Aliteracy : causes and solutions

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Chapter 5

The effect of digital guidance on Fifth Graders' reading motivation and incidental vocabulary learning

Abstract

In this digital era, a fundamental challenge is to design additions to digital reading materials that help children improve their reading skills. Since reading books is challenging for many students in fifth grade, particularly for a minority genetically susceptible to attention problems, the researchers hypothesized that guidance from a digital Pedagogical Agent (PA) could improve students' reading motivation and incidental vocabulary learning. Using a sample of 147 fifth grade students, the researchers carried out a randomized control trial (RCT) with three groups of students reading: (1) hardcopy (print) books, (2) digital books without a PA, and (3) digital books with a PA. For the subsample of students with a genetic predisposition to attention problems, the PA condition resulted in significantly more incidental vocabulary learning. For the whole sample, there were no significant effects of the digitized texts or the PA.

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Although recreational reading is vital for reading skill development, a substantial proportion of students stop reading recreationally late in primary school (Nielen & Bus, 2013). As students loose interest in reading at this early age, their reading skill development levels off (Chall, 1983). Through independent reading students not only acquire an autonomous orthographic lexicon (Share, 2008), but also acquire new vocabulary and comprehension skills (Mol & Bus, 2011) - all necessary for continuation of reading growth. Without sufficient practice these skills remain underdeveloped and students experience a downward causal spiral of disinterest and decreasing time spent reading (Mol & Bus, 2011). A substantial proportion – about half of adolescents - reported that they almost never read for enjoyment (OECD, 2010). It is easy to predict serious consequences of what has been termed 'aliteracy' (Boorstin, 1984) – poor reading due to lack of practice - not only for individual students' academic and professional success (Gottfried, Schlackman, Gottfried, & Boutin-Martinez, 2015; Mol & Bus, 2011; Notten, 2011; OECD, 2010; Taylor, 2013), but also for society as a whole. There is a serious risk that an underclass of people with low literacy skills is emerging, people missing the literacy skills needed to function as full members in contemporary society, and in today's information-age 21st century economy (EU High Level Group of Experts on Literacy, 2012).

Kirschner, Sweller and Clark's (2006) argument that unguided or minimally guided instructional approaches are less effective than guided instruction may also apply to the domain of reading. For many students reading comes too early, as an activity that they feel compelled to practice without support. Especially when students fail to understand age-appropriate reading materials when unguided, reading may be frustrating and this may eventually result in withdrawal from reading. For optimal reading practice, after the initial stage of intensive reading instruction in elementary school, we need to find ways to guide students while reading text. In the current study the researchers explored the potential of a Pedagogical Agent (PA) in digitized books to provide encouragement to foster sustained effort during reading. The researchers modeled the PAs in the books on aspects of adult scaffolding that have proved to sustain reading of fiction, especially showing interest (Teale et al., 2013).

Guidance during reading

Effective adult tutors typically show interest in the book that the child is reading. See experimental evidence from so-called SMART (Start Making A Reader Today; Baker, Gersten, & Keating, 2000) and similar studies (e.g., Rimm-Kaufman, Kagan, & Beyers, 1998). Students in these experiments were individually tutored while reading

for one or two hours a week by trained volunteers who initiated discussion about the book's focal theme, what happened in the book and why, and any relationship of events, characters and situations in the book to the reader's personal life. Students also stay more motivated to read when they have a chance to discuss books with their parents (Nielen & Bus, 2013).

The main aim of the current study was to test whether technology-enhanced fiction books (PAs in books) can foster sustained independent reading, in the fifth grade, resulting in more learning from reading, particularly in incidental vocabulary learning. The researchers focused on this age group because these students are able to read independently, but still require practice to strengthen their reading skills. PAs added to digital fiction books may encourage students to continue reading. Since anthropomorphic characters with spoken, as opposed to written, feedback are most effective (e.g., Heidig & Clarebout, 2011; Lusk & Atkinson, 2007), the PA in the current study was designed as an animated, speaking mouse with anthropomorphic features in appearance and speech. Unlike other digital reading tutors, the PA did not teach specific strategies, such as summarizing and self-questioning or identification of main ideas, followed by elaborate feedback, as students try to apply the learned strategy (e.g., Meyer et al., 2010; Sung, Chang, & Huang, 2008; Mich, Pianta, & Mana, 2013). Instead our PA was modeled after the emotional support human tutors may provide by showing interest and how the story relates to students' personal experiences (e.g., Baker et al., 2000; Rimm-Kaufmann et al., 1998). The PA in the current study complemented the student upon having read each chapter. It summarized main events in the story ("We know now that Faiza is angry with her best friend"), and stimulated students to relate the content of the story to personal events in their own lives ("Have you ever had a fight with your best friend?").

