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## **What works for whom? Differential genetic effects of early literacy interventions in kindergarten**

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# Chapter 6

## General Discussion

Until recently, an educational intervention was considered to be successful if main effects could be established (e.g. Fukkink, Jilink, & Oostdam, 2015). There is however evidence that not every child benefits to the same extent from educational interventions. From the large-scale experiment conducted for this study it appears that effects of additional educational computer programs do not become manifest when the focus is on the complete group, but effects are shown in subsamples.

Two large randomized controlled trials were carried out to examine the effect of educational computer programs. In the first wave - school year 2012-2013 - 90 schools from all over the Netherlands participated in the experiment. Children were randomly assigned to one of the experimental computer programs, *Living Letters* or *Living Books*, or to a control program that does not stimulate early literacy skills (Plak, Kegel, & Bus, 2015). In the second wave - school year 2013-2014 - the randomized controlled trial was expanded by an additional 93 schools (Plak, Merkelbach, Kegel, Van IJzendoorn, & Bus, 2016). The intention was to replicate a Gene x Environment interaction effect, which had been found in the first wave (Plak et al., 2015). To test long-term effects of the educational computer programs in kindergarten, first grade test scores were collected and analyzed (Chapter 4). Big data were used to ascertain differences in on-task behavioral data while working with the experimental technology-enhanced programs *Living Letters* and *Living Books* (Chapter 5). The aim was to show that some children attain “flow” while making the assignments, whereas other do not.

In Kegel, Bus, & Van IJzendoorn (2011) four-year olds who were carriers of the 7-repeat allele of the DRD4 gene benefitted from exposure to *Living Letters*. We were unable to replicate this finding in experiments in which we targeted carriers who were one year older; no effects were found for five-year-old carriers of the 7-repeat allele of the DRD4 gene when exposed to *Living Letters*. It is possible that the five-year-old participants in the current experiments did not benefit from this educational computer program because the tasks were not challenging and exciting enough for their age. In line with this argument, teachers complained that *Living Letters* was too tedious for their students, thus suggesting that *Living Letters* was somewhat boring for most five-year-olds. If the level of the educational program is not tailored exactly right, it is not surprising that no effects were found. It is also possible that the pace of the program is too slow: the push and pull between watching the general introduction, listening to specific instructions, and completing the assignments may make it hard for children to become totally engrossed in *Living Letters*. On the other hand, in parallel studies that focused on another vulnerable subsample, five-year-olds born preterm, *Living Letters* did have added value (Merkelbach, Plak, Kegel, & Bus, under review; Van der Kooy-Hofland, Bus, & Roskos, 2012). These incompatible results for different subsamples, carriers of the 7-repeat allele of the DRD4 gene and children born preterm, emphasize that program characteristics are important, but that fine-tuning matching program

characteristics and child characteristics is indispensable.

The educational computer program *Living Books* was not effective for the sample as a whole, but it was for carriers of the 7-repeat allele of the DRD4 gene. *Living Books* had added value only in this particular subsample compared to the control condition in which children had only the daily book sharing experiences. As most children had book-sharing experiences at home and in school, typically several times a day, it is not surprising that the majority did not benefit from a brief intervention with *Living Books*. The program provides extra books, but they may not add much to most children's daily dose of reading, i.e., it hardly matters whether children received the book reading program or not. In spite of the majority not benefiting from *Living Books*, a minority - carriers of the 7-repeat allele of the DRD4 gene - received a boost as a result of the intervention. In this subsample, a brief intervention with animated storybooks contributed substantially more to literacy skills despite of a wealth of traditional book sharing that children experienced.

The effects found were typical for literacy-delayed children; that is, children that scored in the ranges ( $\leq 40$  percent) of a nationally implemented standardized literacy test for children in kindergarten (Central Institute for Test Development (Cito) Literacy Test for Kindergarten). Effects were not found for children scoring midrange on this test or for carriers of the 7-repeat allele of the DRD4 gene effects, indicating that *Living Books* as used in this large-scale experiment is only effective for those children who struggle to acquire literacy skills. The books that were used in *Living Books* had simple plots, were easy to follow and all contained repeating phrases that create rhythm and structure, as often found in storybooks for very young children. It may be that if more advanced books were to be included in *Living Books*, midrange-scoring children could also benefit from this educational computer program.

The effect of educational computer programs persevere; in first grade, carriers of the 7-repeat allele of the DRD4 gene still outperform their peers in outside-in skills like vocabulary and story comprehension. These long-term effects should probably not only be attributed to direct effects of *Living Books* on those skills. What is more plausible is an indirect snowball effect; the experience with *Living Books* has increased pleasure in book reading for carriers, as a result of which reading motivation in young children grows and they continue to read and ask for books.

#### Toward a theory explaining the effects of *Living Books*

The positive response that carriers of the 7-repeat allele of the DRD4 show to the *Living Books* may support the hypothesis that educational computer programs that include movie-like components can strengthen these children's learning. *Living Books* are designed in such a way that movie-like presentations of the story - including background music - are constantly available. *Living Books* may thus create

a maximally stimulating learning environment for children who may have problems focusing on activities, but who at the same time have a tendency to get carried away by activities that do interest them. Actually the results of analyzing children's online behavior corroborate the hypothesis that the movie-like presentations in *Living Books* may incite a state of deep concentration or "flow" in this specific subsample.

