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Chapter 4
The Potential of Two Technology-enhanced Early Literacy Interventions to Prevent Reading Delays in First Grade

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Plak, R.D., Merkelbach, I., Kegel, C.A.T., & Bus, A. G. The Potential of Two Technology-enhanced Early Literacy Interventions to Prevent Reading Delays in First Grade.
ABSTRACT

The effect of educational computer programs as extra input for delayed children was examined. Children worked with the programs, a book reading program and a game-like program to stimulate phonemic awareness and alphabetic knowledge, in the last half year of kindergarten. On average children spent 2-3 hours with the programs, spread over 2-3 months. As indicators we used standard tests, halfway through and at the end of first grade. Neither of the programs caused main effects in the group of literacy-delayed children. Technology-enhanced books showed effects on text comprehension when assessed six months and a year after the intervention in a subsample with a genetic disposition to attention problems (carriers of the DRD4 gene 7-repeat allele). The digital books including animated pictures, sounds and music, seem to match specific needs of children with a genetic disposition for attention problems. We hypothesize that they elicit a state of hyperfocus, thus being more effective for these children than everyday experiences stimulating the same skills. As a substantial group (about one-third of all children) benefits from Living Books they seem to be indispensable in the kindergarten classroom.

Keywords: Technology-enhanced literacy interventions; digital books including animated pictures, sounds and music; Dopamine D4 receptor gene; differential susceptibility; hyperfocus; randomized controlled trial; long-term effects.
enhanced series of books, but not from another educational computer program that is also intended to stimulate early literacy skills. This educational computer program, *Living Letters*, was composed of a series of highly structured game-like assignments in which phonemic awareness and alphabetic knowledge were trained. Children received continuous feedback from two tutors, thus guiding them through every assignment. We neither found main effects of *Living Letters* nor effects in the subsample of carriers of the DRD4 polymorphism (Plak et al., 2015; Plak et al., 2016).

We speculate that carriers of the DRD4 7-repeat allele typically show diminished dopamine reception efficiency, often resulting in reduced attention and reward mechanisms (Robbins & Everitt, 1999). If, however, activities are satisfactory, there will be an increased release of dopamine in the ventral striatum, creating a route for learned reinforcing; that is, after being challenged and achieving a satisfactory result, dopamine becomes available thereby enabling new achievements (Koepp et al., 1998). Unlike traditional book sharing, *Living Books* may elicit this route in carriers of the DRD4-7 repeat allele and, like is reported about persons with ADHD, they may enter stages of very high levels of concentration (Maher, Marazita, Ferrel, & Vanyukov, 2002). They may show a tendency to focus very intently on things that do interest them (Schecklmann et al., 2008) - watching films or playing (video) games – and become oblivious to the world around them. They enter a state of hyperfocus blocking all other stimuli coming from the environment, and engage for hours in activities like playing games or watching movies.

In line with this argument, we hypothesize that carriers of the DRD4 polymorphism benefit more from *Living Books* than other children because this program may elicit a state of very intensive on-task behavior as only occurs in children with attention problems. The film-like presentation in *Living Books* may attract all attention and result in a state of intensive concentration. The books may even lead to diminished processing of irrelevant auditory stimuli from the surroundings resulting in a state of *inattentional deafness* – the failure to notice auditory stimuli under high visual perceptual load as in *Living Books* (Molloy, Griffiths, Chait, & Lavie, 2015).

Furthermore, it seems plausible that in a subsample of carriers of the DRD4 polymorphism, literacy development can be intensified through the program *Living Books* but not through *Living Letters*. The latter program may lack elements that engage five-year-olds’ attention to the same extent as *Living Books*. Instruction films -as are characteristic of *Living Letters* and the game-like elements of the program- might be engaging to younger children, which may explain the positive effects of this program in a group of four-year-olds (Kegel, Bus, & van IJzendoorn, 2011): Carriers of the DRD4-7 repeat allele benefited from *Living Letters* while non-carriers did not. We noticed that five-year-olds had a different response to the program: they were not enthusiastic about the instruction films and game-like elements of the *Living Letters* program. Teachers complained that five-year-olds’ motivation for *Living Letters* decreased after a few sessions probably due to the repetitive character of both the instruction films and the assignments. In line with our reasoning, we therefore do not expect that playing with *Living Letters* in kindergarten will facilitate learning to read in first grade.

