Improving Preliteracy and Premath Skills of Head Start Children with Classroom Computer Games

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Children from Head Start programs entering kindergarten often score poorly on assessments of preliteracy and premath skills. As part of an effort to strengthen this area of the curriculum, we examined the potential of a Web-based computer program for the classroom in a study with children attending an urban Head Start center in San Diego, CA. Seventy-three children from four classes participated in the study, with 21 randomly assigned to an experimental group; remaining children served as controls. Children in the experimental group played the games on classroom computers for 20 to 30 minutes an average of 25 times over the study period, which lasted for 14 weeks. The computer program employed animated games to teach children recognition of letters, numbers, quantity, shapes, and colors. Each game had built-in assessment of performance, and was constructed with multiple levels of difficulty. At the beginning and end of the study, each child was assessed for specific knowledge within the different skill domains. At the end of the study period, children in the experimental group identified approximately 24 of 26 uppercase letters, 8 out of 10 numerals between 1 and 10, and counted 8 out of 10 items. These scores were approximately double those observed at the study's end from full-day (FD) and part-day (PD) controls ($p < 0.01$). The results indicate that computer-based supplements in the classroom can be an effective way to enhance preliteracy and premath skills in the Head Start classroom

The No Child Left Behind (NCLB) act of 2001 requires assessment of academic skills to receive federal support for public education, a policy that includes preschool education in Head Start. The impact of this policy on Head Start programs is substantial. A recent report to Congress revealed that Head Start children scored in the lowest quartile of a national assessment of preliteracy and premath skills of children entering kindergarten (U.S. Department of Health and Human Services, 2003). It was concluded that one of the reasons why Head Start children are more likely to be retained in kindergarten is because they enter with insufficient preliteracy and premath skills to effectively compete with their middle class peers.

These findings, as well as others reviewed in the report, were instrumental in the creation of the National Reporting System (NRS), a current federal initiative that assesses preliteracy and premath skills each year in 4- and 5-year-old Head Start children. Unlike many assessment measures used with small children that employ categorical information about readiness, the NRS measures specific information related to letters and numeracy, including letters or numbers a child knows and how many items he or she can count. The purpose is to provide comparative data across Head Start programs in order to chart program improvements in acquiring literacy, numeracy, and language skills, as well as to assess the impact of curricular changes that may be employed to address the problem (U.S. Department of Health and Human Services, 2002, 2003)

This national focus on preliteracy and premath skills in Head Start is a significant shift in emphasis from its original approach. Preschool education traditionally is focused on a child-centered curriculum designed to promote physical, emotional, social, and cognitive development (Beatty, 1995). Within this whole child approach, preliteracy and premath skills are a minor focus. The introduction to letters, letter-sound correspondence, number recognition, and counting is often dependent upon both child interest and teacher orientation. For these reasons, the recent federal emphasis on acquisition of preliteracy and premath skills represents a significant shift in curricular orientation.

This shift is complicated by decreased Head Start funding in recent years, combined with limited experience and training for many Head Start teachers. Nationally, fewer than 33% percent of Head Start teachers have a 4-year college degree, and the teacher turnover is high. Current estimates indicate that the Head Start program would need more than a billion dollar increase to provide funding to hire teachers who have 4-year degrees and certification, qualifications that are often required in schools that serve middle-class children and that are being considered in universal preschool initiatives (Gormley & Phillips, 2003, NIEER, 2003).

The NCLB directive challenges Head Start teachers and administrators to devise effective and efficient methods to improve preliteracy and premath skills. Computer programs have been suggested as a potential cost-effective way to close the achievement gap for children from lower socioeconomic circumstances (Whitehurst & Lonigan, 1998), and several studies have demonstrated positive results in preschool-age children using computer-based instruction. For example, computer-based interventions have been found to be effective in teaching phonological skills to young children (Barker & Torgeson, 1995; Foster, Erickson, Foster, Brinkman, & Torgeson, 1994), including a group of children in Head Start (Lonigan et al., 2003). At-risk groups, as well as children with reading or language impairments also have benefited from both intensive tutorial and computer-assisted learning (see Hall, Hughes, & Filbert, 2000; Strickland, 2002). In addition, computer and video technology have been employed successfully to improve mathematical concepts and knowledge of Head Start children (Arnold & Doctoroff, 2003; Arnold, Fisher, Doctoroff, & Dobbs, 2002). Overall, these studies show that computer programs can be used effectively with young children to improve learning in areas related to language and mathematics, including those in Head Start programs. However, no controlled studies have been reported of a computer program designed specifically to improve preliteracy and premath skills in the Head Start classroom.