Digital versus print reading

Although several studies have compared digital reading with print reading, in terms of reading motivation and reading comprehension, the results are somewhat contradictory. Because of distractions, checking emails or social media for instance (Daniel & Woody, 2013), and difficulties with navigation (e.g., scrolling and the lack of an overview of the entire text; Mangen, Walgermo, & Brønnick, 2013), digital reading materials may sometimes result in failure to understand the structure of the text, which in turn negatively impacts reading speed, reading comprehension and reading motivation. However, Taylor (2011) found no differences between digital and print reading on reading comprehension, suggesting that reading of digital text may

be at least as good as reading print. Some studies, suggest that reading of digital texts may also present certain advantages. Reluctant readers may actually prefer to read digital books, because digital reading provides the opportunity to read 'easy' books without their peers noticing (Miranda, Williams-Rossi, Johnson, & McKenzie, 2011). Digital reading may also attract reluctant readers who have negative experiences with traditional reading materials (Tveit & Mangen, 2014). To address the influence of the medium on reading, the researchers compared reading of print books with reading of digital books. As opposed to most prior studies (see Miranda et al., 2011 for an exception), students in the current experiment could choose from a larger collection of books, instead of fragments. They read complete storybooks, which is more authentic and more comparable to students' normal reading activities than the reading activities in previous studies.

Differential susceptibility to pedagogical guidance

Despite large differences in the quality of instruction in school, most students perform reasonably well in a variety of school environments, whatever guidance they receive (e.g., Pressley, 2006). For these students learning outcomes may depend less on the quality of guidance. Building on the evolutionary-inspired proposition that some students may be more strongly affected—both for better and for worse—by the guidance they receive, it is to be expected that some vulnerable children's performance may strongly depend on the quality of guidance (Belsky, Bakermans-Kranenburg, & Van IJzendoorn, 2007). In particular, genetic markers appear to be strong indicators for children's susceptibility to educational input (see for an overview Bakermans-Kranenburg & Van IJzendoorn, 2011; Van IJzendoorn & Bakermans-Kranenburg, 2015). Carriers of the long variant of dopamine-related genes, the DRD4 7repeat allele, are particularly responsive not just to qualities of the social-emotional environment, but also to the way learning is guided (Kegel, Bus, & Van IJzendoorn, 2011; Plak, Kegel, & Bus, 2015).

Electric signals in the prefrontal lobe (the part of the human brain that inhibits inappropriate impulses and emotions), monitoring impulses from the limbic system (the part of the brain that generates emotions), may be less efficient in carriers of the long variant of the DRD4 gene. Susceptible children may therefore be easily distracted and have more problems with staying attentive while solving problems (Kegel et al., 2011). The researchers hypothesize that intensive, closely monitored, and individualized guidance offered by technology-enhanced reading materials may, more than traditional reading materials, direct children's attention toward the task

at hand (keep them on task) and enhance their learning potential. In experiments with 4-year-old emergent readers, studies revealed evidence for the hypothesis that a genetically susceptible group benefited more from technology-enhanced materials than their peers. Carriers of the long variant of the DRD4 genotype benefited more from intensive, closely monitored, and individualized guidance of a computer program, as compared to their genetically less susceptible peers (Kegel et al., 2011; Plak et al., 2015). In other words, there is evidence showing that technology can turn a putative "risk" group into a successful group, when the program is enhanced with individualized guidance. In the same vein, the current study tested whether a PA providing the perception of intensive, closely monitored, and individualized guidance while reading fiction books supports learning in a genetically susceptible group.

Current study

This study focused on fifth grade students reading storybooks during eight hours spread over two months in three experimental conditions, comprised of reading: (1) regular print storybooks, (2) digital storybooks without PA, and (3) digital storybooks with a PA providing guidance during reading. In addition, the researchers accounted for a genetic susceptibility that might influence intervention outcomes. The researchers chose incidental vocabulary learning as an outcome measure to test the effects of reading on learning, assuming that new vocabulary is one of the significant learning effects of reading (Swanborn & de Glopper, 1999) and may be a sensitive measure for the effects of book reading (Mol & Bus, 2011). The researchers also assessed children's interest in reading as indicator for intervention effects.

The following questions were addressed:

1. Does the medium through which books are presented influence reading motivation and vocabulary learning?
   Digital reading may be more motivating for reluctant readers (e.g., Tveit & Mangen, 2014) but may also hamper learning of new vocabulary especially when the text is a hypertext (e.g., Daniel & Woody, 2013).
2. Can a PA providing guidance during reading help students to become more motivated to read and learn more new vocabulary from reading?
3. Can a PA providing guidance during reading help students, with a genetic disposition to attention problems, become more motivated to read and learn more new vocabulary from reading?

The researchers hypothesized that a PA can support susceptible students' reading, and that low-susceptible individuals would be less affected by a PA (cf. Kegel et al., 2011; Plak et al., 2015).

Method

Design

A schematic overview of the design and time course of the study is presented in Table 1. For reading ability, the researchers obtained the results of a standardized reading comprehension test administered by teachers in all participating schools prior to the study. Researchers pre-tested and post-tested reading motivation and vocabulary learning. During the eight week intervention, students independently read about one hour per week in the classroom or another location in the school in one of the three study conditions: (1) reading self-selected hardcopy (print) books, (2) reading self-selected digital books without guidance from a PA, and (3) reading self-selected digital books with guidance from a PA. No more than six students per classroom were included to avoid difficulties with the availability of computers required for digital reading. Because many parents refused to let their children participate in the study, due to the genotyping, there were less than six students available in some classrooms. In that case, the researchers selected three students to participate. In each classroom one or two students were randomly assigned to each condition. Buccal swabs were used to collect saliva for genotyping. After the study the saliva was analyzed to make a distinction between genetically susceptible and low-susceptible individuals.