*Living Books* and *Living Letters*, each target different literacy skills; *Living Letters* focuses on inside-out skills (e.g., letter knowledge and phoneme awareness), while *Living Books* focuses on outside-in skills (e.g., vocabulary and story comprehension). Both inside-out skills and outside-in skills are fundamental to learning to read in first grade and thereafter (Whitehurst & Lonigan, 2001). In the current experiment, we expect the strongest long-term effects of *Living Books* on tests that relate to reading comprehension: vocabulary and listening comprehension. It seems less plausible that the program affects tests associated with technical reading skills: word reading and spelling. As we did not find short-term effects of *Living Letters*, neither in the complete group nor in a subsample, we do not expect long-term effects of this program on tests associated with technical reading skills.

This study

In the current study, all literacy-delayed children included participated in one of the two RCTs (Plak et al., 2015; Plak et al., 2016) in which the two computer interventions, *Living Letters* and *Living Books*, were included. The two exactly similarly designed experiments were carried out during the winter/spring semester in two consecutive years (2012-2013 and 2013-2014). Since in those experiments effects were only found in a group of literacy-delayed pupils, in the current study only literacy-delayed pupils were included. Standardized tests for literacy administered by teachers in January and June in the first grade served as posttests. We expected to find that *Living Books* would be an extra boost for the reading development of delayed children and in particular carriers of the DRD4-7 repeat allele. There may be direct effects of a technology-enhanced book reading program on children's listening comprehension and vocabulary, as well as indirect effects of extra book reading in kindergarten: positive experiences with the *Living Books* program may increase interest in stories, which may start off a snowball effect. Due to an increased interest in book reading, children elicit more reading from adults and thus become more proficient in reading skills (Mol & Bus, 2011).

We expect effects on outside-in skills like comprehension rather than on inside-out skills, such as word recognition and spelling, the technical reading skills. The current long-term study aims at proving that *Living Books* are an important supplement to the regular kindergarten curriculum because they compensate for failure to benefit from traditional book reading at home and school especially when children have a greater risk of attention problems. We hypothesize that technology-
enhanced books may be indispensable for these vulnerable children. Due to a state of hyperfocus elicited by the multimedia stories, they gain more in-depth knowledge from reading technology-enhanced books than from regular book reading. They may even outperform their peers, not only on the short run but also on the long run. In this study, we present long-term effects of reading technology-enhanced books six months and a year after the intervention took place in kindergarten.

**METHOD**

**Participants**

From August 2012 to October 2013 and August 2013 to October 2013 the project was widely advertised via e-mail, mail, social media, and phone in the Netherlands. A total of 183 schools from all over the country responded, 2.7% of all Dutch schools. The participating schools are from urban as well as rural areas. Kindergarten teachers from the participating schools selected eligible kindergarten children between October 2012 and February 2014 and October 2013 and February 2014. The eligible kindergarten children had for example difficulty writing their proper name, rhyming, naming a few letters, and identifying sounds in words. Preferably pupils scored in the lowest 40 percent -between 0 and 59- on a standardized literacy test (i.e., the Central Institute for Test development [Centraal Instituut voor Toetsontwikkeling] (Cito) Literacy Test for Kindergarten Pupils, CLT) administered at most Dutch schools (Lansink & Hemker, 2012). Parents gave written informed consent for participation that also included consent to collect long-term data.

**Design**

After receiving informed consent to participate from parents, we randomly assigned children to one of three conditions: a control program (*Clever Together*), *Living Books* or *Living Letters*. In each class, one child was assigned to *Clever Together*, the control condition, and at least one child to one of the literacy-related programs, that is *Living Letters* or *Living Books*. The intervention, a randomized control trial, took place in the second half, between March and June, of the senior kindergarten year. Children in the *Living Books* condition were offered 8 sessions with 2 books per session and children in the *Clever Together and Living Letters* condition ranging between 8 and 11 sessions (the variable number of sessions depended on the number of errors children made). Each session took about 15 minutes and children practiced once a week. Based on the data that were stored by the program, children completed on average 33.62 out of 34 *Living Letters* games (*SD* = 2.50) and they “read” on average 14.8 out of 16 books (*SD* = 1.8). Immediately following the intervention period of twelve weeks, teachers administered the Central Institute for Test Development (Cito) Literacy Test for Kindergarten (CLT), a standardized literacy test (Lansink & Hemker, 2012). These short-term results are discussed in Plak et al., 2015, and Plak et al., 2016. This study aims at answering the pressing issue of whether additional computer programs in kindergarten targeting early literacy skills facilitate learning to read in first grade. To this end, we collected the results of four Cito tests - Vocabulary, Cito Listening Comprehension, Word Reading and Spelling - administered halfway through first grade and at the end of first grade, see Figure 1. Buccal cell samples were collected halfway during the intervention period. Trained members of the research team visited the schools to collect the samples using a sterile swab designed for collecting buccal cells for DNA analysis (Omni Swabs, Whatman/GE Healthcare, UK). Subsequently the samples were sent to a commercial laboratory for DNA analysis.

