Reading and Writing
https://doi.org/10.1007/s11145-020-10021-9

An eye tracking study of digital text reading: a comparison between poor and typical readers

Karin Bar-Zvi Shaked[1] · **Adina Shamir**[1] · **Eli Vakil**[2]

Abstract
The inclusion of technology in schools, coupled with the importance of promoting reading for students with difficulties in particular, has increased the need for investigating processes that support reading and reading comprehension. The present study therefore focuses on the characteristics of reading from an educational digital book containing an expository text and illustrations, conducted by means of an eye tracking methodology enabling online reflection of the reading process. The effect on reading a highlighted text with illustrations was compared to that of reading a static text with illustrations. Participants included 30 poor readers and 31 typical readers aged 8–10.9, randomly assigned to two groups according to reading mode: An experimental group that read a highlighted text with an illustration and a control group that read a static text with an illustration. The findings indicate that among poor readers, the highlighted text in the digital book evoked greater visual focusing on the text and more transitions between the text and the illustration. The findings of the study contribute to our knowledge on multimedia learning and the process of reading among poor and typical readers while reading highlighted text with illustrations.

Keywords Electronic book · Eye movement · Highlighted text · Poor readers · Primary school children

Introduction

Reading and reading comprehension comprise two of the fundamental skills challenging students in school (Snow & Matthews, 2016); the promotion of literacy skills is therefore extremely important, especially for poor readers (Zawoyski,

✉ Adina Shamir
Adina.Shamir@biu.ac.il

[1] School of Education, Bar-Ilan University, Ramat-Gan, Israel

[2] Department of Psychology and Leslie and Susan Gonda (Goldschmied), Multidisciplinary Brain Research Center, Bar-Ilan University, Ramat-Gan, Israel

Published online: 13 February 2020

Ardoin, & Binder, 2015). Technological advances have expanded the range of tools, such as digital books, available to support the teaching of literacy from as early as kindergarten and continuing through elementary school (National Institute of Child Health and Human Development [NICHD], 2000). Educational digital books (or e-books) usually contain an expository or a narrative text including diverse representations (for example, verbal texts and illustrations) and multimedia effects (highlighted text, narration, dictionaries, etc.) to support learning (de Jong & Bus, 2003; Korat & Shamir, 2004; Shamir & Korat, 2015). These technologies frequently offer innovative solutions for literacy acquisition by poor readers (Eden, Shamir, & Fershtman, 2012; Shamir & Margalit, 2011). Studies on the reading of digital texts, in the field, are therefore necessary in order to test the contribution of digital tools to reading by all students but especially by poor readers.

Although digital storybooks have been investigated extensively (Felvegi & Matthew, 2012; Korat, 2010; Korat, Shamir, & Segal-Drori, 2014; Lefever-Davis & Pearman, 2005; Pearman, 2008; Shamir & Korat, 2007; Takacs & Bus, 2016), little is known about the characteristics of reading expository digital texts and even less about reading a digital text accompanied by illustrations among poor readers (Shamir & Margalit, 2011). When trying to understand the reader's difficulties, it appears to be important to focus on the reading process itself (Mason, Tornatora, & Pluchino, 2013; Mayer, 2009; Zawoyski et al., 2015) and not solely on reading outcomes, which can be revealed with an eye tracking methodology.

Eye tracking methodologies offer advanced opportunities for the online analysis of a child's reading processes when reading digital books, whether containing multimedia effects such as highlighted text, or static texts including a traditional illustration, particularly when the book contains a complex expository text. Highlighting through the addition of color is one way of drawing attention to the text, especially in primary school (Lowe & Boucheix, 2007; Roy-Charland, Perron, Boulard, Chamberland, & Hoffman, 2015). In a study on eye movements during e-book reading, the researchers found that highlighting a digital text helped second-grade readers focus on a text simultaneously narrated by a professional radio personality (Roy-Charland et al., 2015). These results suggest that highlighted text may be a digital feature conducive to attracting the reader's attention to the text. And yet, the scientific literature on this issue is still limited, especially with respect to poor readers. The current research, which examines cognitive processing during reading by means of eye movements, promises to shed some light on this issue.

Within this context, the present study's aim was to characterize the reading of poor readers who read an expository educational digital book including highlighted text and illustrations in comparison to their reading of a static text with illustrations. This research was conducted using an online eye tracking methodology.

Students with reading difficulties

Reading difficulties first appear among 5–10% of all students from the third grade on (Catts & Hogan, 2002; Scarborough, 1998). The fourth grade is sometimes regarded as the critical limit, after which students experience an unexpected

decrease in their reading achievements (Chall & Jacobs, 2003). This decline may occur because reading at this point becomes increasing complex as its focus switches to learning (Aaron, Joshi, Gooden, & Bentum, 2008). Approximately 15% of all fourth-grade students have been found to be poor readers (Etmanskie, Partanen, & Siegel, 2014); 13.4% of second-, fourth-, eighth- and tenth-grade students may be classified as exhibiting comprehension difficulties, reading difficulties, or both (Catts, Compton, Tomblin, & Bridges, 2012). A PIRLS (Progress in International Reading Literacy Study, an international study conducted by the International Association for the Evaluation of Educational Achievement) study conducted in Israel in 2016 found that 25% of fourth graders evidenced poor reading skills when reading a printed text, whereas 23% indicated poor reading skills when reading in a computerized environment (e-PIRLS) (National Authority for Measurement and Evaluation in Education, 2016). In light of the leap in the percentage of students with difficulties appearing in the fourth grade, we focused poor readers in the third-to-fifth grade.

Reading, a central tool for literacy, requires many diverse skills in order to elicit maximum meaning from a text (Cain, Oakhill, & Bryant, 2004; Peng et al., 2018). Poor readers especially experience extreme difficulty in acquiring basic skills such as word recognition and phonological decoding when compared to their age-matched typical peers (Vellutino, Fletcher, Snowling, & Scanlon, 2004). Hebrew (Israel's national language) includes an additional level of difficulty in word decoding due to the concomitant need to decode diacritical marks (i.e., vowel signs added to the word's letters that help in reading the word) up to the fourth grade, after which diacritical marks are no long used. During reading acquisition, poor readers often display impairments in (visual) letter to auditory (sound) conversion, that is, in the conversion of a written word to its correct pronunciation (the grapho-phonemic code). As a result, the reading of these children is characterized by impaired decoding of written words.

Poor readers read less but also avoid challenging texts, such as expository texts. This situation projects on their vocabulary development (Chall, 1983) and on the scope of their personal knowledge, assumed to help them read. The reader's vocabulary store comprises important infrastructure for promoting achievements in written and spoken language as well as an imperative for promoting reading accuracy and comprehension (McKeown & Beck, 2006; National Institute of Child Health and Human Development [NICHD], 2000). Previous research found a significant difference in comprehension performance by the reading strategy applied when reading an expository text among seventh-grade poor readers when compared to good readers. It was also found that poor readers had less motivation to read than do good readers (Lau & Chan, 2003). Due to its characteristics, such as complex sentence structure, abstract organization, less-familiar content and a vocabulary containing words less-frequently used in primary school, the expository text poses difficulties to understanding (Diakidoy, Stylianou, Karefillidou, & Papageorgiou, 2005; Duke, 2000; Sahin, 2013). We thus concluded that it is important to conduct research on digital books having an expository text, as in the present study.

