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Chapter 5

Brief Report: Better Focus, Better Performance: Account of On-task Child Behavior while Working with Online Educational Programs

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Chapter 5

Brief report: Better focus, better performance.

Introduction

Large-scaled randomized controlled trials have shown that Living Books – digital storybooks with movie-like elements, including animated pictures, background sounds and music – can be particularly effective for literacy-delayed kindergarten pupils. Findings show that, due to such a program, the gap in early literacy skills between midrange and delayed children narrows, even when the additional program is of short duration. The strongest effects were found when children were carriers of the 7-repeat allele of the DRD4 gene, a gene that is involved in dopamine production in the brain (see Plak, Kegel, & Bus, 2015; Plak, Merkelbach, Kegel, van IJzendoorn, & Bus, 2016). Children with this genetic characteristic easily catch up and even outperform their peers when they are exposed to Living Books (e.g. Ellis, Boyce, Belsky, Bakermans-Kranenburg, & Van IJzendoorn, 2011; Kegel & Bus, 2013; Plak et al., 2015; Plak et al., 2016, Plak et al., submitted). By way of explaining the effects of Living Books, it was hypothesized that the movie-like features of the digital books are particularly engaging for carriers of this dopamine related gene polymorphism 7-repeat allele of the DRD4 gene. Due to the movie-like presentations, stories as offered by Living Books, may, probably just like other engaging digital game-based activities (see Kühn et al, 2011; Koepp et al., 1998), bring carriers of the DRD4 7-repeat allele in a state of deep engagement or “flow”. This might explain why these children learn intensely and catch up with their peers when exposed briefly (in total 2 to 3 hours) to movie-like animated books. Due to a state of flow, they may not only understand the target stories better and learn more difficult words used in these stories, but may also become more motivated for storybook reading, whether digital or printed.

Children that are carriers have lower dopamine reception efficiency, caused by diminished anticipatory cell firing, which is associated with reduced attention and reward mechanisms (Robbins & Everitt, 1999). In particular these children benefit from the dopamine boost released by activities that are particularly engaging: satisfaction after being immersed in the books releases dopamine, thus enabling a self-reinforcing route and thereby gradually better achievements. Their focus while listening to the stories, may be so intense that they even become oblivious to the world around them, resulting in a state called inattentional deafness (Molloy, Griffiths, Chait, & Lavie, 2015). That is, while “reading” Living Books, children may not notice irrelevant stimuli from their environment. Flow is a state of complete absorption or engagement in an activity: nothing else seems to matter because he or she is so involved with the goal-driven activity. In game-based learning, the flow framework may have particular value. Because the child is captivated by playing the game, time seems to fly and the experience is so rewarding that the player wants to experience it again and again (Killi, de Freitas, Arnab, & Lainema, 2012). We expect that carriers of the 7-repeat allele of the DRD4 gene may be so concentrated while working with Living Books that

Abstract

Carriers of the 7-repeat allele of the DRD4 gene - a gene that is related to efficiency in dopamine production - benefit from extra-curricular animated movie-like books alongside regular print book sharing. This is in contrast to non-carriers for whom movie-like books provide no extra reinforcement. It is hypothesized that the movie-like books are more engaging for carriers of this genetic marker than for non-carriers, whilst other literacy-related computer programs may not produce such differences. The number of errors in computer assignments recorded while playing with the computer programs, so-called big data, were analyzed and used as indicators of children’s engagement. Results corroborate the hypothesis that carriers of the 7-repeat allele of the DRD4 gene were more engaged in digital books than non-carriers, but these differences did not occur while interacting with another program without movie-like features.

Keywords: big data, engagement, the 7-repeat allele of the DRD4 gene, educational computer programs, movie-like books, process data.
comprehension increases and therefore the number of errors in on-task assignments decreases.

The repeated finding in random controlled trials that movie-like books are particularly supportive of a subsample’s learning led to a post hoc formulated hypothesis about children attaining a state of flow when they “read” Living Books. To test this hypothesis we analyzed children’s responses to built-in multiple-choice questions while interacting with educational computer programs. Data for two educational programs were available: the book reading program, Living Books, and a phonemic awareness program, Living Letters. Arguing that carriers of the 7-repeat allele of the DRD4 gene are more engaged when they are exposed to the movie-like animated books, and may even attain a state of flow, we expected in the Living Books group that carriers would make fewer errors in the multiple choice-questions than non-carriers. On the other hand, we did not expect similar differences in number of errors in the multiple-choice questions in Living Letters that may not engage carriers more than non-carriers (Plak et al., 2015; Plak et al., 2016; Plak et al., submitted). In contrast to Living Books, Living Letters lacks characteristics that may elicit a state of intense engagement, such as a movie-like presentation or gamification may do. Educational games should stretch a player’s capacity to its limits and encourage effort to overcome challenges (Killi et al, 2012) and we assume that this is not the case for carriers of the 7-repeat allele of the DRD4 gene interacting with Living Letters. In sum, it was expected that (1) carriers of the DRD4-7-repeat allele would be more successful in answering the questions embedded in the Living Books stories than non-carriers, (2) effects would be only present in a literacy-delayed group (under the 40th percentile of a standardized literacy test) but not in a literacy-midrange group - this is because the books are thought to have a better match with the needs of less literacy-advanced children - and (3) there would be no differences between carriers and non-carriers in on-task behavior while working with a less engaging program, Living Letters, in the literacy-delayed or in the midrange group.

