Emerging Computer Skills: Influences of young children's executive functioning abilities and parental scaffolding...

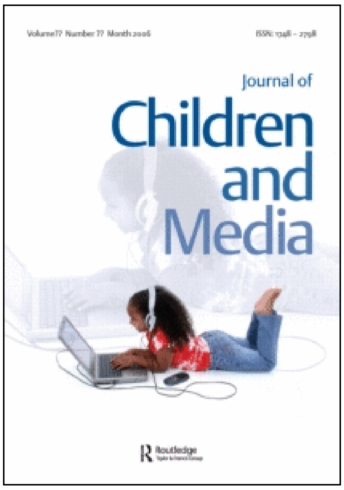
Article *in* Journal of Children and Media · January 2009

3 authors:

Alexis R. Lauricella
Northwestern University

Rachel Barr
Georgetown University

Sandra L Calvert
Georgetown University



Journal of Children and Media
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t741771146

Emerging Computer Skills

Alexis R. Lauricella; Rachel F. Barr; Sandra L. Calvert

Online Publication Date: 01 August 2009

EMERGING COMPUTER SKILLS
Influences of young children's executive functioning abilities and parental scaffolding techniques in the US

Alexis R. Lauricella, Rachel F. Barr and **Sandra L. Calvert**

The purpose of this study was to examine how 4-year-old children learn to use computers, with specific interest in what cognitive factors and parental scaffolding practices are associated with control of the computer via the computer mouse interface. Fifty-three 4-year-old children were videotaped while viewing two computer storybooks. Results indicated that children who had better executive functioning abilities were more likely to control the mouse. When the child primarily controlled the mouse, parent verbalizations were typically related to computer mechanics about how to use the mouse. In contrast, when the parent primarily controlled the mouse, parent verbalizations were focused on story-relevant questions. Regardless of whether the child or parent controlled the mouse, story comprehension was comparable. The results suggest that executive functioning ability is important in young children's development of computer skills and that parents adapt their verbalizations to match the abilities of their children and the tasks that they are doing.

KEYWORDS comprehension; computer skills; executive functioning; inhibition; interactivity; learning; parent–child interaction; preschoolers; scaffolding

Computers are now a ubiquitous presence in American households, including those of very young children. In 2005, 75% of homes with children aged 6 months to 6 years had a computer, and 36% of families owned more than one computer (Calvert, Rideout, Woolard, Barr, & Strouse, 2005). Large-scale survey studies report that 56% of children between the ages of 4 and 6 have used a computer by themselves (Rideout, Vanderwater, & Wartella, 2003). Currently 43% of children aged 4 to 6 use a computer several times a week or more, 26% use a computer on a typical day (average 50 minutes), and 13% use a computer daily (Rideout & Hamel, 2006).

Although nearly half of young children use computers, there is very little research on exactly how they learn to use this technology. The purpose of this study was to answer three main questions regarding preschool-aged children's computer use: what kinds of cognitive skills facilitate early computer use? What kinds of parent–child interactions facilitate children's computer skill development and knowledge of content presented via a computer? How does learning to use a computer mouse influence children's understanding of program content?

Journal of Children and Media, Vol. 3, No. 3, 2009
ISSN 1748-2798 print/1748-2801 online/09/030217-233
 DOI: 10.1080/17482790902999892

Executive Functioning and Computer Use

Executive functioning is a complex cognitive regulatory system that helps guide behavior in a goal-directed manner (Hughes, 2002). Executive functioning encompasses a range of processes including: (1) working memory (the ability to hold information in mind in order to complete a task), (2) inhibition (the ability to refrain from performing an action, particularly those that are incompatible with the task at hand), and (3) the ability to shift attention between two competing tasks. Executive functioning skills develop rapidly in the preschool years (Espy, Kaufmann, Glisky, & McDiarmid, 2001; Zelazo, Carter, Reznick, & Frye, 1997).

One method of testing children's executive functioning abilities to *shift attention*, *inhibit responses*, and use *working memory* involves a measure called Shape School (Espy, 1997). Children are given one set of rules for playing the first part of Shape School, the set of rules changes for the second part of the game, and the child must complete the final part of the game simultaneously utilizing both sets of rules. At age 3, when tested on a similar task, children are able to follow the first set of rules; however, they generally fail at rule switching until about age 5 (Zelazo, Frye, & Rapus, 1996). In the present study, our target age group was 4-year-olds who should be in the midst of acquiring these relevant executive functioning skills.

Executive functioning skills may also be associated with children's abilities to comprehend television content and to use a computer mouse. Although research regarding computer use is still limited, there is research assessing executive functioning skills and television viewing. The capacity model (Fisch, 2000) suggests that children have to allocate working memory to multiple resources when watching television in order to comprehend both the narrative and embedded educational content, such as the alphabet, that are presented by the television program. Since television as a medium does not allow the viewer to stop the presentation of content, the child is forced to simultaneously process the narrative of the story and the educational content. It is likely that these same cognitive skills will be relevant to computer use as well.

When reading computer storybooks with a parent, children need to allocate working memory to process the narrative of the story and educational content as they do with television viewing, but they must also allocate working memory to use a computer mouse. The ability to switch and inhibit behaviors may be a critical cognitive skill relevant to the development of computer skills in young children. According to Strommen's (1993) cognitive load theory, in order to use a cursor or computer mouse, a child must rely on working memory to activate long-term memory of information that was previously learned. The cognitive demand of using a computer mouse may make it more challenging for younger children who have yet to develop the necessary processing skills (Revelle & Strommen, 1990). Additionally, Strommen argues that children must attend to both the cursor's movement on the screen and the rules necessary to operate the specific device. In order to attend successfully to both factors, the child must be able to switch attention between these factors and inhibit the buttonpress on the computer mouse, a problem for young children who are just learning to operate a mouse (Revelle & Strommen, 1990). While performing all of these activities, children must also comprehend the story content presented via the computer, thereby taxing early executive functioning skills to move fluidly between multiple tasks. Based on the findings on the development of computer use, there may be a relationship between the ability to use a mouse and the executive functioning skills of working memory, shifting attention, and inhibition, and the time allowed to complete the task.