**Procedure**

Directly after the administration of the tests, the contact persons received a request to send the scores of the literacy tests to the researchers. This was done by e-mail, phone, and mail, depending on the contact with the school. The number of times the request was repeated could range from 1 to 12 times. In the Netherlands, switching schools as a teacher is quite common, as a result of which we lost many contact persons when we returned to the schools to collect the long-term data. In those cases we contacted their colleagues, who however did not always respond to our request to send the test scores. Moreover, as Dutch schools are free to decide which tests from a nation-wide student tracking system are administered, not all schools administered all tests of interest. Most schools did administer Word Reading followed by Vocabulary and Spelling. The least popular was Listening Comprehension.
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### Intervention programs

**Living Books.** The intervention program Living Books, was made up of eight age-appropriate digital animated storybooks. The animated pictures, sounds, and music support children’s understanding of story events and language (Takacs et al., 2015). When the oral narrative is accompanied by nonverbal information, and both information sources are simultaneously available, the narrative text will be understood and retained better than if conveyed by words alone (Bus et al., 2015). Multimedia books offer optimal guidance in developing mental representations of the story and the language. The movie-like visual representation promotes engagement.

Each reading of a book was interrupted four times for questions about the story and vocabulary. Feedback to the child’s response was adaptive, similar to Living Letters. The first error was followed by a repetition of the question, the second by a clue (“Peeking is secretly watching. Where do you see Little Mouse peeking?”), and the third by demonstrating the correct response together with a spoken explanation (“Of course, this house is Little Mouse’s own house!”). Each book was presented twice and four new questions were included in each session.

**Living Letters.** The second intervention program Living Letters offers a framework that anchors instruction and practice in a personally motivating context of activities using children’s own proper name (Van der Kooy-Hofland, Bus, & Roskos, 2012). The proper name is often the first word that young children can read and write; therefore the child’s name is used to draw attention to phonemes in the spoken name and words (Van der Kooy-Hofland & Bus, 2012). The program adapts automatically to the child’s proper name when available in the name database. If not, the program uses “mama” (mommy) - a word that is just as familiar to many young children. A tutor providing feedback followed up on every response. When children answered a question incorrectly, feedback and clues were provided. More specifically, after the first error the assignment was only repeated: “Listen carefully, in which word do you hear /t/ from Tom?” After the second error children received a clue: “How does your teacher write your name?” If the child failed to give the correct answer after the third attempt, the solution was demonstrated together with a spoken explanation by the digital tutor. After a maximum of three trials, the game ended on a positive note, irrespective of whether a correct response was given, whereupon a new game started. When children failed to give the correct answer at the first try, the assignment was repeated twice in a subsequent session, which explains why some children had a few more sessions than others. In the first games, children practiced how their name (or “mama”) is written, followed by games to train the sound of the first letter of the child’s name (or “mama”) and thereafter by games to identify pictures that start or end with the first letter of the target name.

*Clever Together* supports basic concepts for mathematics like practicing

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**Figure 1**

CONSORT diagram

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**Note:** The teacher selected the pupils, therefore we do not have insight into how many students were eligible to begin with.

**Alloyment**

- Selected by the teacher (n = 1390) *
- Allocated to intervention (n = 1390)
- Received allocated intervention (n = 1390)
- Did not receive allocated intervention (n = 0)

**Allocation**

- Genotype (n = 1375)

**Outcome variables**

- Vocabulary: Halfway first grade lost to follow-up due to missing test scores (n = 734); End of first grade lost to follow-up (missing test scores) (n = 816).
- Listening Comprehension: Halfway first grade lost to follow-up due to missing test scores (n = 1246); End of first grade lost to follow-up (missing test scores) (n = 1277).
- Word reading: Halfway first grade lost to follow-up due to missing test scores (n = 422); End of first grade lost to follow-up (missing test scores) (n = 560).

