-risk for RD. Our first question, stated in general terms, looked for the 'added learning value' of the computer module in comparison to that of more conventional modes. The results clearly indicated that children at high risk for RD who received reading intervention program with computer materials, had made by the end of the year (at the end of the intervention) a significant improvement in their phonological awareness, word recognition, and letter naming skills in comparison to their peers who received a reading intervention program with printed-only materials (without computer) and those who received no formal reading intervention program at all. These findings are consistent with previous results about the contribution of computer-based materials to the acquisition of reading skills by kindergarten children (e.g. Moxley, 1992; Steg *et al*., 1994), and by children with learning disabilities (e.g. Margalit & Roth, 1989; Anderson, 1991). Children seem to benefit from computer-based work not only at the specific skills level but also, as a result of their improvement in academic achievement, in terms of motivational and self-confidence levels (Adam & Wild, 1997; Palty, 1993).

Table 2. Mean, *sd*, % improvement and *F*-values for the three groups at the 11 subtests of the phonological awareness test

	printed + computer (n = 16)		printed without computer (n = 15)		control group (n = 15)			
	increase mean/(*sd*)	**%**	**increase mean/(*sd*)**	**%**	**increase mean/(*sd*)**	**%**	***F***	**between groups**
initial phoneme recognition	2.38 (1.26)	23.8	1.53 (0.99)	15.3	0.36 (0.93)	3.6	13.15 **	1 > 2 > 3
final phoneme recognition	3.56 (1.90)	35.6	1.60 (1.50)	16.0	1.14 (1.17)	11.4	12.78 **	1 > 2,3
identical, initial phoneme recognition in two words	4.06 (1.81)	25.4	1.40 (1.35)	8.8	0.43 (1.40)	2.7	22.68 **	1 > 2,3
identical, final phoneme recognition in two words	2.81 (1.83)	17.6	1.53 (1.13)	9.6	0.36 (0.84)	2.2	12.26 **	1 > 2 > 3
phoneme isolation at the beginning of a word	0.88 (1.54)	8.8	1.93 (2.34)	19.3	0.14 (1.29)	1.4	3.69 *	2 > 3
phoneme isolation at end of a word	5.44 (2.85)	54.4	3.87 (2.20)	38.7	0.93 (1.73)	9.3	14.20 **	1,2 > 3
initial phoneme deletion	0.88 (1.93)	8.8	0.40 (1.92)	4.0	0.50 (0.94)	5.0	0.34	1 = 2 = 3
final phoneme deletion	0.13 (0.34)	1.3	0.00 (0.00)	0.0	0.00 (0.00)	0.0	1.93	1 = 2 = 3
rhythmical rhyme identification	2.69 (1.14)	26.9	1.00 (0.76)	10.0	0.79 (0.98)	7.9	17.62 **	1 > 2,3
unrhythmical rhyme identification	2.43 (1.41)	24.4	1.53 (1.25)	15.3	1.29 (0.91)	2.9	3.78 *	1 > 2,3
rhyme formation	3.38 (2.63)	33.8	2.27 (2.37)	22.7	– 0.07 (1.21)	– 0.7	9.50 **	1, 2 > 3

* $p < 0.05$ ** $p < 0.001$

The important contribution of computer-based instructional materials for high-risk children was also supported by the findings pertaining to the improvements gained in specific phonological awareness skills. The results related to these 11 skills allow us to discuss our second research question, regarding those features of the computer-based materials that were crucial to the acquisition of critical early reading skills.

The computer-based component of the reading program makes extensive use of sound. Sound is used for delivering task instructions, and for returning feedback to the student's responses. It also allows the student to get the audio version of the information displayed on the screen at different levels: character, syllable, word and even sentence level. The main interface device is the touch-screen, by which the child can access characters or words, and perform varied activities (e.g. colouring a drawing on the screen by using one's finger for selecting colours and painting given areas). The information on the screen is presented by multiple means: text, sound, and rich still and animation images. The content is organised and structured to evolve from initial tasks dealing with reading readiness, through progressive acquaintance with the Hebrew alphabet, up to the main objective of the program: the ability to produce significance from written text. Finally the computer modules include a variety of learning modes, i.e. exercises, tutorials, practice games. This comprehensive aggregate of technological, instructional and motivational features seem to affect the children's acquisition of reading skills at different levels, as shown in the following examples.

The ability to understand the relationship between a letter and its sound is critical for the development of phonological awareness, letter identification and spelling (Hohn & Ehri, 1983; Ehri, 1989). The tactile/visual/auditory features of the computer environment support the active identification of letter/sound relationships. When the child touches the letter on the screen this produces immediate feedback in the form of the corresponding sound. Also a given information unit (a letter, a word) is treated simultaneously by different sensorial channels, assisting less able readers in their auditory/phonological or visual/orthographic processing (Montaly & Lewandovsky, 1996).

