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Moved to learn: The effects of interactivity in a Kinect-based literacy game for beginning readers

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ABSTRACT

Reading to young children has a number of benefits, including supporting the acquisition of vocabulary and literacy skills. Digital reading games, including ones with new modes of interface such as the Kinect for Xbox, may provide similar benefits in part by allowing dynamic in-game activities. However, these activities may also be distracting and detract from learning. Children (ages 5–7 years, $N = 39$) were randomly assigned to either i) jointly read a story with an adult, ii) have the story read by a character in a Kinect game, or iii) have the story read by a character in a Kinect game plus in-game activities. Both *Kinect-Activities* and *Book Reading* groups had significant gains for *High Frequency Words*, *Active Decoding*, and *Total Reading Score*, but only *Kinect-Activities* group had significant gain for *Sight* words ($p < .05$). Overall, these findings are encouraging for the next generation of digital literacy games.

1. Introduction

Reading to children remains one of the most important activities for supporting literacy development and fostering language skills (Bus, van Ijzendoorn, & Pellegrini, 1995; Homer, 2009; Mol & Bus, 2011; Mol, Bus, DeJong, & Smeets, 2008; Sénéchal & LeFevre, 2003). Joint reading practices between adults and early readers can support this development in a number of ways, including guiding children's attention to relevant print features or concepts and encouraging metalinguistic awareness through engagement with the language and narratives of books (Justice, Pullen, & Pence, 2008; Zevenbergen & Whitehurst, 2003; Zucker, Ward, & Justice, 2009). Yet as digital technologies increasingly become a part of young children's lives, their relationships with the written word and their shared literacy experiences are changing. To ensure successful learning outcomes from interacting with digital materials intending to promote literacy, designers will need to integrate successful reading practices into effective experiences with new media. The current study investigates this issue by evaluating the potential of a digital storybook with embedded games, delivered via the Microsoft Kinect (a movement based physical gaming device) to promote children's literacy development without the assistance of an adult.

There is some evidence that children can benefit from reading interactive books in ways similar to reading traditional books, with subsequent gains in vocabulary and word recognition (de Jong & Bus, 2004; Korat, 2010). Other studies, however, have found that the interactive components of digital books, which are intended to keep children engaged and actively reading, can be distracting and actually result in less reading, poorer narrative comprehension, and limited language and literacy benefits (Chiong, Ree, Takeuchi, & Erickson, 2012; de Jong & Bus, 2002; Underwood & Underwood, 1998). In their recent review of research on children's digital reading experiences, Miller and Warschauer (2013) conclude that although there is great potential of digital media, we still know little about the specific mechanisms involved in

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learning from them. They argue that one promising area for future work involves examining effects of specific features of digital reading materials. Such a focus on asking which design features of digital reading materials make them more effective, which parallels similar approaches in multimedia learning research in other subject areas (Homer & Plass, 2010; Plass et al., 2013; Plass, Homer, & Hayward, 2009), can make a significant contribution to the growing body of literature on early reading experiences with digital technologies by focusing this research on developing effective designs to promote good reading practices that take advantage of the affordances of new technologies.

The next generation of video game consoles and interfaces, such as the Xbox Kinect, provide great opportunities for developing digital reading games that can improve education through authentic interactive learning scenarios (DePriest & Barilovits, 2011; Hsu, 2011). The gesture- and movement-based interactions create a unique, responsive platform that affords designers new possibilities for embedding dynamic in-game activities that maintain young children's interest in reading and support deeper engagement with language and narrative. However, it is critical to ensure that the storybook interface and activities within the game are well designed and do not detract from the benefits of reading. Research is also needed to determine whether the experience of digital reading games are comparable to having a story read aloud by a caregiver.

To address these questions, we conducted a randomized controlled experiment comparing language and reading outcomes for children who had a story read to them by an adult, to those who had the same story read to them by a character in a prototype of a Kinect game, either with or without the addition of in-game activities. The Kinect versions of the story, *Children Make Terrible Pets* (Brown, 2010), included a number of interactive features that required the children to use gestures or movements to interact with the book/game. These features included a book selection menu navigated by a particular combinations of body movements, turning the pages of the on-screen book with the full body, and, for the *in-game activity* group, a series of activities related to a target vocabulary word and to a plot point in the story.

In the remainder of this section we will first briefly review research on joint reading strategies from traditional books, discuss how insights from this research can be used to design interactive digital storybooks, and then review results from research investigating the effectiveness of such digital storybooks for literacy learning.

1.1. Lessons from joint storybook reading strategies

Joint reading between an adult and a child has been shown to improve literacy development across many reading and language skills, including vocabulary acquisition, story comprehension and word reading (Mol et al., 2008; Mol & Bus, 2011; Whitehurst & Lonigan, 1998). In the design of our study, we orchestrated the interactions between a child and caregiver when reading a print book, and a child and on-screen character when playing on the Kinect, to include various co-reading strategies, giving us the ability to evaluate how a digital versus print experience may affect learning from the different reading activities. These interactions were informed by joint reading practices such as dialogic reading, in which an adult uses questions and comments to engage children in the reading experience (Zevenbergen & Whitehurst, 2003), but were also constrained by the capabilities of the Kinect system. These constraints meant that interactions needed to be scripted and had to focus on strategies that could be recreated by the Kinect system, including print referencing practices like pointing and tracking words, explaining concepts of print and vocabulary in context, and elaborative language uses for target words.

Print referencing strategies have been shown to enhance emergent reading skills as a part of joint reading experiences between adults and children (Ehri & Sweet, 1991; Justice, Kaderavek, Fan, Sofka, & Hunt, 2009). Print referencing occurs when an adult uses both verbal and non-verbal cues to guide an early reader's attention to elements in the storybook. These cues can be an implicit part of the experience, like pointing to and tracking words during reading, or can be explicit techniques such as making comments or providing explanations about concepts of print, and the use of elaborative questions (Justice & Ezell, 2004).

Many aspects of print referencing were directly mapped onto the design of the digital storybook on the Kinect platform. Pointing to and tracking words during joint reading has been shown to increase print concepts and develop internalizations of word features among early readers (Ehri & Sweet, 1991), and was therefore incorporated into the digital storybook in the current study. Other examples of these techniques used in our study include the narrator's explanation of how the word "MOM!" is written in all capital letters because it is meant to be read loudly, or the activity in which children enacted the word "together," which elaborates on the pronunciation and meaning of a word in the story. These kinds of contextualized reading interactions foster metalinguistic awareness and encourage exploration of concepts among early readers (Zucker, Ward, & Justice, 2009).

