Effects of Illustration Details on Attention and Comprehension in Beginning Readers

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Abstract

Reading is a critical skill as it provides a gateway for other learning within and outside of school. Many children struggle to acquire this fundamental skill. Suboptimal design of books for beginning readers may be one factor that contributes to the difficulties children experience. Specifically, extraneous details in illustrations (i.e., interesting but irrelevant to the story elements) could promote attentional competition and hamper emerging literacy skills. We used eye-tracking technology to examine this possibility. The results of this study indicated that excluding extraneous details from illustrations in a book for beginning readers reduced attentional competition (indexed by gaze shifts away from text) and improved children's reading comprehension. This study suggests that design of reading materials for children learning to read can be optimized to promote literacy development in children.

Keywords: attention; reading; reading comprehension; illustrations; eye tracking; book design

Introduction

Learning to read is a critical skill because reading provides a gateway for other learning within and outside of school. However, one-third of U.S. elementary students are not reading at grade level, and many children struggle to acquire the fundamental skill of learning to read (Perie, Grigg, & Donahue, 2005). Many different factors contribute to children's difficulty in learning to read, including (but not limited) to neurodevelopmental disorders, lagging pre-reading skills (e.g., phonological awareness), and vulnerabilities in general cognitive functioning (e.g., Dykman, & Ackerman, 1991; Jacobson et al., 2011; Melby-Lervåg, Lyster, Hulme, 2012). The current research focuses on one other potential factor that has received relatively little attention in the literature, namely the design of reading materials for beginning readers. One way in which the design of reading materials for beginning readers can be suboptimal for the development of literacy skills is the inclusion of entertaining but unnecessary illustrations. Extraneous details—also known as seductive details—are irrelevant additions to educational materials, and are often included to increase motivation and foster situational interest (Harp & Mayer, 1998). Entertaining visuals in children's educational materials have enormous potential to engage children—but if they are unrelated to the story text—these additional visuals might be counterproductive if they distract children from the primary task (i.e., comprehending the story text). Attention regulation skills are still developing during the time when children begin formal schooling (Fisher & Kloos, 2016), therefore it is important to evaluate the possibility that enhancements to the educational materials intended to motivate children might do so at the cost of reducing learning and performance (cf. Kaminski & Sloutsky, 2012; Parish-Morris, Mahajan, Hirsh-Pasek, Golinkoff, & Collins, 2013; Petersen & McNeil 2013; Tare, Chiong, Ganea, & DeLoache, 2010). There is a substantial body of research on the role of extraneous details in educational materials for adult learners. For instance, Cognitive Load Theory suggests that unnecessary extraneous material may increase cognitive load on learners by reducing the amount of cognitive resources available for learning, and have been found to decrease learning performance (McCrudden & Corkill, 2010; Torcasio, & Sweller, 2010). In contrast to the large body of research on the design of educational materials for adult learners *reading to learn*, few studies have examined this issue in children *learning to read*. Conceivably, the detrimental effect of extraneous details on emerging literacy skills may be more pronounced in beginning readers in whom reading has not yet become an automatized skill. It is important to understand how the design of reading materials may affect children's emerging literacy skills because this factor is substantially more malleable than factors intrinsic to

the child, and thus can be leveraged to improve learning outcomes.

The intermixing of extraneous details with relevant illustrations and text (which is common in reading materials designed for beginning readers, see Figure 1-a below) may create a split-attention effect: the learner's visual attention is split between viewing the various illustrations and reading the text (Kalyuga, Chandler, & Sweller, 1999). Only a subset of the information being received concurrently can be selected for further processing in visual working memory. The constraints on processing capacity force children to make decisions about which pieces of incoming information to pay attention to and the degree to which they should build connections among the selected pieces of information (Mayer, 2002). Thus, beginning readers may find it difficult to build a strong understanding of the story if while reading children are less likely to attend to the text and relevant illustrations and instead focus their attention on extraneous details. Consistent with this possibility, there is evidence that children's attentional control is a significant predictor of reading comprehension (Conners, 2009; Wittrock, 1989). Multiple stimuli present in the visual field compete for processing, and dividing attention between more information almost always results in poorer performance than focusing attention on less information (Desimone & Duncan, 1995). When text, relevant illustrations, *and* extraneous visual details are presented on the same page, the stimulus-competition is high. The inclusion of numerous extraneous details may therefore induce attentional competition and hinder learning.

