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Xiaoming Li and Melissa S. Atkins

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Xiaoming Li, PhD*, and Melissa S. Atkins, PhD‡

ABSTRACT. ***Objectives.*** **To explore the association between early computer experience (both accessibility and frequency of use) and cognitive and psychomotor development among young children.**

Methods. **The participants were 122 preschool children enrolled in a rural county Head Start program in the United States during 2001–2002. The following tests were administered to the children: the Bender Visual Motor Gestalt Test; the Boehm Test of Basic Concepts, Third Edition Preschool; the Test of Gross Motor Development, Second Edition; and a short form of the Wechsler Preschool and Primary Scales of Intelligence–Revised. Information pertaining to family characteristics and children's early computer experience was collected from parents. Both bivariate and multivariate analyses were used to assess the association between early computer experience and cognitive and motor development.**

Results. **Of the participating children, 53% had a computer at home. Among families who had a computer, 83% had children's software on the computer. According to parents' reports, 29% of these children played on the home computer on a daily basis, and an additional 44% of the children played on the computer at least weekly. Of those families who did not have a home computer, 49% reported that their children had access to a computer somewhere outside home. Among these children, 10% had daily access to the computer and 33% had weekly access. The presence of a computer in the home was significantly associated with the family's income and the educational attainment of the parents. There was no gender difference in computer accessibility and frequency use among the participating children. Children who had access to a computer performed better on measures of school readiness and cognitive development, controlling for children's developmental stage and family socioeconomic status. The data in the current study did not suggest a relationship between computer experience and visual motor or gross motor skills among the participating children.**

Conclusion. **The findings in the present study suggest that early computer exposure before or during the preschool years is associated with development of preschool concepts and cognition among young children. However, frequency of use did not reveal such a relationship; neither did the ownership of other child electronic or video games in the household.** ***Pediatrics*** **2004;113: 1715–1722;** ***computer, cognitive development, preschoolers, motor development, school readiness.***

ABBREVIATIONS. SES, socioeconomic status; Boehm-3 Preschool, Boehm Test of Basic Concepts, Third Edition Preschool; TGMD-2, Test of Gross Motor Development, Second Edition; WPPSI-R, Wechsler Preschool and Primary Scale of Intelligence-Revised; MANCOVA, multivariate analysis of covariance.

With the advance of information technology and reduction of market price of computers and software, the number of personal computers in the home has increased dramatically in recent decades. For example, the number of households in the United States that owned 1 or more personal computers increased from 8.2% in 1984 to 51% in 2000.[1] A number of demographic and socioeconomic factors were associated with home computer ownership. Higher household income, larger family size, and residence in metropolitan areas or their vicinity all were significantly related to home computer ownership.[1] In addition, the presence of a child in the household was associated with having a computer at home. Nationwide, two thirds of households with a school-aged child (6–17 years of age) had a computer, whereas only 45% of households without a school-aged child had a computer. The percentage of children who were 3 through 17 years of age in the United States and lived in a household with a computer increased from 55% in 1998 to 65% in 2000. Among the families who own home computers and have young children, 70% have purchased educational software for their children to use.[2] Whereas increases in personal computer ownership occurred across households in different socioeconomic niches, families with low socioeconomic status (SES) had substantially less access to computers.[3,4] For example, in 2000, 94% of the children who lived in households with a family income of ≥$75 000 had access to a computer in the home, whereas only 35% of children who lived in households with a family income <$25 000 had access to a computer in the home. Despite such a huge disparity in access to technology between different SES niches, little is known about the actual impact of the technology on the developing minds and bodies of children, particularly those from socioeconomically disadvantaged families. Furthermore, because of the overall increase in personal computer ownership, children may have more access today than ever to a computer in their home or other informal setting (eg, parents' work-

From the *Wayne State University Pediatric Prevention Research Center, Detroit, Michigan; and ‡Ohio University Department of Psychology, Athens, Ohio.

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Reprint requests to (X.L.) Pediatric Prevention Research Center, Wayne State University School of Medicine, 4201 St Antoine, Ste UHC 6D, Detroit, MI 48201. E-mail: xiaoming_li@wayne.edu

place, child care center, baby-sitter's home, a relative's home, community library).