The implementation of strategies that were found to be effective in print books for the design of reading activities in digital books raises the question how we can ensure that these practices are effectively mapped onto reading experiences in digital media? We cannot assume that all implementation of such strategies will be effective. In fact, a number of studies have found that adding interactive elements to a digital learning environment can actually interfere with learning outcome (Moreno & Valdez, 2005; Tuovinen & Sweller, 1999). Although new research methods are necessary to more fully explore the potential of digital media for literacy learning (see Lemke, 1998; Leu & Kinzer, 2000; Unsworth, 2003), many of the findings from successful joint storybook reading strategies can be integrated into the design of technology for interactive reading experiences.

Our review of the literature has not revealed any empirical investigation of literacy learning and employable reading strategies on the Kinect platform. Since the commercial release of the Kinect in 2011, the majority of research on this technology has investigated learning concepts within science, technology, math and engineering (STEM) education (see Isbister, Karlesky, & Frye, 2012; Norris, Goza, & Shores, 2011; Underwood, Hung, Click, & Russell, 2012). Thus, to inform the present research we look to research that has been conducted on e-books, ranging from early investigations with CD–ROM technology and "Talking Books" to work with web-based platforms and, most currently, touch screen tablets.

1.2. Designing interactive storybooks for literacy learning

Interactive reading experiences, most generally referred to as e-books, have evolved in their design to include some general common features. Among these is the convention of "written text together with synchronized narration" (Korat, 2010, p. 30), often including an animated character reading the storybook in children's titles. As the words are read aloud, the text generally will become highlighted in real time, and pauses in the story will be made at the end of each page, prompting the reader to turn the page with forward and backward buttons or by swiping the screen.

Additionally, features such as a dictionary function with definitions and pronunciation may be available in the form of hyperlinks or hot spots to activate words. Just as print salient storybooks emphasize print and may embed text in illustrations (Smolkin, Conlon, & Yaden, 1988), interactive features of these hot spots may be integrated into literacy learning by repeating the audio, spelling the word, or showing a video or animation or focus on images, allowing the reader to interact with clickable or touchable objects on screen. Alternatively, hot spots may completely take the reader away from the page to other activities such as games, drawing, or videos, among others. Additional enhancements within an interactive storybook may include music and sound effects, cinematic elements like zooming in and out of a storybook page, or other features such as taking a picture or recording a voice; see Guernsey, Levine, Chiong, and Stevens (2012) for a full list of the most common features in touch screen based e-books.

The role of an adult in a reading experience is a final design aspect to take into consideration as a part of this body of research. Although there are no accepted design standards for creating shared reading experiences with digital storybooks, styles of interaction and engagement may be mediated by the presence or absence of an adult (Moody, 2010). Many research studies include an adult's guidance as a variable or as a separate condition in a study, however, our review of the literature has found no evidence of improved learning or increased engagement as a result of a child interacting with a digital storybook *without* an adult present. For example, in Wood, Pillinger, and Jackson's (2010) investigation of interactional style between children reading with adult tutors versus children using talking books, the authors found that children only engaged in spontaneous dialogic reading practices in the print book condition. Similarly, in a study of joint storybook reading with or without an adult, the most significant gains in emergent reading skills (including word reading) occurred in the condition of a child reading via an electronic medium with additional adult instruction (Segal-Drori, Korat, & Shamir, 2010).

Although the amount of research available on the ability of interactive technologies to support literacy development is growing, there is still a lack of consensus as to what benefits children gain when reading e-books and how these experiences should be designed to best support learning. Lankshear and Knobel (2006) identify both "old literacies", which are practices associated with print text, and "new literacies", which take advantage of digital and connected nature of new media. They argue that educators need to be aware of how their students are using these new literacies and identify ways to integrate them into their classrooms. In her review of the research on digital technologies and early childhood literacy, Burnett (2010) similarly argues that educational practice is becoming increasingly outdated by ignoring digital literacies. She suggests there is a critical need for more research on how young people interact with digital texts – and, we would add, on the educational and cognitive consequences of specific modes of interaction. Of particular importance in the current study is therefore to deepen our understanding of how interacting with a digital text can support literacy development in young children.

1.3. Reading gains from interactive storybook reading: mixed results

Studies that found improved literacy development through e-books seem to agree that learning improvements are due to the dual processing of visual and verbal information when words are read aloud while displayed on a screen (Kamil, Mosenthal, Pearson, & Barr, 2000; Lewin, 1998). Further, some researchers suggest that additions to a print version of a book, such as dynamic visuals and activities providing additional content beyond the printed text, may supplement children's knowledge and lead to gains in story comprehension (James, 1999; Korat, 2010). However, similar research on particular features within e-books and their overall influence on a child's reading experience has yielded mixed results.

In studies including a variety of common design features, it has been generally found that children's attention may be more drawn to animations unrelated to text and hamper story comprehension as a result (Burrell & Trushell, 1997; Miller & Olsen, 1998; Underwood & Underwood, 1998). For example, Underwood and Underwood (1998) observed interactions of pairs of children working together on "Talking Books" and found that during reading, children accessed irrelevant animations that were not integrated into the story more often than word pronunciations related to the text. When asked later to recall the experience, children were more likely to discuss irrelevant features than story content, supporting the notion that it is the most salient features that attract learners' attention, not the most useful ones (Plass et al., 2009).

de Jong and Bus (2002) also examined the role of distracting features, with a focus on time spent engaging with the text as a measure of reading activity in a study comparing children's reading across conditions of print book, e-book with games, restricted e-book without games, and a control group receiving general school curriculum. Over the course of six sessions, children in the e-book with games condition spent less time engaged with written word and more time on activities deemed distracting, such as games and animated hot spots. In terms of story comprehension (measured via quality of recall and language use in emergent readings), it was found that only the participants in the print book condition were able to reproduce the story's meaning more successfully than the control group. In contrast, participants in the restricted e-book condition appeared to benefit from higher quality digital experiences with the story in terms of word reading, where they made comparable progress to children in the print book group. These findings suggest that well designed e-book experiences may yield similar results to reading with print books, yet highlight the need for further investigation into what level of learning outcomes can be expected from different types of design features (de Jong & Bus, 2002), which reflects similar findings in other fields of learning from digital materials (Wallen, Plass, & Brünken, 2005).

In an examination of co-reading sessions with parents and preschool age children, researchers attempted to further unpack this relationship between quality reading experiences and the design of e-books by examining "basic" e-books versus "enhanced" e-books with highly interactive features and activities tangential from the written text (Chiong et al., 2012). Through a within- and between-subjects design with counter-balanced subgroups, parents and children read either a print book and basic e-book or a print book and enhanced e-book. The study found that "enhanced" e-books with extra features negatively affected comprehension and resulted in disengagement and behaviors not related to story content, while "basic" e-books prompted similar behaviors to print books, resulting in comparable levels of engagement and story comprehension (Chiong et al., 2012).