Eye-tracking technology utilizes eye movement measures to investigate the relation of eye movements and cognitive processes (Zagermann, Pfeil, & Reiterer, 2016). Researchers have employed eye-tracking to explore cognitive and information processing with respect to different components of educational material to reveal how students spend their cognitive resources while learning from text and illustrations (Van Gog & Scheiter, 2010). Incorporating physiological measures such as eye-tracking into assessments while reading may identify subtle changes that precede or underlie changes in attention while reading. In this study, we focused on average eye gaze shifts away from the text, to measure children's ability to read accurately without getting distracted.

We examined whether the removal of extraneous details in an educational book designed for beginning readers would reduce gaze shifts away from text and thereby increase reading comprehension.

Method

Participants

The sample consisted of thirty 2nd-grade students (M_{age}=7.93 years, SD = 0.52 years, 12 females, 11 males, and 7 children whose sex was not reported). Participants were recruited from schools in and around Pittsburgh, PA. Signed consent was obtained from the parents of participants. Children were tested individually by hypothesis-blind trained research assistants and given a small prize for their participation.

Design and Procedure

The Storybook To maintain a high level of ecological validity, children read a commercially available book designed for beginning readers from the *Hooked on Phonics Learn to Read* series entitled *Good Job Dennis* written by Amy Kraft. Children read the story aloud. The type of book layout was manipulated within-subjects: Half of the book was presented to children in a commercially available "Standard" layout condition, and in the other half of the book the extraneous details in illustrations were removed ("Streamlined" layout condition). The order of the layout conditions (Standard first vs. Streamlined first) was counterbalanced across participants. Children were randomly assigned to read either Version 1, in which the first half of the book was presented in the Standard layout and the second half of the book was presented in the Streamlined layout; or Version 2, in which the presentation order was reversed. There were a total of 12 pages in the book (with six pages per condition). The average number of words per page in the first half of the book was 43.0; the average number of words per page in the second half of the book was 42.3. The book was presented on a laptop computer. Reading was self-paced; participants advanced to the next screen by pressing a button on the keyboard. After reading the story, children's reading comprehension was assessed (see the details below). Each testing session was videotaped with a Logitech C920 HD Pro Webcam.

The Classification of Extraneous Details A calibration study with undergraduate fluent readers (n = 15) was conducted to determine which illustrations were extraneous. Participants were presented with a copy of the Standard layout of *Good Job Dennis* and instructed to outline in red marker the details in illustrations they believed were relevant to the story content. The details that participants reached over 90% agreement on were included in the Streamlined layout condition (see Figure 1 a-b below).

Figure 1-a: Sample page of the Standard layout condition

Figure 1-b: Sample page of the Streamlined layout condition

Measure of Attention

Gaze Shifts Eye gaze is a common measure of attention in a variety of settings and is a particularly appropriate measure in the context of reading (Rayner, Ardoin, & Binder, 2013). SMI RED250 mobile eye tracker (SensoMotoric Instruments, Inc.) was used to measure children's eye movements while reading. On each page of the book, text, illustration, and white space Areas Of Interest (AOI's) were created. SMI BeGaze Eyetracking Analysis Software was then used to calculate gaze shifts away from the text AOI's and the average number of gaze shifts per page was then calculated.