The children may access/use a computer in a number of ways: free playing, typing, playing games or learning software on the computer; playing or striking computer input devices (eg, keyboard, mouse, joystick); watching pictures, colorful images, or motion displays on the screen; or observing or imitating parents/adults using a computer. A recent national survey found that young public school children with access to home computers used them 3 to 4 days a week with the purposes of use varying by children's gender, ethnicity, and family SES.[3] A growing number of children also use home computers to access the Internet. For example, ~7% of children 3 through 5 years of age, 25% of children 6 through 11 years of age, and 48% of children 12 through 17 years of age in the United States accessed the Internet at home.[1]

Children's access to computers and the Internet at schools has become rapidly prevalent in recent years. According to survey data from the US Department of Education, the nationwide ratio of students to instructional computers was ~6 to 1 in the late 1990s, with a majority of public school teachers indicating that computers were available in their schools.[5] In addition, Internet access in public schools has increased from 35% in 1994 to 95% in 1999 nationwide.[6] Although national data showed no relationship between home and school computer use in terms of accessibility and frequency of use, the same data did indicate that kindergarten children from minority or low-SES families without home computers were less likely to attend schools that provide students access to the Internet.[3]

Given the increased prevalence of access to computers and the Internet in schools, it seems that preschool years offer the most promising opportunity to close the socioeconomic gap in access to computer technology. However, the potential value of a personal computer in early child development has been debated consistently among parents, schoolteachers, and researchers for decades.[2,7–11] Although a number of child developmental theories have been used in the literature to speculate whether (or how) the computer would affect early childhood (either positively or negatively),[12–15] the empirical evidence is scarce and conflicting. Studies have found that computer use enhances children's fine motor skills,[16] alphabet recognition,[17] concept learning,[18] numerical recognition,[19] counting skills and premathematical knowledge,[20,21] cognitive development,[14,22–24] and self-esteem or self-concept.[23,25] Ainsa[26] implemented a computer curriculum among children from low-income families (Head Start preschools) and found that the computer curriculum led to increases in cognitive, motor, and language scores (as measured by an early screening test) when compared with children in a regular Head Start curriculum. In contrast, a number of studies found no effect of computer use on children's knowledge of prereading concepts,[27] discourse skill,[28] and/or cognitive development.[29–31] Some authors have argued that computers are too abstract or too symbolic for the developmental stage of preschool or younger children. The arguments also include the notion that computers might replace some early childhood activities that are essential experiences to children's physical, psychological, and social development (eg, playing with tangible toys and interacting with peers).[10,12,13,32] Similarly, limited data also revealed conflicting findings regarding the potential impact of home computer use on children's social and cognitive development.[33–35]

On the basis of their review of limited research on the effects of home computer use on children's physical, cognitive, and social development, Subrahmanyam et al[33,34] indicated that playing computer games could be an important building block to computer literacy. They believe that home computer use enhances children's visual intelligence skills, such as the ability to read and visualize images in 3-dimensional space and trace multiple images simultaneously. However, in a quasiexperiment home/school computer project among 289 fourth and fifth graders, Miller and McInerney[36] suggested no relationship between home computer use and academic achievement in reading, language, and mathematics. In their study, the treatment group ($n = 142$) received a computer, printer, and telecommunications equipment for learning activities in their homes. Follow-up data over 2 years indicated that participation in the project was not associated with improvement in academic achievement.

The discrepancies in findings from various studies may be related to methodologic issues in study design and measurements.[8,9,24] Nevertheless, it is apparent that the majority of the conflicting results or debates on the issue involved the use of a computer in formal teaching and learning activities in a school environment or involved older children (eg, school-aged children),[4,36] among whom the use of a home computer was heavily confounded by the use of computers at schools. To the best of our knowledge, few empirical data are available to date about the effect of early childhood computer experience at home before formal schooling on the physical and mental well-being of young children. Therefore, the current study was designed to explore the association between early computer experience (both accessibility and frequency of use) and cognitive and psychomotor development among young children. There are a number of research questions that the current study attempted to answer. First, what is the general pattern (in terms of accessibility and frequency of use) of early childhood computer experience among a rural low-income population? Second, is there a relationship between early childhood computer experience and family demographic characteristics? Third, is there a relationship between early computer experience (both accessibility and frequency of use) and cognitive and psychomotor development, as measured by standardized assessment instruments, among young children? Finally, what is the effect of early computer use on cognitive and motor development in relative to use of household child electronic or video games? As the data in the current study were derived from a larger study with a set of different objectives, the results reported here should be considered as hypothesis generating rather than hypothesis testing.