Some work in this area has focused specifically on the possibility of e-book technology to improve vocabulary among early readers. In a study conducted with kindergarten and first grade learners reading an interactive e-book specifically designed to improve reading outcomes, Korat (2010) found that children who had e-book experiences showed greater gains in word reading ability and vocabulary compared to children in the regular school program. Korat describes the design of the book with regard to improving vocabulary skills as being based on NICHD standards including: repetition of word learning, embedded vocabulary in meaningful contexts, and offering children

an "active role" in vocabulary acquisition process (Korat, 2010; National Reading Panel, 2000). In alignment with these standards, previous studies to validate the e-book's design also indicated improvement in word reading and sight recognition of words that occurred in the story with high frequency (Korat, 2009; Korat & Shamir, 2008). Perhaps because of these possibilities for providing additional context and making learning more active, there is also particular interest in the potential benefits of multimedia experiences like e-books to reduce vocabulary gaps between learners of second languages and children with language delays or learning disabilities (Korat & Shamir, 2008; Shamir, Korat, & Fellah, 2010; Verhallen & Bus, 2010).

In summary, the question of how to best design interactive features for learning is a highly significant issue for reading with interactive storybooks. While there is still much to be investigated in this area, most research agrees that the potential for improved literacy learning through digital media is great but strongly dependent upon effective designs of relevant features. Furthermore, these designs need to be grounded in a developmental framework for literacy acquisition, with interactive experiences that are designed to meet children's specific developmental needs (Korat, 2010).

In the present study, we were particularly interested in (1) whether digital storybooks without a caretaker who is reading to children can be as effective as a child reading with a caretaker from a print book, (2) whether added gesture-based activities related to the reading content would support learning or distract from it, and (3) whether there were differences in children's interest and engagement, and (4) what difficulties, if any, they may experience in reading with the digital gesture-based materials.

To address these questions, we conducted a randomized controlled experiment comparing language and literacy gains in children who either had the story, *Children Make Terrible Pets* (Brown, 2010), read to them by an adult to children who had the same story read to them by a character in a Kinect game, either with or without in-game activities. Language and literacy pre- and post-test measures were included with a focus on vocabulary, story comprehension and word reading, as were measures of engagement and interest.

2. Method

2.1. Participants

Participants in the current study ($N = 39$) were kindergarten ($n = 21$) and first grade ($n = 18$) students who ranged in age from 5- to 7-years ($M = 6.2$ years). All of the children were fluent in English. The students came from a school system that uses a "balanced literacy" approach that begins in kindergarten. The two primary schools from which the students were recruited have diverse student populations, both in regard to ethnic background, with 34% minority students in one school and 83% minority students in the other school, and socio-economic status, with approximately 30% of the students at the schools qualifying for free or reduced lunch. There were 22 boys and 17 girls in the study with roughly equal numbers of boys and girls in each condition: *Book Reading* had 6 boys and 8 girls; *Kinect without activities* had 8 boys and 5 girls; and *Kinect with activities* had 8 boys and 4 girls.

2.2. Materials

2.2.1. Print storybook

Children in all conditions heard the story "Children Make Terrible Pets," by Peter Brown (2010). The paper-based version used in the study was the hardcover edition. The book is generally considered appropriate for children in kindergarten through third grade. It is 34 pages in length and has a reading grade level equivalent of 1.8 (i.e., at the expected reading level of a first grade student in their 8th month). The story is about a young bear named Lucy who finds a human boy hiding in the woods. She decides to keep the boy as a pet and names him Squeaker. Lucy's mother reluctantly agrees to allow her to keep him but warns that children aren't very good pets. Lucy promises to take care of Squeaker and subsequently faces a series of challenges trying to care for him. One day Squeaker disappears. Lucy goes searching for him and eventually finds Squeaker having a picnic with his family. Lucy realizes that Squeaker is happier with his own family and decides to let him go. Lucy returns home and tells her mother what happened. In the end, Lucy agrees that children make terrible pets.

2.2.2. Digital storybook

Microsoft Games Studio created the digital version of *Children Make Terrible Pets* (Brown, 2010). This was a prototype designed to run on Microsoft's Xbox 360 video game console with a Kinect unit. The Kinect is a hardware addition to the Xbox that uses cameras and voice recognition to track players and allows them to interact with the console using a natural user interface of gestures and spoken commands, replacing the need to use a game controller with buttons. The research team provided some advice that informed the development of the prototype, such as suggestions for age-appropriate activities that could support language and literacy acquisition, see description of these features in Section 2.2.3.

The digital version of *Children Make Terrible Pets* is faithful to original story in that it contains the same characters, dialog, plot, artwork, and setting as the print version. There are, however, a number of important differences. In the digital version of the story, the "reader" (or player) stands in front of a screen as an on-screen animated character, Kenzie, welcomes them and introduces the story (Fig. 1A). After the introduction, Kenzie reads the entire story to the reader/player. While reading the story, Kenzie's animated hand traces the words being read aloud. As she traces over a given word, it turns white to highlight the word being read (Fig. 1B). The artwork is true to the print edition of the story, but the characters in the digital version are animated. At times, the full page and story text is displayed, while other times, Kenzie (or one of her animated friends), will talk directly to the reader/player, commenting on events in the story.

2.2.3. Interactive digital storybook

In the interactive version of the Kinect-based story, a number of features were added that required the children to use gestures or movement to interact with the book/game. These features include a book selection menu navigated by a particular combinations of body movements, turning the pages of the on-screen book with hand gestures, and a series of in-game activities related to a target vocabulary word and to a plot point in the story (Fig. 2). There were also four in-game activities designed to bring the reader/player into the world of the story and enhance vocabulary and literacy skill learning.

