Using a Computer Game to Teach Young Children About Their Brains

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Abstract

Objective: Neuroscience is often considered too advanced of a subject to teach young children; however, helping children to understand the connection between their body and brain can promote a positive attitude towards proper care of the brain. This study investigated if playing a computer game increased knowledge and interest in the brain compared with more traditional methods of learning.

Subjects and Methods: Participants included 169 children, 4–6 years old, attending either preschool or an afterschool program. Comparisons were made among computer game, story, and control groups. Outcomes included knowledge about brain function and interest in learning about the brain. Students were assessed after a single exposure and after multiple exposures to the game.

Results: Results indicated that the computer game generated greater knowledge gains and higher levels of interest compared with both the story and control groups. Results were consistent across single exposure and multiple exposure data. Students in the game condition had significantly higher posttest knowledge scores compared with students in both the story ($\beta = -0.40$, $t_{163} = -5.450$, $P < 0.001$) and control condition ($\beta = -0.57$, $t_{163} = -7.812$, $P < 0.001$). For general interest items, students in the game condition reported higher levels of interest compared with the control group ($\beta = -0.24$, $t_{164} = -2.82$, $P < 0.01$). For content-specific interest, students in the game condition reported higher levels compared with the story group ($t_{109} = 2.05$, $P < 0.05$).

Conclusions: This study highlights the potential value computer games play in presenting scientific and health-related content about the brain to young children.

Introduction

BRAIN CELL METABOLISM in young children often burns glucose at twice the rate of the adult's brain, which supports the child's overpopulation of synapses, and underlies the sponge-like, almost effortless ability to learn in children this age.¹ Skills acquired at this age often stay with the child for a lifetime.² Ironically, at a time when their brain is rapidly developing, young children are typically not exposed to information that would help them understand this vital organ.

The National Research Council states that neuroscience and the study of the nervous system should be a part of every child's education.³ Teaching children about the brain exposes students to important science concepts, such as understanding the basic structure and function of the brain and demonstrating how the brain works. This is especially important when children are rapidly gaining knowledge about their body. Teaching young children how their brain functions can

create a healthy respect for their brain, which can potentially lead to positive behavior such as wearing bike helmets. Despite recent research supporting knowledge gains after a brief neuroscience lesson by children as young as first grade,⁴ educators face challenges when trying to teach advanced concepts such as neuroscience to young children. Complicated concepts and curriculum dedicated to older students often hinder these efforts. Using interactive games to teach them about the brain can meet these challenges.

The intersection between technology and education has given rise to "digital game-based learning," and evidence suggests that computer games used in instruction benefit children's achievement, knowledge, motivation, attention, and concentration.^{5–7} Educational computer games provide more engaging and interactive experiences for learners compared with more traditional methods of instruction.^{8,9} "Learning by doing" uses action instead of explanation, which has been shown to be a more effective way for students

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TABLE 1. DEMOGRAPHICS FOR MAIN AND SUPPLEMENTAL PARTICIPANTS

	Main study (n = 169)	Supplemental study (n = 68)
Gender (%)		
Boys	47	41
Girls	53	59
Ethnicity (%)		
African American	11	6
Asian	39	50
Latino	4	3
Mixed	7	7
White	35	30
Other	4	3

to learn.^{9–12} Computer games function as powerful learning environments because they can utilize multisensory, experiential, problem-based learning.¹¹ This environment prohibits passive engagement and requires active discovery, analysis, and interpretations.¹² Benefits of learning through computer games include the concept that what is learned in games transfers to real life.¹³ Computer games allow for reinforcement and mastering of skills and accommodate multiple learning styles and skills,¹⁰ which are difficult to accomplish with traditional instruction. Computer games can also be used to teach hard-to-learn concepts by making them more accessible and engaging.¹⁰

Despite evidence supporting the use of computer games in educational settings, only a few comprehensive evaluations have assessed the effectiveness of these games in improving knowledge or cognitive skills.^{6,8,14} Furthermore, there is little empirical research that examines computer games for young children, particularly preschool and early elementary school ages. The goal of the present study was to evaluate whether an educational computer game could teach complicated scientific content to young children. “Every Body Has a Brain” is a computer game created by Morphonix LLC (Sausalito, CA), for children, 4–6 years old, to gain knowledge and understanding about the human brain. The game’s main character, “Phoebe Brainheart,” is seeking knowledge about the brain. Children visit the different parts of Phoebe’s brain and are introduced to various brain characters, play games, hear songs, and interact with stories. The design of each game in