**Analysis**

- Vocabulary: Literacy-delayed (n = 307). Analysed at halfway through first grade (n = 291). Excluded from analysis due to missing data (n = 16).
- Analysed at end of first grade (n = 253). Excluded from analysis due to missing data (n = 54).
- Listening Comprehension: Literacy-delayed (n = 86). Analysed at halfway through first grade (n = 80). Excluded from analysis due to missing data (n = 6).
- Analysed at end of first grade (n = 57). Excluded from analysis due to missing data (n = 29).
- Word reading: Literacy-delayed (n = 451). Analysed at halfway through first grade (n = 428). Excluded from analysis due to missing data (n = 23).
cardinals and visual-spatial reasoning. It includes 40 games. As in Living Letters and Living Books, a tutor provides constructive, detailed feedback for every error and every correct response. Assignments were repeated in later sessions when children made errors.

**Literacy measures**

**Cito Literacy Test for Kindergarten Pupils** [Taal voor Kleuters, groep 2]. To identify the literacy-delayed pupils we used the Cito Literacy Test for Kindergarten Pupils (CLT), a standardized literacy test for kindergarten pupils. The 60-itemed CLT is administered group-wise in January (α = .89) of the senior kindergarten year. Vocabulary, text comprehension, rhyming, hearing the first and last word, sound blending, writing conventions (e.g. reading from left to right), and prediction of book content based on the book cover are assessed (Lansink & Hemker, 2012). The Committee for Test Quality in the Netherlands [Commissie Testaangelegenheden Nederland] evaluated the CLT as adequate.

**Cito Vocabulary, posttest, first grade** [Woordenschat, groep 3]. With Cito Vocabulary for the first grade, the level of receptive vocabulary can be determined. The tests for the first grade consist of 50 assignments in January and at the end of the school year (June). The tests are administered group-wise in class. The students receive classroom instruction and a number of exercises on paper. In first grade the teacher provides the questions orally. For example: “Lena looks at the procession, where do you see a procession?” The students make a choice out of three pictures. Cronbach’s alpha is .81 for grade 1 January and .83 for grade 1 June (Van Berkel et al., 2010). Based on the criteria of the Committee for Test Quality in the Netherlands [Commissie Testaangelegenheden Nederland] the reliability of the Cito Vocabulary test is considered good.

**Cito Listening Comprehension, posttest, first grade** [Begrijpend Luisteren, groep 3]. The test determines the level of listening comprehension. The test measures proficiency in giving meaning to spoken language (Krom, Ouborg, & Kamphuis, 2001). For the first grade two versions are available, one for halfway through first grade and one for the end of first grade. Different stories are played from a CD. After each story, children answer multiple-choice questions about the story presented in a booklet. Answers take the form of pictures since some students still have trouble reading when they are in first grade. Based on the criteria of the Committee for Test Quality in the Netherlands [Commissie Testaangelegenheden Nederland] the reliability of the Cito Listening Comprehension test is considered adequate.

**Cito Word Reading, posttest, first grade** [Drie-Minuten-Toets, groep 3]. The Three-Minute Test (TMT) measures the word reading speed of a child and is administered individually by the teacher. The student is given one minute to read aloud as many words from a reading chart. The words must be read by column, from top to bottom. While reading, the administrator scores which words are read incorrectly. In general, when pronunciation does not match the spelling this is considered to be an error. Stress differences are not included. Spelling out words (/s/ - /a/ - /p/) is incorrect, except if spelling is followed by /sap [juice]/. When a pupil spontaneously corrects him or herself this is considered correct. Raw test scores are the number of correct words. This score can be converted into a standard score, which can be converted, in turn, in a skill level. Cronbach’s alpha is calculated for the combination of TMT cards, categorized in level 1 (kindergarten junior year and senior year) and level 2 (kindergarten junior year, kindergarten senior year and first grade). For the first grade January test Cronbach’s alpha is .964 (level 1, level 2 is not applicable), for the first grade June test Cronbach’s alpha is .967 for level 1 and .971 for level 2. Based on the criteria of the Committee for Test Quality in the Netherlands [Commissie Testaangelegenheden Nederland] the reliability can be considered as adequate (Krom, Jongen, Verhelst, Kamphuis, & Kleinjtes, 2010).

