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Preschoolers' Visual Attention during Electronic Storybook Reading as Related to Different Types of Textual Supports

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Abstract Preschoolers' ($n = 32$) attention to print and pictures was documented during an electronic storybook reading session. Children ($M = 51.06$ months; $SD = 7.34$ months) looked at a 12-page book that contained three types of pages, each of which was presented four times over the course of the book: (1) silent presentation of print, (2) print that was read aloud, and (3) print that was both read aloud and highlighted. Our research objectives were to analyze whether the way in which print was presented related to the ways in which children attended to print and pictures during the reading session. Gaze fixation duration to print and pictures was assessed using a Tobii X2-60 portable eye tracking unit, which captured corneal reflection data for each child. Children's total fixation duration to print was greatest when print was read aloud and highlighted as compared to when it was presented silently or read aloud. In addition, children looked at print more when it was displayed silently than when the computer read the story to children, although this difference was much smaller in magnitude. Children attended to pictures more than print across pages, but this difference was most notable when the story was read aloud. Results demonstrate the potential utility of nonverbal print referencing strategies during book reading.

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Types of Textual Supports

Technology use in classrooms has increased substantially with close to 100% of classrooms in the United States containing tools to support the growth of technical knowledge (Snyder and Dillow 2015). Electronic storybooks (e-books) are one type of technological application ubiquitously used in schools (Moody et al. 2010; Shamir and Korat 2015; Shamir and Shlafer 2011). E-books are digital forms of text that may be similarly formatted as printed text (i.e., without multimedia features) or include enhanced features such as narration, animation, text-highlighting, and interactivity (e.g. embedded activities within e-book pages; Takacs et al. 2015). Generally, e-books are presented without adult interaction and supplemental teacher-led instruction, often viewed as an activity that can free teachers to work with other students (Salmon 2014; Shamir and Korat 2015). Some describe this practice as "edutainment", placing greater value on a fun, engaging experience than educational benefit (Parette et al. 2015). However, the International Reading Association (2009) states that literacy teachers have a responsibility to infuse technology into curriculum. Further, the National Association for the Education of Young Children (2012) specifies that technology integration, including the use of e-books, should be tied to educational goals and objectives. Relatively little is known about how best to use e-books in a manner that supports the early literacy learning of young children, which is a problem that must be addressed with research that evaluates how children respond to the various features of e-books.

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Print Knowledge

Acquiring print knowledge is an important milestone for children to achieve before they enter into kindergarten (Hammill 2004; National Early Literacy Panel 2008). Print knowledge encompasses a number of competencies related to children's developing skills surrounding the form and purpose of written language (Breit-Smith et al. 2009). Key skills associated with print knowledge include letter knowledge, concept of word (i.e., letters can be combined to form words and spoken words can be represented by words in print), and the understanding that print is read from left to right, often called text directionality (Justice and Ezell 2004). Caregivers have been encouraged to explicitly teach these skills to children during early childhood in an effort to prepare them for success in kindergarten (Justice and Ezell 2001, 2002). Intervention efforts have shown that increasing children's interactions with print during preschool boosts their reading-related skills in kindergarten and first grade, including in areas related to comprehension, reading, and spelling (Piasta et al. 2012). This is particularly important given that young children who are at-risk for later reading difficulties, such as children from low-income homes and those who have language impairment, are more likely to show lower print concept knowledge (Justice et al. 2006).

Book reading is a useful context whereby children can learn about the functions and use of print. It is the most common activity that parents use at home to teach their children early literacy skills and participation in book reading activities has been related to children's early literacy development (Bingham 2007). This familiar activity is highly structured and has the potential to provide an optimal context through which to focus on print concept knowledge. However, without supports, children are not likely to pay much attention to print independently during book reading (Evans and Saint-Aubin 2005, 2013; Evans et al. 2009; Justice et al. 2005). For example, using eye gaze analyses, Justice et al. (2008) found that 4-year-old children only attend to print about 5–6% of the time independently, leading these researchers to advocate that caregivers spend more time explicitly teaching children about print.