The need to improve preliteracy and premath skills in Head Start children transitioning to kindergarten prompted the present investigation. Staff from Neighborhood House Association (NHA) of San Diego, CA, which is a nonprofit agency funded to administer 128 Head Start centers in San Diego County, worked with researchers from San Diego State University to explore the potential of a computer-based approach to improving the preliteracy and premath curriculum in the Head Start classroom. The study employed a custom program created for the preschool classroom that uses computer games to teach different preliteracy and premath skills.

Methods

Participants

The study was conducted over a 14-week period between March and June, 2004 at an urban San Diego Head Start center that serves approximately 60 children in the FD program and another 50 in the PD program. Seventy-three children from both FD and PD classes participated in the study. Forty-one of the participants were girls and 32 were boys, with an average age at the beginning of the study of 50.2 months (SEM, ± 1.2). The center served an ethnically and culturally diverse population, which was reflected in the sample of children in the study that included 30 Hispanic, 19 African-American, 6 Asian, 12 White, and 6 whose ethnicity was not defined, mixed, or did not fall into one of these categories.

The experimental group assigned to play the computer games was derived from children in two FD classes. The two classes were comprised of 39 children who shared a common space, as well as the same teachers. These factors made the curricular environment similar. Therefore, from this group of 39 children, 21 were randomly selected to participate in the experimental computer program group, with the other 18 children assigned to the control condition. Children in the PD program occupied different classrooms and were taught by different teachers at the center. The 34 children included in the study from two PD classes served as additional controls for the center's ongoing curriculum.

Procedures

Knowledge Assessment

The assessment protocol was developed in conjunction with kindergarten teachers from a local school district. Its creation was prompted by two factors: (a) the need for specific information about what a child knew in kindergarten-related domains, similar to the NRS procedure being employed nationally, and (b) the need for a relatively quick and child-friendly instrument that could be used with this age group. The items assessed were chosen from screening instruments used by the local school district for assessing children's knowledge at the beginning of Kindergarten. The reliability of the instrument was established with a sample of 12 children. Three experimenters tested each child on separate occasions (within-subject CV = 0.91; interrater CV = 0.97).

At the start and end of the study, all children were individually tested in a quiet room, at the Head Start center, for specific knowledge related to five areas: (a) 26 uppercase letter recognition; (b) number recognition from 1 to 10; (c) counting from 1 to 10; (d) color recognition of eight colors (red, green, light blue, dark blue, purple, yellow, orange, brown); and (e) shape recognition of a square, triangle, rectangle, circle, oval, and diamond. The children were assessed 1 to 3 weeks prior to the start of the experiment in March, and 1 week after the games were terminated in June. The assessment procedure took 15 to 20 minutes and required children to identify specific stimuli from a choice of three to five cards laid out on a table in front of them. Two trained personnel experienced with the instrument and testing of young children conducted all the assessments. These individuals were blind to the child's experimental assignment.

Computer Program

The computer program resided on a server located at the main office of NHA during the study. The program used Flash-based animation for the games, accompanied by a structured query language database to collect responses and construct reports for teachers. Each animated game was designed to address an individual skill and took children approximately 3 to 6 minutes to play. The games were constructed in hierarchical levels of difficulty, or sequence, so that children built their skills in small segments. Material learned previously was interspersed throughout subsequent levels in most games.

Children made their responses in the games with a mouse following an audio query. Therefore, at the beginning of the study, children were first required to master a game in the program designed to help them achieve proficiency in using a mouse before proceeding to the games that addressed other skills. All the games were designed around the normal attention span of preschool children and presented at a slow pace for learning, rather than the faster pace used in games designed for entertainment.

Each response was recorded to a database. The program tracked a child's progress, and each time the child signed on, the games began at the level where the child was when he or she was last using the computer. The program also tracked each response a child made, and depending upon the game and its design, 75 to 100% of the responses were required to be correct to move to the next level. After the first level, if a child failed to reach criterion on two successive tries, the computer automatically returned the child to the previous level.

