

Book Design, Attention, and Reading Performance: Current Practices and Opportunities for Optimization

Karrie E. Godwin¹ (kgodwin1@kent.edu)

Cassandra M. Eng² (cassonde@andrew.cmu.edu)

Grace W. Murray¹ (gmurray5@kent.edu)

Anna V. Fisher² (fisher49@andrew.cmu.edu)

¹Kent State University, Department of Educational Psychology, 150 Terrace Drive, Kent, OH 44243 USA

²Carnegie Mellon University, Department of Psychology, 5000 Forbes Ave. Pittsburgh, PA 15213 USA

Abstract

Becoming a proficient reader is a critical skill that supports future learning. Toward the end of the primary grades, reading becomes increasingly automatized, and children begin to transition from *learning-to-read* to *reading-to-learn*. Yet, the design of beginning reader books may be suboptimal for novice readers. Colorful illustrations that contain irrelevant information (i.e., seductive details) presented in close proximity to the text may increase attentional competition between these sources of information; thus, hampering decoding and reading comprehension. Study 1 examines this hypothesis by experimentally manipulating components of the book design (e.g., presence/absence of seductive details) and investigating its effect on attention and reading performance in first grade students. In Study 2, we conduct an analysis in which we identify common design features in books for beginning readers and examine the prevalence of design features that were found to tax attention in Study 1 and in prior research. Collectively this work identifies an important opportunity in which instructional materials can be optimized to better support children as they learn-to-read.

Keywords: attention; selective sustained attention; reading comprehension, decoding, reading, book design

Introduction

Learning to read is an important skill that enables future learning (National Association for the Education of Young Children, 1998). As reading becomes increasingly automatized, children begin to transition from *learning-to-read* to *reading-to-learn*, and thus can more readily apply this skill to learn novel information. But acquiring this skill set is challenging due to a number of factors including (but not limited to) deficits in prior knowledge (e.g., pre-reading skills such as phonological awareness; Kirby, Parrila, & Pfeiffer, 2003), learning disabilities (e.g., dyslexia), as well as cognitive limitations (e.g., working memory, processing speed; Jacobson et al., 2011). The difficulty many children experience in becoming competent readers is reflected in a 2005 report in which only 31% of 4th grade students in the

United States were identified as “Proficient” or above on the NAEP reading assessment and rates were lower still for some groups of minority students: Black 13%, Hispanic 16%, American Indian/Alaska Native 18% (Perie, Grigg, & Donahue, 2005, pp. 3-4). These sobering statistics highlight the need to identify malleable factors that can be leveraged to better support children’s reading achievement. One potential factor is book design.

The design of beginning reader books may not be optimized to support early reading, which may further increase the difficulties children experience acquiring this skill. Prior research has found that the close proximity between text and illustrations in books for beginning readers increases attentional competition between these sources of information hampering reading performance (Godwin, Eng, Todaro, Murray, & Fisher, 2018; Torcasio, & Sweller, 2010). By increasing the spatial separation between text and illustrations (Godwin et al., 2018) or reducing extraneous details from illustrations (Eng, Godwin, & Fisher, 2018), attentional competition is reduced (indexed by gaze shifts away from the text), and reading comprehension improves. These results are promising, as they point to a malleable factor (i.e., book design) that could in principle be optimized to better scaffold young readers’ attention to the text and in turn enhance their developing literacy skills. However, it is currently unknown whether these design choices (e.g., close proximity between text and illustrations, inclusion of irrelevant details in illustrations) are typical in beginning reader books. If these design choices represent a standard design practice, then this emerging body of research points to an unrecognized opportunity for intervention.

The present paper reports two studies. Study 1 provides a conceptual replication of Eng et al. (2018), but also extends prior work with second grade students to a younger age group, first-graders. In Study 1, we investigate experimentally whether an element of the book design (i.e., presence/absence of attention-grabbing, but irrelevant to the text, details in illustrations) negatively affects children’s

attention to the text, diminishing their reading performance. Study 1 makes an important contribution given growing concerns regarding the replicability crisis (e.g., Camerer et al., 2018; Nosek et al. 2015). Study 2 makes a novel contribution by examining issues of generalizability, namely examining whether the design features of the book utilized in prior research are commonplace and thus represent a potential avenue for intervention. In Study 2, we conduct an analysis of 100 beginning reader books in which we identify common design features and assess how prevalent the design choices that were found to tax children's attention in Study 1 (and in prior research) are in children's books.