Children's attention to print can be increased with the intentional use of print referencing techniques, which include both the nonverbal and verbal prompts that adults use to help direct children's attention to print on a page (Breit-Smith et al. 2009; Evans et al. 2008). Nonverbal print referencing strategies direct children's visual attention to print by pointing to instances of narrative print or the print embedded within illustrations. It also can include tracking print as it is read to children. Verbal prompts include things that caregivers say which draw children's attention to print (e.g., That word says dog.). These strategies have been shown to help children with a variety of backgrounds and abilities gain in their print-related knowledge (Justice and Ezell 2001; Justice et al. 2011; Lovelace and Stewart 2007).

Electronic Storybooks

Frequent engagement with high-quality e-book materials has been linked to language and literacy gains for young children (Korat et al. 2014), including gains in print-related knowledge (Moody et al. 2014). It has even been argued that, when used with appropriate adult support, e-books can be more effective for promoting early literacy than printed texts (Korat et al. 2009). Unfortunately, it can be difficult to know whether adult support is provided to children who access e-books, thereby creating questions about whether all children who interact with e-books obtain the potential educational value of doing so.

Visual Supports with Electronic Storybooks

Many popular e-book programs (e.g., *One More Story; Learning A-Z*) incorporate features designed to help children attend to print, including both auditory and visual supports. Reading the book aloud to the child is one common auditory support provided, although listening to a storybook being read is not always sufficient to improve children's print knowledge in the absence of other types of supports (Gong and Levy 2009; Korat and Shamir 2008). Visual supports, such as highlighting print, can be paired with auditory supports (i.e., reading the book to the child) and combining these features has been recommended as a means by which to maximize the effectiveness of e-books (Korat et al. 2014; Zucker et al. 2009). For example, using a bouncing ball to direct children's attention to words as they were read aloud over the course of 4 weeks improved 4-year olds' letter knowledge when measured 6 months later, perhaps by helping children to connect letters with their sounds (Gong and Levy 2009). Training children in letter-sound correspondence can amplify the effects of other types of literacy instruction needed for reading (Castles et al. 2011), suggesting that helping children to focus their attention on words and their sounds can facilitate children's literacy learning.

Although attending to print is important for children as they learn to read, the use of pictures in storybooks also serves a critical purpose in contributing to children's comprehension of text and vocabulary acquisition (Carney and Levin 2002; Evans and Saint-Aubin 2013; Smeets and Bus 2015). Effective use of pictures in storybooks helps to clarify, illustrate, and extend understanding of text (Carney and Levin 2002). Evans and Saint-Aubin (2013) explored whether receptive vocabulary positively correlated with attention to pictures in preschool children aged 4-to-5-years-old. Results of eye-gaze analysis indicated that the children who spent the most time visually attending to the

illustrations achieved higher posttest scores on the corresponding vocabulary assessments. Therefore, attempts to increase attention to text should not preclude attending to pictures among young children as listening comprehension and story recall can be enhanced among emergent readers who do attend to pictures (Carney and Levin 2002).

Research Questions

The need for carefully designed e-books to support emergent literacy of young children is an important though minimally investigated area of computer-based instruction. Children's attention to print and pictures during e-book interactions are likely to vary based on features built into the technology and empirically derived information about how this occurs could improve the development and use of e-books in schools. The current study therefore examined how textual features associated with book reading relate to the ways in which children attended to print and pictures during an e-book reading session.

(1) Do changes in the way that print is presented (i.e., silent presentation of print, print that was read aloud only, and print that was both read aloud and highlighted) relate to the way in which children attend to print during one electronic storybook reading session?

(2) Do changes in the way that print is presented (i.e., silent presentation of print, print that was read aloud only, and print that was both read aloud and highlighted) relate to the way in which children attend to pictures during one electronic storybook reading session?

Methods

Participants

Children ($n = 32$) from two preschools in the Midwest United States were recruited to participate in the current study. Both preschools were associated with a university and had received National Association for the Education of Young Children accreditation, indicating that they were high-quality educational settings. Nine of the children were male and children ranged in age from 37 to 63 months (M_{age} = 51.06 months; SD = 7.34 months). Parents reported that 24 of the children were Caucasian, 3 were Asian, 1 was African American, and 4 were multiracial. English was the only language spoken in most homes ($n = 27$); other languages spoken in the home included Spanish, Mandarin, Korean, and German. Mothers varied with regard to their educational attainment, although most were well educated; 23 had at least a bachelor's degree,

3 had a 2-year degree, 3 had some college, 1 had a high school diploma, and 2 had some high school. Parents reported all children to be developing typically and no children were reading independently.