Apparatus and Procedures for Playing the Games

The games were available throughout the school day on four classroom computers with Internet access. The computers were located together in a corner of the classroom, and the children played the games using headphones. The physical computer environment was adapted for young children. Small computer screens (15-inch flat screens), mice, and headphones, as well as tables and chairs were all child-size.

To play the games, each child entered a unique password that provided entrance into a "game room" where they could click on any of the icons that started the different games. The password screen consisted of a 5 x 5 array of pictures of objects or numbers. The first column contained five common objects (e.g., house, tree, etc.), columns 2 and 3 contained five different animals, and columns 4 and 5 contained the numbers 1 through 5. Since children at this age normally have a short-term memory capacity of 3 to 4 items, the password was constrained to sequences of pictures of objects and numbers. This grouping strategy allowed children to easily chunk the password into three groups (e.g., object, animal, and number).

Although the complete program contains more than 15 different games, in this study, we used only 5 games to teach colors, shapes, letter recognition, number recognition, and quantity knowledge. A sixth game was also used to train children to track an object on the screen and click on it. This game was used at the start of the study to teach children to use the mouse.

The program allowed teachers to individualize the games available to children when they entered the game room. Children with little computer experience had only one game available at the beginning, the game that familiarized them with the mouse and how to click on an object. When this game was mastered, the teacher made the skills-based games available when the children went into the game room. Children could stop playing the games at any time. When they returned to play at a later time, the program started each game at the level where they left off.

The game approach was reward based. Children earned a sticker for playing the games, and additional stickers for mastering a level. These stickers were given to children immediately upon completion, and they pasted them into their personal sticker book. At the end of the week, the students traded their stickers for small prizes.

Results

We performed an initial analysis of the raw scores from the assessment in March to look at baseline knowledge at the start of the study. Results showed that 30 to 50% of the children in each group knew more than half of the material related to letter identification, number recognition, and quantity knowledge, and all children knew 75% or more of the colors and shapes. Because most children knew the shapes and colors at the start of the study, these scores were not used for analyses. Eight students who started the study were not included in the final analyses. These students were distributed equally across the experimental and the FD control group. Three left the Head Start program after the start of the study; one was unable to sit long enough to provide information for a baseline assessment; three left the program early for summer break; and one student was absent for 6 weeks during the middle of the study.

To assess the impact of the games on learning, the score on the first assessment from each domain was employed as a covariate for the score on the second assessment. Thus, data from each domain were analyzed separately using a one-way ANCOVA. Post hoc analyses were conducted with the Tukey-Kramer multiple comparison test using the group means.

To gain a better picture of the impact of the games on learning, we performed an additional subanalysis using only data from children in all three groups who knew 50% or less of the material related to alphabet knowledge, number recognition, and quantity at the time of the first assessment (recognition of 13 or fewer letters, 5 or fewer numbers, or counting 5 or fewer items). Mean scores on both assessments are shown in Table 1.

As shown in Figures 1 through 3, children in the computer group showed significant improvement in the areas of letter recognition, number recognition, and quantity knowledge. When all children were included, the children in the experimental computer group showed significantly greater improvement at the end of the pilot study in the areas of letter recognition ($F[2, 69] = 7.72$; $p < 0.0001$), number recognition ($F[2, 69] = 11.42$; $p < 0.001$), and quantity knowledge ($F[2, 69] = 4.47$; $p < 0.02$) compared to controls who were exposed to the classroom curriculum alone. Post hoc analyses showed that the children in the experimental group scored significantly higher than both sets of controls ($p < 0.05$ or greater).

The impact of the games on learning was particularly notable in the analyses of scores from children who knew 50% or less of the material in a domain at the start of the study. When the initial knowledge level was relatively low, the gains were dramatic. Compared to children exposed to the classroom curriculum alone, those playing the games identified approximately twice as many letters. Similar results were observed for number recognition and quantity knowledge.

Discussion

The results of this study indicate that a computer-based game format can be an effective supplemental tool to improve children's preliteracy and premath skills in the Head Start classroom. Compared to children

Table 1. Mean (SEM) raw scores for pre- and postassessments for students who knew less than 50% of the material prior to the introduction of the games. Those students are identified in the numerator, with the total number of students in the group listed in the denominator. The number of items assessed in each domain is shown in parentheses.