“Every Body Has a Brain” mirrors the content. For example, in the “Cerebellum,” games involve coordination and balance; in the “Hippocampus,” they engage memory; and in the “Cerebral Cortex,” they elicit creativity and problem solving. It is hypothesized that children, 4–6 years old, will (1) learn more information about the brain and (2) have more interest in the brain when exposed to the computer game than when exposed to a non-interactive story or to a control using standard classroom work activities. It is also hypothesized that after multiple exposures to the game, mimicking a more naturalistic game playing setting, these children will have even greater knowledge gain and higher levels of interest.

Subjects and Methods

Participants

The sample for the study included 169 students, 4–6 years old. The sample was 17 percent preschoolers, 46 percent kindergartners, and 37 percent first graders, from regular education classes. These students came from one preschool program and three afterschool elementary school programs in a large urban area. A subset of students was selected to investigate the hypothesis about knowledge gain and increased interest after multiple exposures. The students in this supplemental study included 68 students (49 percent kindergartners and 52 percent first graders) of the original sample, from two of the after-school elementary school programs that agreed to further efforts at their sites. Demographics for the two samples can be found in Table 1. Study sites were offered a \$150 flat rate incentive to participate in the study, as well as \$10 per participating child.

Procedures

After consent was obtained from parents, students were randomly assigned to one of three conditions (game, story, or control) after group matching based on gender and age for each location. Each group was administered a pretest questionnaire, followed by their condition (detailed below), and concluding with a posttest questionnaire.

Each student in the game condition was paired with a research assistant and guided through a predetermined “click-path” so that all students would play the same parts of the game. Students played one game, listened to one story or song, and watched one video for each of the four parts of the

TABLE 2. LEARNING OBJECTIVES FOR “EVERY BODY HAS A BRAIN”

Objective	Matching “click-path”/game content
Every body has a brain.	“Brain Train” game
Animals have a brain.	“Brain Train” game and song
Your cerebellum helps you balance, dance, ride a bike.	“Brainboard” game and “Cerebellum Helps You Move and Go” song
The brain has different parts that do different things.	“Working Together” song and “Game Introduction”
It’s important to protect your brain.	“Brainboard” game and “Cerebellum Helps You Move and Go” song
Your brain stem helps you breathe, swallow, blink, and more.	“Work, Work, Work in the Brain Stem” song and “Brain Train” game
Your cerebral cortex helps with thinking, decisions, and creativity.	“Zippo Hippos” game and “Cerebral Cortex Brothers” story
Your hippocampus helps you remember.	“Your Hippocampus” song and story and “Hiding Hippos” game

TABLE 3. MAIN STUDY: KNOWLEDGE MEASURE
PRE- AND POSTTEST GRAND MEAN, STANDARD DEVIATION,
AND DIFFERENCE SCORES

	Pretest	Posttest	Difference
Full sample Condition	0.74 (0.13)	0.80 (0.15)	0.06 ^c
Game	0.75 (0.14)	0.90 (0.10)	0.15 ^c
Story	0.71 (0.13)	0.77 (0.15)	0.06 ^a
Control	0.74 (0.14)	0.72 (0.13)	-0.02
Gender			
Boys	0.74 (0.13)	0.79 (0.15)	0.05 ^a
Girls	0.73 (0.13)	0.81 (0.15)	0.08 ^c
Age proxy			
Preschool	0.79 (0.12)	0.82 (0.13)	0.03
Kindergarten	0.72 (0.12)	0.79 (0.15)	0.07 ^b
First grade	0.73 (0.15)	0.81 (0.16)	0.08 ^c

Knowledge measure items range from 0 to 1.

^a $P < 0.05$, ^b $P < 0.01$, ^c $P < 0.001$.

brain that they visited. The click-path aimed to expose students to the main learning objectives of the game (Table 2). After the click-path was completed, students were allowed to revisit any of the games on the click-path while waiting for the other students to finish.