Stimuli

The storybook "I'd Like to Be" (Page 2014) was presented to children electronically. This 12-page book had between 10 and 12 words on each page and was used as part of the Learning A–Z library as a Level E book. Learning A–Z is a series widely used within school systems across the United States and has received numerous awards for the quality of its products (Learning A–Z, 2015). Level E books are generally considered to be appropriate for reading instruction in the beginning of first grade and, as such, it is unlikely that children in the present study were able to decode this print independently, although the print was still relatively simple to comprehend. This book was chosen for several reasons. There were minimal distractors (e.g., no hot spots or animations) included as part of the book, as these are often considered to be detrimental to e-book reading sessions (Lefever-Davis and Pearman 2005). Rather, each page had one photograph of a person located in the center of a white page. Print was highly salient and placed in a conventional format on the page. On every page, print was situated directly under the photograph; the text on each page started with the phrase "I'd like to be...," which enhanced the ability to compare children's gaze patterns across pages. Across pages, white space accounted for the most space on each page ($M = 73.21\%$, $SD = 3.36\%$), followed by the picture ($M = 20.03\%$, $SD = 3.55\%$). Print took up the least amount of space per page ($M = 6.76\%$, $SD = 0.62\%$); to understand the size of each letter, note that the letter 'a' was 616 pixels and was representative of the other letters displayed. In order to examine where children were attending during the storybook session, each page included two areas of interest (AOIs), one capturing the print and the other capturing the picture. We used the total time children spent looking at the AOIs (i.e., total fixation duration) to indicate the amount of attention resources that were allocated to the related spatial area, as has been done in prior research (Peterson et al. 2004).

Three types of pages were developed for use in the current study: silent presentation of print, print read aloud to children, and print both read aloud and highlighted. For the highlighted pages, individual words were highlighted in yellow as the print was read to children, similar to the way in which an adult may point to words as they are read aloud during book reading. These three types of pages reflect the reading scenarios that children are most likely to encounter within their homes and classrooms.

Procedure

The e-book was presented to each child individually in a quiet room. An examiner sat next to the child during the testing session, but did not interact with the child, except if the child asked the examiner a question (e.g., Is that a real mermaid?). In those instances, the examiner would tell the child "Let's talk about that after the story is finished." Within each three-page block, each of the three pages was presented once; thus, over the course of the book, every child was exposed to each type of page four times. The order of pages presented was counterbalanced across a total of four blocks. Specifically, children were shown pages in the following order: (1) read aloud, (2) highlighted and read aloud, (3) silent, (4) highlighted and read aloud, (5) silent, (6) read aloud, (7) read aloud, (8) silent, (9) highlighted and read aloud, (10) read aloud, (11) highlighted and read aloud, and (12) silent. After showing children the title page, which was not included in any analyses, each page within the storybook was presented for 8 s, similar to methods used to capture multimedia learning in previous work (Mayer and Johnson 2008), resulting in a total presentation time of 96 s. Children were not given a break during any point in the book reading session and were presented the book immediately after their eye gaze was calibrated. The entire session typically lasted about 10 min.

Apparatus

A Tobii X2-60 portable eye tracking unit was used to assess gaze fixation duration to the print and pictures presented on each page using corneal reflection data. The laptop contained a i7-4940MX CPU @ 3.10 GHz processor, included 8.0 GB of RAM, and a 64-bit operating system. The book was displayed on a 17.3 inch screen. Before children were presented with the storybook, an infrared light on the eye tracker system was used to ensure that the eye tracker was properly calibrated. As part of this procedure, children were asked to focus on items on the screen, known as calibration dots, during which time several images of the eyes were recorded. These images allowed the Tobii system to determine where children were directing their attention when presented with materials. Gaze data were collected for each child at 60 Hz, which indicates that 60 data points were recorded for each eye every second. The percent of time that the Tobii was able to capture children's eye movements varied across children, as some children looked away at some point during the session (e.g., to point out something of interest to the examiner) or exhibited vigorous movement (e.g., bouncing up and down) that momentarily disrupted calibration. Nevertheless, the percentage of time that the Tobii system was able to capture corneal reflection data during each session, on average, was 81.16% of the time across

children ($range = 47$–98%; $SD = 13.75$%). Thus, although the Tobii measured where children were looking the majority of the time, the seconds presented below may be an underestimation of the amount of time children attended to the electronic storybook, as some of their gaze patterns may not have been captured (i.e., there were some missing data).