Group	Letters (26)	Numbers (1–10)	Quantity (1–10)	Shapes (6)	Colors (8)
Full Day Control (18)	N = 11/18	N = 11/18	N = 10/18	N = 18	N = 18
Preassessment	4.73 (1.19)	2.45 (0.34)	3.00 (0.42)	5.0 (0.30)	6.56 (0.56)
Postassessment	12.09 (2.52)	4.45 (0.97)	4.63 (0.71)	5.28 (0.25)	7.78 (0.15)
Part Day Controls (34)	N = 22/34	N = 28/34	N = 21/34	N = 34	N = 34
Preassessment	3.73 (0.79)	2.58 (0.29)	2.28 (0.41)	4.65 (0.30)	6.09 (0.42)
Postassessment	10.0 (1.84)	4.00 (0.60)	3.83 (0.59)	4.12 (0.32)	7.35 (0/21)
Experimental (21)	N = 11/21	N = 15/21	N = 11/21	N = 21	N = 21
Pre-Assessment	6.55 (1.46)	3.31 (0.24)	3.90 (0.35)	5.52 (0.21)	7.62 (0.21)
Post-Assessment	24.09 (1.25)	8.38 (0.47)	8.20 (0.83)	6.00 (0.00)	8.0 (0.00)

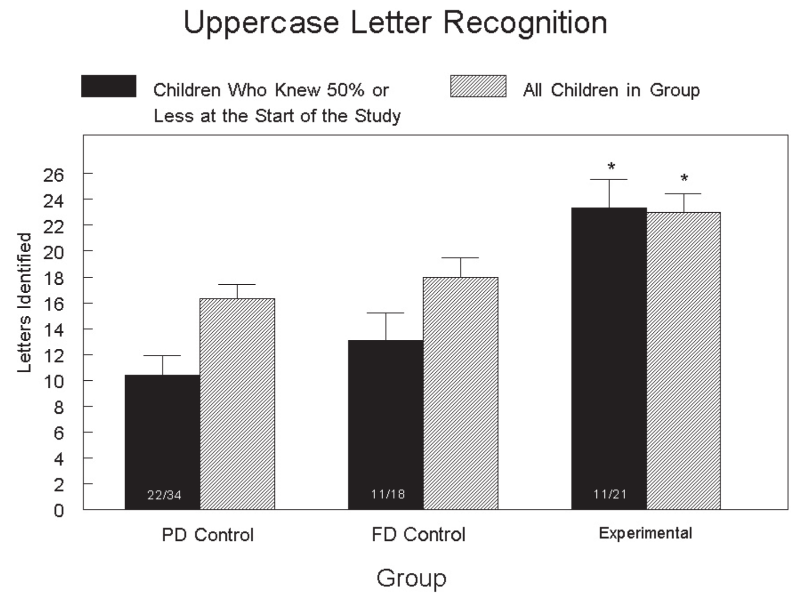

Figure 1. Data shown are the adjusted mean (± SEM) number of uppercase letters recognized by children at the conclusion of the study. The number of children in the subgroup is shown at the base of the column as a fraction of the total number of children in each group. $^*p < 0.05$ from both controls.