The digital book

A digital book, also called an electronic storybook, electronic book, e-reader or e-book, is a book produced in a computerized format that offers narratives and information, usually a text and an illustration (Shamir & Korat, 2006; Shamir, Segal-Drori, & Goren, 2018). Educational digital books (Shamir & Korat, 2013, 2015) have been shown to support learning because they include educational multimedia applications, properties such as highlighted written text, vocal effects, a dictionary and simultaneous narration that reinforce the text and the illustrations or images and thus support reading among young students (de Jong & Bus, 2003; Felvegi & Matthew, 2012; Korat, 2010; Lefever-Davis & Pearman, 2005; Pearman, 2008; Shamir & Korat, 2007; Shamir et al., 2018). Neuman's (2009) Theory of Synergy argues for the inclusion of multimedia in learning and literacy curricula by claiming that every multimedia device (for example, computers, I-pads, and television) has properties that define the form and organization of information in a variety of ways; they can therefore add additional dimensions to the knowledge that children acquire and to the means by which they will learn in the future.

The introduction of different digital tools (including e-books) into the classroom obligates the entire education system to constantly update its efforts for implementing the new technologies among diverse populations (Shamir & Margalit, 2011). Most studies on the digital book's effectiveness among students with difficulties focus on stages of emergent reading (de Jong & Bus, 2003; Korat & Shamir, 2004; Labbo & Kuhn, 2000; Shamir, Korat, & Barbi, 2008), mainly achievement of reading fluency and reading comprehension (Doty, Popplewell, & Byers, 2001; Fletcher, 2006). In primary school, the digital book serves as a source for learning factual information as well as exposure to narratives (stories). Research conducted by Korat, Levin, Ben-Shabat, Shneor, and Bokovza (2014) indicates that narrative content (with and without the dictionary often found in digital books) can support literacy skills (vocabulary and spelling) among typically developing second graders of low socioeconomic status. Because most of the research on the effectiveness of printed and digital books has focused on students with typical development (Joseph, Nation, & Liversedge, 2013; Luke, Henderson, & Ferreira, 2015; Roy-Charland et al., 2015), we need to expand our understanding of the process of reading a digital text with illustrations and the advantages of the respective multimedia characteristics for poor readers as well.

Reading a text with illustrations from a digital book

Digital books that contain expository content usually include verbal descriptions together with illustrations (pictures, graphs, images) that require the spatial processing by the reader. Each type of visual representation (such as text and illustrations) offers a different perception of the content at new and more complex stages of learning (Ainsworth, 2006), thereby improving retention of the learned content (Ozcelik, Karakus, Kursun, & Cagiltay, 2009). Researchers agree that the combination of text and illustrations supports understanding by all learners due to their simultaneous

integration when transmitting information. Mason, Pluchino, Tornatora, and Ariasi (2013) and Mason, Tornatora et al. (2013) found that a combination of text and a concrete or an abstract instructional illustration was most effective for learning an expository text among eleventh-grade students with typical reading development. Other research findings have shown that a higher level of reading comprehension was found among first and third graders after reading a book that contained text and illustrations when compared to reading a book having only text or illustrations (Brookshire, Scharff, & Moses, 2002). Hannus and Hyona (1999) found that the fourth-grade typical readers, when reading a text with illustrations, focused mainly on the text area. They also found that only 6% of the children's fixations when reading an expository text in biology that included illustrations were on the area of the illustration, regardless of the student's abilities. Findings from other studies employing think-aloud protocols have indicated that fifth- to ninth-grade students focused more on the information detailed in the text, with the accompanying visual illustrations (graphs, diagrams, etc.) perceived as random or unrelated to the text (Moore & Scevak, 1997). It has therefore been suggested that combining text with illustrations may help children with difficulties to learn (Mason, Pluchino et al., 2013; Mason, Tornatora et al., 2013).

Eye movement studies reflect the cognitive process of reading. Highlighting text thus offers advantages for learning and understanding, as research performed by Lowe and Boucheix (2007) has indicated; among second graders with typical development, highlighting text in regular books leads to longer fixation on the text when compared to the neutral mode. Furthermore, Roy-Charland et al. (2015) found that when reading a book written at a high level of difficulty, highlighting, when compared to the neutral mode, induced a greater number of fixations on the area of the written text even when the text was read aloud in parallel.

To date, the level of support afforded by highlighting during reading of a digital book by poor readers has not been investigated. Hence, a comparative study of typical and poor readers appeared warranted (Shamir & Korat, 2015).

Eye tracking as reflections of reading processes

The increasing inclusion of technology in education enables direct monitoring of students' learning processes (see for example, Jian, 2015). Alongside assessment of learning products, eye tracking methodologies are used in research assessing cognitive processes and learning strategies (Clifton et al., 2016; Lai et al., 2013; Luke et al., 2015; Zawoyski et al., 2015) since a person's gaze at a visual space is usually purposeful rather than random (Miellet, Vizioli, He, Zhou, & Caldara, 2013). Eye tracking is characterized by objectivity, contrary to traditional measurement tools that, as a rule, are based on learners' self-reports (usually questionnaires) but provide limited information on thinking process per se. In recent years, the turn to eye movement methodologies has therefore gained popularity in the field of educational research.

The primary assumption held by researchers is that it is possible to identify the products of cognitive processes via eye tracking, a method that can capture a

reader's visual behavior (Giuliani & Schenk, 2015; Lai et al., 2013; Nitzan-Tamar, Kramarski, & Vakil, 2016; Rayner, 1998; Vila & Gomez, 2016). The findings of a study conducted by Rayner, Chace, Slattery, and Ashby (2006) among native English-speaking students indicated that patterns of eye movements reflect the text's difficulty for the reader, that is, the higher the level of the text, the greater the number of fixations. Similar findings, reflecting differences in eye movements according to the reading skill tested, were obtained among second graders. Fewer fixations, and at shorter durations, were found among children at high reading levels when compared with children at low reading levels (Zawoyski et al., 2015), with the latter characterized by a higher number of prolonged fixations when compared with the former (Olson, Kliegl, Davidson, & Foltz, 1985; Rayner, 1998; Solan, 1985). Other findings showed that typically developing readers focused more on text that matched their reading ability; when the text's level was higher than the child's reading level, the reader's attention turned to the illustrations, actions similar to those characterizing kindergarteners who do not read (Roy-Charland, Saint-Aubin, & Evans, 2007). We can summarize by stating that to date, most studies on this subject have focused on the reading of a printed text by students with typical development. However, questions regarding the reading characteristics of poor readers remain unanswered (Peng et al., 2018; Zawoyski et al., 2015), especially while reading digital texts (Korat, Levin et al., 2014; Korat, Shamir et al., 2014; Shamir & Margalit, 2011).