Table 1 *Schematic overview of the design and time course of the experiment.*

Study phase	Time	Activities / tests (administered by)
Pretest	Week 1	- Reading ability (teacher) - Saliva collection for genotyping (researcher) - Reading motivation (researcher) - Vocabulary (researcher)
Intervention	Week 2-9, 8 hours in total	- 3 or 6 students per classroom - Randomly divided over three conditions, 1 or 2 students per condition - Condition 1: Reading hardcopy (print) books - Condition 2: Reading digital books without guidance - Condition 3: Reading digital books with PA guidance
Posttest	Week 10	- Reading motivation (researcher) - Vocabulary (researcher)

Participants

Twenty-eight fifth grade classrooms in 21 regular primary education schools across the Netherlands participated in this study. On average the researchers received informed consent for 30% of students approached. The number of students with

informed consent per classroom varied from four to 17. After the selection of three or six participants per classroom, and the exclusion of one participant who missed the posttest, 146 participants (M_{age} = 11.10 years, SD = .53, range: 10.17-12.92 years) remained, 76, or 52.1%, of which were girls

Materials

Books. Thirteen Dutch age-appropriate books were selected for inclusion in the digital reading conditions (see Appendix A for an overview of the books). The books differed in length (51-197 pages), difficulty, and genre including a mix for boys' interests (e.g., horror), girls' (e.g., horses) and unisex themes (e.g., history). Researchers avoided the selection of popular children's books, books high on bestseller lists and books used to create television series or films, but rather selected recently published books, to prevent student familiarity with the books. Prior to the intervention, students recognized an average of 1.47 out of 13 of the target books (*SD* = 1.79). Books were selected from three difficulty levels so students would not read books inappropriate for their reading level. Each book selection contained seven books. Classification was partly based on the book's length ('above average' M_{pages} = 141, 'average' M_{pages} = 100 and 'below average' M_{pages} = 89) and partly on the first author's estimate of the difficulty of the books' content. The two criteria were not always concordant. For instance based on length, a book might fall in the 'average' category, but based on the content - only short, single line sentences and a simple story structure - it was placed in the 'easy' category. The first author's estimate was used when the criteria were not concordant. Students were assigned to a difficulty level based on their score on a standardized reading comprehension test (Weekers, Groenen, Kleintjes, & Feenstra, 2011). Students scoring in the lowest 25% were assigned to the easy selection (n = 20), students scoring average were assigned to the average selection (n = 48), and students scoring in the upper 25% to the difficult books selection (n = 29).

Infrastructure for delivery of digital books. For the delivery of the digital versions of the books, the researchers used a web-based application called IMapBook (Smith, 2013; www.imapbook.org) that has been used in prior studies on reading and vocabulary learning (Smith et al., 2013). IMapBook provides convenient authoring of game-like interaction in web-based books, user logins, customized bookshelves, interface in a variety of languages (English, Dutch, Spanish, Chinese, etc.) and tracking of participants reading, interaction and game-play behavior in the web-based books. In the current study, IMapBook enabled the researchers (non-programmers) to create interactive digital versions of the 13 Dutch fiction books appropriate for

nine- to 11-years-olds. The text and illustrations in the digital books were exactly the same as in the print versions. The number of words on pages of books was adjusted to avoid the need for scrolling. Students in the digital reading conditions had access to their own personal bookshelf by logging into the IMapBook website. They saw only the selection of books at their appropriate reading level. The IMapBook database registered how much time each child spent reading per session, in total, and on which pages, as well as a record of their interactions with the PA.

Pedagogical Agent Guidance. The guidance in the Digital-PA condition was provided by an animated mouse (see Figure 1 for a screen shot of the PA) with accompanying pre-recorded sound fragments. The PA that students liked a lot was designed to encourage the perception of intensive, closely monitored, and individualized guidance. Guidance was book-specific and always provided at the end of a chapter, 11 to 15 times in each book (preferably 15 times, but less if the book contained less than 15 chapters). Each cycle had a duration of 25-60 seconds and included the following components:

1. The mouse complimented the reader, for example: "You finished another chapter, great job!"
2. The mouse summarized the key information in the chapter(s) the reader has just finished to support reading comprehension: "Faiza has had an argument with her best friend."

Figure 1. A screen shot showing the animated Pedagogical Agent used in the study. The guidance is presented in written as well as oral form.

3. The mouse asks a question to increase the reader's engagement in the story: "Have you ever had a fight with your best friend?"
4. The reader responds to the question by clicking on one of the multiple-choice options (e.g., 'yes' or 'no').
5. The mouse responds to the reader's answer and encourages the reader to continue reading: "Alright, let's read on to find out what Faiza will do to solve the problem." The mouse's responses were general statements to encourage the reader to continue reading.