**METHOD**

**Design**

In the current study the focus was on process data that were collected as part of a randomized control trial testing effects of two educational computer programs, Living Letters and Living Books. In both programs, children’s responses to built-in multiple-choice questions were sent to and stored on the server of Bereslim, the provider of both programs. In the current study, the number of errors in answering the questions throughout all sessions was the dependent variable, and predictors were child characteristics: (1) literacy-delayed children - a group of children scoring under the 40th percentile on a standardized literacy test - versus children scoring midrange on literacy, and (2) carriers of the 7-repeat allele of the DRD4 gene versus non-carriers.

**Participants**

The early literacy project was advertised nationwide from August 2012 to October 2013 and August 2013 to October 2013 via phone, social media, and (e-) mail. Between October 2012 and February 2013 and October 2013 and February 2014, teachers from the 183 participating schools, (from both urban and rural areas) selected eligible kindergarten children to participate in the study. If the parents of the selected children gave informed consent, children were randomly assigned to the experimental conditions, Living Books or Living Letters.

**Procedure**

Participants in this study worked online with one of the two educational computer programs, once a week for 15 minutes over a period of about 12 weeks. Based on the process data that were stored by the program (big data), 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).

**Educational computer programs**

The program Living Books, was made up of eight age-appropriate digital animated storybooks. The animated pictures, sounds, and music may support children’s understanding of story events and language (Bus, Takacs, & Kegel, 2015). Each book was interrupted four times for questions about the story and vocabulary. If children had difficulty with the questions and therefore failed to answer the question correctly, they received feedback and guidance in order to find the correct answer. 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!”). When all the answers were incorrect and the maximum amount of time was taken to answer each question, children spent a maximum of 2 minutes (approximately 25% of the time) answering questions. So for most of the time, children were listening to the story. Each book was presented twice, i.e. two series of 8 books, and in each session four new questions were included. The program Living Letters offered 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 program adapted automatically to the child's proper name when available in the name database. If the name of the child was not available, the program used 'mama' (mommy) - a word that is just as familiar as their own name to many young children. Feedback provided by a tutor followed up on every response of the child. The program Living Letters included five sets of assignments targeting name recognition, targeting recognition of the target word “mama”, recognizing the first letter of the name among other letters, and identifying pictures that start with or contain the first letter of the child’s name. When children answered a question incorrectly, feedback and clues were provided. 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 first try, the assignment was repeated twice in subsequent sessions; therefore some children had a few more sessions than others.

Measures

The Central Institute for Test Development (Cito) Literacy Test for Kindergarten (CLT). CLT is a standardized literacy test for kindergarten pupils that is administered group-wise in January (α = .89) and June (α = .87) of senior kindergarten year used in almost all primary schools in the Netherlands. The items assess vocabulary, listening comprehension, rhyme, 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 (Lansink & Hermer, 2012).

DNA analysis. Halfway during the intervention period, buccal cell samples were collected by trained members of the research team that 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). The samples were sent to a commercial laboratory for DNA analysis.

On-task behavior. Children’s scores on the multiple-choice questions in Living Letters and Living Books were stored and made available to the researchers. The responses were formatted as Incorrect, Correct or No response. E.g., when a child gave the correct response at the first try, the format was C (first response Correct). When no response was given at the first try, but then the correct answer was given, the format was NC (No response at the first try & second response Correct). If the child needed feedback twice (made an error twice) before giving the correct answer, the format was IC (first response Incorrect & second response Correct & third response Correct) and when the child needed feedback twice (made an error twice) before giving the incorrect answer, the format was II (first response Incorrect & second response Incorrect & third response Incorrect).

For Living Books we calculated per book (16 in total) the average score on four questions. For Living Letters average scores per set of assignments, five in total, each including 36 unique questions, were calculated.

Genetic screening for DRD4 polymorphisms. 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 region of interest of the DRD4 gene was amplified by PCR using the following primers: a FAM labelled primer 5’-GGCACTACGGGTCTTACTCG-3’, and a reverse primer 5’-AGGACCCCTATGGCCTTTG-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 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 at 95 °C, 30 sec at 60 °C, 60 sec at 65 °C and a final extension step of 10 min at 65 °C.