METHODS

Participants

The participants for the present study were 122 preschool children (57 boys and 65 girls) who were enrolled in the Monongalia County Head Start Program in northern West Virginia. The Monongalia County Head Start Program was operating in 8 sites that served 181 families during the time of the study. The majority (90%) of the families who were enrolled in the program met federal income eligibility for Head Start. A total of 134 students were enrolled in the Monongalia County Head Start Program for the 2001–2002 school year. Of the enrolled students, 12 did not participate in the current study for various legitimate reasons (5 children had significant developmental or behavioral problems; 4 were consistently absent and not available for testing; 1 was enrolled after testing had completed; 1 refused to participate; and 1 was not tested because of the teacher's concerns).

The age of children ranged from 38 months to 61 months with a mean of 52 months. Approximately 82% of the mothers and 74% of the fathers had completed high school. The enrolled children had a median family annual income of $11662 (range: $0–$62 000). All children were participating in a randomized controlled trial designed to examine the effect of computer use on preschoolers' cognitive and motor development. The present study is based on the data collected at baseline assessment in fall 2001. The study protocol was approved by the Institutional Review Board at the West Virginia University (Morgantown, WV).

Measures

Family Demographic Characteristics and SES

Parents were asked to complete a brief family survey during Head Start preenrollment home visits. The survey contained family demographic information (eg, number of young and older siblings living in the same household) and children's experience with computer. Each family also provided information regarding family income, education attainments, and occupations of both the father (male guardian) and the mother (female guardian).

Early Computer Experience

Parents were asked whether there was a computer at home (yes/no). Those who gave a positive response were asked whether there was child software (either educational or entertainment) on the home computer (yes/no). Parents were also asked whether the child had access to a computer outside the home (eg, parents' workplace, baby-sitter's home, child care center, relative's home, computer library). Parents who had a computer at home or whose children had access to a computer outside home were asked to indicate how often their child played on the computer (daily, at least once a week, at least once a month, less than once a month, occasionally, never). In addition, parents were asked whether there was any other type of child electronic/video game at home (eg, Nintendo, Sony Playstation, Atari, Gameboy). For the purpose of data analysis in the present study, 2 composite scores were derived from the responses to computer-related questions. The first composite score, based on responses to 2 items (have access to a computer at home or somewhere else), indicates the children's accessibility to a computer with a 3-point response option (no access at all, either at home or outside home, both at home and outside home). The second composite score, also based on responses to 2 items (frequencies of use at home or somewhere else), represents the frequency of use among children who had used (eg, played) a computer (either at home or somewhere else). The frequency of use composite score has 3 response choices: daily, weekly (at least once a week), and infrequently (at least once a month, less than once a month, and occasional use). For children who did not have any access to a computer or had a computer at home but never played on it, a missing value was assigned to the second composite score.

Visual Motor

The Bender Visual Motor Gestalt Test (Bender)[37] was used to assess children's visual motor development. To administer this test, a child is shown 8 cards 1 at a time, each with a figure on it. The child is asked to draw each figure as best as she or he can. The tester moves to the next card when the child completes 1 figure. Children's drawings are then scored by assigning 1 point for each significant mistake that is made (eg, preservation) such that higher scores indicate lower levels of visual motor development.

School Readiness

The Boehm Test of Basic Concepts, Third Edition Preschool (Boehm-3 Preschool)[38] was used to assess children's understanding of basic concepts relating to size, direction, position, time, quantity, and classification. To administer this test, the experimenter shows a child a picture and reads a corresponding statement. The child is asked to point to the part of the picture that best matches what the experimenter says. The child receives a score of 0 for an incorrect response and 1 for a correct response. The raw score is converted into a percentile score.

Gross Motor

Test of Gross Motor Development, Second Edition (TGMD-2)[39] was used to measure children's gross motor abilities in the following 2 areas: locomotor (running, jumping, etc) and object control (catching, hitting, kicking, etc). To administer this test, the experimenter demonstrates each action and asks the child to repeat it twice. The child receives a score of 1 if he or she correctly performed the action in both trials or a score of 0 otherwise. A child's scores for each action are summed, and all actions within a subtest are then summed; this raw score is converted to a percentile. The 2 subtest standard scores are summed and then converted into a total gross motor percentile score.