After completing the pretest, students in the story condition were read a story that paralleled the game content and were presented with screenshots from the game. This condition was meant to mimic "traditional" lecture-type delivery methods. After completing the pretest, students in the control condition were given packets of age-appropriate letter and math worksheets to work on. These worksheets did not contain any material about the brain.

For the supplemental study, students who had already played the game in the main study were allowed to play the game in an unstructured way for 45 minutes in each of two sessions. Students who were previously in the story or control condition were required to follow the click-path procedure in the first session of the supplemental study and then allowed to have unstructured play in the second session. Therefore, students in the supplemental study were exposed to the game twice at the minimum and three times at the maximum. This method also afforded the students the opportunity to play the game in a more "naturalistic" way, rather than as dictated by the click-path. One posttest was given to all students after the second supplemental study session.

Measures

Knowledge. The knowledge measure was given both pretest and posttest. It consisted of 12 items that were made up of seven general knowledge questions and five brain area-specific questions (Appendix A). All conditions received the same knowledge measure items. The supplemental study surveys only had the posttest questions because the pretest baseline questions were obtained during the main study. For analysis, knowledge measure items were collapsed into grand mean scores across all 12 items, creating one pretest score and one posttest score.

Interest. The interest measure was given only at the posttest and consisted of different items based on the condition. All three conditions had four general interest items

related to learning about the brain. Each condition also had two interest items specific to condition, such as how much fun they had playing the game, listening to the story, or doing the worksheets. The story and game condition had eight additional questions about interest in the content they were exposed to, such as how much they liked hearing about or playing the "Brain Train" game. The total number of questions for the control condition was six, while the story and game condition both had 14 (Appendix B). Response choices were based on a 5-point Likert scale using "smiley" faces ranging from "very sad" to "very happy." For analysis, interest measure items were collapsed into a grand mean score. Because the number of interest measure items varied based on condition, two types of interest measure grand mean scores were created. General interest measure items included six items across all three conditions. Content-specific interest measure items included eight items across the story and game group only.

Baseline exposure. All three groups in the main study were asked about (1) their prior experience playing computer games with a frequency response of once per day, once per week, once per year, and never and (2) prior instances of learning about the brain from their teachers, parents, friends, books, TV programs, or none of the above.

Demographics. Basic demographic data of age, grade, gender, and ethnicity were collected. For all analyses, grade was used as a proxy for age because 5 year olds were found across both preschool and elementary school locations.

Results

For baseline exposure, mean scores for the full sample show their computer use as "once per week" (mean, 3.0; standard deviation, 0.95; range, 1-4), implying familiarity with computers. For baseline exposure of sources that taught them about the brain, 35 percent learned from a teacher, 33 percent from their parents, 28 percent from books, 24 percent from TV, 19 percent from their friends, and 28 percent from some other source (none of the above). There was no difference in baseline exposures by grade across both questions and no difference by gender for computer use.

Main study

Knowledge scores. Mean scores showed that posttest knowledge scores were significantly higher than pretest scores ($t_{166} = -5.01$, $P < 0.001$) (Table 3). By condition, results showed that students in the game condition had significantly higher posttest knowledge scores compared with pretest knowledge scores ($t_{60} = -7.39$, $P < 0.001$). The students in the story condition also showed a significant increase in knowledge scores ($t_{50} = -2.29$, $P < 0.05$), but the gain was much larger for the game group. There was no significant difference in knowledge scores for the control condition between pre- and posttest. Boys and girls both showed an increase in knowledge scores (respectively: $t_{88} = -4.41$, $P < .001$ and $t_{77} = -2.59$, $P < 0.05$). Kindergarteners and first graders also showed an increase in knowledge scores (respectively: $t_{76} = -3.02$, $P < 0.01$ and $t_{61} = -3.99$, $P < 0.001$); however, there were no significant differences in pre- and posttest knowledge for preschoolers.