Parent–Child Interactions and Scaffolds

According to Vygotsky's theory (1978), social interaction plays an essential role in children's cognitive development. Vygotsky's theory focuses heavily on the importance of parental interaction falling within the child's "zone of proximal development", meaning that the interaction is somewhat challenging for the child but remains within the child's ability level. By challenging the child within his zone of proximal development but appropriately increasing the level of difficulty as the child matures and improves, the parent is engaging in a process known as "scaffolding". Through parental scaffolds, the child is continually supported in achieving new skills.

Studies on book reading provide support for the importance of scaffolds for the development of more general cognitive skills. In particular, studies with preschoolers during joint book reading find that parents adjust their verbal demands to meet the communication abilities of their children (Pellegrini, Brody, & Sigel, 1985). Further, Reese and Cox (1999) found that parents' interaction styles with children during joint book reading were associated with preschoolers' vocabulary development and literacy skills.

The kind of scaffolds that parents provide during book reading changes with age. DeLoache and DeMendoza (1987), for example, found that mothers of infants provide the most information to their children at the youngest ages but decrease the amount of information provided as children mature. Changes in the amount of information provided are probably due to parents' recognition of the improved cognitive capacities of their children. In other words, rather than provide the information for the child, the parent shifts and requires the child to perform more complex behaviors. These findings suggest that similar shifts in the kinds of scaffolds provided by parents during television viewing and computer interactions may also occur as a result of children's developing cognitive skills.

Research on parent–child interaction during television viewing also supports Vygotsky's (1978) scaffolding theory. Specifically, preschoolers and elementary school children who coviewed with an adult who elaborated on the central, plot-relevant program content understood the program material better than those who did not have such adult scaffolds (Collins, Sobol, & Westby, 1981; Watkins, Calvert, Huston-Stein, & Wright, 1980). Studies of parent–infant interaction during television viewing have found that when parents used more labels and descriptions when watching, infants had higher levels of visual attention and more child participation with the program than when parents used less engaging interaction styles (Barr, Zack, Muentener, & Garcia, 2008). Since visual attention during viewing is related to preschoolers' comprehension of program content (Calvert, Huston, Watkins, & Wright, 1982), higher infant attention to the program may also be an indicator of better comprehension of the program.

Unlike television coviewing, little research is available about parent–child interaction when reading a computer storybook. Only 35% of children aged 4 to 6 years who use computers on a typical day are doing so with parental help (Rideout & Hamel, 2006). It is possible that parent–child interaction during computer use may serve an additional purpose beyond just improving the child's comprehension of the story narrative and central content. Scaffolding by parents during computer use can also expand children's cognitive skills, such as vocabulary development, that occur while reading the story, as well as provide assistance using the actual computer mouse interface, a task that is challenging for young children. Since parents or children can stop the computer storybook when needed, parents have time to interact with their children without interfering with the story presentation, thus increasing the opportunity for learning.

Hypotheses

Based on previous computer use research (Calvert et al., 2005; Rideout & Hamel 2006), on Strommen's (1993) cognitive load theory, the degree to which working memory and executive function improve with age (Espy et al., 2001; Zelazo et al., 1997), and on the beneficial effects of parent–child interaction during television coviewing or book reading for children's comprehension of the content (Collins et al., 1981; DeLoache & DeMendoza, 1987; Watkins et al., 1980), we made the following hypotheses:

H1: By age 4, there would be a mix of children who would control the mouse (child clickers) and children who would not control the mouse (child nonclickers) when reading a computer story with parents.

H2: Children with better executive functioning skills would be more likely to control the mouse than would those with poorer executive functioning skills.

H3: Parents of children who were nonclickers would provide scaffolds for story comprehension during computer stories as they do during television viewing and book reading, but the parents of children who were clickers would provide scaffolds to improve their children's computer literacy skills, i.e. their skills at using a computer mouse.

Method

Participants

Children were originally recruited as infants to participate in studies by placing advertisements in local newspapers in the Washington, DC metropolitan area, through commercial mailing lists, and through word-of-mouth advertising. If permission was granted by the parent, these infants then became part of a database.

Parents of children were recontacted at the child's fourth birthday to participate in this follow-up study. Fifty-three children (thirty females, twenty-three males) and their parent(s) participated when the children were 4-years-old ($M = 49.74$ months, $SD = 1.21$). The vast majority of the participating parents were mothers (only six were fathers). Although there were not enough fathers to allow for a statistical analysis, a close look at individual data for each father revealed that their parent–child interaction measures were within the average range of data from mothers.

Parental education was very high in this sample. Seventy-two percent of parents had college degrees, 26% had post college degrees, and 2% had high school degrees. Based on parental reports of occupations, the socioeconomic index (SEI) was calculated using a system created by Nakao and Treas (1992) that calculates a score from census data and ratings. The SEI ranks 503 occupations listed in the 1980 US census from a range of 1 to 100, with higher paying occupations (e.g. physician) being accorded higher ranks (Nakao & Treas, 1992). The mean rank of socioeconomic index for this sample was 78.99 ($SD = 12.76$).