Cognitive Development

A short form of the Wechsler Preschool and Primary Scale of Intelligence–Revised (WPPSI-R)[40] was used to assess children's cognitive development. The short form consists of 4 subtests (Information, Block Design, Picture Completion, and Similarities). Previous studies suggested significant correlations between estimates of IQ based on this short form of the WPPSI-R and IQ scores based on the administration of the full scale.[41] The short form was used in the present study because of constraints in assessment time (eg, 6 of the 8 Head Start classrooms were half-day programs). The Information subtest involves asking children to identify pictures of everyday objects and to answer questions about everyday information; children receive a score of 1 for each correct answer and 0 for each incorrect answer. For the Block Design subtest, children are asked to copy designs either from a design made by the experimenter or from a design in a book. Children can receive a score from 0 to 4, depending on how quickly they complete the design. The Picture Completion subtest involves showing children an incomplete picture and asking them to identify the missing part; children receive a score of 1 for correct responses and 0 for incorrect responses. Finally, the Similarities subtest involves having children identify similar pictures and then also explain similarities between items; children receive a score of 0 for incorrect responses and 1 for correct responses on the first part of the subscale. Children's scores range from 0 to 2 on the second part of this subtest based on the sophistication of the child's response. Raw scores are computed for each test and then converted into standard scores with a mean of 100 and standard deviation of 15. A child's estimated IQ is derived on the basis of the sum of the child's standard scores on the 4 subtests following a converting table commonly used in previous research and testing practices.[41]

Procedure

Written informed consent and family demographic information were obtained from the parents before the start of the 2001–2002 school year. The parents were informed about the purpose and design of the study, as well as the scope of the assessments. Trained psychology graduate students tested the children during regular school hours. Each child was typically tested on only 1 test in any particular day, although some children were administered the Bender and Boehm-3 Preschool (2 relatively short assessments) during the same day. Two licensed clinical psychologists at the West Virginia University provided the graduate students with additional training before the assessment and supervised the assessments and scoring.

Statistical Analysis

First, the association of early computer experience (accessibility and frequency of use) with the demographic variables and family SES was assessed using χ^2 test for linear-by-linear association (for categorical variables) or 1-way analysis of variance for linear trend (for continuous variables). Second, linear trend of children's test scores was compared across different levels of computer accessibility (no access, access either at home or outside home, access both at home and outside home) and frequency of use (monthly or less frequently, weekly, and daily) using 1-way analysis of variance polynomial contrasts (in which the between-groups sums of squares were partitioned into a linear and quadratic components). Because home computer ownership is associated with family SES (eg, family income),[1] an association between psychomotor development and early computer experience is potentially confounded by family income as well as children's age and gender. Therefore, multivariate analysis of covariance (MANCOVA) was conducted to assess the effects of accessibility and frequency of use on test performance in 2 separate models. In the first model, the accessibility variable served as the main between-subjects factor. Scores of the 4 cognitive and psychomotor scales (Bender, Boehm-3 Preschool, TGMD-2, and WPPSI-R) were used as multiple dependent variables. Children's gender, as a categorical variable, was entered into the MANCOVA model as an additional between-subjects factor, whereas children's age and family income were entered into the model as covariates. The second MANCOVA model followed the same design except the frequency of use variable was used as the main between-subjects factor. To explore whether the effect of computer use is similar to that of electronic/video games, the third MANCOVA model used the ownership of any other electronic/video game at home as the main between-subjects factor. Pillais F test was used for evaluating multivariate significance because the test retains statistical power when violations of homogeneity of matrices and distributional normality are present.[42] The conventional F test was used for univariate testing, and t statistic was used to assess the significance of covariates.