TABLE 4. MAIN STUDY: MEANS AND STANDARD DEVIATIONS FOR INTEREST MEASURE ITEMS

	<i>General interest</i>	<i>Content-specific interest</i>
Full sample Condition	4.20 (0.77)	4.26 (0.65)
Game	4.43 (0.61)	4.37 (0.64)
Story	4.21 (0.58)	4.12 (0.64)
Control	3.98 (0.94)	—
Gender		
Boys	4.15 (0.81)	4.10 (0.72)
Girls	4.27 (0.69)	4.39 (0.56)
Age proxy		
Preschool	4.12 (0.74)	4.45 (0.47)
Kindergarten	4.30 (0.78)	4.26 (0.66)
First grade	4.28 (0.72)	4.16 (0.71)

Interest measure items range from 1 to 5.

A linear regression was run controlling for pretest knowledge scores to see if condition membership was significantly related to the increase in posttest knowledge scores. Results indicated that students in the game condition had significantly higher posttest knowledge scores compared with students in the story condition ($\beta = -0.40$, $t_{163} = -5.450$, $P < 0.001$) and control condition ($\beta = -0.57$, $t_{163} = -7.812$, $P < 0.001$). Game condition membership also explained a significant proportion of variance in knowledge posttest scores ($R^2 = 0.33$, $F_{2,163} = 32.62$, $P = 0.000$). Similar models were run for gender and grade; however, no significant differences were found.

Interest scores. Students rated their interest level fairly high ("happy") across both general and content specific items. Girls scored higher compared with boys across both interest measure questions. No consistent pattern emerged for interest scores by grade (Table 4).

Linear regressions and t tests were run for general interest and content-specific interest items to see if condition membership was related to interest scores. Results indicated that, for the general interest items, the game condition was only significantly different from the control group ($\beta = -0.24$, $t_{164} = -2.82$, $P < 0.01$) but not the story group ($\beta = -0.10$, $t_{164} = -1.20$, $P = \text{not significant}$). For the content-specific interest items, which were only administered to the game and story groups, the game condition reported higher levels compared with the story group ($t_{109} = 2.05$, $P < 0.05$). Similar

models were run to examine the role of gender and grade on interest scores. There were no significant differences by gender for the general interest items, but girls did score significantly higher than boys for the content-specific items ($t_{109} = 2.45$, $P < 0.05$). There were no significant differences across grades for either general interest items or content-specific interest items.

Supplemental study

Knowledge scores. The follow-up posttest scores, taken after multiple exposures to the game, were significantly higher than pretest scores ($t_{67} = -9.43$, $P < 0.001$) (Table 5). To further explore the impact of prolonged exposure, main study posttest scores were also compared with follow-up posttest scores and were shown to be significantly higher than main study posttest scores ($t_{67} = -4.71$, $P < 0.001$).

Boys and girls showed an increase in scores in both pretest versus follow-up posttest (respectively: $t_{27} = -5.45$, $P < 0.001$ and $t_{39} = -7.77$, $P < 0.001$) and in main study posttest versus follow-up posttest (respectively: $t_{27} = -3.31$, $P < 0.01$ and $t_{39} = -3.33$, $P < 0.01$) comparisons. Kindergarteners and first graders also showed an increase in knowledge scores across both pretest versus follow-up posttest (respectively: $t_{32} = -2.32$, $P < 0.05$ and $t_{34} = -7.96$, $P < 0.001$) and in main study posttest versus follow-up posttest (respectively: $t_{32} = -5.50$, $P < 0.001$ and $t_{34} = -4.50$, $P < 0.001$) comparisons.

Linear regression models were run to examine whether gender or grade was related to the significant increase in knowledge scores, controlling for both pretest and main study posttest knowledge scores. There were no significant differences found for gender. Results did indicate a difference for grade such that the first graders had significantly higher follow-up posttest knowledge scores compared with kindergarteners ($\beta = 0.06$, $t_{64} = -2.20$, $P < 0.05$).

Interest scores. Students in the follow-up study rated their interest level fairly high ("happy") across both the general and content specific items (Table 6). Interest ratings did increase significantly from the main study posttest and the follow-up study posttest for both the general interest items ($t_{67} = -3.25$, $P < 0.01$) and content-specific interest items ($t_{39} = -2.44$, $P < 0.05$).