Procedure

This study took place on multiple days in the child's home in order to observe how children interact and learn from media in their natural environment. Two computer storybooks were presented on two separate days with each visit lasting approximately 1 hour. On one day, the child viewed either the computer storybook *Elmo Goes to the Doctor* or *Rumble, Grumble, Gurgle, Roar*. On another day, the child viewed the other computer storybook. After each computer storybook was read, the child completed a set of comprehension questions related to the computer storybook. The child also completed Shape School, an assessment of executive functioning abilities. At the completion of the study, parents were given a movie gift certificate in appreciation for their participation.

Computer storybook presentation Parents were instructed to remain in the room with their child during the computer storybook presentations and to assume their normal behaviors as their child interacted with the computer. The child and his or her parent (when the parent was in close enough proximity to the child) were videotaped during *Elmo Goes to the Doctor* and *Rumble, Grumble, Gurgle, Roar*. Siblings or other family members were also permitted, but not required, to be present, as this would be representative of the child's normal environment.

The two computer storybooks differed in the verbal techniques they employed. *Elmo Goes to the Doctor* was a thirty-eight-page computer storybook that was not narrated, so the parent had to read the story to the child, which took approximately 12–15 minutes to complete. The story was about Elmo going to the doctor because he did not feel well. Elmo enters the doctor's office and meets his friends in the waiting room before he goes to see Dr. Naomi. The child is allowed to select from three options of what they think is bothering Elmo (i.e. cold, tummy ache, earache) and then the story continues based on that choice. Elmo then sees the doctor and the doctor checks to see what is wrong with Elmo. At the end of the story, Elmo goes home to rest and drink juice so that he will get better. Each page of the computer storybook contained between two and twenty words. The storybook encouraged the audience to click around the pages and to see how various toys and objects moved and made noises.

Rumble, Grumble, Gurgle, Roar, in contrast, was narrated, so the parent did not need to read the story to the child. Reading of the story took approximately 5 minutes to complete. The story was about a little penguin that is hungry and looking for food. Throughout the story the little penguin's "tummy" is so hungry it keeps saying "Rumble, Grumble, Gurgle, Roar." The little penguin searches for food and bites into a partially hidden walrus, polar bear, and his "daddy penguin" at different points in the story. The daddy penguin tells the little penguin that little penguins eat little fish when they are hungry. The little penguin then swims around the ocean chasing after little fish to eat. *Rumble, Grumble, Gurgle, Roar* only contained ten pages, but each page had between eleven and forty-four words. A few objects moved and made sounds when the mouse rolled over them, but this storybook never explicitly told the audience to move the mouse around.

The storyline in *Rumble, Grumble, Gurgle, Roar* was easier than the storyline in *Elmo Goes to the Doctor*. Specifically, *Rumble, Grumble, Gurgle, Roar* had fewer pages, took less time for children to complete the story, and had only one main storyline. Although *Elmo Goes to the Doctor* also had a main storyline, a variety of additional activities that could distract the child from the main storyline were possible when navigating through the computer storybook. For example, in this storybook, readers were told to click on Elmo's friends in the waiting room to see why they are at the doctor's office.

Parent questionnaire and media use diary Parents completed a questionnaire about their children's media use patterns. The questionnaire included questions about the child's first experience with a computer, the amount of time the child spent on the computer, the computer games played by the child, the amount of time the child spent using the Internet, and the parents' reasons for allowing their child to use a computer. Parents also completed a media use diary. For a 24-hour period, parents reported the amount of time that each family member spent watching television or video programs, reading books, using a computer, and listening to music.

Shape School Shape School measures children's ability to shift and inhibit behaviors, key factors for executive functioning (Espy, 1997). The measure was presented as a traditional storybook with four different scenes. The storybook included colored circles and squares. Children were told that these colors and shapes are "students in a school." In the first scene, the participants were asked to identify the "students" by their color (control condition). In the second scene, participants were asked to say the names of those "students" who were ready for lunch which were indicated as those with happy faces, and not to say the names of those who were not ready which were indicated as those with sad faces (inhibit condition). In the third scene, participants were asked to name the "student" by their shape if the "student" was wearing a hat and to name the "student" by their color if the "student" was not wearing a hat (shift condition). The fourth scene includes "students" with and without hats who were smiling or frowning, and the participants were required to name only the "students" who were ready for lunch as indicated as those with happy faces; again they were instructed to name the "student" by their color if the student was wearing a hat and by their shape if the "student" was not wearing a hat (shift and inhibit condition) (Espy, 1997). Only the score from the fourth scene was used in analyses for this study because it was the most challenging, and it assessed children's abilities to both shift and inhibit simultaneously, skills that are necessary when simultaneously using a mouse and reading a computer story.

Program comprehension Following procedures developed by Calvert and colleagues (e.g. Calvert, Strong, Jacobs, & Conger, 2007), a small group of researchers interacted with each computer storybook and generated questions about the plot. Questions were then put into an open-ended questionnaire. Next, research assistants and college students rated each question as being central, plot-relevant, or as incidental, plot-irrelevant material. Each answer with a minimum centrality rating of 70% was retained. This procedure yielded ten central questions for each computer storybook. The ten central questions were made into multiple-choice questions to assess the child's comprehension of the two computer storybooks. A sample central question for *Elmo Goes to the Doctor* was "Where is Elmo's mommy taking him?" The response options were: (a) to his friend's house, (b) to the doctor, or (c) to school. A sample central question for *Rumble, Grumble, Gurgle, Roar*, was "Throughout the story, what is little penguin looking for?" The response options were: (a) something good to eat, (b) something to dry off the cold water with, or (c) her mommy. The experimenter read each question and response option to the child who selected an answer, typically by saying their choice aloud.

Using procedures developed by Wright and his colleagues (1984), comprehension was also assessed using a picture sequencing task. For each computer storybook, four central photographs of scenes sampled throughout the program were created. The experimenter presented the child with the four pictures and asked the child to put them in order from the first thing that happened in the story to the last. The experimenter then recorded the child's order from words on the back of the picture that reflected the correct order.