The present study

Recent studies have examined the influence of digital books on the literacy achievements of children (Shamir & Maor, 2019; Shamir et al., 2018; Shamir & Korat, 2013, 2015), but little research has been conducted on the actual process of reading digital books. Roy-Charland et al. (2015) have shown the effect of highlighting narrative text on the reading process of typical beginner-level readers but not on primary school students exhibiting reading difficulties. The current study therefore focuses on the reading process of poor readers when reading in different highlighted-text modes, including illustrations. Based on the literature (Hannus & Hyona, 1999), we introduced illustrations into a specially designed digital book in order to explore the reliance of poor readers on illustrations during reading. To do so, we chose to measure eye tracking, considered an effective empirical tool for examining the process of reading (Navarro, Molina, Lacruz, & Ortega, 2015; Zawoyski et al., 2015) among poor readers.

The eye movement variables were measured by calculating the sum of the transitions between the text area and the illustration area on the reading screens (AOIs, i.e., areas of interest) as well as the percentage of fixations (on text and on illustrations) and dwell time on the text. To the best of our knowledge, similar eye tracking has not been performed to date among poor readers during their reading of an expository educational digital book in a highlighted versus a static mode. Hence, the main research question became: Will differences be found between the research groups (poor and typical readers) in their reading of an educational digital book

in a highlighted text mode versus a static text mode and will those differences be expressed in eye movements in the areas of interest (text and illustrations)?

Based on the research literature indicating that the lower the reading level, the higher the number of fixations (Rayner et al., 2006; Zawoyski et al., 2015), the study's first research hypothesis stated that poor readers will show a higher level of fixations on the text area when compared with typical readers. Our second research hypothesis stated that poor readers will perform more transitions between the areas of interest (text and illustration) than will typical readers because illustrations provide greater support for their understanding of the text's meaning; typical readers, it has been found, rely mainly on the text for understanding and are therefore less in need of support from illustrations (Roy-Charland et al., 2007).

Method

Participants

The school system in Israel is essentially a public system consisting of three levels: primary education (grades 1–6, ages 6–12), middle school (grades 7–9, ages 12–15) and high school (grades 10–12, ages 14–18). The Ministry of Education determines educational standards and curricula for literacy education, which comprises a major portion of learning beginning in the first grade (Israeli Ministry of Education, 2017).

A total of 61 children (mean age: 9.3 years, $SD = .73$ months) participated in the study (31 girls, 30 boys), including 39 third graders (age: $M = 8.93$ years, $SD = .51$ months; 17 girls, 22 boys), 19 fourth graders (age: $M = 9.8$ years, $SD = .63$ months; 12 girls, 7 boys) and 3 fifth graders (age: $M = 10.6$ years, $SD = .3$ month; 2 girls, 1 boy). All participants were native Hebrew speakers and came from middle-class socio-economic backgrounds. Among the participants, 30 were poor readers and 31 typical readers. Eleven children were excluded from the study for various reasons. The inclusion criteria for poor readers were: (a) they had been diagnosed as belonging to the 25th percentile and below of literacy according to national standards (see research tools); and (b) they did not exhibit other cognitive, sensory, emotional, communicational, or physical limitations. The children's reading level was measured prior to the experiment by means of standardized reading tests (see research tools) with significant t test values for the differences between the reading levels of the poor and the typical readers ($t = 4.68$, $p < .001$). Among the participants in the research, typical readers achieved scores above the 25th percentile ($M = 47.29$; $SD = 11.33$). Poor readers received scores significantly below those of typical readers ($M = 36.27$; $SD = 6.24$) (see Table 1). A reading comprehension test suggested additional inclusion criteria for poor readers. A significant difference was also found in the reading comprehension levels of poor versus typical readers ($t = 3.27$, $p < .01$). Poor readers achieved significantly lower scores in reading comprehension ($M = 7.10$; $SD = 3.50$) than did typical readers ($M = 8.64$; $SD = 2.71$). A significant correlation was found between reading level and reading comprehension level ($r = .47$, $p < .001$).

Table 1 Reading of the two groups: means and standard deviations

	Poor readers (n = 30)		Typical readers (n = 31)	
	M	*SD*	*M*	*SD*
Words/min (number)	29.61	9.91	49.61	17.54
Errors/min in word reading (%)	30.00**	11.40	12.74**	6.46
Speed and accuracy of text reading (scores)	77.03*	17.81	124.00*	32.26
Errors in text reading (%)	8.45*	4.03	2.83*	2.40

*$p < .05$; **$p < .01$

Gender distribution was similar in both groups ($\chi^2 = .25$, $p > .05$). No differences were found between poor and typical readers on the cognitive level ($t = .89$, $p > .05$; standard score = 85 or higher) based on the Raven Standard Progressive Matrices (Raven, 1964).

Research tools

Reading ability test

Selected segments of the *Ma'akav* reading test kit were administered (Shani, Lachman, Shalem, Habet, & Zieger, 2003) in order to assess the initial reading ability of the two research groups. These test segments included the following reading measures: Number of words per minute, percentage of errors per minute, speed and accuracy of text reading and percentage of errors in text reading (the test–retest reliabilities ranged from 0.62 to 0.92).

The educational digital book

The educational digital book was specially developed for the current study and is not part of the school curriculum; its content focused on winter puddles. The book includes instructions for the reader and seven reading screens, with an average of 40 words per screen. Each screen contains two Areas of Interest (AOIs)—text on the right side of the screen and a photograph on the left side (reading direction in Hebrew is from right to left). The expository text was compiled mainly from articles taken from a children's nature magazine and adapted to the participants' age and reading level. Three primary school teachers confirmed that the text, its content, illustrations, vocabulary level and text length were suitable for this age group.

Two modes of the digital book were created: A 'static' and a 'highlighted' mode. The 'static' mode offered the entire text without any additions. The 'highlighted' mode included separate highlighting in red, timed for each word: one second for

regular words and half a second for one-syllable words. The highlighting times were determined according to the mean reading rate of readers with typical reading development, tested before the research began.

Eye movements

Eye movement measures

Eye movement measures were collected using SMI BeGaze™ Eye Tracking Analysis Software; they included fixations, transitions (number of movements from text to picture, and vice versa) and dwell time. Pearson correlations between the three measures revealed a high correlation between fixations and dwell time ($r = .94$, $p < .001$). We therefore employed the data on fixations and transitions only.

Eye tracking apparatus

Eye movements were recorded using the Senso Motoric Instruments (SMI) RED-m remote eye tracker that allows free head movements; sampling rate was 120 Hz, with a high accuracy rate of 0.5° (version 2.5 SMI, Berlin, Germany). A 9-point calibration cycle, programmed at the beginning of the experiment, provided spatial resolution of 0.1°. A camera with an infrared source was placed in front of the laptop screen, below eye level, and approximately 60 cm away from the participant. The digital book was presented on a 15.600 laptop screen; its monitor was driven at a refresh rate of 60 Hz with a resolution of 1366×768 pixels (laptop screen and monitor: Fujitsu, Japan), using the E-prime 2.0 software (Psychology Software Tools, Pittsburgh, PA) that controlled and recorded the temporal parameters of the digital book display and linked the timing of the presentation with the computer that recorded the eye movements.