**Cito Spelling, posttest First Grade** [Spelling voor groep 3]. With the Cito Spelling test a child’s ability to spell words can be established. This test is administered group-wise. During the administration of the Cito Spelling in the first grade January (M3) and June (E3) tests, words from different levels of complexity are dictated (for example words with 1 to 3 syllables; words with an intermediate sound that is not written, et cetera).

**Genetic screening for DRD4 polymorphisms**

An assortment of characteristics inherited from the parents is a genotype. Genotyping is the process of determining differences in the genetic make-up (genotype) of an individual by examining the individual’s DNA sequence. Biological assays are used and compared to another individual’s DNA sequence. The details are explained below.

**PCR Amplification.** The region of interest of the DRD4 gene was amplified by PCR using the following primers: a FAM-labelled primer 5’- CCGACTACGTGGTCTACTCG -3’, and a reverse primer 5’- AGGACCCTCATGGCCTTG -3’. Typical PCR reactions contained between 10 and 100ng genomic DNA template, 10pmol of forward and reverse primer. PCR was carried out in the presence of 7.5% DMSO, 5x buffer supplied with the enzyme and with 1.25U of LongAmp Taq DNA Polymerase (NEB) in a total volume of 30µl using the following cycling conditions: initial denaturation step of 10 min at 95 ºC, followed by 27 cycles of 30 sec 95 ºC, 30 sec 60 ºC, 60 sec 65 ºC and a final extension step of 10 min 65 ºC. Analysis of PCR products for repeat number. One µl of PCR product was mixed with 0.3µl LIZ-500 size standard (Applied Biosystems) and 11.7µl formamide
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Results

Characteristics of the Sample

Table 1 shows the characteristics of the 428 participants. Participants at pretest (halfway through senior kindergarten year) had a mean age of 67.00 (SD = 4.30). The mean score for father’s education was 3.64 (SD = 1.69) on a scale ranging from 0 – 6, with 0 representing primary school and 6 representing university-level education. Of the participants, 57% was male (n = 244) and 43% female (n = 184). Across the three experimental conditions: Living Letters (88 males/64 females), Living Books (88 males/64 females), and Clever Together (68 males/56 females), there was no significant difference between the number of children with a DRD4 7-repeat allele: Living Letters (35.5%), Living Books (35.5%), and Clever Together (29.0%), \( \chi^2 \) (df = 2, N = 428) = .939, p = .62.

Table 1: Characteristics of the Experimental Conditions Living Letters, Living Books, and Clever Together of Participants Scoring Below 40th Percentile (Literacy-Delayed)

<table>
<thead>
<tr>
<th>Complete group</th>
<th>Living Letters</th>
<th>Living Books</th>
<th>Clever Together</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age months (SD)</td>
<td>67.00 (4.30)</td>
<td>67.35 (4.33)</td>
<td>66.85 (4.35)</td>
</tr>
<tr>
<td>CLT pretest (SD)</td>
<td>53.82 (4.38)</td>
<td>53.74 (4.89)</td>
<td>54.34 (3.89)</td>
</tr>
<tr>
<td>Male/Female</td>
<td>244/184</td>
<td>88/64</td>
<td>88/64</td>
</tr>
<tr>
<td>DRD4 7+/7-R (%)</td>
<td>37.5/64.3</td>
<td>38.2/61.8</td>
<td>32.9/67.1</td>
</tr>
</tbody>
</table>

We first checked per dependent measure whether scores of missing cases differed from the scores included in the analyses. The group with missing data for Word Reading January/June and Spelling January/June differed significantly from the group with complete data on the pretest. The scores of the group with complete data were somewhat higher than scores in the missing group. For the complete group, the mean for Vocabulary/January was 60.11 (SD = 8.42) vs. 58.10 (SD = 9.51) for the missing group. The complete group had a mean of 59.99 (SD = 8.01) for Vocabulary/June, while the missing group had a mean of 58.81 (SD = 9.85). The complete group mean for Spelling/January was 60.45 (SD = 8.81), and for the missing group 58.55 (SD = 8.69). Finally, the complete group mean for Spelling/June was 60.41 (SD = 8.49), while for the missing group it was 58.82 (SD = 8.98). Since we expected the effects of the programs to be stronger the more children were delayed, the outcomes of the current experiment may therefore underestimate the effects of the programs. Furthermore, the group with missing scores was somewhat younger.