Procedure

In each classroom all parents were asked for informed consent for both participating in the reading experiment and genotyping based on saliva. After the pretest was administered, the participants read books for eight hours, approximately one hour per week, for eight weeks. In the digital reading conditions, the progress was registered in a database that was only accessible by the researcher. This information enabled the researcher to check whether students spent sufficient time reading the books. Access to the digital reading program was blocked after students reached eight hours of reading. Once a week teachers received an overview of time spent reading per student. If students had not read at least one hour per week, the researcher called the teachers to suggest that students should read more. Teachers were also asked to urge the students in the print book control condition to read. Which books this group read and whether this group indeed spent the same time reading was difficult to monitor.

Pre- and posttests were administered by the first author and/or trained research assistants. The results were coded by Bachelor students, who had been instructed and trained appropriately, and who were blinded from the condition in which students had practiced reading. A random selection of 25% of the data was also coded by the first author. Intra-class correlation coefficients (ICC) for all measurement instruments was satisfactory; *r* equaled .98 (vocabulary measure) or higher.

Measurement instruments

Reading motivation. Participants were asked to rate 16 words and 24 pictures on a six point Likert-scale ranging from 0 for "very negative," to 5 for "very positive." The words were eight reading-related and eight neutral words matched on word length (see Appendix B) and familiar (e.g., 'book' and 'building') to fifth graders. The pictures were twelve depictions of everyday activities that were not expected to elicit strong emotions matched with twelve reading-related pictures (see Figure 2 for an example).

The criteria for matching reading-related and neutral images were the size and color of objects in each image. Pictures were also matched on the presence or absence of human faces and animals.

Figure 2. A reading picture (left) and a matched neutral picture (right) used in the picture evaluation task.

Alpha reliabilities for reading items and matched neutral items were .94 (pre- and posttest) and .85 (pre- and posttest), respectively. The researchers calculated difference scores by subtracting the average neutral score from the average reading score, as an indicator of reading motivation. Students with negative scores rated neutral items higher than reading items, indicating that they were not enthusiastic about reading. Students with positive scores rated reading items higher than neutral items, indicating a high reading motivation. The main advantage of this measure is that it does not explicitly asks students about their reading motivation. Instead, it is a more implicit measure that reduces the risk of socially desirable answering by the participants. The average of the neutral items provides an indication of how participants rate pictures and words in general. Comparing this average to the average rating of the reading-related pictures provides an indication of the participants' attitude towards reading. Meta-analytic findings have shown that, compared to typical students, rarely reading students score significantly lower on this task (Nielen et al., under review).

Vocabulary. Vocabulary learning was measured via a researcher-designed book-based word recognition checklist, using the yes/no test (Anderson & Freebody, 1983). This is a method to test receptive vocabulary knowledge using a list of difficult words from the target books to which the researchers added pseudo-words. Participants were explicitly told that the list contains pseudo-words and were asked to indicate for each word whether it is an existing word or not. The percentage of pseudo-words checked

by students was subtracted from the percentage of real words checked to correct for guessing. Higher percentage scores reflect higher levels of vocabulary. This yes/no test has previously been used in studies targeting first and second language learning (e.g., Mochida & Harrington, 2006) and is strongly related to reading comprehension (Anderson, Wilson, & Fielding, 1988). The alpha reliability of the word recognition checklist was satisfactory (pretest α = .93; posttest α = .95).

Five low-frequency words (e.g., 'miraculous', 'agitated') were selected from each of the 13 experimental books according to the following criteria: (1) a frequency below one occurrence per million words according to SUBTLEX-NL database (Keuleers, Brysbaert, & New, 2010), (2) the words appeared in the books, but not with more than a frequency of once per chapter, (3) the words did not occur more than twice in any one book. The researchers added 33 pseudo-words to this list as foils (e.g., 'howrelsers'), created by inserting low-frequency words from the target books (e.g., 'roddelpers'), not included in the checklist, into Wuggy, a multilingual pseudo-word generator (Keuleers & Brysbaert, 2010).

Reading ability. Students reading ability was assessed using a standardized reading comprehension test (Cito Reading Comprehension; Weekers et al., 2011) that was administered in all participating schools prior to this study. Reading ability scores were thus available only as a pretest measure. Students scored in one of the following five categories based on Dutch national norms: 0 = lowest 10%, 1 = 15% well below average, 2 = 25% right below average, 3 = 25% right above average, and 4 = highest 25%.

Genotyping. Based on the genotyping results, children were assigned to one of two groups: (1) a susceptible group with at least one DRD4 7-repeat allele (36%, n = 52) and (2) a low-susceptible group with no DRD4 7-repeat alleles (n = 94). The two genotypes were in Hardy-Weinberg equilibrium, χ^2 (1,146) = .06, p = .81.