Procedure

The procedure was comprised of three stages, conducted in two sessions. In the first stage, all potential participants were individually tested to assess their reading and cognitive level so as to determine their inclusion in the research. In the second stage, the participants were divided into groups of poor and typical readers and then randomly divided into two groups: Two experimental groups (poor and typical readers), in which the children engaged in reading with the highlighted mode of the educational digital book, and two control groups (poor and typical readers), in which the children were engaged in reading the book in its static mode. In the third stage (the second session), all the children read the digital book independently (once) while eye movements were registered.

Results

Fixation on highlighted text as a function of group

A dependent-samples t test demonstrated significant differences in fixations on the text when compared with the illustrations ($t = -121.54$, $p < .001$). The findings indicated that all the participants focused significantly more on the text area ($M = 94.77$; $SD = .35$) than on the illustration area ($M = 5.22$; $SD = .35$). A $2 \times 2 \times 2$ MANOVA (groups x digital book mode x fixation area) yielded significant differences in the number of fixations on the text area in the digital book mode (highlighted or static) ($F(1, 57) = 4.52$, $p < .01$, $\eta^2 = .007$). The mean of all participants obtained ($M = 95.53$; $SD = 2.80$) indicated more fixations on the text area in the highlighted mode when compared with the static mode ($M = 94.03$; $SD = 2.80$). An analysis of variance indicated an interaction effect between the digital book mode (highlighted or static) and the reading group (poor or typical readers). However, the variance obtained between the groups was only marginally statistically significant ($F(1, 57) = 3.04$, $p = .08$, $\eta^2 = .05$). An interaction effect was found for fixations in the text area ($F(1, 57) = 3.04$, $p = .08$, $\eta^2 = .05$). We should note that the current research design involved two independent samples. We therefore chose a between-subject design. Given these limitations, we could not construct a measure for comparing improvement in reading between the highlighted and the static mode. Hence, we were unable to estimate the correlation between eye movements and literacy.

Separate independent sample t tests were calculated for the purpose of comparing fixations on the text area and on the illustration area between the digital book modes (highlighted or static) by group, poor and typical readers ($t = 3.12$, $p < .05$). Significant differences were found among poor readers in the number of fixations, such that more fixations on the text area were found in the highlighted mode ($M = 96.23$; $SD = 2.72$) when compared with the static mode ($M = 93.48$; $SD = 2.05$). This difference is represented in Fig. 1. Furthermore, among poor readers, significant differences were found in the number of fixations with reference to the illustrations area, such that more fixations were found in the static mode ($M = 6.52$; $SD = 2.05$) when compared to the highlighted mode ($M = 3.77$; $SD = 2.72$). Among typical readers, no significant differences in fixations on the text area ($t = -.25$, $p > .05$) were found between the highlighted mode ($M = 94.83$; $SD = 2.80$) and the static mode ($M = 94.56$; $SD = 3.33$). Table 2 presents the means and standard deviations of the percentages of fixations in the highlighted mode compared to the static mode of the educational digital book for poor and typical readers.

Transitions in highlighted text as a function of group

The sum of the transitions between the AOIs (text and illustration), that is, transitions from the illustration area to the text area and vice versa, was calculated for each participant. Since a correlation of nearly 1.0 exists between the directions of the transitions, the data presented refer solely to the mean transitions from the text

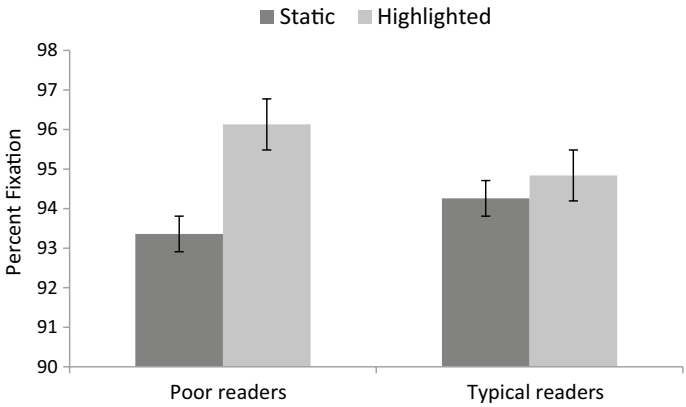

Fig. 1 Percent fixations on the text area in the highlighted mode compared to the static mode in the educational digital book among the research groups (poor and typical readers)

area to the illustration area. A 2×2 ANOVA (groups×digital book mode) was performed in order to test differences in the number of transitions between the AOIs (text and illustration) between the research groups (poor and typical readers). A significant difference in transitions between AOIs was found between poor and typical readers ($F(1, 57)=4.17$, $p<.05$, $\eta^2=.07$), such that the mean number of transitions among the poor readers ($M=4.21$; $SD=1.87$) was higher than among the typical readers ($M=3.18$; $SD=2.17$). A significant difference was also found between the two digital book modes (highlighted or static) ($F(1, 57)=3.90$, $p<.05$, $\eta^2=.05$), with a higher mean number of transitions in the highlighted mode ($M=4.20$; $SD=2.31$) compared to the static mode ($M=3.20$; $SD=1.74$). A significant interaction of group (poor or typical readers) x digital book mode (highlighted or static) was also found ($F(1, 57)=5.57$, $p<.05$, $\eta^2=.09$); see Fig. 2.

It can be seen from Fig. 2 that a significant difference was found in the number of transitions between AOIs when comparing the highlighted mode to the static mode only among the typical readers, where more transitions between AOIs were found in the highlighted mode ($M=4.28$; $SD=2.61$) than in the static mode ($M=2.16$;

Table 2 Fixations by the two groups in the highlighted mode compared to the static mode: means and standard deviations

	E-book mode	Text Area		Illustration area	
		M	*SD*	*M*	*SD*
Poor readers (n=30)	Highlighted	*96.23	2.72	*3.77	2.72
	Static	*93.48	2.05	*6.52	2.05
Typical readers (n=31)	Highlighted	94.83	2.80	5.16	2.80
	Static	94.56	3.33	5.44	3.33

*$p<.05$

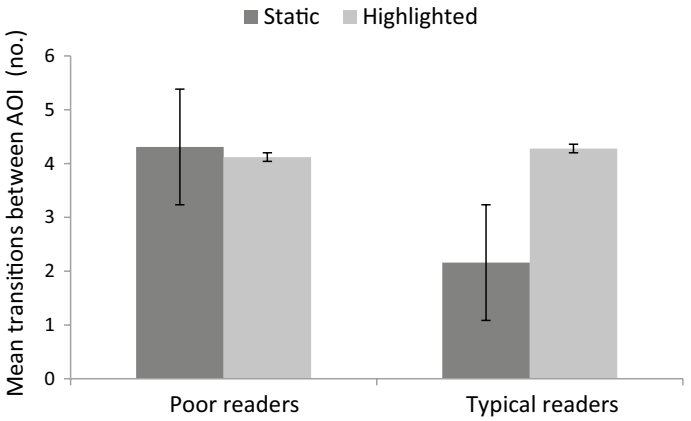

Fig. 2 Transitions between areas of interest (text and illustration) in the highlighted mode compared to the static mode among the research groups (poor and typical readers)

$SD = .86$), ($F(1, 57) = 9.55$, $p < .01$, $\eta^2 = .14$). In contrast, among the poor readers, no difference was found in the mean number of transitions in the highlighted mode ($M = 4.12$; $SD = 2.06$) when compared to the static mode of the digital book ($M = 4.31$; $SD = 1.73$); ($F(1, 57) = .07$, $p > .05$). Among the poor readers, the mean number of transitions in both digital book modes was found to be similar to the mean obtained for the highlighted mode of the digital book among the typical readers.