Data Analysis

In the literacy-delayed group (scoring below the 40th percentile according to national norms), we regressed the posttest scores including vocabulary, listening comprehension, word reading, and spelling on Vocabulary, Listening Comprehension and Word Reading, Living Letters (contrast between the control condition Clever Together and Living Letters), Living Books (contrast between Clever Together and Living Books), DRD4 (7-repeat allele vs. others), two-way interactions involving interventions, and DRD4, Age, sex, and father’s education were entered as covariates.
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Table 2: Outcomes of Multilevel Analysis Using Posttest Vocabulary, Comprehension, Word Reading, and Spelling Halfway of First Grade as an Outcome Variable of participants scoring below 40th percentile (literacy-delayed)

<table>
<thead>
<tr>
<th></th>
<th>Outside-in skills</th>
<th>Inside-out skills</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fixed effects</strong></td>
<td>Vocabulary Jan</td>
<td>Vocabulary June</td>
</tr>
<tr>
<td>Intercept</td>
<td>46.79 (12.33)*</td>
<td>72.65 (14.81)*</td>
</tr>
<tr>
<td><strong>Background</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>-32 (1.18)*</td>
<td>-49 (2.1)*</td>
</tr>
<tr>
<td>Sex</td>
<td>-1.56 (1.50)</td>
<td>-0.03 (1.82)</td>
</tr>
<tr>
<td>Fathers educational level</td>
<td>0.15 (0.41)</td>
<td>0.13 (0.48)</td>
</tr>
<tr>
<td><strong>Main Effects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Living Letters (vs. control)</td>
<td>1.20 (1.35)</td>
<td>1.99 (1.62)</td>
</tr>
<tr>
<td>Living Books (vs. control)</td>
<td>-1.09 (1.27)</td>
<td>-3.34 (1.51)**</td>
</tr>
<tr>
<td>DRD4 variant</td>
<td>4.07 (1.56)*</td>
<td>3.80 (1.91)*</td>
</tr>
<tr>
<td><strong>Interaction Effects</strong></td>
<td>-2.20 (1.28)</td>
<td>-2.16 (2.04)</td>
</tr>
<tr>
<td>DRD4 variant X Living Letters</td>
<td>-2.87 (2.23)*</td>
<td>5.56 (2.70)*</td>
</tr>
<tr>
<td>DRD4 variant X Living Books</td>
<td>1.01 (1.91)</td>
<td>1.58 (2.07)</td>
</tr>
<tr>
<td><strong>Random Effects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variance</td>
<td>138.03 (12.96)</td>
<td>173.31 (17.43)</td>
</tr>
<tr>
<td>Level School</td>
<td>52.25 (15.02)</td>
<td>78.53 (22.59)</td>
</tr>
<tr>
<td>Note: *p&lt;.05, **p&lt;.10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Multilevel analysis

To test whether or not it is necessary to allow the intercepts and slopes to differ between schools (Twisk, 2006), we tested the difference between the -2log likelihood of the model with only a random intercept and the -2log likelihood of the model with a random intercept and the difference between the -2log likelihood of the model with a random intercept and the -2log likelihood of the model with both a random intercept and a random slope. The differences were highly significant (χ² < 5.99). Therefore, a multilevel analysis with a random intercept and a random slope was not significant (P < .05). Therefore, a multilevel analysis with a random intercept and a random slope was applied (Luke, 2004). The variance in scores halfway through and at the end of first grade was calculated by dividing random variance related to school and child. As may be expected, intraclass correlations were higher for Vocabulary January/June (27%/ 31%) and Listening Comprehension January/June (26%/ 29%), than for Word Reading January/June (27%/ 31) and Listening Comprehension January/June (26%/ 29). See Table 2 for estimates and significance levels. Apparently, home and school input is more diverse for comprehension skills resulting in higher intraclass correlations.