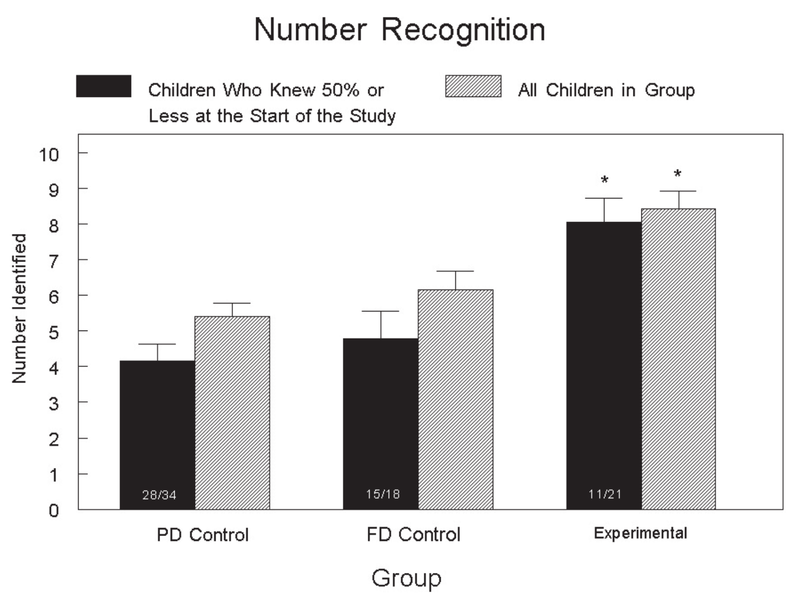

Figure 2. Data shown are the adjusted mean (± SEM) number of numerals between 1 and 10 recognized by children at the conclusion of the study. The number of children in the subgroup is shown at the base of the column as a fraction of the total number of children in each group. $^*p < 0.05$ from both controls.

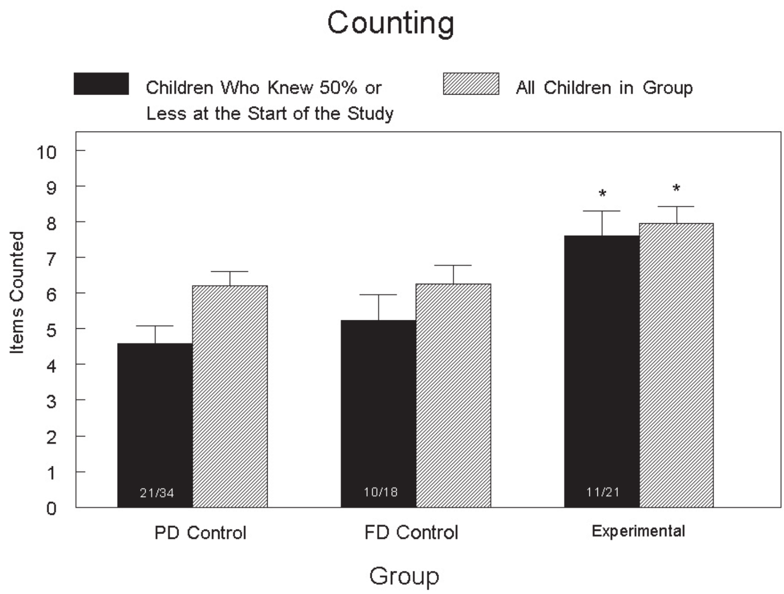

Figure 3. Data shown are the adjusted mean (± SEM) number of items counted between 1 and 10 by children at the conclusion of the study. The number of children in the subgroup is shown at the base of the column as a fraction of the total number of children in each group. *$p < 0.05$ from both controls.

exposed only to the teacher-directed curriculum, children who also played the computer games exhibited significantly greater gains over the 14-week study period in alphabet knowledge, number recognition, and quantity knowledge. This was most notable for children who knew 50% or less of the material in these areas when they were assessed at the beginning of the study. At the conclusion of the study, these children knew 80 to 95% of the material in these three domains compared to the controls, who knew 35 to 45%. Thus, compared to the curriculum alone, the addition of the games more than doubled the information children learned in these areas.

The improvement in preliteracy and premath skills associated with the games was assessed by independent measures. However, we observed a close parallel between the built-in computer tracking and the final assessment results in June; this means that mastery of the hierarchical levels of the games closely mirrored the independent knowledge assessment at the end. Only two children playing the games did not complete all levels of the alphabet game by the time of the second assessment, and three did not complete the quantity sequence. All the children completed the number recognition levels on the computer games. Interestingly, almost all the errors made in number recognition involved reversal of the numbers 6 and 9, which is considered a normal perceptual mistake at this age. The correspondence between the game performance and the results of the independent assessment suggests that the game structure is accomplishing the intended purpose of reinforcing the learning of specific skills.

This kind of structured use for computers in the preschool classroom is novel, and one of the goals of this study was to determine how quickly children would adapt to the computer game approach. We found that most of the children at the center had little, or minimal, experience with a computer. Thus, the introductory game proved to be a critical factor for many children to learn to efficiently move the mouse and click it on the object of interest. Many children, especially younger ones, had initial problems clicking the button on the right instead of the left when they made a response. On average children with no computer experience took 5 to 10 sessions of supervised help to effectively master the use of the two-button mouse and use the program independently.