Buccal swabs were collected from individuals to assess the DRD4 marker for differential susceptibility. The swabs were incubated in a lysis buffer (100 mM NaCl, 10 mM EDTA, 10 mM Tris pH 8, 0,1 mg/ml proteinase K, and 0,5% w/v SDS) until further processing. Genomic DNA was isolated using the Chemagic buccal swab kit on a Chemagen Module I workstation (Chemagen Biopolymer-Technologie AG, Baesweiler, Germany). The region of interest of the DRD4 gene was amplified by PCR using the following primers: a FAM-labeled primer 5'-GCGACTACGTGGTCTACTCG -3', and a reverse primer 5'- AGGACCCTCATGGCCTTG -3'. Typical PCR reactions contained between 10 and 100 ng genomic DNA template, 10 pmol of forward and reverse primer. PCR was carried out in the presence of a 7.5% DMSO, 5x buffer

supplied with the enzyme and with 1.25U of LongAmp *Taq* DNA Polymerase (NEB) in a total volume of 30 µl using the following cycling conditions: initial denaturation step of 10 min at 95°C, followed by 27 cycles of 30 sec 95°C, 30 sec 60°C, 60 sec 65°C and a final extension step of 10 min 65°C. One µl of PCR product was mixed with 0.3 µl LIZ-500 size standard (Applied Biosystems) and 11,7 µl formamide (Applied Biosystems) and run on a AB 3730 genetic analyser set up for fragment analyses with 50 cm capillaries. Results were analysed using GeneMarker software (Softgenetics).

Data analysis

To assess main effects of intervention conditions and susceptibility and the interaction of intervention conditions and susceptibility, the posttest scores on reading motivation and vocabulary were regressed on the pretest score on reading motivation and vocabulary, genetic susceptibility (DRD4 7-repeat allele absent versus present), and two contrasts: The first contrast, print versus digital, compared the hardcopy book reading condition with the two digital reading conditions (paper coded as -2, Digital-NoPA and Digital-PA coded as +1). The second contrast compared the Digital-NoPA with the Digital-PA group (Digital-NoPA coded as -1, paper book group coded as 0 and the Digital-PA group coded as +1).

Results

Intervention fidelity

Researchers asked students how they considered the difficulty level of their sets of books in the digital conditions. On a four-point scale, only a minority of students reported that the books were 'much too difficult' (2%) or 'much too easy' (17%). The remainder of the students reported the books were 'slightly too easy' (74%) or 'slightly too difficult' (7%), which validated the procedure used to assign students to the difficult, average or easy book collection, based on their reading ability scores.

The reading time, as registered in the online database, provided the opportunity to monitor whether students indeed read at least an hour per week. In seven of the classrooms, students read at least one hour per week without any encouragement from the researcher. In the other 21 classrooms, it was less common to read on a regular basis and researchers had to encourage teachers bi-weekly or weekly. Despite the regular encouragement, there were 40 children in the digital reading conditions (41%) who read less than 8 hours over 8 weeks (M = 7 hours and 16 minutes, SD

= 52 minutes). However, there were no differences between the average amount of time spent reading in the Digital-PA condition (M = 7 hours and 47 minutes, SD = 45 minutes) and the Digital-NoPA condition (M = 7 hours and 48 minutes, SD = 40 minutes), $t(95) = .07$, $p = .96$. Most students read approximately three books during the intervention. This meant that the students in the Digital-PA condition were encouraged by the PA approximately 45 times.

Missing data

For the word/picture evaluation task, there was 0.25% and 0.08% missing data for the pre- and posttest (respectively), and 0.35% and 0.35% for the vocabulary measure. Missing scores were imputed based on the non-missing scale items.

Validity of measurement instruments

To test the validity of our measurement instruments the researchers have examined the correlation between reading ability, reading motivation and vocabulary. Table 2 shows correlations for both pretest (reading ability, reading motivation and vocabulary) and posttest (reading motivation and vocabulary). Correlations between the three measures are moderate and correlations between the pre- and posttest of the motivation and vocabulary measure equal .77 and .79, respectively. This indicates a rather high test-retest stability.

Table 2 *Correlations between pre- and posttest measures.*

	1	2	3	4	5
1. Reading ability	-				
Pretest					
2. Vocabulary	.50	-			
3. Reading motivation	.29	.30	-		
Posttest					
4. Vocabulary	.48	.79	.31	-	
5. Reading motivation	.38	.35	.77	.37	-

Note. All correlations are significant at the $p < .01$ level.

Similarity of participants in the three conditions

Susceptible children (children with the DRD4 7-repeat allele) were equally distributed over the conditions, as shown in Table 3. Both susceptible and low-susceptible students were slightly more positive towards the reading pictures than the neutral

pictures on both the pre- and posttest. For the vocabulary test, they recognized about 35% (23 out of 65) of the difficult words on the pretest and 38% (25 out of 65) of the difficult words on the posttest. ANOVAs with condition (paper book reading, Digital-NoPA, Digital-PA) and susceptibility (DRD4 7-repeat allele absent versus present) as between-subject factors and pretest scores on motivation, reading ability and vocabulary as dependent variables did not reveal significant effects which indicates that the randomization was successful ($F < 1.40$, $ps > .25$).

Table 3 *Means (standard deviations) for the pre- and posttest reading motivation and vocabulary measure.*

		n	Reading motivation		Vocabulary	
			Pre	Post	Pre	Post
Paper	Susceptible	17	.36 (0.85)	.67 (0.78)	34.49 (15.85)	39.15 (18.81)
	Low-susc.	32	.43 (0.83)	.45 (1.01)	29.97 (16.82)	32.49 (15.99)
Digital-NoPA	Susceptible	17	.34 (1.00)	.46 (1.30)	34.46 (15.73)	34.65 (15.97)
	Low-susc.	31	.63 (1.20)	.76 (1.09)	36.60 (16.87)	39.86 (17.31)
Digital-PA	Susceptible	18	.64 (1.03)	.82 (1.03)	39.82 (17.33)	45.10 (17.50)
	Low-susc.	31	.57 (1.41)	.52 (1.04)	33.89 (13.80)	34.67 (15.35)

Effects of the intervention on motivation and vocabulary

The researchers regressed reading motivation and vocabulary learning on pretest scores, contrasts (print versus digital and Digital-NoPA versus Digital-PA), susceptibility (DRD4 7-repeat allele absent versus present) and the interactions between the contrasts and susceptibility. The regression models explained 61% (F (6, 139) = 36.06, $p < .001$) and 63% (F (6, 139) = 39.77, $p < .001$) of reading motivation and vocabulary post test scores, respectively; see Table 4.

