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

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### Citation

Plak, R. D. (2016, December 15). *What works for whom? Differential genetic effects of early literacy interventions in kindergarten*. Retrieved from <https://hdl.handle.net/1887/45043>

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**Issue Date:** 2016-12-15

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# Chapter 1

## General Introduction

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## INTRODUCTION

There are various ways for young children to come in touch with written language at school and in their home environment. Book sharing is often considered as one of the most important activities parents and teachers can do to promote young children's early literacy skills (Bus, van IJzendoorn, & Pellegrini, 1995; Mol & Bus, 2011). In addition, literacy-related experiences in homes and schools include reading and writing of words such as the child's proper name or other people's names (Both-de Vries & Bus, 2010). More than three decades ago, Emilia Ferreiro and Ana Teberosky (1982) showed the importance of the early years for the development of literacy. Their research had a strong impact on the research community and since then a spate of articles has appeared to explain such early learning processes. As research in the field of early literacy underscores the importance of the early years for developing the foundation for future literacy, the interest in early interventions has strongly increased as well.

This dissertation explores whether computers can contribute to assisting and supporting teachers when emergent literacy skills lag behind. Since it is easier to tailor the format and content of web-based programs to individual differences than to ensure that classroom instruction meets the needs of all individual pupils, computer programs may be an attractive tool for providing additional home- and school-like experiences with literacy in order to advance early literacy skills of young children at risk. Unfortunately, there is a lack of evidence with regard to computer programs as tools to provide young children with relevant practice, even though there is increasing interest in computer programs in support of instruction in early stages of becoming literate. Moreover, the number of computers or tablets with Internet connections in Dutch kindergarten classrooms has grown from one computer per 17 pupils in 1999 to one device (computer, laptop or tablet) per four students in 2015 (Kennisset, 2015). In recent years, there has been a gradual increase of the role that digital learning material plays in the curriculum (Blockhuis, ten Voorde, & Sluijsmans, 2014; Kennisset, 2013). This trend is continuing and teachers are using more and more digital content. The share of digital learning materials in the curriculum was according to teachers 15% in 2007-2008, this increased in 2014-2015 to about 25%. Teachers use ICT, but do not make optimal use of the possibilities ICT can offer, for example offering students personalized learning with ICT applications (Kennisset, 2015).

The focus in this dissertation is on two educational computer programs targeting emergent literacy skills. One program, *Living Books*, includes technology-enhanced animated books that offer extra nonverbal information that matches the story text and may thus provide guidance in understanding the text. Examples of such additions are animated illustrations, zooming, sounds, and background music (Bus, Takacs, & Kegel, 2015; Takacs, Swart, & Bus, 2015). *Living Books* are formatted as

an attractive movie-like representation of the story that closely matches the events presented in the story text. The nonverbal additions may, if well designed, replace any scaffolding provided by an adult because the additional nonverbal information directs attention to details in pictures, just as adults do while sharing a story with a child (Takacs, Swart, & Bus, 2014). Even more remarkable is that the movie-like presentation of the story, including background sounds and music, may make the books more compelling and engaging than a traditional print book (Verhallen & Bus, 2009), and that children may achieve "flow" while listening to the stories. Persons "in flow" can be described as being deeply involved in an activity that they find enjoyable and they do not have to make any effort to concentrate while involved in the activity (Kiili et al., 2012).

The second 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. It is designed according to the principle that verbal responsiveness is important to stimulate young children's learning (Tamis-LeMonda, Cristofaro, Rodriguez, & Bornstein, 2006). Verbal responsiveness implies that a tutor responds to all attempts that children make to solve assignments. The program's responses are not only prompt and dependent on the child's focus of attention but they have a positive, supportive tone and add constructive information. For instance, a first error in an assignment is followed by a repetition, a second by a hint, and a third by a demonstration of the correct solution.