Study 1

Method

Thirty first-grade children participated in the present study ($M = 7.09$ years, $SD = .32$ years, 16 females, 12 males, 2 did not report). The sample represents local diversity with children being 63.3% White, 13.3% African American, 16.7% Multi-Racial, and 6.7% reported as other. Participants were recruited from schools in and around a mid-sized city in the Northeastern United States. Participants were tested individually by trained hypothesis-blind research assistants.

Design and Procedure

In order to ensure ecological validity, Study 1 utilized a commercially available beginning reader book selected from the *Hooked On Phonics Learn to Read* series. Children were asked to read aloud the book "Good Job Dennis," by Amy Kraft. Following Eng et al. (2018), the book design was manipulated within-participants such that half of the book was presented in the Standard layout of unaltered pages from the commercially available book, and half of the book was presented in the Streamlined layout in which the illustrations were simplified by removing the irrelevant details. The presentation order of conditions (Standard condition or Streamlined condition first) was counterbalanced across participants. Each half of the book contained 6 pages. Minor modifications were made to the text to ensure that each half of the book had approximately equivalent number of words (average number of words per page: 43.0 first half, 42.3 second half). Identification of irrelevant details was based on a separate calibration study (Eng et al., 2018). Fifteen college students were given photocopies of the book and were asked to outline details in the illustrations that they believed were *relevant* to the story text for each page. The illustration details in which participants reached over 90% agreement were included in the Streamlined condition and all other remaining details were removed (See Figure 1A and 1B).

The book was presented on a laptop computer and children's gaze shifts away from the text were recorded using eye tracking technology. Decoding was assessed prior to reading the story (Word Recognition in Isolation Test)

and while children read aloud (Running Record). Following the story, a post-test was administered to assess reading comprehension.



Figure 1A: Sample page of the Standard layout condition



Figure 1B: Sample page of the Streamlined layout condition

Measures

Gaze Shifts Children's attention allocation to the text was measured using a RED250 mobile eye tracker (SensoMotoric Instruments, Inc.) in which gaze shifts away from the text were recorded. For each page of the book, Areas of Interest (AOIs) were created for the text, white space, and illustrations. The number of gaze shifts away from text AOIs (to illustration AOIs or white space AOIs) was calculated using the SMI BeGaze software and the average number of gaze shifts per page is reported.

Decoding Measures Decoding is thought to be an important component of reading Fluency (Rasinski, 2004). The decoding measures assess children's ability to accurately

identify words (either in isolation or embedded in text). Two decoding measures were employed: the Word Recognition in Isolation task and a Running Record.

Word Recognition in Isolation Task Children completed a modified Word Recognition in Isolation (WRI) task which served as an independent measure of children's ability to decode words fluently (Morris, 2013). The WRI was administered prior to children reading the story. Children are shown leveled lists of words and asked to read the words aloud as quickly and accurately as possible. The number of words read correctly (out of 100 possible words) within the time limit was recorded.

Running Record (RR) The research assistant manually recorded the child's decoding accuracy for each word in the story and the proportion of correct responses was calculated (Clay, 1972).

Reading Comprehension Measure Children were asked six open-ended comprehension questions. Responses were recorded by hypothesis-blind research assistants. We slightly modified the questions provided by the book manufacturer to maintain the ecological validity of the comprehension assessment. Questions were designed such that they probed memory for content presented on specific pages. The post-test included six questions, three questions from each half of the book. Rather than scoring children's responses in a binary fashion (correct vs. incorrect), partial credit was possible. In each half of the book, children completed two 2-point questions and one 3-point question and thus could earn up to 7 points per condition. For example, children were asked to recall Dennis' job. Children earned full credit (2 points) if they stated that Dennis directs traffic and helps children cross the street. Partial credit (1 point) was awarded if children provided an incomplete answer (e.g., "he helps children"), and 0 points if children provided an incorrect answer or failed to recall Dennis' job. The percentage of correct responses (out of 7) is reported. Scoring was completed by condition blind research assistants. To ensure inter-rater reliability, the data was scored twice by two research assistants and Cohen's Kappa (Cohen, 1960) was calculated (.88).