RESULTS

Early Computer Experience

As shown in Table 1, of the 122 participating children, 53% had a computer at home and 49% had a children's electronic/video game at home. Among families who had a computer, 83% had children's software on the computer. According to parents' reports, 29% of these children played on the home computer on a daily basis and an additional 44% of the children played on the computer at least weekly. Approximately 1 half of the participating families and 56% of families without a home computer reported that their children had access to a computer somewhere outside the home. Among these children, 10% had daily access to the computer and 33% had weekly access. Accessibility composite score indicates that 56% of the children had access to a computer either at home or outside home, and an additional 24% had access both at home and outside home. Among children who had access to a computer, one quarter of them used it on a daily basis, 43% used it at least once a week, and approximately one third used it once a month or less frequently. Although girls were more likely to access a computer outside home than were boys (55% vs 42%) and boys tended to use computers more frequently than did girls (eg, 28% vs 23% for daily use), there was no

TABLE 1. Pattern of Computer Access and Test Performance Among 122 Preschoolers

	Overall	Boys	Girls
N (%)	122 (100%)	57 (47%)	65 (53%)
Had a computer at home	65 (53%)	30 (53%)	35 (54%)
Had children's software on home computer*	54 (83%)	23 (77%)	31 (89%)
How often did child play on the computer*			
Daily	18 (29%)	9 (32%)	9 (26%)
At least once a week	28 (44%)	11 (39%)	17 (49%)
At least once a month	7 (11%)	2 (7%)	5 (14%)
Less than once a month	1 (2%)	0	1 (3%)
Occasionally	2 (3%)	2 (7%)	0 (0%)
Never	7 (11%)	4 (14%)	3 (9%)
Had access to a computer outside home	58 (49%)	23 (42%)	35 (55%)
How often did child play on the computer†			
Daily	6 (10%)	2 (9%)	4 (11%)
At least once a week	19 (33%)	9 (39%)	10 (29%)
At least once a month	11 (19%)	3 (13%)	8 (23%)
Less than once a month	2 (3)	0	2 (6%)
Occasionally	20 (34%)	9 (39%)	11 (31%)
Had a child video game at home	58 (49%)	28 (51%)	30 (47%)
Computer accessibility (composite score)			
Nowhere	24 (20%)	14 (26%)	10 (16%)
Either home or elsewhere	67 (56%)	29 (53%)	38 (59%)
Both home and elsewhere	28 (24%)	12 (22%)	16 (25%)
Frequency of use (composite score)			
Daily	22 (25%)	10 (28%)	12 (23%)
Weekly	38 (43%)	16 (44%)	22 (42%)
Monthly or less	28 (32%)	10 (28%)	18 (35%)
Test performance			
Visual motor (Bender)	13.84 ± 2.86	14.35 ± 2.59	13.42 ± 3.01
School readiness (Boehm-3 Preschool)	29.75 ± 26.46	26.66 ± 23.21	32.53 ± 29.00‡
Gross motor (TGMD-2)	16.39 ± 11.86	16.61 ± 11.47	16.21 ± 12.28
Cognitive development (WPPSI Estimated IQ)	91.35 ± 12.31	89.07 ± 12.38	93.35 ± 11.98

* Data were available only from families with a computer at home (n = 65).
† Data were available only from children who had access to a computer elsewhere (n = 58).
‡ $P < .05$.

statistically significant gender difference in terms of the pattern of computer accessibility and frequency use.

Test Performance

Children's scores on the visual motor test (Bender) ranged from 5 to 21, with a mean score of 13.84 (standard deviation [SD]: 2.86). Children's percentile score on the school readiness (Boehm-3 Preschool) ranged from 1 to 99, with a mean of 29.75 (SD: 26.46). Percentile scores of the gross motor (TGMD-2) locomotor subtest ranged from 0 to 50, with a mean of 17.36 (SD: 11.48), and percentile scores on the TGMD-2 object control subtest ranged from 1 to 63, with a mean of 23.21 (SD: 13.16). The mean TGMD-2 gross motor percentile score was 16.40 (SD: 11.86; range: 0–73). The WPPSI-R short form yielded an estimated IQ score ranging from 63 to 119 (mean: 91.35; SD: 12.31). Although there was a gender trend in test performance with girls performing better than boys on all 4 tests (Table 1), none of the differences achieved statistical significance except for the school readiness ($P = .043$).