Even though it is likely that educational computer programs - modeled on children's daily literacy-related activities - contribute to children's literacy development, they may not do so to the extent that they have added value when compared to common experiences at home and in school. Given the usual circumstances are that children have daily literacy experiences in school, including (book) reading and writing of (the proper) name(s), educational computer programs may only imply a minor expansion in the amount of time spent on these literacy activities. It is therefore not plausible to have high expectations of effects of an educational computer program on language and literacy skills in kindergarten even when children are delayed in language and literacy skills.

On the other hand, it is quite possible that educational computer programs can have an added value to common literacy experiences due to special functionalities built in the educational computer programs that respond to children's specific needs. E.g., it is conceivable that the computer programs are especially helpful when children have problems concentrating on tasks. Some program features may help children to achieve flow, that is, children are deeply involved and do not have to make any effort to be highly concentrated (Kiili et al., 2012).

### *Genetic differential susceptibility*

There is increasing evidence in the field of child development and pathology showing that children with a specific genetic make-up are more susceptible than others to the quality of their environment, including educational program. In a less optimal or stimulating environment they are more prone to abnormal development than their peers (e.g., Ellis, Boyce, Belsky, Bakermans-Kranenburg, & Van IJzendoorn, 2011). However, in an adaptive learning situation they may even outperform their peers (Belsky, Bakermans-Kranenburg, & Van IJzendoorn, 2007; Ellis et al., 2011). Ellis and Boyce (2008) described the individual differences in genetic make-up by means of a metaphor. Similar to how dandelions are able to survive and bloom, irrespective of soil, sun, drought, or rain, some children thrive whether or not the learning environment is optimal. Dandelions are known to exist in open fields, but also between the cracks of paving stones. Orchids by contrast can, similar to more susceptible children, be considered as context-sensitive. Their survival and flourishing is intimately tied, like that of the more susceptible children, to the nurturing or neglectful qualities of the environment.

Based on ample research, both correlational and experimental, the D4 Receptor Gene, with the polymorphism DRD4 7-repeat, is widely used as a marker in relation to the child-rearing environment (e.g. Bakermans-Kranenburg & Van IJzendoorn, 2006, 2011, 2015; Ptáček, Kuželová, & Stefano, 2011). The DRD4 gene is a 48-bp variable number tandem repeat (VNTR) with on its third exon repeats varying from 2 to 11. Two alleles are most common, the 4 repeat and the 7-repeat (Chang, 1996). The greater part of the population is carrier of the 4-repeat allele, while about one third is carrier of the polymorphism 7-repeat allele. Carriers of the 7-repeat allele of the DRD4 gene, also nicknamed “the long variant”, are thought to be more susceptible to the quality of their environment than non-carriers (see for an overview Bakermans-Kranenburg & Van IJzendoorn, 2011). Carriers have lower dopamine reception efficiency, caused by a diminished anticipatory cell firing, which is related to reduced attentional and reward mechanisms (Robbins & Everitt, 1999). Although the dopamine receptor D4 is associated with (in)attention and motivation (Hsiung, Kaplan, Petryshen, Lu, & Field, 2004; Tripp & Wickens, 2008), and even with ADHD (Maher, Marazita, Ferrel, & Vanyukov, 2002) and novelty seeking (Ebstein, 1996, 1997), disappointingly there are no associations between the DRD4 gene and cognitive abilities and behavioral traits (Pappa et al., 2011). However, if the 7-repeat allele of the DRD4 gene is considered in interaction with environmental qualities it does predict outcomes like cognitive performance; e.g., four-year-old carriers of 7-repeat allele of the DRD4 gene made great progress in literacy skills when pupils were exposed to the highly responsive computer program, *Living Letters*, whilst non-carriers did not benefit from this educational computer program (Kegel, Bus, & van IJzendoorn, 2011).