Transcribing and Coding

Clicker status Clicker status assessed the extent to which the child or parent was in control of the mouse during the computer storybook. Clicker status was computed by counting the number of times either the parent or child clicked the mouse in relation to the total number of times the mouse was clicked during the presentation of the computer storybook. Experimenters counted clicks either during the actual session with paper and pencil or by viewing the videotapes at a later time.

The percent of child clicks to total clicks was calculated for each participant to measure the degree of control the child exerted over the mouse, and hence their control of the computer game experience. Clicker status was computed separately for each computer storybook. Frequency distributions of clicker status indicated that twenty-two children never clicked the mouse during *Elmo Goes to the Doctor*, ten children clicked between 1% and 50% of the time, thirteen clicked between 51% and 99% of the time, and eight children clicked the entire time. During *Rumble, Grumble, Gurgle, Roar*, twenty children never clicked the mouse, seven clicked between 1% and 50% of the time, thirteen clicked between 51% and 99% of the time, and ten children clicked the entire time. Interobserver reliability was measured using intraclass correlations (McGraw & Wong, 1996). Twenty-five percent of computer book sessions were coded by two observers. The intraclass correlation of the proportion of child to adult clicks for both computer storybooks was above .95, well within the acceptable range of .7 – 1.0.

It was hypothesized that at age 4, there would be a mix of children who either primarily controlled the mouse or whose parents primarily controlled the mouse. Given that approximately half of the children never clicked the mouse, a median split was used to classify the participants as child clickers or child nonclickers. For *Elmo Goes to the Doctor*, children who clicked 18% or more of the total clicks were coded as child clickers. For *Rumble, Grumble, Gurgle, Roar*, children who clicked 14% or more of the total clicks were coded as child clickers. For *Elmo Goes to the Doctor*, twenty-six children were classified as child clickers (thirteen boys, thirteen girls). Twenty-seven children were classified as child nonclickers (ten boys, seventeen girls). For *Rumble, Grumble, Gurgle, Roar*, twenty-five children were classified as child clickers (ten boys, fifteen girls). Twenty-six children were classified as child nonclickers (eleven boys, fifteen girls). There were no gender differences in the clicker status of the children. Pearson's chi-squared analyses for both *Elmo Goes to the Doctor* and *Rumble, Grumble, Gurgle, Roar* were not significant, $\chi^2(1) = 2.79$, $p = .34$, and $\chi^2(1) = 2.58$, $p = .87$, respectively. The vast majority of parents that participated in this study were mothers so it was not possible to test for gender differences in the parents' behaviors. Kappa was used to assess reliability for categorizing into clicker or nonclicker status. Reliability was 100% (kappa = 1.0) for both computer stories.

Parent–child interactions Using the videotapes of the computer storybook sessions, all verbal utterances by parent and child were transcribed. Transcripts were coded by adapting a system based on parent–child interaction during book reading studies (DeLoache & DeMendoza, 1987; Haden, Reese, & Fivush, 1996; Lemish & Rice, 1986; Potter & Haynes, 2000; Reese, Cox, Harte, & McAnally, 2003). Parents and children could also talk about computer mechanics (i.e. how to use the mouse). Utterances by both parent and child were coded, but only parent utterances were used for these analyses. The categories were as follows.

Story-relevant questions were all questions that were related to the content presented in the story. Story-relevant questions included: "wh questions," which were all questions beginning with what, who, when, or how such as: "Where is Elmo?"; "yes/no questions," such as: "Is that Elmo's mommy?"; "tag questions," which were phrases or questions that support yes/no question such as, "That's the doctor, right?"; "directives/requests," which were verbalizations that direct the child to do something related to the story such as, "Can you point to Elmo?"

Mechanics were defined as an utterance, or question, that was related to working the computer or controlling the mouse. Examples are "I clicked it," "Turn the page," "Hit the arrow," and "Did that work?"

The proportion of total parent utterances was calculated for story-relevant questions and mechanics. Proportions were used for analyses to control for the large range in talkativeness by some parents (see also Haden et al., 1996). Categories were mutually exclusive. Reliability, which was calculated for over 20% of available transcripts, was 90% (kappa = .81).

Program comprehension A comprehension score was calculated by summing the number of correct answers for the multiple choice comprehension questions. Using procedures developed by Wright and colleagues (1984), a picture sequencing score was calculated for each child based on two criteria: how close each picture was to its correct absolute position and how many pictures were sequenced correctly, regardless of absolute position. To calculate these scores, each picture was initially numbered from 1 to 4 indicating its correct order. Then one point was given for every picture with a lower number that was placed to the left of it (maximum possible score of 6), and one point was given for each correctly sequenced adjacent pairs of pictures (maximum possible score of 3). These two scores were summed, yielding a maximum score of 9.

Attention Videotapes of the sessions were used to code the child's attention to the computer storybook. Attention was defined as the percentage of time the child spent looking at the computer screen. A look began when the child's eyes were directed towards the screen and terminated when the child looked away from the screen (see e.g. Anderson & Levin, 1976; Calvert et al., 1982). Due to variations in the amount of time that it took to complete the computer games, attention was calculated by dividing the child's total looking time by the total time recorded. Twenty percent of computer book sessions were coded by two observers. Interobserver reliability was measured using intraclass correlations (McGraw & Wong, 1996). The intraclass correlation of the proportion of time the child spent looking at the screen for both computer storybooks was above .80, well within the acceptable range of .7–1.0.