Results

There were no significant differences in average reading time per page in the Standard condition ($M = 55000.21$ ms; $SD = 35065.49$ ms) compared to the Streamlined condition ($M = 54066.81$ ms; $SD = 37571.03$ ms), paired-sample $t(29) = .27$, $p = .79$. There were also no significant differences in participants' Running Record scores while reading in the Standard condition ($M = 94.78\%$; $SD = 5.13\%$) compared to the Streamlined condition ($M = 94.87\%$; $SD = 5.03\%$), paired-sample $t(29) = .34$, $p = .74$.

Reading Comprehension Children's comprehension scores were significantly higher in the Streamlined condition ($M =$

80.48% , $SD = 20.37\%$) than in the Standard condition ($M = 51.90\%$, $SD = 24.74$), paired-sample $t(29) = 4.72$, $p < .0001$ (see Figure 2); Cohen's $d = 1.26$. In order to test for order effects, we conducted a mixed factorial analysis of variance (ANOVA), factoring condition order as the between-subject variable and comprehension as the within-subject variable. There was no main effect of condition order, $F(1, 28) = .02$, $p = .90$, and no significant interaction between order and comprehension, $F(1, 28) = 2.09$, $p = .16$. These results indicate that reading in the Streamlined condition resulted in higher comprehension compared to reading in the Standard condition, regardless of the amount of time spent reading, the quantity of words a child accurately read aloud, and the order in which the layout was presented.

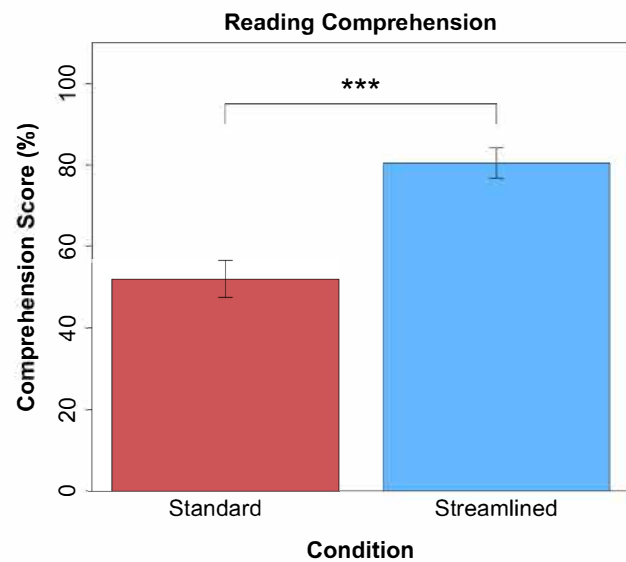


Figure 2: Percentage of correct answers on the story questions as a function of book layout. *** $p < .0001$.

Gaze Shifts On average, children switched their point of fixation away from the text 27.78 times per page ($SD = 26.48$) in the Standard layout compared to 13.71 times in the Streamlined layout ($SD = 11.07$), paired-sample $t(29) = 4.67$, $p < .0001$; Cohen's $d = .69$. Three outliers were identified. With the removal of these outliers, there was still evidence of a significant main effect of book layout on children's gaze shifts (paired-sample $t(26) = 5.65$, $p < .0001$; Cohen's $d = .89$). Children looked away from the text almost twice as much in the Standard condition than they did in the Streamlined condition (See Figure 3).

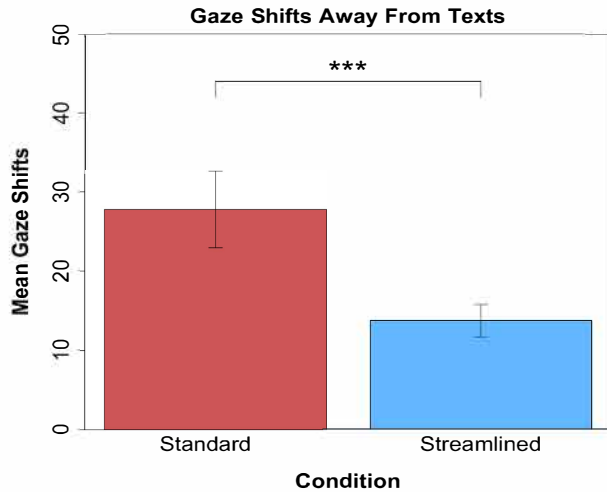


Figure 3: Average gaze shifts away from the text per page as a function of book layout. *** $p < .001$.