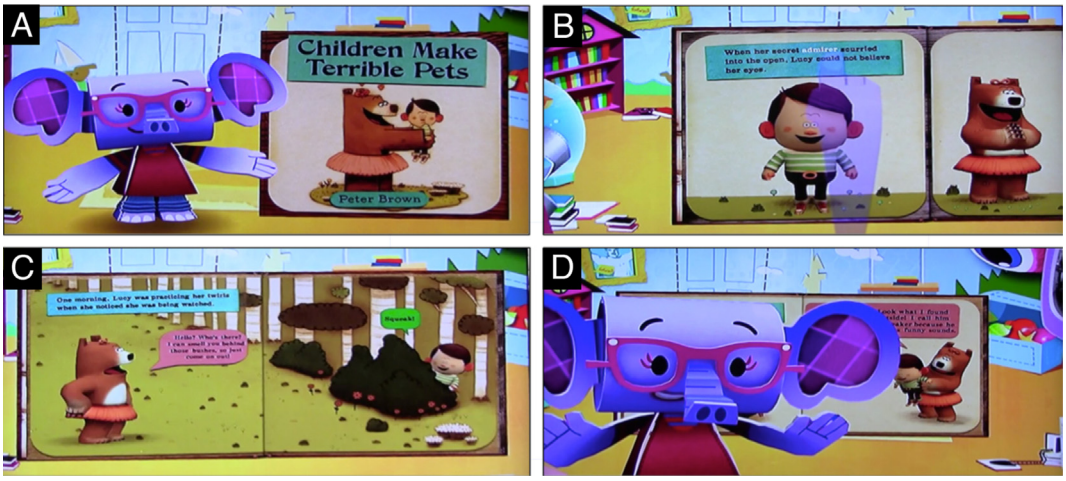

Fig. 1. Screenshots from the digital version of Children Make Terrible Pets, adapted for the Kinect Xbox 360 console. A) Kenzie, in her playroom, introducing the book she is about to read. B) Words turn white as Kenzie reads them aloud and traces them with her finger. C) The book is shown in the foreground of the game, with Kenzie's room in the background. The characters in the Kinect version are animated. D) Throughout the book/game, Kenzie stops reading the story to address the reader/player directly.

The first three activities focus on the word "together" and come one after another. The first activity shows Lucy wearing a Kangaroo costume and carrying Squeaker in her pouch. As they jump up and down, Squeaker repeatedly bounces out and rolls on the ground. The player's goal is to pick Squeaker up and toss him back to Lucy using a throwing motion with both hands. The activity lasts approximately 90 s.

In the second activity, Lucy holds a basket of berries and throws them in the air for Squeaker to catch. The reader/player's task is to help Squeaker catch the berries by moving their bodies from side to side to make Squeaker move to the place where the berry is going to land. This activity lasts approximately 60 s.

In the third activity, Lucy and Squeaker are napping on a long branch of a tree. The player's task is to slide the two characters together by pushing them together using his/her hands. This activity lasts less than 30 s, and at the end, the reader/player hears the word "together" sounded out one syllable at a time, "To-geth-er." At this point the player is returned to the book to continue hearing the story.

The fourth and final activity occurs when Lucy, separated from Squeaker, searches for him by following his scent throughout the forest. The reader/player's "mission" is to help Lucy find Squeaker by following the scent trail. The player moves his/her body from side to side to "catch" green scent markers and avoid obstacles such as logs, stones, and trees. This activity lasts approximately 2 min, and then the player is returned to the book to finish hearing the story.

2.3. Procedure

All research occurred in a university research lab. In a between-subjects experimental design, children were randomly assigned to one of the following three conditions: *Book Reading*; *Kinect without Activities*; and *Kinect with Activities*. Each condition is described in detail below.

2.3.1. Book Reading

In this condition, children heard the print version of the book read aloud by an experimenter. The experimenter sat next to the child, read title and author, and then read the story aloud. Efforts were made to match, as closely as possible, the experience offered in the Kinect version of the story. For example, the researcher ran her finger along the words as she was reading, and read in a style similar to the character in the digital version. In addition, the researcher made similar comments about the story as the character in the digital version makes. For example, the researcher read the word "MOM!" (p. 6) with more volume and commented that readers should read words more loudly when they are written in large print. This same experience unfolds in the Kinect version of the story.

To account for the experience offered by the in-game activities, the researcher also made comments or asked questions specifically relating to the words "together" and "scent." When the word "together" appeared in the book, the researcher asked "Do you know what 'together' means?" The research assistant waited for a response from the participant and then pointed to the picture in the book. "Look, they're together here. What kinds of things do you think they might do together?" Ample time was given for the child to respond to the prompt. After the participant's response, the researcher continued saying, "You know if we had something over here [gesturing with left hand] and over here [gesturing with right hand] we could push them close to each other and then they would be together [sliding hands together]."

Fig. 2. The selection gesture required to select a book (left) with a vertical progress bar on the left signaling how long to hold the gesture. Stills from video recordings show children's interpretations of the expected gesture before receiving guidance from experimenters.

When the book shows the words "sniff, sniff," the researcher read the words aloud and commented that Lucy is sniffing with her nose and thinks she can smell Squeaker. The researcher explained that "catching a whiff of Squeaker," means she can smell him. After the word "scent" itself appeared in the book, the researcher stopped reading and explained that Lucy was looking for Squeaker by following his scent. The researcher explicitly stated, "She's searching for him by following his smell." This marked the final interjection by the researcher, who then continued to read the story through the end. Reading the story with interjections took approximately 8 min.

2.3.2. Kinect Without Activities

In this condition, children heard the digital version of the book read aloud by the animated character, but did not participate in any in-game activities. The children were positioned approximately eight feet in front a TV or projector screen upon which the digital version of the story was displayed. They were shown the Kinect sensor bar and told that the sensor would keep track of where they were standing. Participants were also shown the two video cameras set-up to record the activity. One camera was positioned to shoot the participant from the front and the other from about a 45-degree angle from the side. Digital audio recorders were also used to capture verbal responses. A research assistant stood off to the side, out of the Kinect sensor's view, with an XBox 360 controller in-hand, to start and control various aspects of the game.

Participants were told that they were going to hear a story and that all they should follow along. The activity was described as "playing a reading game." Throughout the experiment, the research assistant answered participants' questions, and, when needed, provided verbal and physical help with gestures needed to control the digital version of the book.

Participants started by selecting a book from the bookshelf, as described in Section 2.2.3 (they were instructed to select *Children Make Terrible Pets).* During this activity, the Kinect sensor detected the participant's image and displayed a live video-feed of the child on-screen. To help participants realize that the Kinect sensor was actively "tracking" his or her movements, research assistants asked participants to wave to themselves on the screen. After selecting the book, children were introduced to Kenzie, who introduced and eventually read the story aloud. At this point, participants were told to simply follow along as Kenzie told them what to do. Research assistants used the Xbox controller to skip over the in-game activities, which resulted in a slight delay in the flow of the story. Researchers told participants, "Just a second, the next page is coming," but did not mention that any activities were being skipped. The Kinect version of the story ends with Kenzie reading, "The End." The entire *Kinect without Activities* sequence, including the introduction with the Kenzie character and choosing the book, took approximately 12 min from beginning to end.