Analysis of PCR products for repeat number. 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 an ABI 3730 genetic analyser set up for fragment analyses with 50 cm capillaries. Results were analysed using GeneMarker software (Softgenetics). The genetic variable was coded as 0 or 1 for absence or presence, respectively, of a 7-repeat allele at one or both alleles. Of the 593 participants ten children could not be genotyped; 199 children (34%) were carriers of the 7-repeat of DRD4. The distribution of DRD4 polymorphisms was in Hardy-Weinberg equilibrium, χ² (df = 1, N = 428) = .069, p = .793.

Statistical analyses

Repeated measures ANOVAs were conducted on number of errors as a within-subjects variable and results of genotyping as a between-subjects factor.
For *Living Letters*, repeated measures were average scores for each of five sets of assignments (name recognition, recognition of "mama", recognition of the first letter of the name, and identifying pictures that contain the first letter or a middle letter of the child's name) and for *Living Books* repeated measures were average scores for each of the 16 books. Analyses for both *Living Books* and *Living Letters* were carried out for the literacy-delayed group and the literacy-midrange group separately. DRD4 was entered as a between-subject variable, age, sex, and father's education were entered as covariates.

**RESULTS**

There were 661 participants with a mean age of 67.19 months ($SD = 4.55$) of which 57% was male ($n = 374$). The mean score on father’s education was for *Living Books* $3.84 (SD = 1.62)$ and for *Living Letters* $3.80 (SD = 1.70)$ on a scale ranging from 0 – 6; 0 represents primary school and 6 university-level education. There were no significant differences in father's education between *Living Letters* and *Living Books*, $\chi^2 (df = 7, N = 661) = 2.069, p = .956$.

Between the two experimental conditions, *Living Letters* and *Living Books*, there were no significant differences in the percentage of children with a DRD4 7-repeat allele, 34.9% and 33.3%, respectively; $\chi^2 (df = 1, N = 661) = .984, p = 1.00$. Comparing *Living Letters* and *Living Books* no significant differences were found for age, $t(659) = .21, p = .212$, or gender, $\chi^2 (df = 1, N = 661) = .344, p = .558$.

Within the *Living Books* condition, the number of errors between literacy-midrange and literacy-delayed children differed, $t(203.46) = 4.30, p = .000$; literacy-midrange children made fewer errors ($M = 1.37, SD = .17$) than literacy-delayed children ($M = 1.48, SD = .22$). Similarly, within the *Living Letters* condition there was a significant difference in the number of errors between literacy-midrange and literacy-delayed children, $t(430.71) = 3.70, p = .000$. Children scoring midrange made fewer errors ($M = 1.56, SD = .31$) than literacy-delayed children ($M = 1.68, SD = .38$).

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**Living Books**

Overall. The significant Maulchy’s test for both literacy-delayed and literacy-midrange - $\chi^2 (119) = 194.30, p = .000$ and $\chi^2 (119) = 244.69, p = .000$, respectively - showed that the assumption of sphericity was violated. Therefore degrees of freedom were corrected with Greenhouse-Geisser estimates of sphericity ($\varepsilon = .794$ and $\varepsilon = .752$, respectively). These estimates were closer to 1 than the lower limit of $\varepsilon = .067$ for both literacy-delayed and literacy-midrange, indicating that there was limited deviation from sphericity (Field, 2009).

**Literacy-delayed vs. literacy-midrange.** In the literacy-delayed group, the number of errors did not differ across books, $F(2.39, 253.73) = 1.00, p = .452$, whilst this did differ in the literacy-midrange group $F(2.58, 107.00) = 2.88, p = .044$, indicating that, for this group, the books were not of a similar level of difficulty. The interaction *Living Books* and DRD4 , and the interaction *Living Books* and the covariates did not show significant effects for the literacy-delayed group or the literacy-midrange group. DRD4 did not cause a significant between-subjects effect in the literacy-midrange group $F(1, 107) = .500, p = .823$, while in the literacy-delayed group DRD4 caused a significant between-subjects effect $F(1, 103) = 4.53, p = .000$. The significant Maulchy's test for both literacy-delayed and literacy-midrange - $\chi^2 (119) = 194.30, p = .000$ and $\chi^2 (119) = 244.69, p = .000$, respectively - showed that the assumption of sphericity was violated. Therefore degrees of freedom were corrected with Greenhouse-Geisser estimates of sphericity ($\varepsilon = .794$ and $\varepsilon = .752$, respectively). These estimates were closer to 1 than the lower limit of $\varepsilon = .067$ for both literacy-delayed and literacy-midrange, indicating that there was limited deviation from sphericity (Field, 2009).
.036). In the group of literacy-delayed children, carriers of the DRD4 gene made fewer errors ($M = 1.42, SD = .22, n = 38$) than non-carriers ($M = 1.52, SD = .22, n = 70$).