Discussion

The primary aim of the current study was to acquire additional knowledge regarding the process of reading a highlighted expository text at the word level in the context of an educational digital book when the text is accompanied by an illustration, with a focus on poor readers. An eye tracking methodology was adopted to obtain online reflections of the natural reading process exhibited by all four study groups. We should note that the eye tracking technology chosen was selected because it enables the assessment of reading processes by means of objective cognitive data gathered during online learning sessions.

The first research question addressed the identification of hypothesized differences in reading a highlighted compared to a static text in a digital book by poor when compared to typical readers. The findings indicate, for the first time, that highlighting a digital text increases poor readers' attention to the text, indicated by the greater percentage of fixations on the highlighted than on the static text. Based on previous studies among typical readers (Mason, Tornatora, & Pluchino, 2015; Rayner, 1998; Zawoyski et al., 2015), we suggest that the greater attention of poor readers may reflect the integration of content when focusing on highlighted text. A higher percentage of fixations at first reading may thus indicate greater exposure to the written text, a process that may support improved reading (Rayner, 1998). Greater attention to highlighted text may also reflect the longer process needed to

follow highlighted text by poor readers, who read more slowly than do typical readers (Zawoyski et al., 2015). It remains unclear as to whether a higher percentage of fixations on highlighted text by poor readers increase their reading and literacy levels. Further studies are needed to examine the extent to which exposure to different modes of highlighting digital texts promote those skills.

Whereas the research findings indicate the influence of highlighting text on poor readers, no indications were found for such influence on typical readers, that is, no changes were observed in the latter's fixations on highlighted versus static text. These findings are consistent with those obtained by Roy-Charland et al. (2015) with children younger than those participating in the current research. Roy-Charland et al. found that typical readers made more fixations on printed text in the highlighted versus the static condition when reading both easy and difficult books. We should note here that the children taking part in the research reported, although older, exhibit reading difficulties that place them at a reading level similar to that of the children tested in the Roy-Charland et al. research. The current findings also reveal similar fixation patterns among the two age groups—first- to second-grade typical readers and third- to fifth-grade poor readers—when reading highlighted text. This similarity may reflect the longer time poor readers in a broader chronological age group require to acquire reading skills when compared to the time required by their typical reading peers.

While innovative with respect to poor readers, these findings support those obtained in prior studies on the reading and learning processes of students with typical reading skills (Luke et al., 2015; Navarro et al., 2015).

Similar to other studies, the current findings indicate that written text comprises the center of attention for all readers, poor and typical, and that the greater focus on this area reflects common learning processes (measured by fixations) (Hannus & Hyona, 1999; Moore & Scevak, 1997; Schmidt-Weigand, Kohnert, & Glowalla, 2010).

A second finding of this study indicates a higher frequency of transitions between AOIs (text and illustration) among all readers when reading an educational digital book in the highlighted as compared with the static mode. However, it is important to note that poor readers exhibited transitions similar in number to that of typical readers only in the highlighted mode; in the static mode, poor readers made a greater number of transitions. It can therefore be concluded that poor readers tend to make numerous transitions in any mode, highlighted or static. Consistent with the findings in Schnotz et al. (2014), a greater number of transitions from text to figure or illustration were observed as the text's difficulty increased at all levels of learning. Since poor readers make numerous transitions, regardless of highlighting, it may be assumed that they need the support offered by the illustration in order to understand text they have difficulty reading. Based on previous findings from research with typical readers (Mason, Pluchino et al., 2013; Mason, Tornatora et al., 2013; Mason et al., 2015; Schnotz et al., 2014; Schroeder et al., 2011) the present study's findings indicate that poor readers perceive illustrations as sources of information. Support for this conclusion can be found in the approach positing that instructional illustrations, such as graphic representations, are better understood by readers than is written text alone.

One explanation for the differences in the reading strategies of poor and typical readers is based on the Instance Theory of Automatization (LaBerge & Samuels, 1974). This theory states that readers must achieve automatic reading (a continuous, independent process) during the preliminary, basic stages of text processing (e.g., word decoding and recognition) before they can direct their attention to more-advanced processes (LaBerge & Samuels, 1974). We can therefore conclude that poor readers, that is, those who have not achieved automatization of reading, will have greater difficulty in understanding a text when compared to typical readers capable of automatically decoding texts. We can therefore expect poor readers to initiate a higher percentage of fixations on the highlighted text and more transitions from text to illustration for the sake of improving their understanding, a learning strategy requiring great effort.

Another possible explanation for these findings may lie in poor readers' inability to optimally switch their focus from text to illustration (and vice versa) for purposes of comprehension. This may imply that the visual preferences of poor readers reflect reading strategies that do not contribute to understanding. This conclusion is based on previous research findings indicating that unskilled readers have limited metacognitive knowledge about reading (Paris & Winograd, 1990), that they monitor their understanding less and remember less of what they read (Flavell, 1979).

In addition, and quite surprisingly, text highlighting induced more transitions among typical readers that did static text, actions that may improve understanding of the text. Those readers with typical reading levels may, moreover, better allocate the resources needed to improve scanning the text as well as the illustrations screened when searching for information. The current findings regarding eye movements link children's visual behavior when reading highlighted text with their reading level: Taken together, the current findings on fixations and transitions clearly indicate that poor readers apply reading strategies and resource allocation patterns when reading highlighted text with illustrations (a greater percentage of fixations and a higher number of transitions) that differ from those of typical readers (no differences in fixation in situations of highlighted versus static text but more transitions when reading highlighted text).

Conclusion, limitations and future research

The use of multimedia devices in the schools must be prudent; the findings of the current study can support the demanded decision making by providing additional knowledge on multimedia learning. Previous studies have focused on educational products (such as content questions) primarily among typical readers (e.g., Jian, 2015; Luke et al., 2015), reading strategies (Mason, Pluchino et al., 2013; Mason, Tornatora et al., 2013) and electronic strategies coordinated with narration for the purpose of channeling attention to print (Roy-Charland et al., 2015). By directing research to poor readers as well, the current research offers a more precise description of the role of highlighting (a digital feature) when directing the attention of this group of readers to text. The findings therefore contribute to the specification of reading processes among poor as well as typical readers.

The findings thus support the hypothesis that highlighting directs the poor reader's attention to the text more than does the static mode, even without adult mediation. In addition, the same findings imply that poor readers may cull information from text and illustrations in a manner different from that of typical readers. Programs targeting metacognitive awareness, regulation and monitoring should therefore be investigated (Moore & Scevak, 1997).