Results

Descriptive Statistics

Questionnaire data on computer use were collected from forty-six subjects. Some data were lost due to technical difficulties with the video camera, parents' failure to return materials, and children's refusal to complete assessments. As a result, the *N* is smaller for some statistical tests. According to the questionnaire data, children in this sample began using computers at approximately 30 months of age. Of the 64% of the sample who used a computer at home, 65% had between zero and six computer games and 27% had more than seven computer games. Almost all parents (92%) reported that their child used computers for entertainment and educational reasons. Nearly 50% of parents had their child use a computer so that the parents could get things done, and 19% of parents used computers to regulate their child's mood, i.e. to relax or calm their child. There was not a significant difference in parental attitudes toward computers by whether the child or parent was the primary clicker of the mouse.

Parents completed the media diary for a randomly selected 24-hour period. Based on the media diary reports, 92% of children watched television. Of these children, the amount of television exposure ranged from 10 minutes to 4.5 hours with an average of 1.4 hours. In contrast, the vast majority (83%) of the sample did not use a computer at all on the day we sampled media use patterns. Of the 17% of children that did use a computer on the day the media diary was completed, 50% used a computer for 30 minutes, 25% used a computer for 45 minutes, and 25% used a computer for 1 hour or more that day.

Computer Storybook Differences

Independent samples *t*-tests were used to assess the differences between child clickers and nonclickers for each computer storybook separately. As seen in Table 1, children spent significantly more time reading *Elmo Goes to the Doctor* than reading *Rumble, Grumble, Gurgle, Roar*. Multiple-choice and picture sequencing scores were also significantly different, favoring *Rumble, Grumble, Gurgle, Roar* over *Elmo Goes to the Doctor*. These differences indicate that *Elmo Goes to the Doctor* was a more challenging computer storybook for 4-year-old children to comprehend than *Rumble, Grumble, Gurgle, Roar*. Therefore, we analyzed the two computer storybooks separately.

Clicker Status

Even though the level of difficulty of the computer stories differed, children tended to remain clickers or nonclickers for both computer storybooks. Eighty percent of the children were consistent child clickers or child nonclickers across both computer storybooks. Of the remaining 20% of the sample, 9% were child clickers for *Elmo Goes to the Doctor* but child nonclickers for *Rumble, Grumble, Gurgle, Roar*, and 11% were child clickers for *Rumble, Grumble, Gurgle, Roar* but child nonclickers for *Elmo Goes to the Doctor*.

Executive Functioning

Correlational analyses were conducted to determine the relationship between the executive functioning score (as measured by Shape School) and child clicking proportions.

TABLE 1
Descriptive statistics for child clickers and child nonclickers by computer storybook

	Elmo Goes to the Doctor			Rumble, Grumble, Gurgle, Roar			Compare Stories
Comparison	**Clicker**	**Nonclicker**	**Unpaired** ***t*****-test (*****df*****)**	**Clicker**	**Nonclicker**	**Unpaired** ***t*****-test (*****df*****)**	**Paired** ***t*****-test (*****df*****)**
Comprehension % score	73.08 (22.31)	71.54 (20.53)	−0.27 (50)	88.36 (10.66)	85.31 (12.87)	−0.919 (49)	−5.25** (51)
Sequencing score	6.77 (2.61)	7.63 (2.45)	1.24 (51)	8.42 (1.35)	8.13 (1.60)	0.684 (46)	−2.41* (50)
Overall % looking	96.95 (4.71)	94.91 (8.68)	−0.91 (39)	94.21 (19.23)	92.52 (18.42)	0.300 (43)	0.56 (38)
Total time to read computer book (min)	14.04 (3.23)	9.53 (3.13)	−4.54** (39)	4.65 (1.19)	3.76 (0.72)	3.06** (42)	11.84** (37)

Note. An asterisk denotes a significant difference at the .05 level and two asterisks denote a difference at the .01 level.

For *Elmo Goes to the Doctor*, the Pearson product-moment correlation between child clicking proportion and executive function score yielded a coefficient of $r(47) = .34$, $p = .02$. For *Rumble, Grumble, Gurgle, Roar*, the Pearson product-moment correlation between child clicking proportion and executive function score yielded a coefficient of $r(45) = .28$, $p = .06$.

Because children had to shift tasks and focus attention on both mouse control and story comprehension, it was hypothesized that children with better executive functioning skills would be child clickers rather than child nonclickers. We conducted separate logistic regression analysis with shape school inhibit and shift efficiency (number correct/time) scores as the independent variables and clicker status as the dependent variable for *Elmo Goes to the Doctor* and *Rumble, Grumble, Gurgle, Roar*. As expected, for *Elmo Goes to the Doctor*, executive functioning scores significantly predicted child clicker status (odds ratio $= 4.73$, $p = .04$). For *Rumble, Grumble, Gurgle, Roar*, there was a trend in the same direction with higher executive functioning scores predicting child clicker status (odds ratio $= 4.04$, $p = .08$).

Parent–child Interactions

It was hypothesized that parents of child clickers would focus their verbalizations on teaching the child to use the computer, whereas parents of child nonclickers would focus their verbalizations on helping the child comprehend the story content and develop cognitive skills, such as their vocabulary. The latter two categories were collapsed under the category of story-relevant questions. We conducted separate ANOVAs for *Elmo Goes to the Doctor* and for *Rumble, Grumble, Gurgle, Roar*. Each was a 2 (clicker status: child clicker, child nonclicker) $\times$ 2 (verbalization type: story-relevant questions, mechanics) mixed ANOVA design with verbalizations as the repeated measures and clicker status as the between-subjects factor.