2.3.3. Kinect With Activities

This condition was the same as the Kinect without Activities condition, but included the additional interactive activities embedded into the game (See description of in-game activities above). The remainder of the procedure was identical to the Kinect without Activities condition. The addition of the interactive sequences added approximately 6 min to the story experience for a total of around 18 min.

2.4. Measures

2.4.1. Pre-test interview

Before beginning the study, participants took part in a pre-test interview regarding their reading practices and preferences, as well as their game play preferences and history. These questions were asked orally in a conversational style in an attempt to build rapport with the participant. While the lead research assistant conducted the interview, a second research assistant recorded participants' answers on paper. The questions were asked in the order given in Appendix A.

2.4.2. Concepts about Print Test

The second pre-test item consisted of an abbreviated version of Clay's (2000) *Concepts about Print Test* (including only items 1, 2, 3, 4, 5, 6, 11, 15, 16, 17, 18 and 19). Using the book *Follow Me, Moon* (Clay, 2000), the research assistant introduced the activity by saying, "Now I'm going to ask you some questions about reading a book," and asked children a number of questions related to holding, handling, and reading a printed book (see Appendix B). Due to time considerations, the research assistant read only relevant pages of the book required for the test items. As with the pre-interview, a second research assistant sat nearby and recorded participants' answers. Children received one point for each correct answer, resulting in a score from 0 to 12.

2.4.3. Reading vocabulary pre- and post-test

This reading assessment was conducted both before and immediately after children heard the story in one of the three conditions, and was designed to measure participants' knowledge and recognition of 20 target vocabulary words that appeared in the story (see Appendix C). Target words included 10 *Sight Words*, common words recognizable by sight (drawn from the Dolch list of sight words for early readers), and 10 *Active Decoding Words,* which children tend to read by sounding out the letters. Of these 20 words, 10 words (including 5 of the Sight Words, and 5 of the Active Decoding words) were *High Frequency Words* that appeared three or more times in the story.

Target words were printed in a large font on a white sheet of paper (8.5 $\times$ 5.5 in) and were shown to participants one at a time. The words were shown in the same order for all participants. Sight words and active decoding words were alternated, and high frequency words were dispersed throughout the list. Participants were asked to read each word aloud (e.g., with the prompt "Can you tell me this word?"). If a participant was unsure, he or she was encouraged to try (e.g., with the prompt "It's ok, do your best" or "Give it a try."). Importantly, if a participant did not know a vocabulary word shown on the card, the researcher did not say the word, so as to avoid teaching the target word during the test. One researcher administered the test, while a second recorded the results.

Children were given 1 point for each word that they read aloud correctly, and 0 points for words that they did not read correctly. We assessed children's scores for each category of words described above, as well as a *Total Reading Score* for all 20 words.

2.4.4. Definitions pre- and post-test

Children were asked to explain the meaning of a subset of Active Decoding words that appeared in the story and the in-game activities (secret, together, scent, disappeared, terrible). For example, experimenters asked, "Can you tell me what the word 'secret'

means? What does it mean when something is secret?" Children's responses were recorded by a second experimenter, and children were given one point for each conceptually correct definition provided. Examples of correct definitions are listed in the Appendix C.

2.4.5. Interest/motivation self-report

At a mid-point in the story (after the line that begins, "Just when Lucy thought things couldn't get any worse…"), researchers paused the game or stopped reading the book and asked children a series of four questions about their interest in the activity (Appendix D). Participants were told that if they liked something or agreed with what was being said, they should point to the happy face (scored as 2 points). If they didn't like something or disagreed with what was being said, they should point to the unhappy face (scored as 0 points). If they weren't sure they could point to face in the middle, the neutral face (scored as 1 point). This questionnaire was repeated again at the end of the story, resulting in a total motivation score of 0–8 for each time point, and 0–16 overall.

By asking at a mid-point and at the end of the session, we are able to get a more accurate measure of a child's interest and motivation during the activity, and one that captures if interest stays constant or changes by the end (e.g., do they lose interest?). This technique of interrupting a story or game at a mid-point is one that has been successfully used in many previous research studies (see Schuh et al., 2008).

2.4.6. Narrative comprehension and character identification tasks

At the end of the story, researchers asked children to tell what happened in the story. Responses were coded on a scale of 0–3 based on the number of details about the story that children provided in their responses (from no recollection of any details about the story, to three or more details provided about the characters and/or events in the story).

Next, children were shown images of characters from the story printed in color on a sheet of paper. The research assistant showed the child each picture and asked, "Can you tell me who this is?" and "Can you tell me something about her/him?" All participants, regardless of condition, were asked to identify Lucy and Squeaker. Children in the two *Kinect* conditions were also asked to identify Kenzie. Children in the *Book Reading* condition were shown a picture of Kenzie, but were simply asked if they would like to have this character in the story and if they thought they would like her.

Responses were coded using a scale of 0–2: children received a score of 2 if they correctly named the character, 1 if they demonstrated recognition by providing accurate information about the character from the story, and 0 if they said they did not remember the character or failed to provide any accurate information about the character from the story. Scores were compared across groups only for identification of Lucy and Squeaker.

2.4.7. Video coding

Video recordings of participants were analyzed by dividing the story into short sections, bounded by the words that appeared on the each separate screen in the Kinect versions of the book. These sections roughly corresponded to the pages of the print book, but because some book pages appeared on a single screen in the digital version, these pages were included within a single section for video coding purposes.

Video and audio recordings were coded for the following behaviors during each section of the story:

- **On-task behavior:** children's gaze was analyzed to determine whether or not they were on task during each segment. Because the children might look away when thinking or processing information, they were counted as being "on task" for any segment so long as they spent at least half of the time looking at the book/screen.
- **Evidence of reading:** either verbal (i.e., mouthing or verbalizing words) or through pointing (i.e., pointing toward the words as they were being read).
- **Questions asked:** children's questions were recorded verbatim, and were categorized as questions relating to: Letters, punctuation, single words, sentences/phrases/multiple word arrays, book language, oral story (e.g., character identification or character actions), illustrations, books (in general), the act of reading (in general), or "other."

For the two Kinect conditions (with and without in-game activities), the following behaviors related to using the Kinect game were also coded:

- **Page turns:** the number of pages where children's first attempt to turn each page was successful, and the total number of attempts made to turn the page.
- **Gesture confusion:** whether children attempted to use a gesture other than the one required for each activity or interactive feature, regardless of whether this gesture was recognized by the Kinect. For example, if an in-game activity required the child to move both arms, and the child instead moved only one arm.
- **Assistance requested:** whether children requested help from the experimenter (once, repeatedly, not at all).
- **Assistance provided:** including both Amount (once, repeatedly, not at all) and Type of assistance (verbal instruction, demonstration, or both verbal and demonstration).