Awareness of the sound structures (i.e. phonemes) of the words, and ability to manipulate structural phonological units (e.g. phoneme segmentation, replacement, elimination) represent additional sources of difficulty for disabled readers (Felton, 1993). Several tasks involving these abilities were tested in this study (e.g. phoneme identification, rhyme identification), and it was found that the computer-based learning group outperformed the other two groups in most of them. A relevant key feature of the learning environment, which is relevant to these tasks, is that it allows concrete manipulation of letters and word-components in activities and games involving decomposition, recomposition and creation of words. The concrete manipulation of language entities, e.g. by touching, hearing, seeing, constructing, playing and replaying auditory constructs-has significant potential for assisting young children's reading-skills acquisition.

The acquisition process of reading skills is highly individualised (Stuart & Coltheart, 1988). Close observation of the child's performance followed by mindful pedagogical decision-making are of great importance with at-risk children. The computer component of the reading program used includes a management module which allows to keep records of the child's work, the tasks performed and her or his competency level at the different skills. This information allows the teacher to adapt the instructional sequence to individual needs and state of skills mastery. For example, for the game-type activities the teacher determines the skill and the difficulty level to be practised at each stage, and the child chooses the particular computer game she or he wants to work with. New performance information is then recorded, enriching the information-base for subsequent adaptation of activities. This informed way of designing the instructional sequence, based on a more appropriate fit between learner needs and learning activities, has great potential for supporting reading-skills acquisition.

A final comment should be made on motivational issues. The computer environment's features (e.g. multiple representational means, interactivity, varied work modalities, immediate and individualised feedback, choice space, sense of control) have a strong motivational load. In line with previous claims concerning the motivational value of computer-based work for disabled learners (e.g. Margalit *et al*., 1987; Speziale & La-France, 1992), it can be assumed that at this level too, the computer module's features contributed to the learning process.

It is suggested that this study's findings are relevant also for non-Hebrew contexts in several aspects. Reading instruction had a positive effect on the progress made by children at-risk for RD in the areas of phonological awareness, word recognition and letter naming, and the incorporation of computer-based materials had a unique contribution to this progress. The particular features of the technology (e.g. multi-sensory input-output, text-to-speech capabilities) supported processes (e.g. decomposition and re-composition of information units, letter-sound relationship perception) that are significant for the development of reading skills. Student-data management features contributed to informed individualisation of the instructional sequence, a crucial issue with this particular population. Finally, the overall results highlight the value of early intervention to prevent eventual failure in learning to read by means of a structured (print and computer-based) instructional program. To sum up, the observed support to processes both at the skill-acquisition and the motivational levels, as well as at the instruction process level, seem to be of value beyond the particular context of this study.

In conclusion, the presence of technology in early childhood education is becoming more and more a *hardware* reality, but subsequent work is needed to transform it into technology-based *learning* reality. This seems to represent a recurrent pattern (first hardware-based enthusiasm, then pedagogical reflection) in the educational implementation of new technologies. A recent study on about 500 web-based learning environments (Mioduser *et al*., in press) showed that a considerable gap exists between the technological features (e.g. sophisticated graphics, Java applets, multimedia components) and the pedagogical features (e.g. pedagogical rationale, instructional modes, learning opportunities) of educational websites. Only as brief illustration of the study's findings, it appeared that:

- most websites were designed as information repositories following pre-web CD models;
- in most websites the cognitive processes elicited were information retrieval and rote learning, while only a third focused on inference and analysis tasks and even fewer (about 5%) on problem solving processes;
- less than 3% of the sites support collaborative learning;
- only a few sites offer interactive activities, either with peers or experts;
- only few sites make sound educational use of a quintessential feature of the web, namely, communication resources.

After several decades of educational implementation of computer technology, it is agreed that the technology by itself means only the necessary infrastructure upon which should be built robust pedagogical solutions to real learning problems. Notwithstanding, when the new technology, the web, irrupted to the educational scene, the old pattern prevailed once again. Transitional stages at which new technologies are assimilated by means of known models are a reasonable (and perhaps unavoidable) phenomenon, only if they lead to mindful reflection and building of sound pedagogical applications of the new possibilities in response to the learners' needs.

Along these lines, the contribution of computer-based learning materials to the acquisition of early reading skills of at-risk children, as observed in this study is very promising. This indicates that it is advisable to invest efforts in the development of this kind of learning materials for this specific population, and in research aimed to map children's learning processes within these computer environments.

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Price:	£14.99 198 pages, softback ISBN 1-85805-352-8

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Publisher:	Trentham Books Limited, March 1999
Price:	£9.95 (160 pages) ISBN: 1 85856 106 X