Reading Comprehension Measure

Story Questions To preserve ecological validity, children were asked the six open-ended comprehension questions provided by the book manufacturer that probed their memory for story details. Recordings were used to archive the data in case it was necessary to validate the recorded responses of a participant. There were three questions for each half of the book (two 2-point questions, and one 3-point question) for a total of 14 points. Questions were linked to content presented on specific pages, making it possible to clearly distinguish events from the first or second half of the book. For example, in the first half of the book the job of the main character, Dennis, is described; these story details are not part of the content in the second half of the book. For the 2-point story question, children were asked, "What is Dennis' job?" Children received full credit if they identified that Dennis directs traffic and helps children cross the street, 1 point for a partial answer (e.g., *he helps children*), and 0 points if they failed to recall Dennis' job or provided an incorrect response. In the second half of the book, various animals escape from a pet shop including cats, dogs, birds, rabbits, and frogs; these story details are not part of the content in the first half of the book. For the 3-point question, children were asked, "What animals get out of the pet shop?" Children received full credit if they correctly identified all of the animals that escaped, 2 points if they identified at least 3 animals, 1 point if they identified only 2 animals, and 0 points if they failed to recall the animals that escaped or provided an incorrect response. Story comprehension was measured as the percentage of correct responses (out of 7 possible points). The story questions were scored twice by hypothesis-blind research assistants who were blind to the story version assignment. Inter-rater reliability using Cohen's kappa (Cohen, 1960) was .86, indicating substantial coder consistency.

Verbal Fluency Measure The Word Recognition in Isolation Test (WRI; Morris, 2013) was administered to children prior to reading the story. The WRI measures the ability to recognize and decode words on lists that are graded in difficulty. Scores were calculated as the number of words read accurately in 90 seconds out of 100 total possible words. The WRI is a valid predictor of contextual and oral reading levels (Frye & Gosky, 2012; Morris et al., 2011). The experimenter also recorded the child's decoding accuracy for each word in the story (Running Record; Clay, 1972) and the percentage of correct responses was then calculated.

Results

There were no significant differences in total time reading in the Standard layout condition (M = 127.20 s; SD = 39.55 s) compared to the Streamlined layout condition (M = 124.51 s; SD = 35.32 s), paired-sample $t(26) = .121$, $p = .91$.

Reading Comprehension Children's comprehension scores were significantly higher in the Streamlined layout condition (M = 79.89%) than in the Standard layout condition (M = 47.09%), paired-sample $t(29) = 6.91$, $p < .001$ (see Figure 2); this effect was large, Cohen's $d = 1.80$. Independent samples t-tests were used and there were no order effects (all ts < 1.05, all ps > .49). There were also no significant differences in participants' Running Record while reading in the Standard layout (M = 96.60%; SD = 1.91%) compared to the Streamlined layout (M = 96.68%; SD = 3.39%), paired-sample $t(29) = .121$, $p = .91$. The results indicate that reading from the streamlined layout resulted in higher comprehension compared to reading from the Standard layout, regardless of the quantity of words a child accurately read aloud and the order in which the layout was presented.

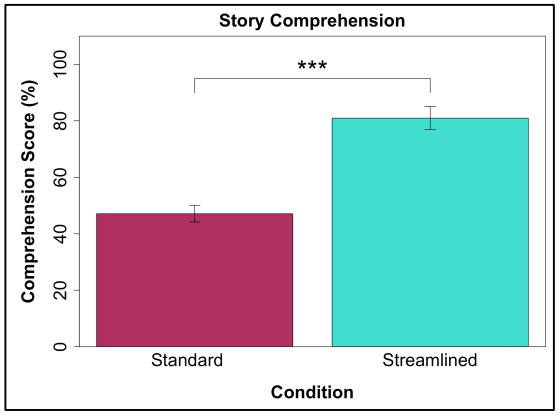

Figure 2: Percentage of correct answers on the story questions as a function of book layout. ***$p < .001$).

Gaze Shifts Data from 3 children were not included in the analyses due to tracking ratios <50%. On average, children switched their point of fixation away from the text 7.43 times per page (SD = 2.39) in the Standard condition compared to 3.53 times in the Streamlined condition (SD = 1.20), paired-sample $t(23) = 6.44$, $p = <.001$. This effect was large, Cohen's $d = 2.06$. Children looked away from the text almost twice as much in the Standard layout condition than they did in the Streamlined layout condition (See Figure 3).