Neither for reading motivation nor vocabulary learning did the print versus digital contrast cause a significant main effect, indicating that reading in a digital format was as effective for reading as the print (hardcopy) format. Also for the full sample, the researchers found no effects of the contrast between digital reading with and without PA, which suggests that the presence of a PA did not motivate the full sample of students to reading or enhance their vocabulary learning.

Based on non-significant interactions between the print versus digital reading contrast and susceptibility, print versus digital reading did not differentially influence motivation or vocabulary learning of the susceptible individuals. In other words, it did not make a difference to the susceptible individuals whether they read print (hardcopy) or digital texts. However, based on a significant interaction between the

Table 4 *Regression analyses examining the effects of the intervention on reading motivation and vocabulary learning accounting for the pretest and susceptibility.*

	B	*SD*	β	*t*	*p*
Reading motivation posttest					
Reading motivation pretest	.74	.05	.77	14.48	<.001
Print versus digital	.02	.05	.03	.46	.65
Digital-NoPA versus Digital-PA	-.10	.09	-.08	-1.15	.25
Susceptibility	.14	.12	.07	1.25	.22
Print versus digital*Susceptibility	-.06	.08	-.05	-.78	.44
Digital-NoPA versus Digital-PA*Susceptibility	.16	.14	.08	1.16	.25
Vocabulary posttest					
Vocabulary pretest	.81	.06	.77	14.71	<.001
Print versus digital	.17	.77	.01	.22	.83
Digital-NoPA versus Digital-PA	-1.50	1.33	-.07	-1.13	.26
Susceptibility	1.72	1.82	.05	.95	.35
Print versus digital*Susceptibility	-.64	1.28	-.03	-.50	.62
Digital-NoPA versus Digital-PA*Susceptibility	4.55	2.22	.13	2.05	**.04**

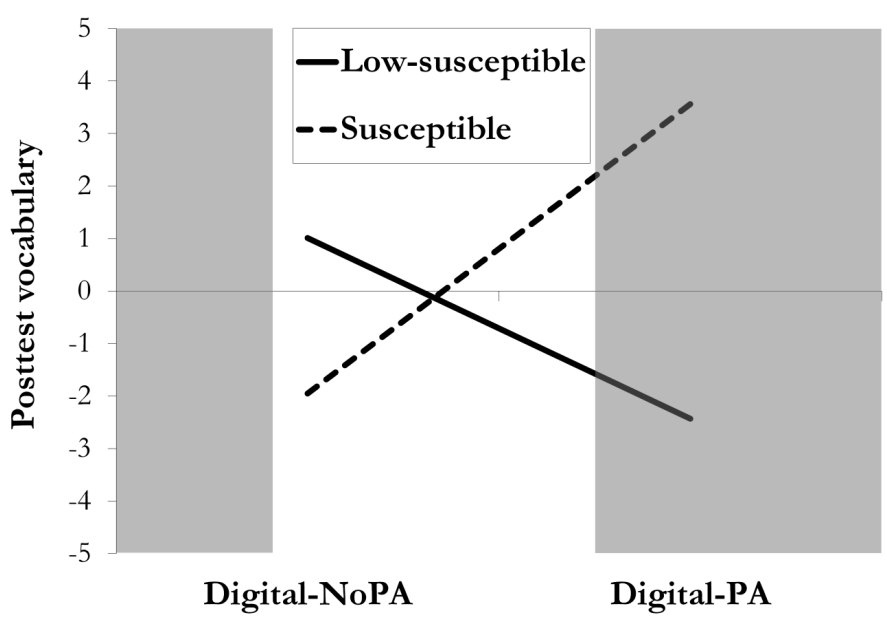

Figure 3. The interaction between the Digital-NoPA and Digital-PA contrast and susceptibility. The grey areas show the boundaries of a 95% CI around the crossover point (Widaman et al., 2012).

Digital-NoPA and Digital-PA contrast and susceptibility (see Figure 3), the presence of the PA did significantly improve vocabulary learning in the susceptible group (p one-sided = .04) with a large effect size (d = .69).