The variance in scores halfway through and at the end of first grade attributable to school by all random intercepts and slopes were higher for Vocabulary January/June (27%/ 31) and Listening Comprehension January/June (26%/ 29) than for Word Reading January/June (27%/ 31) and Listening Comprehension January/June (26%/ 29). See Table 2 for estimates and significance levels. Apparently, home and school input is more diverse for comprehension skills resulting in higher intraclass correlations.
Outcomes were similar for vocabulary and listening comprehension. There were no main effects of the intervention programs or DRD4 gene. We found significant interactions between genotyping and intervention programs in the subsample of children with the DRD4 gene. We also found no main effects of DRD4, indicating that on all tests the DRD4-R subsample outperformed their peers (Est. > 3.80, p = .028), probably due to the strong effects of Living Books in this subsample. With one exception (Listening Comprehension in January, Est. = -4.77), we found significant interactions between genotyping and intervention programs. Living Letters approached significant effects on word reading in June (Est. = -2.59, p = .062) and spelling in January (Est. = -1.17, p = .084). The negative estimates indicate that intervention programs were more effective in children with a lower risk of academic failure. For children with the DRD4-R allele, no differences were found. Overall, carriers of the 7-repeat allele of the DRD4 gene benefited from Living Letters, with effect sizes ranging from .35 (Listening Comprehension/January) to 1.38 (Listening Comprehension/June), which indicates that effect sizes were moderate to large. The non-carriers tended to benefit more from Clever Together, as indicated by negative D's (-.29 for Vocabulary/January; -.40 for Vocabulary/June; -.36 for Listening Comprehension/January; -.40 for Vocabulary/June). June Spelling did not reveal any differential effect. Inside-out skills Living Letters approached significant effects on word reading in June (Est. = -2.59, p = .062) and spelling in January (Est. = -1.17, p = .084). The negative estimates indicate that the intervention programs were more effective in children with a lower risk of academic failure. For children with the DRD4-R allele, no differences were found. Overall, carriers of the 7-repeat allele of the DRD4 gene benefited from Living Letters, with effect sizes ranging from .35 (Listening Comprehension/January) to 1.38 (Listening Comprehension/June), which indicates that effect sizes were moderate to large. The non-carriers tended to benefit more from Clever Together, as indicated by negative D's (-.29 for Vocabulary/January; -.40 for Vocabulary/June; -.36 for Listening Comprehension/January). June Spelling did not reveal any differential effect.

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DISCUSSION

In this randomized controlled trial we proved that a short technology-enhanced educational computer program can be important, as appears from literacy skills, not just directly after the intervention but also in the long term. In first grade, a subgroup of children still benefits from being exposed to a set of Living Books in kindergarten even though the intervention was rather brief and did not encompass more than 2 to 3 hours. An effect across the board was not found for Living Books, but this digital book program was effective in a subsample, with effect sizes ranging from .35 to .42.

These long-term results showed that Living Books is particularly effective for developing outside-in skills. Effects were found on vocabulary (halfway through first grade and at the end of first grade) and on listening comprehension, specifically halfway through first grade. The effect on listening comprehension was substantial a year after the intervention was implemented, but the small number of participants might have played a part in the failure to find a significant effect for this point of measurement. On inside-out skills, no effects of Living Books were found, which makes sense since the books did not include print or other incentives for the development of such skills. Therefore it was not likely that children would develop inside-out skills. In contrast to Living Books, Living Letters did not show significant effects on inside-out or outside-in skills. Considering the earlier lack of findings for Living Letters (see Plak et al., 2015 and Plak et al., 2016), it may come as no surprise that no effects were found six months or a year after the intervention was implemented.

Findings suggest that Living Books are not effective for all children but that a specific group of children, carriers of the DRD4-7 repeat allele, does benefit from being exposed to a series of animated books in addition to traditional book sharing at home and school (Plak et al., 2015; Plak et al., 2016) and that those effects are still measurable six months and a year later. When carriers of the 7-repeat allele of the DRD4 gene are exposed to Living Books, even when it is only for a brief period, they catch up and – as has been proven in the current study – even outperform their non-carrier peers on vocabulary and listening comprehension. Non-carriers do not benefit from Living Books probably because they maximally benefit from daily book reading sessions, in school and at home, and the eight extra Living Books, even when those books include nonverbal support for story comprehension, represent a relatively small expansion of the normal book reading diet. For the majority of kindergarten children, Living Books is more of the same and therefore does not result in any identifiable effects. The close to significant negative effects suggest that in this group the control program, Clever Together, tends to provide a more unique contribution to listening comprehension and vocabulary as compared to Living Books.