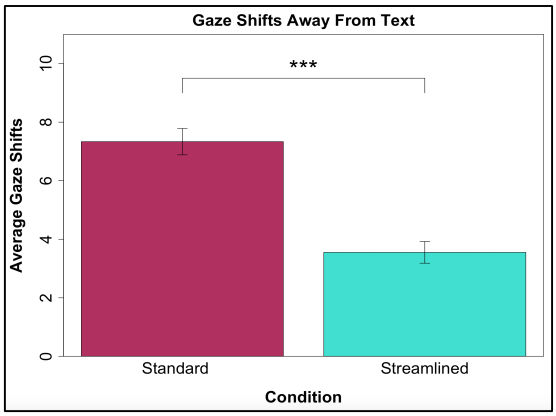

Figure 3**:** Average gaze shifts away from the text per page as a function of book layout. ***$p < .001$).

The Role of Individual Differences Next we examined whether the Streamlined condition might be especially beneficial for children who often shift their attention away from the text. A difference score for each child was calculated by subtracting the Standard comprehension score from the Streamlined comprehension score to create the variable: *Comprehension Gains*. Difference scores ranged from 14.29% to 71.43%, with a mean of 40.21% (SD =18.17%). A score of 0 indicates a participant had the same score on the comprehension assessment in each condition. Children's gaze shifts in the Standard layout condition were positively associated with Comprehension Gain scores (r = .65, p <.001), as shown in Figure 4. Thus, the Streamlined layout was especially helpful for children who frequently shifted their gaze while reading: the more children looked away from the text, the more their comprehension benefited from reading the book in the condition in which extraneous details were removed.

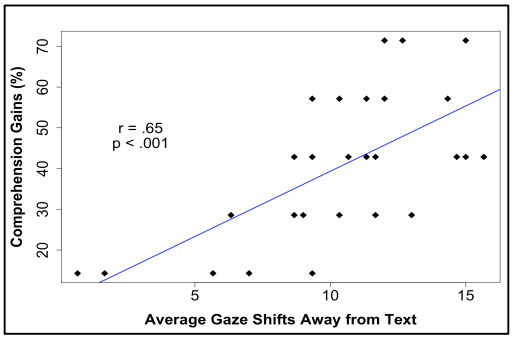

Figure 4**:** Association between gaze shifts and comprehension gains.

Unique Contribution of Gaze Shifts to Comprehension Gains To ensure that the findings were not entirely due to variance shared with verbal ability, children completed the WRI test prior to the reading session to assess participants' verbal ability (M = 77.81, SD = 14.31). Table 1 presents a summary of a multiple linear regression predicting Comprehension Gains scores with the predictors: Gaze Shifts, Age, WRI Scores, and Running Record scores. The coefficients present estimates of the unique effect of each variable on the outcome adjusted for all other terms in the model. Results indicated that gaze shifts away from the text make a significant contribution to Comprehension Gains.

Table 1: Relation of Gaze Shifts to Comprehension Gains

	β	*SE*	t
Eye Gaze Shifts	3.37***	0.86	3.93
WRI Score	0.18	0.25	0.72
Age	4.11	5.85	0.70
Running Record	-1.82	1.41	-1.29
R^2	0.50		
F	5.51		

*** $p < 0.001$

The present results suggest that gaze shifts away from the text while reading are positively associated with comprehension gains, and also account for unique variance in comprehension gains independent of both measures of overall reading fluency and age.

A question that remains is whether these findings generalize to children in different grade levels. We are currently replicating this experiment with first graders (n = 15). Preliminary analyses reveal similar results from the sample of second graders: children's comprehension scores were significantly higher in the Streamlined layout condition (M = 85.75%; SD = 15.82) than in the Standard layout condition (M = 55.09%; SD = 14.57), paired-sample $t(14) = 7.81$, $p < .001$.

Discussion

The results of this study provide the first systematic analysis of whether excluding extraneous details from reading materials for beginning readers could improve story comprehension. We found significant differences in comprehension, with nearly all children exhibiting higher comprehension scores when reading in the Streamlined layout condition compared to the Standard layout condition. Similar to the effects on learning with adults and other educational materials such as textbooks and lectures (e.g., Rowland et al., 2008; Sanchez & Wiley, 2006), when extraneous details were removed, children showed better understanding of the story.

We hypothesized that children who frequently shift their gaze while reading (i.e., less developed attentional control) would have greater gains in comprehension reading in the Streamlined layout condition compared to children who do not frequently look away from the text while reading (i.e., children with more developed attentional control). Our findings supported this hypothesis: the Streamlined layout was especially useful for children who were more easily distracted and who frequently shifted their gaze away from the text. Importantly, the associations between eye gaze shifts away from the text and comprehension gains were not entirely due to variance shared with overall reading fluency (a potential indicator of reading proficiency).