Tobii Studio Professional Software was used to analyze results using fixation data, as this allowed us to understand how children processed and attended to the information presented to them. Fixations were recorded using both temporal (75 ms) and spatial (35 pixels) filters. The default minimum fixation duration was set to 60 ms, which is considered to be a conservative value that allowed the program to capture complicated occulomotor behaviors. The total time spent looking at the page, recorded as fixation duration, was documented as well as the time spent looking at print and pictures. The title page was excluded because its format was different from the other pages included in the book. For each type of page, a sum was created to represent time spent looking at print when it was presented silently, read aloud, and highlighted while read. Each child had the opportunity to look at print or pictures for 32 s during each type of page. In addition, the total amount of time spent looking at print and pictures (i.e., total fixation duration) was summed across pages.

Results

Overall, out of the 96 s that children sat in front of the storybook, children attended to the computer screen for an average of 59.71 s ($range = 16.50$ to 85.66 s; $SD = 20.68$ s). Of the time spent looking at the e-book, 46.94 s were spent on pictures ($SD = 20.81$ s) and 9.24 s were spent focused on the print within the books ($SD = 8.77$ s). The remaining time was spent looking at other areas on the page or transitioning from the print to the picture or vice versa. Children's age in months was not significantly related to the amount of time spent attending to the book overall ($r = .11$, $p = .59$). Also, children who looked at print more overall were not more likely to attend to pictures longer ($r = -.11$, $p = .57$).

Total fixation duration was summed across the book to evaluate how long children attended to print and pictures for each type of page (i.e., silent, read aloud, or highlighted and read aloud). See Table 1 and Fig. 1 for descriptive information about children's attention to each type of page. A repeated measures ANOVA was conducted to examine whether total fixation duration to print differed with regard to the type of page presented. Results indicated that attention to print did significantly differ by page type ($F (2, 31) = 19.57$, $MSE = 5.90$, $p < .001$) and that these differences were large in size ($< eta > 2 = 0.39$). To understand these group differences more fully, three paired-samples t tests were

Table 1 Seconds children spent attending to print and pictures during the storybook reading session

	Range	Mean (SD)
Total time spent looking at the storybook	16.50–85.66	59.71 (20.68)
Fixation duration to pictures		
Silent presentation of text	0.00–27.00	14.22(6.70)
Text read aloud only	1.00–27.00	18.03 (7.50)
Text read aloud and highlighted	1.00–27.00	14.90 (7.54)
Total	2.02–80.01	46.94 (20.81)
Fixation duration to print		
Silent presentation of text	0.00–9.39	2.44 (2.62)
Text read aloud only	0.00–6.42	1.54 (2.01)
Text read aloud and highlighted	0.00–18.81	5.19 (5.11)
Total	0.12–28.46	9.24 (8.77)

conducted. Children attended more to print on pages where it was presented silently ($M = 2.44$ s; $SD = 2.62$ s) than when it was read aloud ($M = 1.54$ s; $SD = 2.01$ s), $t(31) = 2.75$, $p = .01$, consistent with a medium effect size ($d = 0.49$). In addition, children attended more to print that was both read and highlighted ($M = 5.19$ s; $SD = 5.11$ s) than print that was presented silently ($t(31) = 3.79$, $p = .001$, $d = 0.67$) or read aloud only ($t(31) = 5.29$, $p < .001$, $d = 0.94$). These findings are consistent with effect sizes that are medium and large in size, respectively.

A second repeated measures ANOVA was conducted to consider whether total fixation duration also differed in terms of how children attended to pictures. Data demonstrated that attention to picture also differed significantly by page type

($F(2, 31) = 21.24$, $MSE = 6.22$, $p < .001$), with a large effect size ($< \text{eta} > 2 = 0.41$). To investigate these differences further, three paired-samples t tests were computed. Children looked least at pictures presented silently ($M = 14.22$ s; $SD = 6.70$ s), although this was not significantly different from the amount of time children spent looking at pictures when print was both read and highlighted ($M = 14.90$ s; $SD = 7.54$ s, $t(31) = 1.18$, $p = .25$, $d = 0.20$). However, children looked at pictures significantly more when print was read aloud to them ($M = 18.03$ s; $SD = 7.50$ s) than when print was presented silently ($t(31) = 6.23$, $p < .001$, $d = 1.11$) or read aloud and highlighted ($t(31) = 4.64$, $p < .001$, $d = 0.82$). These differences were consistent with a large effect size.