Characteristics of the interaction between susceptibility and feedback

Widaman and colleagues (2012) describe a procedure to test if an interaction is disordinal as may be expected when only part of the students benefit from the intervention. The susceptible group is expected to be responsive to the intervention while the low-susceptible group is not. Following Widaman's procedure, the researchers found that the crossover point (as displayed in Figure 3) was located about halfway between the dummy-coded conditions (-0.38; 95% CI: -1.25 - .49), which is typical for a disordinal interaction (Widaman et al., 2012). Because the lower bound of the confidence interval falls outside the range of the dummy-coded conditions the researchers cannot conclude that the interaction is disordinal in alternative samples as well. In two regression analyses, the researchers predicted the posttest vocabulary scores for the susceptible and low-susceptible children separately controlling for the pretest vocabulary scores. Feedback in the digital reading materials was a non-significant predictor for low-susceptible children (β = -.08, p = .26), explaining 0.6% of the variance in the posttest vocabulary scores. However, for susceptible children, feedback was a significant predictor (β = .13, one-sided p = .05) explaining 1.7% of the variance in the posttest vocabulary scores. This finding provides further evidence for the hypothesis that for the low-susceptible group the presence or absence of feedback did not influence learning whereas susceptible children did profit from the feedback during reading.

Discussion

The researchers found no support for the hypothesis that the medium (print versus digital) influences student reading motivation and reading comprehension (e.g., Daniel & Woody, 2013; Mangen et al., 2013; Miranda et al., 2011; Tveit & Mangen, 2014). The fifth graders in this study reading books in a digital format were not more motivated to read, nor did they learn more new vocabulary than their peers reading hardcopy print books.

The researchers did find support for the notion that students benefit from the presence of a pedagogical agent (e.g., Kegel et al., 2011; Plak et al., 2015). Especially the

susceptible subsample of students benefited from a PA. Susceptible students who read digital books with guidance from a PA learned more new vocabulary than susceptible children reading digital books without guidance. For low-susceptible students, in contrast, the presence of the PA did not result in more vocabulary learning.

Potential of digital reading

Studies comparing digital to print reading often focus on reading comprehension of short texts in an educational setting (e.g., Daniel & Woody, 2013; Mangen et al., 2013; Taylor, 2011). In this study the researchers took a different approach, where students were given the opportunity to choose their own reading materials and read digital texts over a longer period of time. Furthermore, in contrast to previous studies that measured whether students preferred print or digital reading (e.g., Tveit & Mangen, 2014), the researchers explored how digital reading influences the motivation towards reading in general. This may explain why the researchers did not find differences in reading motivation: if students *have* to read they may prefer to read digital texts. Reading digital texts, however, does not necessarily change their motivation to read, even if they have the opportunity to read entire books.

As digital reading is becoming more and more widespread (about 40% of Dutch adolescents and young adults occasionally read digital books; Witte & van Nood, 2014), it becomes vital to focus on how digital reading materials can be designed so that the materials support students during reading. In this study, the researchers tested whether a PA providing guidance during reading supports reading motivation and vocabulary learning. The PA did not have a main effect on the reading motivation and vocabulary learning when the researchers looked at the entire sample. However, the researchers also addressed the question whether the support is particularly effective for susceptible individuals (genetically disposed to attention problems). Based on the differential susceptibility notion - some individuals are more susceptible to quality of instruction than others – the researchers hypothesized that susceptible students would profit from the intervention whereas low-susceptible students would not. Through genotyping the researchers identified susceptible students - carriers of the DRD4 7-repeat allele (e.g., Kegel et al., 2011). Seemingly susceptible students were more sensitive to the encouragements from the PA than their low-susceptible peers. For the susceptible students guidance during reading had a moderately large effect on vocabulary learning (d = .69), whereas it had a non-significant negative effect (d = -.25) on the word learning for low-susceptible students. These findings are in line with the idea that susceptible children not only learn slower in absence of

guidance, but are more responsive to guidance as well. This study thus contributes to the accumulating evidence suggesting that children with the DRD4 7-repeat allele are more responsive to educational interventions with additional support (Kegel, et al., 2011; Plak et al., 2015); current findings extend previous findings in the field of emergent literacy to an older age group in need of reading practice. Further, this study suggests that for children with a genetic disposition for attention problems, carriers of the DRD4 7-repeat allele, even in the short term, PAs in digital books can significantly improve incidental vocabulary learning. One might anticipate even stronger effects with longer interventions.

For the other children, those without the DRD4 7-repeat allele and thus less sensitive to guidance, who actually did non-significantly worse on the vocabulary learning post-test in the PA condition than in the Non-PA condition (see Figure 3), perhaps a stronger and more challenging style of guidance, as opposed to the gentle and nurturing guidance that was effective for the susceptible students, might be better. On the other hand, challenging additions might distract the student from the story line because it implies another task thus affecting story comprehension negatively (cf. Bus, Takacs, & Kegel, 2015). In support of the latter it is worth mentioning that some students commented that they would rather read without the mouse. For interactive books to be effective for the full population, there might need to be adaptive individualization or differentiation but based on the current research it is unclear whether interaction and guidance can be formatted in a ways that it is profitable to all students.

Over the course of primary and secondary school many students stop reading (OECD, 2010) and thus fail to consolidate their reading skills. The reason for the discontinuation of reading may be that many students are expected to read independently too early in their development (Kirschner et al., 2006). Especially for struggling readers, who fail to understand age-appropriate reading materials, reading may become a frustrating activity and eventually students may start to avoid reading. To the best of our knowledge this is the first study demonstrating experimentally that guidance during digital reading can support students at the end of primary school, while reading self-selected fiction books. The significant results (for the susceptible children) strongly suggest the need for more research on interactive books for this age group (10-13 years old), especially also with guidance customized towards other segments of the population (i.e., non-susceptible).