Computer Experience and Demographic Characteristics

As shown in Table 2, there is a linear trend (albeit statistically nonsignificant) between children's age and accessibility and frequency of use, with older children reporting more access to a computer and more frequent use than younger children. Likewise, children who had fewer younger siblings and more older siblings had greater accessibility and more frequent use than those who had more younger siblings and fewer older siblings. The computer accessibility variable is significantly associated with family SES (family income, parents' education attainment), with greater access in higher-SES families. To the contrary, family income was inversely associated with the frequency of use. The children from families with a relatively higher income tended to use computers less frequently than did children who had a lower family income. Children who had children's software at home were using computers more frequently than were children who did not have such software ($P < .001$). There was no association between the ownership of other home electronic/video games and home computer experience (accessibility and frequency of computer use).

Computer Experience and Test Performance

As shown in Table 3, generally there was a linear trend between computer accessibility and all of the cognitive and psychomotor assessments. Children who had more computer access (eg, both at home and outside home) performed significantly better than children who had less access on Boehm-3 Preschool percentile score ($P < .001$) and estimated IQ ($P < .0001$). Children who had access to a computer performed significantly better on all WPPSI subscales (Block Design, $P < .001$; Picture Completion, $P < .05$; Information, $P < .01$; and Similarities, $P < .05$).

The frequency of use did not significantly correlate with scores on any of the measures. The data suggested some mixed trends regarding the potential "dose effect" of computer use among young children. Although there was generally a positive trend between the frequency of use and test performance on Bender and WPPSI-R Picture Completion, frequency of use was inversely correlated with the WPPSI-R verbal tasks (Information and Similarities), TGMD-2 Locomotor subscale, and TGMD-2 total gross motor score. In addition, children who used a computer weekly outperformed on Boehm-3 Preschool and WPPSI-R Block Design than children who used it either daily or much less frequently (monthly or less).

Multivariate Analyses

Table 4 depicts the results from 3 MANCOVA models. There was a significant main effect of accessibility on the cognitive and psychomotor test scores ($P < .05$), controlling for child age and gender and family income. The accessibility variable exerted a significant main effect on both school readiness and estimated IQ. There was a significant main gender effect on the Bender visual motor test, with boys

TABLE 2. Association Between Computer Experience and Demographic Characteristics*

	Access to a Computer†			Frequency of Play‡		
	None	Either	Both	Infrequently	Weekly	Daily
N (%)	24 (20%)	67 (56%)	28 (24%)	28 (32%)	38 (43%)	22 (25%)
Age, mo	50.79 ± 6.30	51.78 ± 6.51	53.46 ± 6.69	51.18 ± 6.46	52.08 ± 6.94	54.41 ± 5.63
No. of young sibling	0.67 ± 0.76	0.76 ± 0.72	0.18 ± 0.39‖	0.71 ± 0.66	0.50 ± 0.65	0.45 ± 0.67
No. of old sibling	1.00 ± 0.88	0.93 ± 0.99	1.36 ± 1.03	0.82 ± 0.67	1.13 ± 1.07	1.14 ± 1.13
Family income ($10 000)	0.96 ± 0.73	1.25 ± 0.78	1.72 ± 1.61‖	1.64 ± 1.59	1.35 ± 0.87	1.18 ± .69
Mother finished high school	14 (58%)	57 (85%)	26 (93%)**	25 (89%)	34 (89%)	18 (82%)
Father finished high school	10 (42%)	47 (70%)	24 (86%)**	18 (64%)	33 (87%)	14 (64%)
Had child software§	NA	30 (81%)	24 (86%)	6 (55%)	27 (93%)	18 (100%)#
Had video games	12 (50%)	29 (43%)	17 (61%)	14 (50%)	14 (37%)	15 (68%)

NA indicates not applicable.
* Numbers in cells are mean ± SD unless noticed otherwise.
† Number of places where child had access to a computer (None = no access; Either = home or elsewhere; Both = home and elsewhere); three families did not provide the information.
‡ Data were available only from children who had access to a computer somewhere ($n = 88$).
§ Data were available only from families with a computer at home ($n = 65$).
‖ $P < .01$.
# $P < .001$.
** $P < .0001$.