Because of the overall unfamiliarity with the computer, more time than anticipated was initially spent by teachers to bring children to a point where they could work independently. Several minutes per child per day was initially required to help the children with their passwords, use the mouse, and activate the games. However, after approximately 12 sessions, all children were able to work independently. This means that they knew their password, how to use the headphones, and how to begin the program.

The initial experimental design called for children to play the computer games for 20 minutes a day for 50 to 60 sessions over the 14-week period of the study. However, in reality, this was a rough estimate. The novelty of the structured game approach in the classroom meant that there was no established basis on which to predict a learning rate for the different preliteracy and premath skills emphasized in the games. In fact, the exposure to the games turned out to be much more limited than planned in the experimental design due to several factors, including school absence and conflicting schedules during the day. Although the average session was 20 minutes after children learned to use the mouse, as planned, the average number of times each child played the preliteracy and premath games was only 27 (range was 15 to 48). In spite of this limited exposure, children appeared to learn quickly once they became familiar with the computer and the game format. The gains observed within this short period supports the potential for this kind of approach to enhance learning in the preschool classroom, as well as the initial investment of time to teach them the computer skills necessary to play.

Although children's enjoyment of the games contributed to their success, other environmental factors also made significant contributions. First was the use of a small mouse and computer screen to accommodate the children's size and motor skills. Another important factor was the physical arrangement of the computers. Grouping the computers into a pod on a table made it possible for a teacher to help several children at once, and it also fostered a group atmosphere that led to both competition and collaboration. Children who were more competitive enjoyed looking at other student's computer screens to see what level they were on. In some cases, children naturally assumed the role of peer teacher with other students who were experiencing difficulty. Surprisingly, the best volunteer "peer coach" in the study was only three and half years old. Although peer coaching was not part of the design, its effectiveness suggests that it should be integrated into learning approaches of this sort where possible.

The acquisition of preliteracy skills and premath skills is most important for children transitioning to kindergarten. However, several 3-year-olds were included in the study to assess their general reaction to the games. Of the four children included in the experimental group who were 3 years old when the study began, two began the study knowing fewer than 3 letters. At the end of the 14 weeks, they knew 24 to 26 letters. The third child knew more than 50% of the material when the study began and 90% of the material at the end. The fourth child was developmentally behind his classmates and not capable of sitting and playing the games.

Mastering a computer to play a game is a complex task for children at this age. When this happens, there appear to be secondary gains for cognitive growth that extend beyond the specific skills learned.

Although we did not formally measure attentional capacity and self-confidence, our informal observations indicate significant improvements took place in these areas as children mastered the games. Although teacher support was provided to guide them, children were generally encouraged to work as independently as possible. In this way, the games fostered a measure of autonomous exploration. For many children, we observed that the independence they experienced in playing on their own was a significant part of the games' appeal. This observation is consistent with findings showing that control is an essential factor in motivation and learning for preschool-age children using computer-based programs (Calvert, Stong, & Gallagher, 2005).

The games also appeared to enhance attentional capacity in many children, likely due to their structured design and the consequences that attended the children's choices when they used the mouse to respond. Initially, a number of children had difficulty selectively attending to the relevant dimensions of the game that were important to succeed. However, through trial and error on their part, as well as some teacher support, children caught on relatively quickly. For some children, "catching on" to the game was one of the most reinforcing and exciting aspects they experienced while playing. Over time, we observed that the initial motivational effect of the stickers was often replaced by the intrinsic rewards of perceived success.

The program provides easily accessed graphic reports of individual progress on each game. However, although the computer game approach can be tailored to the needs of a specific child, we were not able in this study to coordinate daily classroom lesson plans with the computer games. An analysis of this feature will be an important aspect to future studies to help determine the degree to which individualized programming effectively supplements classroom materials introduced by teachers in large and small group activities. It is also important to determine whether this approach can be an effective intervention for children with some kinds of learning and/or developmental disabilities.

In summary, our results indicate that computer-based supplements can significantly enhance learning of preliteracy and premath skills of children in the Head Start classroom. After 14 weeks of exposure, we found that the alphabet and numeracy skills of children playing the games were equal to, or above, those expected of children entering kindergarten.

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