Nonverbal information in Living Books such as animations, background sounds and music increase children’s comprehension, especially when children are at risk for language delays (Takacs, Swart, & Bus, 2015). Living Books are designed in such a way that the same information is presented simultaneously through words and nonverbal information thus enabling that multimedia learning can take place (Mayer, 2005). Maybe due to the film-like presentations, Living Books may incite a state of deep concentration or hyperfocus in this specific group. That is, they focus on what is presented in the computer program, thereby blocking irrelevant stimuli coming from the environment. Actually, findings corroborate the hypothesis that digital storybooks are much more effective for children with a genetic disposition to attentional problems than regular book sharing with adults. Where a teacher or a parent does not have the means to incite deep engagement and thereby high achievement, the technology-enhanced computer program Living Books does.

So far we do not have direct evidence for the hypothesized differences in processing information. Further testing of responses to the sessions is needed. Are they, as a state of hyperfocus implies, indeed “deaf” (Molloy et al., 2015) to sounds coming from the environment while they “read” the books? Living Books meet the criteria of a task with a high visual perceptual load, making it probable that when children -who are highly susceptible to their learning environment- work with the program, experience “deafness”; they enter a state of hyperfocus blocking irrelevant sounds from their surroundings, for example sounds from a noisy classroom.

Furthermore, we do not have information to explain the enduring effects. We hypothesize that a brief period of exposure to multimedia books raises these children’s interest in books, which may explain why they still outperform their peers in vocabulary and listening skills a year after exposure to the books. However, this hypothesis awaits further testing. The program Living Letters is not a source of additional input for carriers of the 7-repeat allele of the DRD4 gene, probably because it lacks characteristics that elicit a state of hyperfocus.

Limitations

The longitudinal design of the current randomized controlled trial has several advantages, such as the opportunity to determine the stability of the effects of technology-enhanced educational computer programs and contributing to the strengths of the current study. A disadvantage of the longitudinal character is the dependence on the willingness of the participants to participate over longer periods of time. In this study, we relied on the schools to send the scores of the various CLT tests administrated in first grade. Because of large turnovers of staff - typical of elementary schools in the Netherlands - the researchers often lost the contact person within the school who was responsible for sending the scores. Data were missing relatively often from schools with many children from families with low incomes and children from
Chapter 4

THE POTENTIAL OF TWO TECHNOLOGY-ENHANCED EARLY LITERACY INTERVENTIONS

In the current longitudinal study, we proved that a brief technology-enhanced program can be vital for a subgroup. Living Books gave a boost to story and word comprehension in a subgroup encompassing about one-third of all children. Carriers of the 7-repeat allele of the DRD4 gene fall behind in vocabulary and listening comprehension when they are not exposed to the books, but catch up and outperform non-carriers when they had a chance to work with Living Books in kindergarten, even six months and a year after the intervention. The non-carriers did not benefit from an extra program, in addition to the traditional book reading experiences, because they benefit from regular book reading experiences and Living Books does not constitute a substantial addition. This suggests that computer programs with particular features, even when they are only temporarily available for a short period of time, can be vital incentives for children with attention problems. Another educational program, Living Letters, as a result of the lack of characteristics that engage children with attention problems, showed no effects; neither carriers nor non-carriers of the 7-repeat allele of the DRD4 gene benefited from Living Letters. We suspect that this learning environment lacked elements that would make it more stimulating for the susceptible group in the current study because it lacks elements that would make this learning environment more stimulating than what children encounter in their everyday environment.

The results of the current study show that with a brief technology-enhanced early intervention in literacy education good long-term results can be achieved. Some children have a hard time keeping up with their peers, but when exposed to an enriched learning environment as offered by Living Books, even for a short period of time (intervention duration ranged between 160 and 220 minutes for a period of 12 weeks), they seize the opportunity and benefit from the extra guidance that they are offered, even a year later. The results support the hypothesis that technology-enhanced programs that include film-like components, and probably also game-like elements, can elicit a state of hyperfocus in subgroups that strengthen their learning attempts and results in outperforming their peers. Traditional forms of education do not offer teachers many means for getting children, who are predisposed to attention problems, to hyperfocus, whilst programs like Living Books and maybe also technology-enhanced computer programs that include gamification - the use of video game elements in non-gaming systems to improve user engagement (Deterding, Sicart, Nacke, O’Hara, & Dixon, 2011) – can respond to the needs of susceptible children by providing a highly engaging learning environment.