Carriers of the 7-repeat allele DRD4 gene may experience problems focusing their attention, and being concentrated on an activity, but some computer activities may elicit them becoming highly engaged (Kühn et al, 2011; Koepp et al., 1998) and so enter a state of flow (Killi et al., 2012). There is still no explanation of which aspects of computer programs are so beneficial to and result in children who are carriers of the DRD4 gene being in a state of deep concentration and learning (flow). Teachers may not be able to offer similar qualities to this particular subsample as focusing attention, explaining and scaffolding, repetitively, can be challenging to teachers. In order to stimulate the learning process, a teacher must not only give special attention to the child with attention problems in a group of 20 to 30 children, but also stay calm, remain positive and patient. Moreover, teachers are not always able to monitor the learning process closely and are therefore unable to provide the exact help the child needs at a particular moment (Van de Pol, Volman, & Beishuizen, 2011). Technology-enhanced computer programs do make it possible to offer children lagging behind personalized adaptive guidance exclusively tailored to the needs of every individual child.

## AIMS AND OUTLINE OF THE PRESENT THESIS

In previous smaller scaled experiments, the effect of educational computer programs was tested and confirmed (Kegel et al., 2011; Van der Kooy-Hoffland, Bus, & Roskos, 2012). The intervention effect moderated by genetic profile was based on a rather small sample, and genetically moderated intervention effects need replication (Van IJzendoorn et al., 2011) and therefore new randomized controlled trials were planned. From August 2012 to October 2012 and August 2013 to October 2013 the project was broadly advertised via e-mail, mail, social media, and phone in the Netherlands. In total 183 schools from all over the country, from urban and rural areas, participated. That is 2.7% of all Dutch schools. We, as researchers, had little involvement in the implementation of the intervention. We asked the kindergarten teachers to select eligible children in their classroom and to provide parents with brochures about the research. After parents gave written informed consent for participation of their child, we randomly assigned children to either one of the programs, *Living Books* or *Living Letters*, or the control condition. In January teachers administered the Central Institute for Test Development (Cito) Literacy Test for Kindergarten (CLT). This is a standardized literacy test (Lansink & Hemker, 2012) that is used on almost all primary schools in the Netherlands. The test consists of two versions with similar items, the first version is administered in January and the second version in June. The intervention period started in March of the senior kindergarten year and ended 12 weeks later in June. Teachers received online accounts to which they could log children in and have

them work with the program to which they were assigned. Immediately following the intervention period of twelve weeks, teachers administered the CLT June. Halfway during the intervention period, buccal cell samples were collected by trained members of the research team. The samples were sent to a commercial laboratory for DNA analysis.

We also examined whether computer training by means of technology-enhanced educational programs of clearly defined academic core language and literacy skills (phoneme awareness & story comprehension and vocabulary) can reduce the risk of developing reading problems in first grade. Based on outcomes of a previous smaller scaled study, we expect that the extra input from technology-enhanced educational programs will not be equally effective for all children. For a deeper understanding of learning processes it is important to find out *who* benefits the most from these interventions. In other words, it is our aim to find moderators of the effects of technology-enhanced programs in kindergarten. In this thesis, the focus will be on a genetic characteristic, i.e., whether or not a child is a carrier of the 7-repeat allele of the DRD4 gene, which may clarify for whom technology-enhanced programs are effective and why.

In **Chapter 2**, a nation-wide randomized controlled trial (RCT) examines whether effects of technology-enhanced educational programs *Living Letters* and *Living Books* were moderated by the dopamine receptor D4. Effects for pupils in the senior year of kindergarten are described for carriers and non-carriers, but also for children that score in the lowest ranges of a standardized literacy test, literacy-delayed children, and children that score midrange i.e. average scoring children.

**Chapter 3** looks at whether the results of the first wave could be replicated in a second wave with new participants. Furthermore, a meta-analysis was conducted to determine whether the outcomes of the Gene x Environment RCT reported in this study matched the results of previous experiments.

Educational programs can be called preventive when long-term effects are present. Since this has not yet been established for the genetic moderator DRD4, long-term effects of *Living Letters* and *Living Books* are examined in **Chapter 4**.

The question of why technology-enhanced programs work for certain subsamples is further explored and discussed in **Chapter 5**.

Finally, the findings of the above studies are integrated and summarized in **Chapter 6**. Furthermore, directions for future research are discussed.

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