The Role of Individual Differences Next we examined whether the Streamlined layout might be especially beneficial for children who often shift their attention away from the text. For this analysis, a difference score for each child was calculated by subtracting the Standard layout comprehension score from the Streamlined layout comprehension score. Difference scores estimated changes in reading comprehension performance from the Streamlined layout, such that higher and positive scores indexed greater gains in comprehension. Difference scores ranged from -57.14% to 85.71%, with a mean of 28.10% ($SD = 33.24\%$). Children's gaze shifts in the Standard layout condition were positively associated with Comprehension Gain scores ($r = .49, p = .003$), 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.

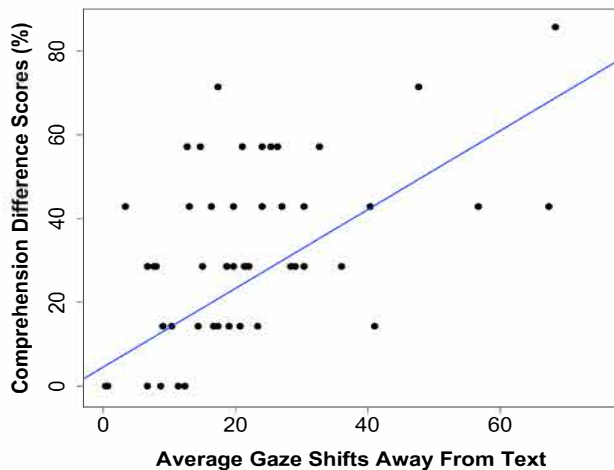


Figure 4: Association between gaze shifts and comprehension gains with outlier removed.

Unique Contribution of Gaze Shifts to Comprehension Gains To ensure that the findings were not entirely due to variance shared with reading ability, children completed the WRI test prior to the reading session to assess participants' decoding fluency ($M = 55.90, SD = 20.04$). To examine the extent to which children's gaze shifts away from the text while reading uniquely predicted how much children's comprehension improved from the Streamlined layout condition, we conducted a multiple regression analysis that included gaze shifts and WRI scores as predictors of children's comprehension difference scores. Results show that gaze shifts ($\beta = 5.57, t = 2.28, p = .003$) accounted for unique variance in comprehension gains when reading from the Streamlined layout, but reading fluency (indexed by the WRI) did not ($p > .10$; see Table 1). The results suggest gaze shifts away from the text while reading account for unique variance in comprehension gains independent of the overall reading ability.

Table 1: Relation of Gaze Shifts to Comprehension Gains

	β	SE	t
Eye Gaze Shifts	3.37**	0.24	2.28
WRI Score	-.55	0.32	-1.72

** $p < 0.01$. $R^2 = .45$. $F = 11.05$. $df = 2, 27$.

Study 1 successfully replicates the results from prior research (Eng et al., 2018) with a younger age group (first-graders) and demonstrates that extraneous illustration details are a source of distraction for beginning readers. Extraneous, nonessential illustration details were found to disrupt attention as evidenced by the increase in gaze shifts away from the text. This design choice not only affected children's patterns of attention allocation, but it also reduced children's reading comprehension.

While the successful replication points to a robust finding, it remained unclear whether the design features characteristic of the book used in Study 1 are prevalent in other books for beginning readers. If the inclusion of irrelevant details in illustrations is a common practice, then it points to an opportunity in which we could better support children's reading by modifying the design of beginning reader books. We begin to address this question in Study 2.

Study 2

Method

Design and Procedure

Guided by a children's librarian, 100 children's beginning reader books were selected from local libraries near a Midwestern town in the United States. The books were subsequently analyzed to investigate common design

elements. Books were pseudo-randomly chosen to ensure representation of multiple publishers (17 total) and topics. The sample of books represent work from 101 authors and 92 illustrators. Trained coders rated each story page, excluding publisher pages, on 10 categories relating to aspects of the book design including: features of the illustrations (e.g., color, alignment, irrelevant details), text (location, enhancements), and general design (layout, use of white space, borders). Of particular interest for the present study was the category irrelevant details as well as page layout given that Study 1 and prior research (Eng et al., 2018) have found that the inclusion of irrelevant details in illustrations as well as including illustrations in close proximity to the text (Godwin et al., 2018) increase attentional competition and reduce reading performance. The remaining 8 categories were included to provide a more comprehensive analysis of the common design features employed in beginning reader books.