For the *Elmo Goes to the Doctor* computer storybook, there was a main effect of clicker status, $F(43, 1) = 5.54$, $p = .02$, which was qualified by a significant interaction between verbalization type and clicker status, $F(43, 1) = 24.70$, $p = .00$. As predicted, post hoc *t*-tests using a Bonferroni correction indicated that parents of child nonclickers ($M = 0.27$, $SD = 0.13$) exhibited a significantly higher proportion of story-relevant questions than parents of child clickers ($M = 0.17$, $SD = 0.08$), $t(43) = 2.95$, $p = .01$. For example, parents of child nonclickers would frequently ask their child "Do you remember what was wrong with Elmo?" In contrast, parents of child-clickers ($M = 0.35$, $SD = 0.15$) exhibited a significantly higher proportion of mechanics utterances than parents of child nonclickers ($M = 0.16$, $SD = 0.11$), $t(43) = -5.09$, $p = .00$. For example, parents of child clickers often said, "Click on the doctor to see what she does." As seen in Figure 1, the Verbalization type $\times$ Clicker status interaction also revealed that parents of child nonclickers used significantly more questions ($M = 0.27$, $SD = 0.13$) than mechanics utterances ($M = 0.16$, $SD = 0.11$), $t(23) = 2.74$, $p = .01$. In contrast, parents of child clickers used significantly more mechanics utterances ($M = 0.35$, $SD = 0.15$) than story-relevant questions ($M = 0.17$, $SD = 0.08$), $t(20) = -4.24$, $p = .00$.

For the *Rumble, Grumble, Gurgle, Roar* computer storybook, there was a main effect of verbalization type, $F(42, 1) = 6.09$, $p = .018$, which was qualified by a significant interaction between verbalization type and clicker status, $F(42, 1) = 4.10$, $p < .05$. Similar to findings for *Elmo Goes to the Doctor*, post hoc *t*-tests using a Bonferroni correction indicated that parents of child nonclickers ($M = 0.29$, $SD = 0.30$) had a significantly higher proportion of story-relevant question utterances than parents of child clickers ($M = 0.11$, $SD = 0.11$), $t(43) = 2.54$, $p = .02$. For example, parents of child nonclickers would frequently ask their child "What is penguin looking for?" However, there was not a significant difference in the proportion of mechanics utterances made by the parents of child clickers when compared to those of child nonclickers. As seen in Figure 1, the Verbalization type × Clicker status interaction revealed that parents of child clickers ($M = 0.43$, $SD = 0.22$) had a significantly higher proportion of mechanics-related utterances than story-relevant question related utterances ($M = 0.11$, $SD = 0.11$), $t(19) = -5.15$, $p = .00$. For example, parents of child clickers often said, "Click on the arrow." However, parents of nonclickers did not significantly differ in the proportion of mechanics and question-related utterances.

Visual Attention and Comprehension

A series of independent *t*-tests were conducted between child clickers and child nonclickers for *Elmo Goes to the Doctor* and *Rumble, Grumble, Gurgle, Roar*. As seen in Table 1, child clickers spent significantly more time reading the story with a parent than child nonclickers did for both computer storybooks. Despite the difference in time spent on the program, the comprehension scores and percentage of attention to the screen for child clickers and child nonclickers for both computer storybooks were similar and did not differ significantly (see Table 1).

Discussion

The purpose of this study was to provide information about how preschoolers are using computers in their natural environments, how their computer skills are related to

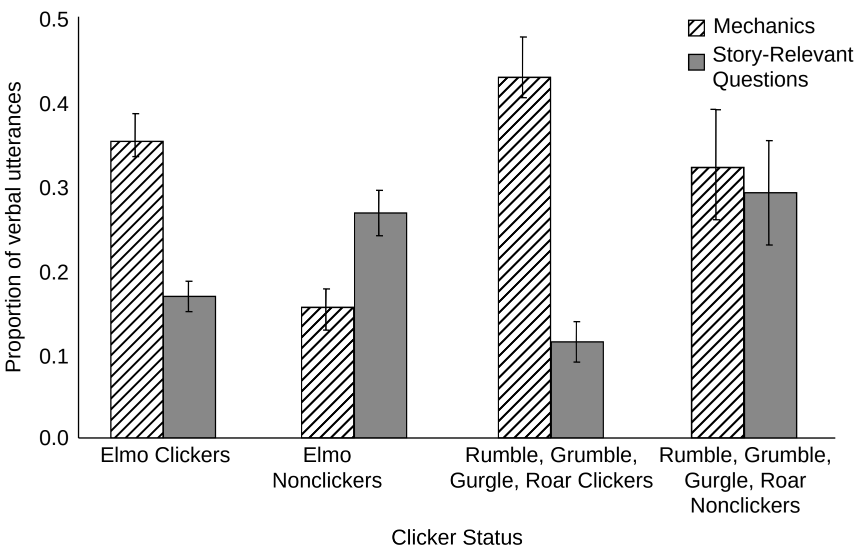


FIGURE 1
Parent verbalization type by clicker status

their executive functioning skills, and what kinds of parent–child interactions occur during computer storybooks. Consistent with the Kaiser Family studies on young children's computer use (Calvert et al., 2005), we found that 64.4% of 4-year-old children in our sample have used a computer and many are able to use a mouse. Even so, a considerable amount of scaffolding occurs as parents work to improve their children's mouse skills. Our results indicate that at age 4, children are still learning the mechanics of computer mouse use, and many children still have difficulty operating the device without some parental assistance.

Because children had to process the story while operating the mouse, the cognitive skills that children brought to bear on this experience, in this case executive functioning skills, provide a glimpse of how children learn to coordinate multiple competing activities simultaneously, i.e. multitask. In particular, children with better executive functioning skills were more likely to be child clickers than nonclickers. These results support the argument made in Strommen's (1993) cognitive load theory: that is, those children who could shift attention and inhibit responses were not only able to understand the story just as well as the nonclickers, but also were able to manipulate the mouse simultaneously. The only cost was that the child clickers took more time to finish the task than the nonclickers did.