For gender differences, boys and girls reported significantly higher general interest scores at the follow-up posttest compared with the main study posttest (respectively: $t_{27} = -2.44$, $P < 0.05$ and $t_{39} = -2.19$, $P < 0.05$). For content-specific interest items, only boys had a significant increase from the main study posttest to the follow-up posttest ($t_{14} = -3.47$, $P < 0.01$). For grade differences, only kindergarteners reported significantly higher general interest scores ($t_{32} = -3.10$, $P < 0.01$) and content-specific interest scores ($t_{19} = -4.15$, $P < 0.01$) at the follow-up posttest compared with the main study posttest.

In order to test whether gender or grade was related to the increase in interest scores, linear regression models were run for the general interest items and content-specific interest items, controlling for the main study posttest scores. There were no significant differences by gender for the either general interest items or content-specific interest items. There were no significant differences by grade for the general interest items, but kindergarteners did score significantly

TABLE 5. SUPPLEMENTAL STUDY: KNOWLEDGE MEASURE PRETEST, POSTTEST, AND FOLLOW-UP POSTTEST GRAND MEAN AND STANDARD DEVIATION

	<i>Pretest</i>	<i>Posttest</i>	<i>Follow-up posttest</i>
Follow-up sample	0.70 (0.14)	0.80 (0.17)	0.91 (0.12)
Boys	0.73 (0.16)	0.77 (0.17)	0.89 (0.12)
Girls	0.69 (0.13)	0.81 (0.16)	0.91 (0.11)
Kindergarten	0.70 (0.12)	0.79 (0.16)	0.87 (0.13)
First grade	0.71 (0.16)	0.80 (0.17)	0.94 (0.09)

Knowledge measure items range from 0 to 1.

TABLE 6. SUPPLEMENTAL STUDY: MEANS AND STANDARD DEVIATIONS FOR INTEREST MEASURE ITEMS

	<i>Posttest</i>		<i>Follow-up posttest</i>	
	<i>General interest</i>	<i>Content-specific interest</i>	<i>General interest</i>	<i>Content-specific interest</i>
Full sample	4.26 (0.71)	4.21 (0.58)	4.60 (0.59)	4.38 (0.71)
Boys	4.21 (0.71)	3.88 (0.58)	4.59 (0.51)	4.31 (0.76)
Girls	4.30 (0.71)	4.41 (0.50)	4.60 (0.64)	4.43 (0.67)
Kindergarten	4.24 (0.69)	4.14 (0.65)	4.64 (0.47)	4.49 (0.72)
First grade	4.28 (0.74)	4.28 (0.51)	4.56 (0.68)	4.28 (0.68)

Interest measure items range from 1 to 5.

higher than first graders for the content-specific interest items ($\beta = 0.39$, $t_{37} = -2.52$, $P < 0.05$).

Discussion

"Every Body Has a Brain" seeks to teach young children about the structure and function of the brain through an interactive and engaging mechanism. Findings from the main and supplemental evaluations support the premise that this can be a more successful way to increase knowledge and interest in learning about the brain compared with traditional classroom learning.

Main study

The results indicate that being assigned to the game condition was associated with greater posttest knowledge about the brain than students assigned to the story or control condition. Knowledge about the brain was best gained in the game condition compared with both the story and control conditions. The interactive nature of the computer game appeared to encourage the children to explore and understand various parts of the brain and how they function above and beyond the basic content conveyed in the story condition. Interacting with the animated visuals, hearing and watching the content-driven music videos, and interacting with stories may have resulted in children gleaned and retaining more information.

The results also indicate that being assigned to the game condition was associated with greater posttest interest in learning about the brain. However, analyses showed that general interest in learning about the brain was only significantly higher for the game group compared with the control group, and not to the story group. For interest in content specific to the storyline and games shown to both the game and story groups, scores were significantly higher for the game group compared with the story group. These results indicate that interest in learning about the brain increased regardless of the mechanism of delivery between the game and the story. Only when interest reflected the specific aspects of the storyline and games was there a difference between the game and story groups. These findings suggest that providing interesting and engaging content about the brain increases students' general interest in learning about it. However, once that content is made interactive on the computer, specific aspects of that content, such as the storyline and games, increases interest more than in just a story-lecture scenario. These results support the notion that the delivery mechanisms matter when seeking to foster specific interest levels related to the content.