TABLE 3. Association of Early Computer Experience With Cognitive and Motor Development

	Access to a Computer*			Frequency of Play†		
	None	Either	Both	Infrequently	Weekly	Daily
Visual motor (Bender)						
Raw Score	14.15 ± 2.75	13.88 ± 2.76	13.44 ± 3.35	14.63 ± 2.36	13.43 ± 3.40	13.54 ± 2.74
School readiness (Boehm Preschool-3)						
Percentile Score	19.50 ± 21.07	27.81 ± 24.24	44.15 ± 31.73‖	29.64 ± 25.38	39.76 ± 31.02	27.27 ± 23.28
Gross motor (percentile score)						
Locomotor	15.32 ± 12.11	18.46 ± 11.32	16.74 ± 11.81	20.07 ± 11.25	17.27 ± 9.79	16.38 ± 12.20
Object Control	19.68 ± 12.64	25.06 ± 14.21	21.48 ± 10.83	24.00 ± 12.03	23.95 ± 13.27	24.48 ± 15.02
Gross Motor Scale	13.32 ± 11.54	18.35 ± 12.82	14.37 ± 9.37	20.48 ± 15.04	15.92 ± 8.90	15.61 ± 11.60
WPPSI						
Block Design	7.04 ± 2.20	8.24 ± 2.59	9.46 ± 2.95‖	8.25 ± 2.61	8.76 ± 2.68	8.09 ± 2.88
Picture Completion	9.50 ± 3.15	10.81 ± 2.78	11.50 ± 3.36‡	10.93 ± 2.73	10.37 ± 3.10	11.95 ± 2.89
Information	7.00 ± 2.19	7.87 ± 2.42	8.75 ± 2.20§	8.39 ± 2.18	8.16 ± 2.58	7.68 ± 2.40
Similarities	7.63 ± 2.36	8.45 ± 2.26	9.14 ± 2.38‡	8.89 ± 2.10	8.55 ± 2.55	8.68 ± 2.30
Estimated IQ	84.96 ± 13.21	91.69 ± 10.88	96.89 ± 12.75#	93.43 ± 11.66	91.68 ± 11.83	93.91 ± 12.22

* Number of places where child had access to a computer (None = no place; Either = home or elsewhere; Both = home and other place).
† Data were available only from children who had access to a computer somewhere (n = 88).
‡ $P < .05$.
§ $P < .01$.
‖ $P < .001$.
\# $P < .0001$.

TABLE 4. Results of Multivariate Analyses of Covariance

	Main Effects and Interaction			Covariates	
	Factor	Gender	Factor × Gender	Family Income	Child Age
Accessibility (factor)					
Multivariate test (Pillais F)	2.08*	2.27	1.60	NA	NA
Visual motor	<1	6.36*	2.06	−1.46	−3.29†
School readiness	3.30*	<1	<1	<1	4.66‡
Gross motor	2.88	1.58	3.71*	<1	−5.45‡
Estimated IQ	5.30†	<1	<1	<1	<1
Frequency of use (factor)					
Multivariate test (Pillais F)	1.40	1.06	<1	NA	NA
Visual motor	<1	2.58	<1	−1.36	−2.31*
School readiness	2.00	<1	<1	<1	3.98‡
Gross motor	<1	<1	2.07	−1.55	−4.09‡
Estimated IQ	<1	1.73	<1	<1	1.52
Had video game (factor)					
Multivariate test (Pillais F)	<1	1.47	1.91	NA	NA
Visual motor	<1	3.44	<1	−1.34	−3.50†
School readiness	<1	<1	<1	<1	4.84‡
Gross motor	<1	<1	2.52	<1	−5.31‡
Estimated IQ	<1	2.25	2.38	<1	1.20

* $P < .05$.
† $P < .01$.
‡ $P < .0001$.

doing better on the test. There was a significant interaction between accessibility and gender for the gross motor test. Additional examination of the cell means revealed that the interaction resulted from the differences in gross motor percentile scores among boys with different levels of accessibility (8th percentile for boys who had no access to a computer, 20th percentile for boys who accessed a computer at either home or outside home, and 13th percentile for those who accessed a computer at both home and outside), whereas the scores for girls were similar among different levels of accessibility (18th percentile, 16th percentile, and 17th percentile, respectively).

There was no main effect of frequency of use and ownership of electronic/video games on test scores. Consistently across all 3 MANCOVA models, children's age was a significant covariate for the Bender, TGMD-2 gross motor, and Boehm-3 Preschool tests, with older children doing better on the visual motor and school readiness tests. However, younger children did better than older children on the gross motor test, in reference to the national norm of their age group.