3. Results

Each reading measure was analyzed separately using a repeated-measures ANOVA with Reading Gain (Pretest score vs. Posttest score) as a within subjects factor, and Condition (*Book Reading, Kinect Without Activities, Kinect With Activities*) as a between subjects factor. One participant (in the *Kinect without Activities* condition) did not complete the Definitions pretest, and therefore was not included in the analysis for that measure. The data was screened for outliers and none were identified. Assumptions of normality, linearity and multi-collinearity were met.

Reading Assessments Motivation self-report, On-task behavior coded from video recordings, and total pretest scores for Clay's Concepts about Print Test were analyzed separately using a Oneway ANOVA with Condition as a between subjects factor. Because the data for Narrative Comprehension and Character Identification were found to not be normally distributed, Kruskal–Wallis oneway ANOVAs with

Condition as a between subjects factor were conducted. The Kruskal–Wallis oneway ANOVA is a non-parametric method for determining if samples are independent that relies on ranks and does not require data to be normally distributed.

3.1. Reading Gains

Mean pretest and posttest scores for each reading measure, along with main effects for Reading Gains are provided in Table 1. Across groups, children showed improvements in all reading measures, including their reading scores for Sight, Active Decoding, and High Frequency Words, as well as their Total Reading Scores. In addition, children showed gains in the number of correct Definitions provided for words that had appeared in the story.

Reading Gains within each condition are illustrated in Fig. 3. *Gain* × *Condition* interactions for Active Decoding words ($F(2,36) = 3.45$, $p = .04$), High Frequency Words ($F(2,36) = 3.62$, $p = .04$), and Total Reading Scores ($F(2,36) = 8.54$, $p < .01$) indicated that reading gains varied between groups. Pairwise comparisons of Pre- and Post-test scores within each condition (Table 2) showed significant reading gains only for the *Kinect With Activities* and *Book Reading* groups. Children in both groups showed improvements in their ability to read Active Decoding and High Frequency words, as well as gains in their Total Reading Scores. In addition, only children in the *Kinect With Activities* condition showed reading gains for Sight Words, although a *Gain* × *Condition* interaction for this measure failed to reach significance. Children in the *Kinect Without Activities* condition showed no significant reading gains on any measure.

3.2. Clay's concepts about Print Test

We found no baseline differences between groups for this measure (*Book Reading:* $M = 9.50$, $SD = 2.10$; *Kinect Without Activities:* $M = 10.08$, $SD = 1.26$; *Kinect With Activities:* $M = 9.25$, $SD = 0.97$). Therefore, we assume that children began the study with a similar level of understanding of general reading concepts.

3.3. Reading questions and evidence of reading (verbal, pointing)

Only one student (in the *Book Reading* condition) asked any type of reading question during the task. This child asked questions relating to Oral Story and Reading in General (3 questions of each type). Because no other students asked reading questions during the task, this measure was not analyzed further. In addition, only 6 out of the 39 children demonstrated evidence of reading during the task, either in the form of verbalizing/mouthing words or pointing to words as they were being read. No differences between groups were found in the frequency of this behavior.

3.4. Additional measures

3.4.1. Motivation and on-task behavior

Participants' self-reports of their motivation and interest indicated that children in all three groups had similar overall levels of interest in the task (*Book Reading:* $M = 15.64$, $SD = 3.69$; *Kinect Without Activities:* $M = 14.92$, $SD = 4.21$; *Kinect With Activities:* $M = 13.67$, $SD = 2.96$). These scores indicate that children across groups responded positively to the reading task. In addition, video coding of participants' behavior indicated that children in all groups spent over 96% of the time attending to the task by maintaining their focus on the screen or the book (*Book reading:* $M = 96.82$, $SD = 0.07$; *Kinect Without Activities:* $M = 97.55$, $SD = 0.04$; *Kinect With Activities:* $M = 98.22$, $SD = 0.05$). No significant differences between groups were found for either measure, indicating that children in all conditions generally attended to and enjoyed the task. Therefore any differences in reading gains between groups cannot be explained by increased attention or motivation.

3.4.2. Character identification

The number of children in each group who recognized or named Lucy, Squeaker, and Kenzie are provided in Table 3. The majority of the children in all three groups were able to identify Lucy and Squeaker at the end of the study, either by naming them or by providing a specific detail about each character from the story. The majority of children in the two Kinect conditions were also able to provide a specific detail about Kenzie from the game, although none remembered her name. No significant differences in identification scores for any of the characters were found between groups.

3.4.3. Narrative comprehension

The number of details about the story provided by participants in each condition is listed in Table 3. The majority of children in all three conditions were able to provide one or more details about the story after participating in the reading activity (*Book Reading:* 14/14 children, *Kinect Without Activities:* 10/13 children, *Kinect with Activities:* 9/12). We found no differences between groups in the number of details provided, indicating that children across conditions had comparable recollection of the story.

Table 1
Means (*SD*) on Pretest and Posttest Reading Measures across groups.

	Pretest	Posttest	$F(1,36)$	p
Sight Words	7.38 (3.32)	7.67 (3.17)	4.82	.035
Active Decoding Words	4.00 (3.98)	5.03 (4.16)	22.39	<.001
High Frequency Words	6.05 (3.28)	6.56 (3.52)	12.21	.001
Definitions	3.5 (1.13)	3.84 (0.92)	6.45	.016
Total Reading Score	11.38 (6.82)	12.69 (6.96)	42.68	<.001

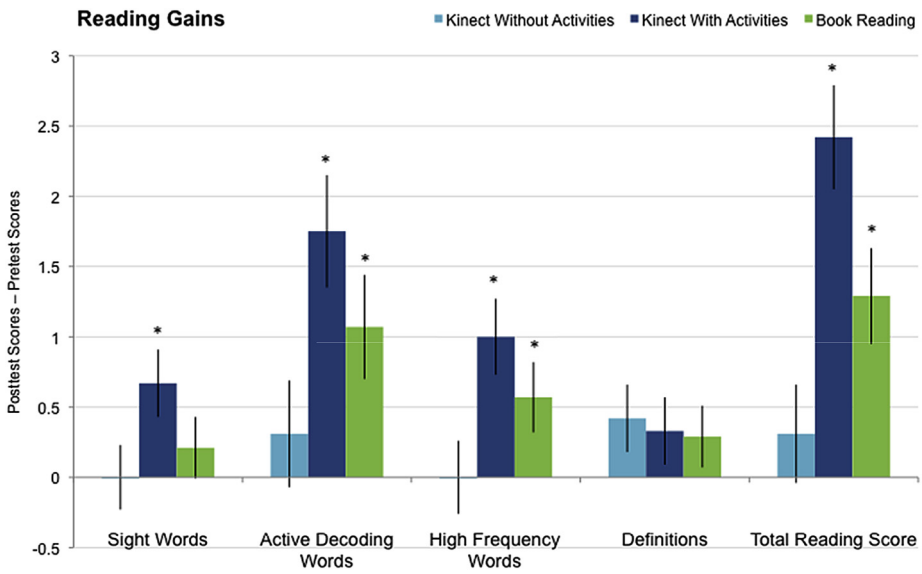

Fig. 3. Reading gains (Posttest–Pretest Scores) observed across conditions. * = Pairwise comparison between pre- and post-test significant at the $p < .05$ level with Bonferroni adjustment for multiple comparisons.