The current study's findings also have practical implications. First, having shown that highlighted stimulates a higher percentage of fixations on text among poor readers, we recommend that book designers and educators incorporate the option of highlighting the text at the word level, a feature that better stimulates poor readers to focus on the text. Second, the finding that poor readers make numerous transitions between text and illustrations in the static as well as in the highlighted mode suggests the necessity of introducing pictures and other illustrations into primary school textbooks.

We should note that despite this study's importance, its limitations must also be taken into account. First, our main research goal was to explore whether highlighting text in educational electronic books would focuses eye movement among poor readers. To achieve this purpose, we adopted a between-subject research design. This design's limitations lie in its inability to provide reading improvement criteria and, subsequently, do not permit estimation of the correlation between changes in literacy and changes in eye movements. In order to obtain such results, a within-subject research design must be constructed and applied.

Second, the current study did not attempt to examine reading outcomes. The conclusions are based on the results of a single reading of only one digital book. We therefore recommend that three readings of digital books be included in future studies (Zawoyski et al., 2015) in order to test for the influence of repeated readings. Hence, despite the findings indicating clear differences in the reading strategies adopted by poor as opposed to typical readers, we recommend conducting follow-up research to investigate the relationship between fixation on highlighted text and literacy gains.

Third, the rate of highlighting words rested on the mean reading rate of typical readers, and was applied uniformly for all the participants. Future studies should test whether adjustment of the highlighting rate can contribute to improved reading by poor readers as well.

Conclusion

In conclusion, as part of the trend toward greater inclusion of digital content into education curricula, it is important to assess each digital tool for its effectiveness and advantages. The current research findings do show a higher percentage of fixations (i.e., greater attention) among poor third- to fifth-grade readers when reading a highlighted versus a static digital text, similar to that of typical first- to third-grade beginning readers (Roy-Charland et al., 2015).

As the features of digital teaching resources (e.g., highlighting) come to light, the educational team will be able to direct these resources to students' individual needs,

especially in the case of poor readers (Gilmour, Fuchs, & Wehby, 2019). Moreover, because technology progresses so rapidly, we suggest expanding collaboration between pedagogy and research with the aim of assisting educators to evaluate multimedia materials and adapt them to students. By indicating that a single exposure to a highlighted text in an educational digital book contributes to the visual focusing and attention of poor readers even without adult mediation, the current research has added to the knowledge required. The development of such materials for readers in the third to the fifth grade, when reading skills have been acquired but literacy gaps tend to widen, it is of utmost importance to support learning achievements on the one hand and to recruit the motivation of children with difficulties on the other.

References

Aaron, P. G., Joshi, R. M., Gooden, R., & Bentum, K. E. (2008). Diagnosis and treatment of reading disabilities based on the component model of reading: An alternative to the discrepancy model of LD. *Journal of Learning Disabilities, 41*(1), 67–84. https://doi.org/10.1177/0022219407310838.

Ainsworth, S. (2006). DeFT: A conceptual framework for considering learning with multiple representations. *Learning and Instruction, 16*(3), 183–198. https://doi.org/10.1016/j.learninstruc.2006.03.001.

Brookshire, J., Scharff, L. F., & Moses, L. E. (2002). The influence of illustrations on children's book preferences and comprehension. *Reading Psychology, 23*(4), 323–339. https://doi.org/10.1080/713775287.

Cain, K., Oakhill, J., & Bryant, P. (2004). Children's reading comprehension ability: Concurrent prediction by working memory, verbal ability, and component skills. *Journal of Educational Psychology, 96*(1), 31–42. https://doi.org/10.1037/0022-0663.96.1.31.

Catts, H. W., Compton, D., Tomblin, J. B., & Bridges, M. S. (2012). Prevalence and nature of late-emerging poor readers. *Journal of Educational Psychology, 104*(1), 166–196. https://doi.org/10.1037/a0025323.

Catts, H. W., & Hogan, T. P. (2002). The fourth-grade slump: Late emerging poor readers. In *Poster presented at the annual conference of the society for the scientific study of reading*, Chicago, IL.

Chall, J. (1983). *Stages of reading development*. New York: McGraw-Hill.

Chall, J. S., & Jacobs, V. A. (2003). The classic study on poor children's fourth-grade slump. *American Educator, 27*(1), 14–15.

Clifton, C., Ferreira, F., Henderson, J. M., Inhoff, A. W., Liversedge, S. P., Reichle, E. D., et al. (2016). Eye movements in reading and information processing: Keith Rayner's 40-year legacy. *Journal of Memory and Language, 86,* 1–19. https://doi.org/10.1016/j.jml.2015.07.004.

de Jong, M. T., & Bus, A. G. (2003). How well suited are electronic books to supporting literacy? *Journal of Early Childhood Literacy, 3*(2), 147–164. https://doi.org/10.1177/14687984030032002.

Diakidoy, I. A. N., Stylianou, P., Karefillidou, C., & Papageorgiou, P. (2005). The relationship between listening and reading comprehension of different types of text at increasing grade levels. *Reading Psychology, 26*(1), 55–80. https://doi.org/10.1080/02702710590910584.

Doty, D. E., Popplewell, S. R., & Byers, G. O. (2001). Interactive CD-ROM storybooks and young readers' reading comprehension. *Journal of Research on Computing in Education, 33*(4), 374–384. https://doi.org/10.1080/08886504.2001.10782322.

Duke, N. K. (2000). 3.6 minutes per day: The scarcity of informational texts in first grade. *Reading Research Quarterly, 35*(2), 202–224. https://doi.org/10.1598/rrq.35.2.1.

Eden, S., Shamir, A., & Fershtman, M. (2012). Making a difference: Using laptops as a support for spelling improvement among students with learning disability. In A. Shamir & O. Korat (Eds.), *Technology as a support for literacy achievements for children at risk* (pp. 199–209). Dordrecht: Springer. https://doi.org/10.1007/978-94-007-5119-4_13.

Etmanskie, J. M., Partanen, M., & Siegel, L. S. (2014). A longitudinal examination of the persistence of late emerging reading disabilities. *Journal of Learning Disabilities, 49*(1), 21–35. https://doi.org/10.1177/0022219414522706.

Felvegi, E., & Matthew, K. I. (2012). eBooks and literacy in K–12 Schools. *Computers in the Schools, 29*(1–2), 40–52. https://doi.org/10.1080/07380569.2012.651421.

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive–developmental inquiry. *American Psychologist, 34*(10), 906–911. https://doi.org/10.1037/0003-066X.34.10.906.

Fletcher, J. M. (2006). Measuring reading comprehension. *Scientific Studies of Reading, 10*(3), 323–330. https://doi.org/10.1207/s1532799xssr1003_7.

Gilmour, A. F., Fuchs, D., & Wehby, J. H. (2019). Are students with disabilities accessing the curriculum? A meta-analysis of the reading achievement gap between students with and without disabilities. *Exceptional Children, 85*(3), 329–346. https://doi.org/10.1177/0014402918795830.

Giuliani, F., & Schenk, F. (2015). Vision, spatial cognition and intellectual disability. *Research in Developmental Disabilities, 37,* 202–208. https://doi.org/10.1016/j.ridd.2014.11.015.