Discussion

The main research objectives for the present study were to provide evidence for how preschoolers respond to auditory and visual supports when engaging with print and pictures during an e-book reading session. Such considerations are important, as early print knowledge provides a critical foundation for children as they learn to read (Hamill 2004; National Early Literacy Panel 2008) and pictures are often used to ascribe meaning to a story (Evans and Saint-Aubin 2013; Smeets and Bus 2015). The ways in which print was presented were related to the amount of time children spent focused on print, as children spent almost twice as much time attending to print that was read aloud and highlighted as compared to when it was presented silently or read aloud only. In addition, children attended to print more when it

Fig. 1 Total fixation duration to print and pictures for each of the three conditions are depicted here. Standard errors are represented by the *error bars* attached to each column in the figure
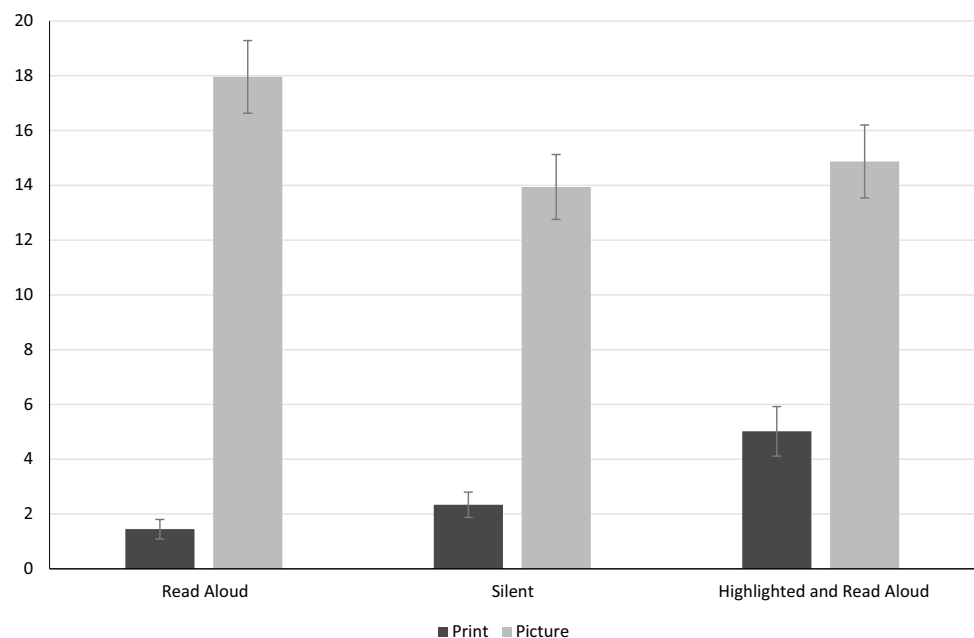
was presented silently than when the computer read the story aloud to children. It should be noted that children's attention to pictures also varied with regard to the types of support provided, as children attended most to pictures when the print was read aloud. Findings are discussed at greater length below.

The nonverbal print referencing technique used in the present investigation (i.e., text highlighting) was an effective means to encourage children to attend to print during an e-book reading session. These results align with previous intervention studies showing that, when teachers directed children's attention to print, children attended to print more frequently (Piasta et al. 2012). The current work extends these previous findings by suggesting that children's attention to print can be increased during e-book interactions without direct adult intervention. This is important because e-books are often provided to children for their independent use (Salmon 2014; Shamir and Korat 2015), and a caregiver may not be routinely available to help children to engage in book reading interactions. Although e-book interactions are not likely to replace the communicative and social learning opportunities that occur during book reading with a caregiver (Moody et al. 2010), the present study suggests that e-books that include explicit interactive design features, such as highlighting text as it is read aloud, may be used to augment children's interactions with print.