**Living Letters**

Overall. The assumption of sphericity was violated, as is indicated by a significant Mauchly’s test for Living Letters for both the literacy-delayed and literacy-midrange groups $\chi^2(9) = .756, p = .000$ and $\chi^2(9) = .774, p = .000$, respectively - but the deviation from sphericity was limited; Greenhouse-Geisser estimates, for both literacy-groups, $\varepsilon = .874$ and $\varepsilon = .884$, respectively, were closer to 1 than the lower limit of $\varepsilon = .250$ for both groups.

**Literacy-delayed vs. literacy-midrange.** In the literacy-delayed group the effect of the set of assignments approached significance, $F(3.54, 222.30) = 2.26, p = .069$, but the number of errors did differ significantly in the literacy-midrange group, $F(3.50, 205.95) = 2.71, p = .036$, indicating that the sets of assignments differed in difficulty. For literacy-delayed children, all sessions were of such a consistent level of difficulty that little variation between the sessions was found, in contrast to literacy-midrange children; overall they made fewer errors ($M = 1.55, SD = .34$) than literacy-delayed children ($M = 1.68, SD = .38$), and the level of difficulty of the program seemed to be a better fit for the literacy-midrange group. The interaction *Living Letters* with DRD4 and the covariates did not show significant effects for the literacy-delayed group or the literacy-midrange group. For both the literacy-delayed group ($F(1, 222) = 1.24, p = .267$), and for the literacy-midrange group DRD4 ($F(1, 209) = .679, p = .411$), DRD4 was not significant.

**DISCUSSION**

Based on the results of two large-scaled RCTs it is possible to conclude that movie-like books may be particularly successful in engaging the attention of children who are carriers of the 7-repeat allele of the DRD4 gene. The results of the data, stored while children interacted with the educational computer programs, are in line with the post hoc formulated hypothesis that programs that include movie-like presentations with nonverbal additions such as background music, and zooming may be particularly engaging for carriers of the 7-repeat allele of the DRD4 gene as these additions direct attention to details in pictures (Bus et al., 2015; Takacs, Swart, & Bus, 2015). Due to the movie-like presentation of stories in *Living Books* that closely match the narratives, carriers of the 7-repeat allele may achieve “flow” while “reading” the stories; they are so engaged and involved that concentrating on the stories goes effortlessly (Kiili et al., 2012).

The program *Living Books* elicited higher levels of concentration and engagement in carriers than non-carriers as can be derived from the significantly lower number of errors in the built-in multiple choice-questions. Another program, *Living Letters*, which also included multiple choice-questions, revealed no differences between carriers and non-carriers in the number of errors. This finding supports the conclusion that movie-like features, typical for *Living Books*, stimulate engagement.

However, we cannot disregard the possibility that differences in number of errors may also mean that carriers of the 7-repeat allele of the DRD4 gene have more knowledge about storylines than non-carriers and are more capable of figuring out the meaning of difficult words used in the stories by means of the context. This is, however, not a very likely explanation when we take into account that carriers had a similar baseline level on a standardized language and literacy test as non-carriers.

When children scored midrange on a standardized literacy test, no differences between carriers and non-carriers were found in the number of errors in multiple-choice questions while reading the books. This may indicate that the *Living Books* program, as used in the current study, was not particularly effective for children at a more advanced level, probably because the selection of books was attuned to low performers and rather simple for the midrange group as is indicated by the error rate; children scoring midrange made significantly fewer errors than their literacy-delayed peers.

The current findings offer further support to the hypothesis that movie-like books may be an indispensable element of the kindergarten curriculum for a substantial group of pupils. For carriers of the 7-repeat allele of the DRD4 gene, about one third of all children, programs such as *Living Books* are more engaging and therefore are a valuable addition to regular book reading sessions (Bus et al., 2015; Takacs, Swart, & Bus, 2015). A movie-like presentation may boost their dopamine production, as a result of which carriers of the 7-repeat allele of the DRD4 gene may enter a state of flow (Kiili et al, 2012) and make substantially fewer errors in questions about the storyline and difficult words used in the story by means of the context. This is, however, not a very likely explanation when we take into account that carriers had a similar baseline level on a standardized language and literacy test as non-carriers. During traditional book reading, children who are carriers of the 7-repeat allele of the DRD4 gene may experience difficulty staying attentive, whilst they are extremely focused when they interact with *Living Books*, consequently showing more progress in literacy skills with this program than their peers.
REFERENCES