3.5. Video coding of gestures in Kinect Conditions

Video recordings of the 25 children in the two Kinect Conditions were analyzed for usability issues relating to the gestures required in the digital book.

3.5.1. Page turns

Children were successful on their first attempt to turn the page of the digital book an average of 67% of the time ($M = 67.03\%$, $SD = 24.06$). No significant difference was found between the two *Kinect* conditions in either the success of page turning (*Without Activities:* $M = 67.50\%$, $SD = 28.99$; *With Activities:* $M = 66.53\%$, $SD = 18.58$), or the total number of attempts made to turn the pages of the digital book (*Without Activities:* $M = 12.15$, $SD = 6.27$; *With Activities:* $M = 15.17$, $SD = 2.92$).

3.5.2. Gesture confusion and assistance provided during in-game activities

The number of children in the *Kinect With Activities* condition ($N = 12$) who demonstrated confusion regarding the gestures required in the game, requested assistance from researchers, and received assistance during each of the In-Game Activities is provided in Fig. 3. Across the four activities, between six and ten of the 12 children in the *Kinect with Activities* condition demonstrated confusion relating to the required gestures. In total, children attempted to use incorrect gestures an average of 2.92 times ($SD = 1.62$) over the course of the digital book.

Despite the prevalence of gesture confusion in the in-game activities, children often did not request assistance from the researcher. Children were most likely to request assistance during the first in-game activity (*Together: Pick up*), when 7 of the 12 children asked for help. In the remainder of the activities, very few children (only 2–3 in each case) asked for assistance, even when they demonstrated confusion about the gestures required.

Analysis of the video recordings indicated that researchers often offered brief instructions and/or demonstrations when children either did not attempt any gesture at the start of an in-game activity, or attempted incorrect gestures that were not recognized by the Kinect sensors. Researchers provided assistance to 3–8 children in each in-game activity, and offered help an average of 6.58 times ($SD = 2.78$) in total over the course of the digital book. Researchers provided assistance mainly through verbal instructions ($M = 3.33$ instances, $SD = 1.72$), but also through simultaneous verbal instruction and physical demonstration of the appropriate gesture ($M = 1.58$, $SD = 1.08$). For example, researchers might have told the child, "Move your arm like this" and then demonstrated the required action. In other cases, children were not offered assistance after showing initial gesture confusion because the Kinect sensors recognized an "incorrect" gesture, or because children corrected the gesture through trial-and-error or an instruction from the game itself.

Table 2
Mean (*SD*) on pretest and posttest reading measures by condition.

	Book reading			Kinect without Activities			Kinect with Activities		
	Pretest	Posttest	*p*	Pretest	Posttest	*p*	Pretest	Posttest	*p*
Sight Words	8.00 (2.77)	8.21 (2.29)	.34	6.92 (4.31)	6.92 (4.31)	1.00	7.17 (2.82)	7.83 (2.69)	<.01
Active Decoding Words	4.29 (4.12)	5.36 (4.31)	<.01	5.15 (4.45)	5.46 (4.70)	.43	2.42 (2.94)	4.17 (3.56)	<.01
High Frequency Words	6.50 (2.88)	7.07 (2.98)	.03	6.38 (4.11)	6.38 (4.35)	1.00	5.17 (2.76)	6.17 (3.35)	<.01
Definitions	3.36 (1.08)	3.64 (1.01)	.21	3.50 (1.31)	3.92 (0.90)	.09	3.67 (1.07)	4.00 (0.85)	.18
Total Reading Score	12.29 (6.44)	13.57 (6.42)	<.01	12.08 (8.49)	12.38 (8.78)	.39	9.58 (5.30)	12.00 (5.75)	<.01

Note. *p*-values represent the results of posthoc pairwise comparisons (pretest vs. posttest scores).

Table 3
Character identification and narrative comprehension across conditions (number of children).

		Book Reading	Kinect Without Activities	Kinect With Activities	Total
Lucy	Not recognized	4	3	1	8
	Recognized but not named	8	7	7	22
	Named	2	3	4	9
	Total	14	13	12	39
Squeaker	Not recognized	2	0	0	2
	Recognized but not named	4	2	1	7
	Named	8	11	11	30
	Total	14	13	12	39
Kenzie	Not recognized	–	1	4	5
	Recognized but not named	–	12	8	20
	Named		0	0	0
	Total	–	13	12	25
Narrative	0 details provided	0	3	2	5
	1 detail	2	1	3	6
	2 details	5	2	3	10
	3+ details	7	7	4	18
	Total	14	13	12	39

4. Conclusion and discussion

Overall, the data from the current study are encouraging for the next generation of digital literacy games. All groups started with equivalent literacy skills (as indicated by the Concepts of Print task), and children in the book reading and both Kinect groups showed high interest and engagement during the activities. Also, after reading the story from the book or game, all the groups showed similar levels understanding of the story narrative, indicating that the activities in the Kinect game were not distracting. In fact, the activities seem to have helped the children in this condition acquire reading vocabulary from a digital game: Both the Book Reading and the Kinect with activities group had significant gains in reading vocabulary, while the Kinect without activities group did not. These findings indicate that reading books on a gesture-based digital system can be an interesting, engaging activity for children, and with the addition of well-designed activities, can support children's acquisition of language and literacy.

These findings extend previous work on the importance of specific strategies for supporting children's language and literacy acquisition during joint book reading. Specifically, the current study has implications for dialogic reading approaches such as print referencing (Justice & Ezell, 2004) and asking open-ended questions about the text (Whitehurst et al., 1988). There is considerable evidence that these types of activities support children's language and literacy acquisition during joint book reading with an adult (Arnold & Whitehurst, 1994; Zevenbergen & Whitehurst, 2003). The current study illustrates that these same approaches can support children's language and literacy acquisition with digital media as well.