Previous work has suggested that children actively try to connect auditory stimuli, such as listening to a story, with pictures that are presented to them, perhaps facilitating children's acquisition of new vocabulary words (Evans and Saint-Aubin 2013). This may help to explain why, in the present study and others (Evans and Saint-Aubin 2005; Evans et al. 2008), children attended more to pictures than print across every type of support provided. Further evidence for the possible utility of pictures during book reading sessions comes from research demonstrating that children who actively labeled and pointed to pictures learned more words from book reading sessions than children who listened to a story passively (Sénéchal et al. 1995). Data from the present work showed that children attended to pictures more when print was read to them than when it was presented silently or highlighted as it was read. Thus, auditory supports, when presented without co-occurring visual prompts, may encourage children to focus more closely on the pictures rather than print, perhaps to help children create meaning from the story more effectively.

The differential effects of the two support conditions, read aloud only and read aloud with highlighting, offer potential guidance for educators. Specifically, it may not be the case that one type of e-book is going to be universally better than another, but instead that different features lead to different outcomes. As such, educators might actively plan to incorporate a range of e-books within their curricula in order to offer read-aloud experiences that may increase attending to pictures and benefit vocabulary development, as well as e-books with features that draw attention to text, in order to teach print knowledge to pre-readers. Note that presenting a book silently did not appear to advantage children's attention to print or pictures, suggesting that children do benefit from some supports when interacting with e-books. In addition, there may be value to presenting the same e-book multiple times with different features so that children may benefit from the varied impact of the full range of features, as children often participate in reading activities more actively if they are familiar with the book (McDonnell et al. 2003; Skibbe et al. 2010).

Particularly for children who might not have many interactions with books or print within their homes, e-books could be used as an effective tool to help children interact with print more regularly within a school setting, an activity which has predicted higher literacy scores in other work (Piasta et al. 2012). However, there was a lot of variability in the amount of time that children looked at print in the present study. Thus, even the embedded supports that can be provided during e-book reading sessions may not be sufficient for all children to utilize materials in the ways intended by educators and other professionals. Given the increased scholastic attention to electronic literacy materials (Moody et al. 2010; Shamir and Korat 2015; Shamir and Shlafer 2011), educators should monitor reading sessions closely and confirm that children who are provided with these materials are able to access them independently. Although individual reading sessions are often short, they are one of the most common literacy activities observed in preschool classrooms (Skibbe et al. 2013). Thus, providing high quality supports to children during e-book reading sessions, as well as evaluating whether children are attending to these supports, is critical for fostering early literacy achievement.

Limitations

The book chosen to examine children's attention to print incorporated many features associated with higher quality, including salient print and few distracters (e.g., hot spots, see Zucker et al. 2009, for an evaluation of features associated with e-books). Previous work has indicated that children exposed to books which include these features attend to print more frequently than when shown books with less salient print (Justice et al. 2005). As with printed books, e-books vary quite a bit in terms of quality (Schugar et al. 2013), so it is unclear whether results would replicate using books without these features. In addition, the overall time spent attending to print remained relatively low, even when print was both read aloud and highlighted. It is unclear whether the time spent attending to print independently would increase

over time with subsequent exposure to the various conditions or lend itself to gains in literacy achievement, an avenue of inquiry that should be investigated as part of future work in this area. Also, an adult was present during testing sessions and, although she did not actively work to engage children in the activity or focus their attention on print, it is possible that the mere presence of the examiner encouraged children to attend to the activity more than if they had completed the activity by themselves. Finally, the sample size was relatively small and all children in this study attended a high quality preschool, so future research should be conducted to examine the generalizability of results.

Conclusion

Understanding how e-book features relate to children's attention to print and pictures has important implications for the way in which e-book reading sessions are structured. Results from the present work suggest that highlighting print as it is read aloud serves as an important nonverbal print referencing technique that is associated with increased attention to print relative to simply reading the print aloud or presenting it silently. Given that an understanding of the function and use of print is a core aspect of learning to read (National Association for the Education of Young Children 2008), this may be a promising strategy to use when selecting and developing e-books for reading sessions for children. In addition, it appears that children look at pictures most when print is read aloud to them, perhaps helping children to assign meaning to what they hear. These findings suggest that teachers should use the features associated with e-books strategically to help children to focus on specific educational goals.

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