Our findings also provide support for a modified version of Fisch's (2000) capacity model. Fisch argues that there are demands on working memory when children have to learn educational content that co-occurs within a narrative structure. In particular, children have to understand the story while trying to comprehend the educational material, a process that is complicated by the linear nature of television programs where events come and go quickly. In our study, children had to understand the story and process the narrative while also mastering the use of the computer mouse, a navigational task that was required to advance the story. Although it did take child clickers more time to complete the activity, an option that is not available for television viewing, children who were clickers were able to do both tasks without a loss in narrative comprehension.

According to Vygotskian (1978) theory, once a child has mastered a skill in a supportive social context, the skill will be internalized, and therefore enable the child to apply this skill in new contexts. By providing these scaffolds both verbally and physically, parents are providing the building blocks necessary for their children to learn to use a computer. Parents are also giving them the opportunity to practice these skills with an adult present to help them when they get stuck. Because this study was conducted in a naturalistic environment, we were able to examine how parents interact with children during computer use and describe how they socialize their children to think about computers. Parent–child interactions during computer activities were associated with the child's cognitive skills as well as their clicker status. Specifically, parents used more mechanics verbalizations when a child was a clicker than a nonclicker in order to provide scaffolds for their child's use of the mouse, thus fitting with Vygotskian (1978) theory. Many parents taught their child to use a mouse through joint interaction such as turn-taking exchanges or literally holding the mouse together, providing additional support for Vygotsky's emphasis on social interaction for learning to take place.

In contrast, parents of children who did not click the mouse asked more story-related questions than the parents of children who did, focusing their scaffolds on story comprehension. It is likely that parents adjusted their interaction styles and comments to fit their young children's level of development. If children had better executive functioning skills and were learning to click the mouse, parents focused their interactions on helping the child use the computer mouse. However, if their executive functioning skills were lower and the child was not in control of the mouse, the parent matched the child's level of development by focusing their interactions on story-related content.

We were also able to understand how parental and child control of the mouse occurred and what physical interactions occurred during this decision process. Most children in our sample were consistent in their clicking status, acting as clickers or nonclickers for both computer storybooks as opposed to switching from clickers to nonclickers from one computer storybook to the next. Most children and parents assumed their clicker status at the onset of the story. That is, a child typically began a session as the clicker or the parent did and that person continued to be the clicker throughout the story. Changes in mouse control from child to parent typically occurred only when the child got stuck. In these instances, parents would often help their child momentarily by modeling how to use the mouse or by getting their child back on track with the story. These observations offer insight about how parent–child interactions shape the development of early computer skills.

While this study provides new information about how preschool children use computers, there are limitations to this study. First, the sample size was relatively small, which limited the statistical power of our analyses. Second, the children in our sample came from families with a higher socioeconomic status than the national average. Children from higher income families, who tend to be more educated, may be different in some ways from children growing up in lower income households. For instance, families with a higher income may be more likely to have a computer at home, allowing their child more computer exposure compared to children that do not have a computer in their home. Additionally, parents with higher education may be more inclined to talk with their young children as they develop computers skills compared to parents with less education. Language, particularly labeling, aids comprehension (Watkins et al., 1980). Finally, this study is correlational. Therefore, there is no way to know whether executive functioning abilities are predicting mouse control or vice versa; in fact, the relation could be bidirectional. Given the findings from this naturalistic study, it is important that further experimental research assess the relation among computer mouse control, executive functioning, and comprehension of the computer storybook. Finally, it is possible that children who were nonclickers may also have been the children that would have had a difficult time comprehending the story; thus, their parents may have decided to focus their interactions and attention on helping the child grasp the content rather than learn mouse control. Future studies should experimentally manipulate both clicker status and verbal scaffolds.

From a practical point of view, parents and teachers should recognize the importance of their presence and involvement when their children are learning to use computers and developing computer mouse skills. Further, teachers and parents should be aware of the potential relationship between executive functioning and mouse control when deciding when and how to teach children to use a computer.

In conclusion, computer skills are developing during the preschool years and children are gradually making improvements in cognitive functioning that enable them to shift and inhibit their attention successfully in order to use a mouse while comprehending a storyline. The development of the ability to change focus from mouse control to storyline comprehension may be the beginning of children's abilities to multitask, an increasingly central aspect of children's information processing activities in the twenty-first century.

ACKNOWLEDGMENTS

This research was supported by a grant from the National Science Foundation (No. 0126014) and a gift from the Stuart Family Foundation to the Children's Digital Media Center. We gratefully acknowledge their financial support. We also thank the parents and children who participated in this project as well as Samhita Kumar, Elizabeth Zack, Dr. Tiffany Pempek, Amanda Exner, and Katrina Pariera, and the Children's Digital Media Center and the Early Learning Project for their assistance.

REFERENCES

Anderson, D. R., & Levin, S. R. (1976). Young children's attention to "Sesame Street". *Child Development*, *47*, 806–811.

Barr, R., Zack, E., Muentener, P., & Garcia, A. (2008). Infants' attention and responsiveness to television increases with prior exposure and parental interaction. *Infancy*, *13*, 30–56.

Calvert, S. L., Huston, A. C., Watkins, B. A., & Wright, J. C. (1982). The relation between selective attention to television forms and children's comprehension of content. *Child Development*, *53*, 601–610.

Calvert, S. L., Rideout, V., Woolard, J., Barr, R., & Strouse, G. (2005). Age, ethnicity, and socioeconomic patterns in early computer use: A national survey. *The American Behavioral Scientist*, *48*, 590–607.

Calvert, S. L., Strong, B. L., Jacobs, E. L., & Conger, E. E. (2007). Interaction and participation for young Hispanic and Caucasian girls' and boys' learning of media content. *Media Psychology*, *9*, 431–445.