For each book, the percentage of pages in each category level was calculated and means for the data set are reported. Coders received extensive training on the coding protocol using worked examples. Coders also completed a training set, consisting of 7 beginning reader books in order to establish interrater reliability (Cohen's kappa = .80, range: .76 to .85).

Results

All of the books were leveled for beginning readers. The average number of pages per book was 27 ($SD = 8.77$).

Features of the illustrations

Beginning reader books tend to contain illustrations that are very colorful and detailed: on average 93.42% of a book's pages contained illustrations that included five or more colors and 97.79% of a book's pages contain some or intermediate levels of detail. Most book pages contained a single illustration (93.19% of a book's pages), and the illustrations were generally aligned to the text (86.98% of a book's pages). However, the inclusion of irrelevant details in illustrations was found to be a common practice with 86.56% of a book's pages containing some or several irrelevant details.

Features of the text and general layout

Text location varied, but common text locations included centered at the top (35%) or bottom of the page (21.8%), or in multiple locations (13%). Design features intended to enhance the saliency of the text including text boxes, fading, or bubbles were rare (4.65% of a book's pages) as were the use of borders (6%). Surprisingly, white space was not utilized on 28.73% of a book's pages. Although publishers

Table 2. Mean percentage of a books' pages coded in each category level

Features of the Illustrations:											
	Black & White			1-2 Colors		3 Colors		4 Colors		5+ Colors	
Color	0%			2.36%		1.50%		2.67%		93.42%	
	Minimal Detail			Some Detail		Intermediate Detail		Rich Detail			
Detail	< 1%			50.55%		47.24%		1.88%			
	Reiterates			Disambiguates		Topical		Unrelated			
Alignment to text	86.98%			7.33%		5.36%		0%			
	None			Some		Several					
Irrelevant Visual Details	13.44%			33.38%		53.18%					
	No			Yes							
Multiple Illustrations	93.19%			6.81%							
Features of the Text:											
	Left	Right	Top	Bottom	Middle	Multiple Locations	Full Page	Top L	Top R	Bottom L	Bottom R
Location	3.5%	2%	35%	21.8%	4.5%	13%	2%	10%	3.6%	2.6%	2%
	No Enhancements					Enhancements					
Text Enhancements (e.g., Fading, Text Boxes or Bubbles)	95.34%					4.65%					
General Design Features:											
	Text & illustration presented on sequential pages			Text & Illustration presented on adjoining pages		Text & illustration presented on same page with some spatial separation		Mixed Layout		Text embedded in illustration	
Page Layout	0%			8.79%		62%		1.63%		27.46%	
	None			Intermediate		A lot					
Use of White Space	28.73%			56.49%		14.78%					
	No			Yes							
Use of Borders	94%			6%							
Note. For every book, the percentage of pages in each category-level was calculated, and means are reported.											

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tended to include some spatial separation between text and illustrations (62% of a book's pages), embedding the text *inside* illustrations was also a frequent design choice (27.46% of a book's pages).

Discussion

During the primary grades, young children are just beginning the challenging work of learning how to decode text. The difficulty many children experience acquiring literacy skills may be compounded by the design of beginning reader books. These instructional materials may fail to take an important cognitive constraint into consideration; namely, children's immature attention regulation system (e.g., Ruff & Rothbart, 2001). Placing text and illustrations in close proximity may unintentionally create attentional competition between these sources of information, hampering reading comprehension. Such attentional competition may be particularly disadvantageous when illustrations contain irrelevant information. The present work explored this possibility with a group of first grade students (Study 1) and provides an extensive analysis of book design features that may influence children's attention allocation across 100 beginning reader books (Study 2).

Several notable findings emerged from this work: Study 1 informs our understanding of how beginning readers allocate their attention while reading independently, and identifies a design feature that influences children's ability to maintain attention to the text. The inclusion of irrelevant details in illustrations for beginning readers was found to disrupt attention allocation and hampered reading comprehension. This finding corroborates prior work (Eng et al., 2018) and provides an important conceptual replication with a novel age group; thus, demonstrating the robustness of the effect. Study 2 examined the prevalence of this design choice, as well as other design features, in books for beginning readers by conducting a detailed analysis of 100 books. The results point to several common design features that may increase attentional competition for young readers including: embedding the text within the illustrations and often not including white space. Critically for the present work, illustrations containing irrelevant details was found to be a common design practice. The prevalence of these design choices point to an opportunity in which we could better support children's emergent literacy skills by modifying the design of beginning reader books.

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