Although dialogical reading approaches can translate to digital media, this may not often happen with many e-books. For example, a recent study, Parish-Morris, Mahajan, Hirsh-Pasek, Golinkoff, and Collins (2013) found that when parents read to their children with electronic versions of books (i.e., electronic console books), they made few dialogical and story-related utterances and more behavior-related utterance than when reading the same story as a traditional, paper-based book. Furthermore, the authors found younger children (age 3) had less narrative comprehension with the e-books. This may help explain some of the discrepancy in the findings in the literature on whether or not digital books can support children's language and literacy acquisition. If features of a digital book are created simply to capture and maintain children's interest and attention, then they may have a detrimental effect, however, if a digital book is designed to support children's thinking about the narrative and language of a story, then it can have a beneficial effect that is comparable to engaging in dialogical reading with a adult. This is in line with results from research on the design of multimedia learning materials and related cognitive load effects (Plass, Moreno, Brünken, 2010; Plass et al., 2009).

The current study also has more general implications for designing interfaces for young children. Examination of the video data for difficulties experienced by the children when interacting with the digital gesture-based Kinect books indicated that a majority of the children needed some support to figure out the proper way to interact with the system and had some confusion about the proper actions required during the gesture-based Kinect activities. Nonetheless, children were able to successfully engage in book reading and related activities with minimal guidance, and most of the children's questions occurred during the first activity, suggesting that an introduction or tutorial of some sort may be of great benefit to children of this age. Furthermore, once children learn the gestures for interacting with the system, it should easily transfer to subsequent books and activities.

There are some limitations to the current study that should be addressed in future research. First, a majority of the studies in the reading strategies literature suggest that reading gains come primarily from repeated readings of books and multiple exposures to new words: On average, it is suggested that a new storybook be read 3 to 4 times to a child for there to be benefits (Stahl, 1999). In contrast, our study is based on a single experience with a book. The fact that there were learning gains even with a brief single exposure suggests that prolonged and repeated exposure would be even more beneficial. Additionally, the current findings are from a single book, and results should be replicated with other books. Similarly, future research should examine the possible benefits of other types of activities to support educational benefits of reading with digital media. The activities that were built into the literacy game in the current study were drawn from dialogical reading, a joint reading approach that has been shown to be effective particularly with younger children. Other types of activities may also beneficial. Future work should examine the benefits of design features drawn from other bodies of research. For example, more explicit teaching may be necessary for older child or for the acquisition of specific literacy skills (Sénéchal, Lefevre, Thomas, & Daley, 1998). Finally, any effort to promote literacy through joint storybook reading strategies need to be evaluated within the contexts of diverse cultural backgrounds. Although the children in our study were ethnically diverse, we do not know details about the cultural background of the

participants and did not exam culture as a possible mediating factor. Several researchers have identified different shared reading styles among families from different cultural groups (e.g., Anderson-Yockel & Haynes, 1994; Justice & Kaderavek, 2002). Future research should exam the potential effects of a match (or mismatch) of the reading approaches used in e-books or digital literacy games and children's home literacy experiences.

In conclusion, the findings suggest that new digital technologies, such as the Kinect system, are promising media for developing games to support children's literacy and language acquisition. The successful learning from the digital story with gesture-based activities but without caretaker, which resulted in vocabulary learning and story comprehension that was at the same level as in the printed book with caretaker condition, shows great promise for this technology in the context of an informal learning environment like the home. Future research and development will be necessary to take full advantage of this medium, particularly with the younger children for whom literacy games are typically intended. In particular, the embodiment and immersion made possible by technologies such as the Kinect represent exciting opportunities for novel approaches to learning that are worthy of exploration.

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Appendices

Appendix A

Pre-test interview questions

1. Do you have a favorite book?
   - If the child answers 'yes' ⇛ Ask, "Can you tell me about it? Do you know the title of the book?" [If the child gives a title, move on, if not, ask, "Can you tell me what it's about?"
   - If the child answers 'no' ⇛ Ask, "Do you have any book that is read to you a lot?"
   - ○ If the child answers 'yes' ⇛ Ask, "Can you tell me about it? Do you know the title of the book?" [If the child gives a title, move on, if not, ask, "Can you tell me what it's about?"]
2. Does anybody read books to you?
   - If the child answers 'yes' ⇛ Who?
   - If the child answers 'no' ⇛ continue to the next question
3. Do you like books?
4. Does someone read you a book [almost] everyday?
5. Do you like playing games?
6. Do you have a favorite game?
   - If yes, ask "Where do you usually play it?"
7. Do you have any brothers or sisters?
8. Do you play any video games by yourself or with others?
   - If yes, ask "Where do you usually play video games?"
9. Do you play video games with your parents/bother(s) or sister(s), friends?
10. Do you play any Kinect games? Xbox games? Wii games?
11. Do you play any games on a phone or iPad?
12. If relevant, ask, "Do you play games almost everyday?"

Appendix B

Concepts about print test items and correct responses:

Prompt	Correct response(s)
Show me the front of this book (Cover)	Cover
I'll read this story. You help me. Show me where to start reading. Where do I begin to read? (p. 2–3)	Print, text
Show me where to start (p. 4–5)	Top left
Which way do I go? (p. 4–5)	Left to right
Where do I go after that? (p. 4–5)	Return sweep, or moving down page
Point to it while I read (p. 4–5)	Exact matching of words
Where do I start reading? (p. 12–13)	Left page
What's this for? (question mark) (p. 14–15)	"question mark", "a question", "asks something"
What's this for? (period) (p. 16–17)	"full stop", "period", "tells you when you've said enough", "it's the end"
What's this for? (comma) (p. 16–17)	"a little stop", "a rest", "a comma"

Appendix C

Reading vocabulary pre- and post-test items

Item#	Sight words	Active decoding words
1	children[a]	
2		practicing
3	home	
4		**secret**
5	him[a]	
6		squeak[a]
7	the[a]	
8		**together**[a]
9	look	
10		brought
11	just[a]	
12		**scent**
13	morning	
14		**disappeared**
15	into	
16		impossible[a]
17	one[a]	
18		**terrible**[a]
19	where	
20		cutest[a]

Bold = Definition word.
[a] High frequency word.

Examples of correct definitions:
Secret – "can't tell anyone", "keep it to yourself", "whisper it in their ear", "don't want anyone to hear it"
Together – "doing it as a group", "doing something with another person", "opposite of alone", "people are with or next to each other"
Scent – "a kind of smell", "dog smells something"
Disappeared – "vanished", "can't see something", "there, then goes away", "gone"
Terrible – "really really bad", "not something good", "when something happens and it's bad"

Appendix D

Interest/Motivation Questionnaire (mid- and post-story)

How much fun are you having?
How much do you think your friends would like doing this?
How much do you like doing this?
How much do you want to keep going?

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