Supplemental study

The results from the supplemental study indicate that prolonged exposure to the "Every Body Has a Brain" game was associated with greater increase in knowledge and interest about the brain compared with a single exposure. These findings support efforts to integrate computer games into standard curricula over the course of a school year. First graders did have higher knowledge scores compared with kindergarteners over time, and kindergarteners had higher general and content-specific interest compared with first graders over time. These results suggest that the older children might grasp some of the conceptual knowledge information more quickly than the kindergarteners but may lose interest sooner, especially once they have mastered the material. Given that kindergarteners were the mean age of the targeted group, these findings suggest that the interest level was appropriately targeted for this specific age group.

This study faced some challenges and limitations that should be considered when examining the findings. Because of the timing of the afterschool program, some children exhibited difficulty in concentrating and lower energy levels, possibly impacting levels of interest and ability to retain knowledge. The students had added attention and interaction with a team of college-aged research assistants, making it difficult to separate out what increased levels of interest were due to the added engagement compared with just the content alone. This issue is particularly salient for the computer group, who had 1:1 ratios with the research assistants due to the need for assistance with the computers. Research assistants sought to minimize interactions with the students to prevent contamination, and future efforts should seek to equalize the ratios across the three groups. Future efforts should also seek to replicate the findings of this study in order to advance widespread use of the computer game over the story lesson because it also showed gains in interest and knowledge, but not as significantly as the computer game.

Conclusions

The goal of this study was to evaluate whether an educational computer game could generate increased knowledge and interest in complicated scientific content for young children; "Every Body Has a Brain" serves as an example of an effective effort to achieve this for children 4–6 years old. By using interactive, creative storylines, characters, songs, and games, "Every Body Has a Brain" draws in children and exposes them to learning content in a manner that imparts knowledge about and interest in the brain. By demonstrating that a computer game can substantially increase knowledge

and interest about the brain compared with more traditional learning methods, this study supports efforts to include the use of computer games in presenting important neuroscience-based content to young children.

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Author Disclosure Statement

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APPENDIX A: KNOWLEDGE MEASURE ITEMS

General knowledge

- Your brain is inside your head. (YES)
- A school bus has a brain. (NO)
- Dogs have brains. (YES)
- Your brain only has only one part that does everything. (NO)
- When you dance, you do NOT use your brain. (NO)
- Different parts of the brain do different things. (YES)
- You can protect your brain by wearing a bike helmet when you ride your bike. (YES)

Brain area-specific knowledge

- You are using your cerebellum when you dance. (YES)
- You use your hippocampus when you remember where you put your toy. (YES)
- Your cerebral cortex helps you think and solve mysteries. (YES)
- Your brain stem helps you swallow and blink. (YES)
- Your cerebellum is NOT a part of your brain. (NO)

APPENDIX B: INTEREST MEASURE ITEMS

General interest (all conditions)

- Mark the face that shows how fun it is to learn about the brain.
- Mark the face that shows how learning about the brain made you feel.
- Mark the face that shows how you would feel learning more about the brain on another day.
- Mark the face that shows how interesting you think it is to learn about the brain.
- Mark the face that shows how doing the worksheets/hearing the story/playing the game made you feel.
- Mark the face that shows how much fun you had doing the worksheets/hearing the story/playing the game.

Content-specific interest (game and story conditions only)

- Mark the face that shows how much you liked the story about "Phoebe Brainheart."
- Mark the face that shows how much you liked seeing the kids dance to the song sung by "Sara Bellum."
- Mark the face that shows how much you liked hearing about/playing the "Brainboard" game where "Sara Bellum" hit(ing) the clouds and helmets.
- Mark the face that shows how much you liked hearing about/playing the "Hiding Hippos" game in the hippocampus.
- Mark the face that shows how much you liked hearing about/playing the game where you fixing/ed the slide in the cerebral cortex.
- Mark the face that shows how much you liked hearing about/playing the "Brain Train" and which one has a brain.
- Mark the face that shows how much you liked learning about the different animal brains.
- Mark the face that shows how much you liked listening to the different stories in each brain land/songs and stories.