The researchers did not find any evidence for changes in students' attitude towards reading in general after just eight hours of digital reading with guidance.

However, the reciprocal causal relationship between reading comprehension and reading motivation suggests that an appropriately differentiated intervention that supports reading comprehension may eventually support reading motivation as well (Becker, McElvany, & Kortenbruck, 2010; Morgan & Fuchs, 2007; Mol & Bus, 2011). The researchers therefore expect that, in the long run, guidance during reading may enhance the motivation to read as well.

Limitations

In this first study, with a PA supporting students during the reading of self-selected books in school, the researchers incorporated several elements of evidence-based practices with human tutors into the PA design. The PA praised the students, helped them to understand the story, related story elements to students' personal experiences and encouraged students to continue reading. A disadvantage of this extensive guidance is that it remains unclear whether a combination of these elements or a single element (e.g., praise) helps susceptible children to learn more from reading. Because it is unsure which elements of the PA cause the effects on reading comprehension it is difficult to deduce the type of support susceptible students miss when reading without PA. It is, however, likely that the susceptible students are easily distracted and become more stressed when a task is difficult (Kegel et al., 2011). Future studies may compare different types of feedback to assess what kind of support is most beneficial for susceptible students to focus on the reading and canalize feelings of stress.

The biochemical and behavioral mechanisms underlying the effect of feedback on susceptible students' vocabulary learning are not explicitly tested in the present study. A single gene cannot be responsible for protein and neurotransmitter production leading to learning (Kegel et al., 2011). The underlying mechanisms are not explored in the present study. Gaining more insight in these mechanisms may help unravel the underlying genetic pathway and biochemical processes that make carriers of the DRD4 7-repeat allele more susceptible to educational interventions providing individualized feedback. Ideally more easily observable characteristics, such as behavior and attitudes inferred from interactions with PAs, may be found that indicate whether or not individuals are susceptible (Plak et al., 2015). Despite these uncertainties an increasing number of studies indicates the usefulness of the DRD4 polymorphism to detect differential susceptibility, both in psychopathology and education (Van IJzendoorn & Bakermans-Kranenburg, 2015).

Conclusions

This study provides preliminary evidence for the potential of digital reading with PAs. Especially in the domain of independent reading of self-selected books, both in school and in leisure time, there seems much to win. This type of reading practice is important to develop literacy skills and thereby for educational attainment and professional success (Gottfried et al., 2015; Mol & Bus, 2011), but is generally considered to be the student's own responsibility. Some students manage to keep practicing and become skilled and enthusiastic readers. A large group of students, however, loses interest in reading over the course of primary and secondary education (e.g. OECD, 2010). This study shows that digital reading can provide new ways to continuously support the reading development, particularly for readers with a predisposition towards attention problems.

This study also shows that reading comprehension and motivation of fifth graders does not seem to be hampered by reading in a digital instead of a print format. Furthermore, accumulating evidence (Kegel et al., 2011; Plak et al., 2015) including the results presented in this article suggest that for a minority of children (carriers of the DRD4 7-repeat allele) learning outcomes are strongly dependent on the presence or absence of guidance. In the present study the researchers have shown that guidance provided by a PA helps susceptible students to learn more from reading. Although less susceptible students may adapt to a variety of learning environments without as large impact on their performance as students with attention problems, other styles of feedback in digital books might be explored for them, as the trends for discontinuation of recreational reading go well beyond students with genetic attention problems (OECD, 2010). As students' learning environment becomes increasingly digital, the opportunities to provide frequent, adaptive and individual feedback grow (Vasilyeva, 2007). More research into the characteristics that make digital reading programs effective, and for whom, should inform the design of evidence-based programs that help students to reach their full potential.

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Appendix A: Dutch children's books used in the experiment.

	Author	Title
1.	Nicolle Christiaanse	De Bleshof: Alles voor mijn paard
2.	Cornelia Funke	Ridder zonder hart
3.	Hans Hagen	Het hanengevecht
4.	Annet Jacobs	Het geheim van de dansende beer
5.	Netty van Kaathoven	Faiza is mijn held
6.	Mirjam Oldenhave	Control & copy
7.	Mirjam Oldenhave	Rampenkamp
8.	Hans Petermeijer	Potvis op het strand!
9.	Ruben Prins	Het geheim van de vergiftigde hond
10.	Daan Remmerts de Vries	Bernie King en de magische cirkels
11.	Lydia Rood	Marietje Appelgat
12.	Jacques Vriens	Strijd om de kathedraal
13.	Anna Woltz	De pizza spion

Appendix B: Words in the word/picture evaluation task (Dutch translation).

	Reading words	Matched neutral words
1.	book (boek)	door (deur)
2.	cover (kaft)	flat (vlak)
3.	read (lezen)	kettle (ketel)
4.	title (title)	next to (naast)
5.	comic strip (strip)	wagon (wagen)
6.	letter (letter)	building (gebouw)
7.	page (pagina)	finger (vinger)
8.	story (verhaal)	headlight (koplamp)