Frequent switching between two different tasks—reading the text to understand the story on one hand and exploring engaging illustrations on the other hand—might place too much extraneous load on young children's working memory resulting in decreased story comprehension (Mayer & Moreno, 2003). Because illustrations matched the story text in the Streamlined layout condition, children did not have to visually explore and encode the details of the illustrations that were not relevant to the text; instead, in the Streamlined layout condition the visuals helped children integrate nonverbal information and language to develop a better representation of the story.

The inclusion of only story-related illustrations may be beneficial to children who frequently look away from the text because these children's ability to selectively attend to relevant information while suppressing irrelevant, extraneous information is less efficient. Researchers have found that children's attentional control and ability to focus are significant predictors of reading achievement not only when they enter formal schooling, but continue to predict reading achievement until several years later in development (Guo, Connor, Tompkins, & Morrison, 2011; McClelland, Acock, & Morrison, 2006). Attentional control—a foundational component linked to school readiness and reading achievement—should be taken into account when designing educational materials not only for fluent readers who are reading to learn, but also for beginning readers who are learning to read.

One limitation of this study is that it remains unclear whether children shifted their gaze away from the text frequently in the Standard condition because of less developed attentional control, or if they were consistently searching for relevant illustrations to help build an understanding of the story. We are currently pursuing this outstanding question by defining the AOIs for relevant text and relevant illustrations on each page of the book, as well as the irrelevant details in the illustrations. After this procedure, we will be able to determine the sequence of children's eye-gaze patterns (e.g. *are they reading "dogs" and then looking at illustrations of dogs, or are they reading "dogs" and then looking at illustrations of cars?),* and also examine whether children are frequently shifting their gaze away from the text in the Standard layout because they are looking at extraneous details, or relevant content in the illustrations. We hypothesize that children are shifting their gaze away from the text because at this age, children's attention regulation is still developing and children can be easily distracted by the irrelevant elements of the illustrations. However, it has also been found that children's selective attention to salient features congruent with verbal content predicts comprehension (Calvert, Huston, Watkins, & Wright, 1982; Grassmann and Tomasello, 2010; Scofield, Miller, & Hartin, 2011).

Another limitation of this study is that it remains unclear whether these findings generalize to children from different backgrounds than participants in this study (e.g., children for whom English is not their first or only language), and to reading materials other than the book selected for this study. We intend to pursue these questions in future research through collaborations with a number of community partners. If the findings of this study are replicated with other reading materials and across a broad range of students, this research can point to a malleable, cost-effective, and easy to scale general principle for more optimal design of reading materials for beginning readers.

Not all beginning reader storybooks are the same, and content drives both the experience and the outcomes. Illustration choice and layout are important to the educational potential for children learning-to-read, not just students reading-to-learn. These findings highlight the importance of establishing a new industry standard. Enhancements to storybooks should serve a clear purpose to engage the child with the appropriate story content ensuring that motivational enhancements do not interfere with learning and performance. The consideration of potential costs from motivational enhancements may be especially important for children with less developed attentional control. When well-deployed and designed, illustrations in books for beginning readers have the potential to enrich, not hinder learning experiences for children.

Acknowledgments

We thank Amy Lin, Rebeka Almasi, Hyunji Do, Graciela Garcia, Sara Jahanian, Elaine (Zhuyi) Xu, Smriti Chauhan, Isabel Rozario, Matt King, Xavier Artache, and Marie Shaw for collecting data and assisting with the storybook design. We are grateful to the children, parents, and educators at the following schools: Sacred Heart Elementary, Carlow University, Winchester Thurston, Propel East, and Propel Mckeesport, for their participation in our research. This work was supported in part by a National Science Foundation award (BCS-1730060) to A.V.F and K.E.G. and by the Institute of Education Sciences, U.S. Department of Education, through grant R305B150008 to Carnegie Mellon University. The opinions expressed are those of the authors and do not represent the views of the Institute or the U.S. Department of Education.

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