Carriers of the 7-repeat allele of the DRD4 gene may 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 reinforcement; that is, after being challenged and achieving a satisfactory result, dopamine becomes available thereby enabling new achievements (Koepp et al., 1998). *Living Books* may elicit this route in carriers of the 7-repeat allele of the DRD4 gene and, as have been reported about persons with ADHD, they may then enter stages of very high levels of concentration (Schecklmann et al, 2008).

In other words, it is plausible that carriers of the DRD4 7-repeat allele reach a state of hyperfocus. That is, they focus on what is presented in the computer program, thereby blocking all other stimuli coming from the environment, and engage in activities. Things like playing games or watching movies that do really interest them elicit such a state. In this state it may be hard for them to "shift gear": to stop the task at hand and take up boring but necessary tasks. However a tendency to become immersed in activities that do interest them may turn out to be a good thing when it is used to reach optimal performance. With *Living Books*, carriers of the DRD4 allele even can outperform non-carriers because these books, due to the engaging film-like elements, afford a state of hyperfocus, which supports more intense learning than occurs in non-carriers (Plak et al., 2015; Plak et al., 2016).

It is possible that carriers of the 7-repeat allele of the DRD4 gene, while playing with *Living Books* and watching movie-like images, experience flow that often leads to *inattentional deafness* - not noticing irrelevant stimuli from their environment (Molloy, Griffiths, Chait, & Lavie, 2015) like their somewhat noisy and chaotic classroom. As a result, their attention is solely focused on *Living Books*. Nothing else may matter because the child is deeply involved in reading a story (Kiili, de Freitas, Arnab, & Lainema, 2012). Direct evidence for the state of deep concentration is not yet available although we did find some proof from analyzing children's responses to questions that were built in the stories. The carriers of the 7-repeat allele of the DRD4 gene made significantly fewer errors in those questions than non-carriers, thus indicating that they were much more concentrated on and involved in the task than non-carriers.

Similarly, game-like elements in educational computer programs may elicit flow in subsamples of children. *Gamification* may therefore be a potential beneficial addition to educational programs for carriers of the DRD4 gene. Gamification is the use of video game elements in non-gaming systems to improve user engagement (Deterding,

Sicart, Nacke, O'Hara, & Dixon, 2011). Gamification can take many forms and is used in corporate settings, marketing and education. When playing games, children's level of engagement - a challenge in education - may increase (Van den Boer, 2013). Flow is especially important when involved in game-like activities; a child is highly engaged and tunes out irrelevant stimuli from their surroundings. Because such children are so captivated by playing, and the experience was so rewarding, the children want to experience it again and again (Kiili et al., 2012).

### Recommendations for future research

Since it remains unclear whether movie-like images contribute to the effect of *Living Books*, a comparison should be made in which carriers of the 7-repeat allele of the DRD4 gene are presented with digital animated books or with static books.

Furthermore, the focus in the current thesis was solely on the DRD4 gene. In further research however, other candidate genes or pathways should be included in experiments in order to expand our knowledge of markers of differential effects on learning. In addition to this, educational computer programs that include different functionalities than the programs included in this study should be included in future research.

In order to identify children who are carriers of the 7-repeat allele of the DRD4 gene, we used genotyping in the current thesis. For mere research purposes, this is defensible, but it is rather laborious and charged with ethical issues. By including the genetic marker, we were able to prove that *Living Books* are an indispensable element of the kindergarten curriculum. Teachers should make the books part of their daily activities, even though they are unable to identify the children for whom the books are most beneficial. In this study we noticed that for teachers it is hard to believe that the books *do* facilitate learning in subsamples and free reading time is a necessary element of the curriculum, as is the case in higher grades. Integrating *Living Books* in the curriculum is only possible when teachers recognize that free reading time adds to the shared book reading activities.

Finally, in further research the focus should be on specifying underlying mechanisms that explain the efficacy of technology-enhanced books for subsamples, like the hypothesis that some children attain a state of flow when they read the books.

## CONCLUSION

The current findings have far-reaching consequences for kindergarten schools and how to use educational computer programs. In this study it was possible to prove that, for a substantial subsample of kindergartners, the *Living Books* program was more instructive than regular book reading experiences. For one third of the children, the educational program *Living Books* has an added value when compared to conventional reading situations. For those children, the program is indispensable and therefore should be part of the curriculum. The program should not be seen as a bonus for children as is often the case with computer programs. Reading independently with *Living Books* should be implemented in their daily routine. With this program only used as little as once or twice a week, a substantial proportion of the students experience increasing success since the extra guidance in these books is crucial for them. In the current experiments, *Living Books* enabled literacy-delayed children who are carriers of the 7-repeat allele of the DRD4 gene to show their full potential. A selection of more complex books may result in similar effects in more literacy-advanced subsamples. For non-carriers, the *Living Books* program does not contribute to their learning, although the program is not harmful to their learning process. For them, the program is only an extension of reading moments, but it does not add value compared with the regular book reading experiences. The finding that for some children a computer program is more effective than an approach that involves teacher-student interaction is surprising, and for many educators, counterintuitive.

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