Hannus, M., & Hyona, J. (1999). Utilization of illustration during learning of science textbook passages among low-and-high ability children. *Contemporary Educational Psychology, 24*(2), 95–123. https://doi.org/10.1006/ceps.1998.0987.

Israeli Ministry of Education. (2017). *Development of the educational system: Facts and data* [In Hebrew]. Retrieved January 17, 2018 from http://meyda.education.gov.il/files/MinhalCalcala/uvdot_venetunim_stat_2017.pdf.

Israeli Ministry of Education, National Authority for Measurement and Evaluation in Education (RAMA). (2016). *PIRLS 2016: Progress in international reading literacy study*. Retrieved October 1, 2019 from http://www.meyda.education.gov.il/files/Rama/PIRLS_2016_REPORT.pdf.

Jian, Y. C. (2015). Fourth graders' cognitive processes and learning strategies for reading illustrated biology texts: Eye movement measurements. *Reading Research Quarterly, 51*(1), 93–109. https://doi.org/10.1002/rrq.125.

Joseph, H. S., Nation, K., & Liversedge, S. P. (2013). Using eye movements to investigate word frequency effects in children's sentence reading. *School Psychology Review, 42*(2), 207–222.

Korat, O. (2010). Reading electronic books as a support for vocabulary, story comprehension and word reading in kindergarten and first grade. *Computers & Education, 55*(1), 24–31. https://doi.org/10.1016/j.compedu.2009.11.014.

Korat, O., Levin, I., Ben-Shabat, A., Shneor, D., & Bokovza, L. (2014a). Dynamic versus static dictionary with and without printed focal words in e-book reading as facilitator for word learning. *Reading Research Quarterly, 49*(4), 371–386. https://doi.org/10.1002/rrq.78.

Korat, O., & Shamir, A. (2004). Do Hebrew electronic books differ from Dutch electronic books? A replication of a Dutch content analysis. *Journal of Computer Assisted Learning, 20*(4), 257–268. https://doi.org/10.1111/j.1365-2729.2004.00078.x.

Korat, O., Shamir, A., & Segal-Drori, O. (2014b). E-books as a support for young children's language and literacy: The case of Hebrew-speaking children. *Early Child Development and Care, 184*(7), 998–1016. https://doi.org/10.1080/03004430.2013.833195.

Labbo, L., & Kuhn, M. (2000). Weaving chains of affect and cognition: A young child's understanding of CD-ROM talking books. *Journal of Literacy Research, 32*(2), 187–210. https://doi.org/10.1080/10862960009548073.

LaBerge, D., & Samuels, S. J. (1974). Toward a theory of automatic information processing in reading. *Cognitive Psychology, 6*(2), 293–323. https://doi.org/10.1016/0010-0285(74)90015-2.

Lai, M. L., Tsai, M. J., Yang, F. Y., Hsu, C. Y., Liu, T. C., Lee, S. W. Y., et al. (2013). A review of using eye-tracking technology in exploring learning from 2000 to 2012. *Educational Research Review, 10,* 90–115. https://doi.org/10.1016/j.edurev.2013.10.001.

Lau, K. L., & Chan, D. W. (2003). Reading strategy use and motivation among Chinese good and poor readers in Hong Kong. *Journal of Research in Reading, 26*(2), 177–190. https://doi.org/10.1111/1467-9817.00195.

Lefever-Davis, S., & Pearman, C. (2005). Early readers and electronic texts: CD-ROM storybook features that influence reading behaviors. *The Reading Teacher, 58*(5), 446–454. https://doi.org/10.1598/RT.58.5.4.

Lowe, R. K., & Boucheix, J. M. (2007). Eye tracking as a basis for animation design. In *Paper presented at the bi-annual meeting of the European association of research on learning and instruction*, Budapest, HU.

Luke, S. G., Henderson, J. M., & Ferreira, F. (2015). Children's eye-movements during reading reflect the quality of lexical representation: An individual differences approach. *Journal of Experimental Psychology. Learning, Memory, and Cognition, 41,* 1675–1683. https://doi.org/10.1037/xlm0000133.

Mason, L., Pluchino, P., Tornatora, M. C., & Ariasi, N. (2013a). An eye-tracking study of learning from science text with concrete and abstract illustrations. *The Journal of Experimental Education, 81,* 356–384. https://doi.org/10.1080/00220973.2012.727885.

Mason, L., Tornatora, M. C., & Pluchino, P. (2013b). Do fourth graders integrate text and picture in processing and learning from an illustrated science text? Evidence from eye-movement patterns. *Computers & Education, 60*(1), 95–109. https://doi.org/10.1016/j.compedu.2012.07.011.

Mason, L., Tornatora, M. C., & Pluchino, P. (2015). Integrative processing of verbal and graphical information during re-reading predicts learning from illustrated text: An eye-movement study. *Reading and Writing, 28*(6), 851–872. https://doi.org/10.1007/s11145-015-9552-5.

Mayer, R. E. (2009). *Multimedia learning* (2nd ed.). New York: Cambridge University Press.

McKeown, M. G., & Beck, I. L. (2006). Encouraging young children's language interactions with stories. In D. K. Dickinson & S. B. Neuman (Eds.), *Handbook of early literacy research* (Vol. 2, pp. 281–294). New York, NY: The Guilford Press.

Miellet, S., Vizioli, L., He, L., Zhou, X., & Caldara, R. (2013). Mapping face recognition information use across cultures. *Frontiers in Psychology, 4,* 1–12. https://doi.org/10.3389/fpsyg.2013.00034.

Moore, P. J., & Scevak, J. J. (1997). Learning from texts and visual aids: A developmental perspective. *Journal of Research in Reading, 20*(3), 205–223. https://doi.org/10.1111/1467-9817.00033.

National Reading Panel, US National Institute of Child Health, & Human Development. (2000). *Teaching children to read: An evidence-based assessment of the scientific research literature on reading and its implications for reading instruction*. National Institute of Child Health and Development. Retrieved January 30, 2018 from https://www.nichd.nih.gov/sites/default/files/publications/pubs/nrp/Documents/report.pdf.

Navarro, O., Molina, A. I., Lacruz, M., & Ortega, M. (2015). Evaluation of multimedia educational materials using eye tracking. *Procedia-Social and Behavioral Sciences, 197,* 2236–2243. https://doi.org/10.1016/j.sbspro.2015.07.366.

Neuman, S. B. (2009). The case for multi-media presentation in learning: A theory of synergy. In A. G. Bus & S. B. Neuman (Eds.), *Multimedia and literacy development: Improving achievement for young learners* (pp. 44–56). New York: Taylor & Francis.

Nitzan-Tamar, O., Kramarski, B., & Vakil, E. (2016). Eye movement patterns characteristic of cognitive style. *Experimental Psychology, 63,* 159–168. https://doi.org/10.1027/1618-3169/a000323.

Olson, R. K., Kliegl, R., Davidson, B. J., & Foltz, G. (1985). Individual and developmental differences in reading disability. In G. MacKinnon & T. Waller (Eds.), *Reading research: Advances in theory and practice* (Vol. 4, pp. 1–64). London: Academic Press.