DISCUSSION

Data in the current study indicate that among this low-income rural community, computers were present in more than half of the children's homes, and there was children's software on most of these computers. Consistent with the national data,[1] children who were from higher income families and had parents who had higher levels of education were more likely to have a computer in their home. Most of these children played on a computer at least once a week if not more often. Of children who did not have a computer at home, more than half had access to a computer somewhere else. These children did not play on the computer nearly as often as children with computers at home, most likely because of inconvenience in access (eg, time, location). The data suggest a significant association between computer accessibility and children's performance on the school readiness and cognitive tests, controlling for developmental and socioeconomic differences among children and their families. However, data in the current study did not suggest a relationship between computer accessibility and visual motor or gross motor skills among the participating children.

The present study found that children who had access to a computer performed better on school readiness (Boehm-3 Preschool) and cognitive development (WPPSI-R), suggesting that computer access before or during the preschool years is associated with the development of preschool concepts and cognition. The frequency of access did not reveal such a relationship, and neither did ownership of other child electronic/video games in the household.

A major potential limitation of the present study is the lack of information on the duration and specific activities (or software) that these children had on their computers and whether (or how) parents (or other adults) provided any guidance for their children to use a computer. The absence of the information further precluded any meaningful theoretical speculation or interpretation of the findings in the current study. Previous studies suggested that 2 of the critical issues with computer use among young children were the appropriateness of the software that they used[8,22] and adult supervision.[43] Lehere et al[31] found that improvement in specific cognitive skills by using computers in classrooms was a direct function of the type of software used. Haugland et al[8,23] also suggested that computers can reduce children's creativity if nondevelopmentally appropriate software (eg, drill-and-practice) is used. Earlier studies of home computing revealed that most school-aged children used the computer to play games, followed by educational software, creativity software, and other activities.[4] A random telephone survey of 1000 US households that own a personal computer found that two thirds of the families used computers to help with children's homework (68%) and run educational programs (65%).[44] Similarly, a recent national survey found that >85% of young children with a home computer used it for educational purposes.[3] Children of younger age often use computers with help from parents or other adults (or even older siblings). The US household survey[44] also revealed that on average, parents spent 2.4 hours a week using the computer with their children, and in 16% of the families, parents spent at least 5 hours a week on the computer with their children.

Together with the previous research findings that children in underserved (eg, poor, rural) communities have limited access to computers and/or are more likely to use drill-and-practice software,[1,9] the inverse relationship between the family SES and frequency of use in the current study provides cautionary evidence that use of a computer among some families might not be as constructive (or optimal) as it should be. However, previous research suggested that the value of the computer for children at this particularly young age group (eg, 3–5 years) is in its process (eg, open-ended use) rather than its content (eg, making a specific product).[45] In addition, the different associations of children's test performances with computer accessibility and electronic/video game ownership suggested a beneficial role of a computer rather than other electronic/video games in children's school readiness and cognitive development. Nevertheless, future studies need to examine closely the context of home computer use (eg, software, parental supervision or guidance) among young children.

The lack of association of the frequency of use with cognitive and motor development among children may need to be interpreted with caution. The measure of frequency use was based solely on parental report in a very general term, which might be subject to errors in estimation and recall. However, that data in the current study are consistent with findings from a recent national survey[3] that the frequency of home computer use among kindergarten and first-grade children did not differ by child or family characteristics. Another limitation of the current study is that the Bender Visual Motor Gestalt Test did not seem to be an appropriate measure of visual-motor development for children of this age group. Whereas the test has been widely used in assessing maturation of visuoperceptual and visuomotor functioning in children,[37] it seemed to be difficult for children younger than 5 years to perform the tasks, as it is difficult to keep the children's attention focused on the task. In addition, no test norm was available for children of this age group (younger than 5 years of age). Other age-appropriate standardized measures that are easier to administer may provide more meaningful results of visual motor assessment.

Given the retrospective nature of the measures of computer experience and the early developmental stage among the participating children, one may speculate a causal influence from the computer use to children's school readiness and cognitive development. However, there is a possibility that the direction of causality is in the opposite direction. Cross-sectional and retrospective research, as the current one, provides a good beginning for understanding the relationship between early computer experience and cognitive development among young children, but longitudinal and prospective studies are needed in the future to test rigorously the nature and direction of the causality of computer use on early child development.

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