Collins, W. A., Sobol, B. L., & Westby, S. (1981). Effects of adult commentary on children's comprehension and inferences about a televised aggressive portrayal. *Child Development*, *52*, 158–163.

DeLoache, J. S., & DeMendoza, O. A. (1987). Joint picture book interactions of mothers and 1-year-old children. *British Journal of Developmental Psychology*, *5*, 111–123.

Espy, K. A. (1997). The Shape School: Assessing executive function in preschool children. *Developmental Neuropsychology*, *13*, 495–499.

Espy, K. A., Kaufmann, P. M., Glisky, M. L., & McDiarmid, M. D. (2001). New procedures to assess executive functions in preschool children. *The Clinical Neuropsychologist*, *15*, 46–58.

Fisch, S. M. (2000). The capacity model of children's comprehension of educational content on television. *Media Psychology*, *2*, 63–91.

Haden, C. A., Reese, E., & Fivush, R. (1996). Mothers' extratextual comments during storybook reading: Stylistic differences over time and across texts. *Discourse Processes*, *21*, 135–169.

Hughes, C. (2002). Executive functions and development: Why the interest? *Infant and Child Development*, *11*, 69–71.

Lemish, D., & Rice, M. L. (1986). Television as a talking picture book: A prop for language acquisition. *Journal of Child Language*, *13*, 251–274.

McGraw, K. O., & Wong, S. P. (1996). Forming inferences about some intraclass correlation coefficients. *Psychological Methods*, *1*, 30–46.

Nakao, K., & Treas, J. (1992). *The 1989 Socioeconomic Index of Occupations: Construction from the 1989 Occupational Prestige Scores* (No. 74). Chicago: NORC.

Pellegrini, A. D., Brody, G. H., & Sigel, I. E. (1985). Parent's book-reading habits with their children. *Journal of Educational Psychology*, *77*, 332–340.

Potter, C. A., & Haynes, W. O. (2000). The effects of genre on mother-toddler interaction during joint book reading. *Infant Toddler Intervention*, *10*, 97–105.

Reese, E., & Cox, A. (1999). Quality of adult book reading affects children's emergent literacy. *Developmental Psychology*, *35*, 20–28.

Reese, E., Cox, A., Harte, D., & McAnally, H. (2003). Diversity in adults' styles of reading books to children. In A. van Kleeck, S. Stahl, & E. Bauer (Eds.), *On reading books to children: Parents and teachers* (pp. 37–57). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Revelle, G. L., & Strommen, E. (1990). The effects of practice and input device used on young children's computer control. *Journal of Computing and Childhood Education*, *2*, 33–41.

Rideout, V., & Hamel, E. (2006). *The media family: Electronic media in the lives of infants, toddlers, preschoolers and their parents*. Menlo Park, CA: Kaiser Family Foundation.

Rideout, V., Vanderwater, E. A., & Wartella, E. A. (2003). *Electronic media in the lives of infants, toddlers, and preschoolers*. Menlo Park, CA: Kaiser Family Foundation.

Strommen, E. (1993). Preschoolers: A cognitive model of device difficulty. In M.R. Simonson & K. Abu-Omar (Eds.), *15th annual proceedings of selected research and development presentations, AECT '93*, New Orleans, LA (pp. 991–999). Washington, DC: Association for Educational Communications and Technology.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Watkins, B. A., Calvert, S. L., Huston-Stein, A. C., & Wright, J. C. (1980). Children's recall of television material: Effects of presentation mode and adult labeling. *Developmental Psychology*, *16*, 672–674.

Wright, J. C., Huston, A. C., Ross, R. P., Calvert, S. L., Rolandelli, D., Weeks, L. A., et al. (1984). Pace and continuity of television programs: Effects on children's attention and comprehension. *Developmental Psychology*, *20*, 653–666.

Zelazo, P. D., Carter, A., Reznick, J. S., & Frye, D. (1997). Early development of executive function: A problem-solving framework. *Review of General Psychology*, *1*, 198–226.

Zelazo, P. D., Frye, D., & Rapus, T. (1996). An age-related dissociation between knowing rules and using them. *Cognitive Development*, *11*, 37–63.

Alexis R. Lauricella recently received a Master's degree from the Georgetown Public Policy Institute and is a doctoral candidate in the Psychology Department at Georgetown University. Alexis currently works in the Children's Digital Media Center and studies how young children learn from media. She received her Bachelor's degree from the University of Massachusetts, Amherst, where she wrote her honors thesis under the mentorship of Dr. Daniel Anderson. Correspondence to: Department of Psychology, Georgetown University, 309B White-Gravenor, 37th and O Streets NW, Washington, DC 20057, USA. Tel.: 202 687 7019; Fax: 202 687 6050; E-mail: alexislauricella@gmail.com

Dr. Rachel F. Barr (PhD) is an associate professor of psychology at Georgetown University. She is currently the director of the Georgetown Early Learning Project, where she studies how infants learn from television, computers, or books, and how the home environment influences such learning. She received her PhD in developmental psychology from the University of Otago, New Zealand and completed a postdoctoral fellowship at Rutgers University before moving to Georgetown University in 2001. Dr. Barr was a ZERO TO THREE fellow in 2005.

Dr. Sandra L. Calvert is Chair and Professor of Psychology at Georgetown University. She is also the Director of the Children's Digital Media Center which is funded by the National Science Foundation. Dr. Calvert has published numerous empirical articles, authored *Children's Journeys through the Information Age* (McGraw Hill, 1999), coauthored *Food Marketing to Children and Youth* (The National Academies Press, 2006) and *Youth, Pornography, and the Internet* (The National Academies Press, 2002), and coedited *Children in the Digital Age* (Praeger, 2002) and *The Handbook of Children, Media, and Development* (Wiley-Blackwell, 2008).