Ozcelik, E., Karakus, T., Kursun, E., & Cagiltay, K. (2009). An eye tracking study of how color coding affects multimedia learning. *Computer and Education, 53*(2), 445–453. https://doi.org/10.1016/j.compedu.2009.03.002.

Paris, S. G., & Winograd, P. (1990). Promoting metacognition and motivation of exceptional children. *Remedial and Special Education, 11*(6), 7–15. https://doi.org/10.1177/074193259001100604.

Pearman, C. J. (2008). Independent reading of CD-ROM storybooks: Measuring comprehension with oral retellings. *The Reading Teacher, 61*(8), 594–602. https://doi.org/10.1598/RT.61.8.1.

Peng, P., Fuchs, D., Fuchs, L. S., Elleman, A. M., Kearns, D. M., Gilbert, J. K., et al. (2018). A longitudinal analysis of the trajectories and predictors of word reading and reading comprehension development among at-risk readers. *Journal of Learning Disabilities, 52*(3), 195–208. https://doi.org/10.1177/0022219418809080.

Raven, J. C. (1964). *Colored progressive matrices set A, AB, B*. Oxford: Oxford Psychologists Press.

Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological Bulletin, 124,* 372–422. https://doi.org/10.1037/0033-2909.124.3.372.

Rayner, K., Chace, K. H., Slattery, T. J., & Ashby, J. (2006). Eye movements as reflections of comprehension processes in reading. *Scientific Studies of Reading, 10*(3), 241–255. https://doi.org/10.1207/s1532799xssr1003_3.

Roy-Charland, A., Perron, M., Boulard, J., Chamberland, J., & Hoffman, N. (2015). "If I point, do they look?": The impact of attention–orientation strategies on text exploration during shared book reading. *Reading and Writing: An Interdisciplinary Journal, 28,* 1285–1305. https://doi.org/10.1007/s11145-015-9571-2.

Roy-Charland, A., Saint-Aubin, J., & Evans, M. A. (2007). Eye movements in shared book reading with children from kindergarten to Grade 4. *Reading and Writing: An Interdisciplinary Journal, 20*(9), 909–931. https://doi.org/10.1007/s11145-007-9059-9.

Sahin, A. (2013). The effect of text types on reading comprehension. *Mevlana International Journal of Education, 3*(2), 57–67. https://doi.org/10.13054/mije.13.27.3.2.

Scarborough, H. S. (1998). Predicting the future achievement of second graders with reading disabilities: Contributions of phonemic awareness, verbal memory, rapid naming, and IQ. *Annals of Dyslexia, 48*(1), 115–136. https://doi.org/10.1007/s11881-998-0006-5.

Schmidt-Weigand, F., Kohnert, A., & Glowalla, U. (2010). A closer look at split visual attention in system-and self-paced instruction in multimedia learning. *Learning and Instruction, 20*(2), 100–110. https://doi.org/10.1016/j.learninstruc.2009.02.011.

Schnotz, W., Ludewig, U., Ullrich, M., Horz, H., McElvany, N., & Baumert, J. (2014). Strategy shifts during learning from texts and pictures. *Journal of Educational Psychology, 106,* 974–989. https://doi.org/10.1037/a0037054.

Schroeder, S., Richter, T., McElvany, N., Hachfeld, A., Baumert, J., Schnotz, W., et al. (2011). Teachers' beliefs, instructional behaviors, and students' engagement in learning from texts with instructional pictures. *Learning and Instruction, 21,* 403–415. https://doi.org/10.1016/j.learninstruc.2010.06.001.

Shamir, A., & Korat, O. (2006). How to select CD-ROM storybooks for young children: The teacher's role. *The Reading Teacher, 59,* 532–543. https://doi.org/10.1598/RT.59.6.3.

Shamir, A., & Korat, O. (2007). Developing an educational e-book for fostering kindergarten children's emergent literacy. *Computers in the Schools, 24*(1–2), 125–143. https://doi.org/10.1300/J025v24n01_09.

Shamir, A., & Korat, O. (2013). Introduction: Technology as a support for literacy achievements for children at risk. In A. Shamir & O. Korat (Eds.), *Technology as a support for literacy achievements for children at risk* (pp. 1–8). Dordrecht: Springer. https://doi.org/10.1007/978-94-007-5119-4_1.

Shamir, A., & Korat, O. (2015). Educational electronic books for supporting emergent literacy of kindergarteners at-risk for reading difficulties—What do we know so far? *Computers in the Schools, 32*(2), 105–121. https://doi.org/10.1080/07380569.2015.1027868.

Shamir, A., Korat, O., & Barbi, N. (2008). The effects of CD-ROM storybook reading on low SES kindergarteners' emergent literacy as a function of learning context. *Computers & Education, 51,* 354–367. https://doi.org/10.1016/j.compedu.2007.05.010.

Shamir, A., & Maor, R. (2019). E-Books for promoting vocabulary among students with intellectual disability as opposed to children with learning disability: Can repeated reading make a difference? *Journal of Cognitive Education and Psychology, 17*(2), 164–177. https://doi.org/10.1891/1945-8959.17.2.164.

Shamir, A., & Margalit, M. (2011). Special issue: Technology and students with special educational needs: New opportunities and future directions. *European Journal of Special Needs Education, 26,* 279–282. https://doi.org/10.1080/08856257.2011.593816.

Shamir, A., Segal-Drori, O., & Goren, I. (2018). Educational electronic book activity supports language retention among children at risk for learning disabilities. *Education and Information Technologies, 3,* 1–22. https://doi.org/10.1007/s10639-017-9653-7.

Shani, M., Lachman, D., Shalem, T., Bahet, A., & Zieger, T. (2003). *Ma'akav: Mapping of reading and writing according to national norms: Manual for the teacher in elementary school [Hebrew]*. Holon: Yesod.

Snow, C. E., & Matthews, T. J. (2016). Reading and language in the early grades. *The Future of Children, 26*(2), 57–74. https://doi.org/10.1353/foc.2016.0012.

Solan, H. A. (1985). Deficient eye-movement patterns in achieving high school students three case histories. *Journal of Learning Disabilities, 18*(2), 66–70. https://doi.org/10.1177/002221948501800201.

Takacs, Z. K., & Bus, A. G. (2016). Benefits of motion in animated storybooks for children's visual attention and story comprehension. An eye-tracking study. *Frontiers in Psychology, 7,* 1591. https://doi.org/10.3389/fpsyg.2016.01591.

Vellutino, F. R., Fletcher, J. M., Snowling, M. J., & Scanlon, D. M. (2004). Specific reading disability (dyslexia): What have we learned in the past four decades? *Journal of Child Psychology and Psychiatry, 45*(1), 2–40. https://doi.org/10.1046/j.0021-9630.2003.00305.x.

Vila, J., & Gomez, Y. (2016). Extracting business information from graphs: An eye tracking experiment. *Journal of Business Research, 69,* 1741–1746. https://doi.org/10.1016/j.jbusres.2015.10.048.

Zawoyski, A. M., Ardoin, S. P., & Binder, K. S. (2015). Using eye tracking to observe differential effects of repeated readings for second-grade students as a function of achievement level. *Reading Research Quarterly, 50*(2), 171–184. https://doi.org/10.1002/rrq.91.