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Brief computer interventions enhance emergent academic skills in susceptible children: A gene-by-environment experiment

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ABSTRACT

In this study we examined the potential of technology-enhanced educational programs for young children lagging behind in emergent literacy skills. Differential effects of technology-enhanced educational programs for poor performers were tested in a randomized controlled trial. Our previous study showed that children with a dopamine-related genetic polymorphism – DRD4 7-repeat – are more susceptible to their learning environment than children without this polymorphism, serving as a proxy for the dopamine-system related genetic pathway. In the current study, we aimed to replicate and extend these results in a sample of 583 kindergarteners from 136 schools. As predicted by the genetic differential susceptibility theory, carriers of the DRD4 7-repeat allele profited significantly from *Living Books* (d = 0.75), whereas non-carriers did not benefit (d = 0.02). *Living Letters* did not show a Gene × Environment interaction. We discuss why carriers of DRD4 7-repeat allele particularly benefit from *Living Books*.

1. Introduction

In this study we examined the potential of educational computer programs for young children lagging behind in emergent academic skills and therefore at risk for learning problems in primary education. Building on the Simple View of Reading, Bowyer-Crane et al. (2008) proposed a two-dimensional model of early reading interventions with phonological skills positioned on one dimension, and non-phonological skills (e.g., semantics and syntax) positioned on the other. We explored the efficacy of both types of programs in kindergarten age: *Living Letters* to prevent the risk of word-level decoding difficulties, and *Living Books* to prevent the risk of reading comprehension difficulties associated with deficits in non-phonological language skills.

Average effects of technology-enhanced educational programs for young children are unfortunately rather disappointing unless subsamples are formed (e.g. Saine, Lerkkanen, Ahonen, Tolvanen, & Lyytinen, 2011). We argue that the average effects do not reflect true effects that are hidden in a subgroup of children who are more *susceptible* to environmental experiences, such as child rearing and school environment. Children who are thought to be susceptible to environmental factors not only catch up and perform at a level similar to other children, but they actually outperform their non-susceptible peers. It appears from child development research that children with specific genetic or temperamental characteristics are more susceptible to the quality of the environment than others, and are at risk of a delayed development in comparison with their peers when they grow up in less stimulating families or other child rearing contexts (e.g., Ellis, Boyce, Belsky, Bakermans-Kranenburg, & Van IJzendoorn, 2011). These susceptible children easily catch up and even outperform their peers in an optimal environment. This is the *For Better and For Worse* principle of the Differential Susceptibility Theory (Belsky, Bakermans-Kranenburg, & Van IJzendoorn, 2007; Ellis, Boyce, Belsky, Bakermans-Kranenburg, & Van IJzendoorn, 2011).

In the popular press, susceptible children have been compared to orchids - these flowers only bloom when temperature and humidity are optimal -, in contrast to less susceptible species, like dandelions, which grow irrespective of the quality of the environment (Dobbs, 2009). This Differential Susceptibility Model

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challenges the traditional Diathesis Stress Model in which the idea is promoted that children with specific characteristics are more vulnerable to adversities or negative experiences and that others are less affected by the same experiences (Belsky & Pluess, 2013; Belsky, Bakermans-Kranenburg, & IJzendoorn, 2007). Boyce and Ellis (2005) stated that the Differential Susceptibility Model is fundamentally different from the Diathesis Stress Model in that individuals not only vary in the extent to which they are susceptible to negative experiences but also their malleability; individuals who are more malleable are thought to be more susceptible to negative and positive experiences (Belsky et al., 2007). Children, who due to specific characteristics are thought to be less susceptible, are less influenced by negative or positive environmental factors.

Correlational and experimental studies showed that children with a specific dopamine-related genetic polymorphism - Dopamine D4 Receptor Gene, with the polymorphism DRD4 7-repeat - are thought to be more susceptible to their environment than children without this polymorphism (Bakermans-Kranenburg & Van IJzendoorn, 2006, 2011, 2015). For example, in a randomized parent training experiment, carriers of the 7-repeat variant showed less externalizing behavior when their parents were coached to enhance their sensitive caregiving, whereas with the same coaching non-carriers did not make progress (Bakermans-Kranenburg & Van IJzendoorn, 2008). Children with the 7-repeat allele of the DRD4 gene (the long variant of the DRD4 gene) have a lower dopamine reception efficiency - caused by diminished anticipatory cell firing - which is associated with reduced attentional and reward mechanisms (Robbins & Everitt, 1999). It is hypothesized that these children are more sensitive to an environment that helps to structure their activities and is supportive of reward and attentional mechanisms (Bakermans-Kranenburg and Van IJzendoorn, 2015). A crowded noisy classroom can therefore be regarded as a negative learning environment for children with the DRD4 7-repeat allele. Due to reduced attentional mechanisms, they are at risk of wandering off and failing to use the learning opportunity.

Educational computer programs may be especially helpful for supporting these children's learning processes especially when they do not just offer practice but also provide scaffolding during learning, thus helping them to stay task-focused (Kegel & Bus, 2012). *Living Letters* – a program promoting alphabetic knowledge – includes a tutor, one of the characters in the games, who responds to all attempts children make to solve the tasks. If children do not start solving a problem or their first attempt fails, the tutor encourages the child to try. After the second failure, the tutor provides a cue for finding a solution and after the third failure, the tutor models and explains the correct solution. Because of the scaffolding, children may be able to solve tasks that are just above the level that they normally can solve on their own (e.g., Kegel & Bus, 2012). *Living Books* is a technology-enhanced book reading program composed of eight different stories each repeated twice. The animated pictures, sounds, and music appearing simultaneous with the story text help to make sense of the story and the story text and thus enable the child to understand story events and language even when the oral text is difficult for the child (Bus, Takacs, & Kegel, 2015). This format stimulates building combined verbal and non-verbal representations, also referred to as multimedia learning (Mayer, 2005). If the music is congruent to the narration, it facilitates story comprehension and learning words from the narration (Takacs, Swart, & Bus, 2015). Furthermore, additions to the story, like movie-like presentations and background music, are engaging and may therefore be helpful in staying focused while hearing the story.

In particular, carriers of the 7-repeat allele of the DRD4 gene that has been associated with ADHD (Maher, Marazita, Ferrel, & Vanykukov, 2002) may benefit from these computer programs. Lower dopamine reception efficiency may result in being less attentive during the learning process when the learning environment is not sufficiently structured and supportive (Kegel & Bus, 2012). Because carriers of the 7-repeat variant of the DRD4 gene might be less able to focus on a task in a somewhat chaotic environment, such as in regular classrooms, and therefore are often distracted from core learning processes, they may be dependent on special tailored programs that help them to focus. Even when part of the tailored programs have overlap with the regular curriculum, carriers of the DRD4 7- repeat allele may benefit from additional educational computer programs. *Living Letters* might be very helpful to them because it includes an Intelligent Tutoring System providing consistent feedback to all of the children's responses. *Living Books* retains and guides attention with the help of a movie-like presentation. It may be that children with attentional problems benefit from the movie-like presentation in the *Living Books*. Acevedo-Polakovich, Pugzles Lorch, and Richard (2007) showed that children with ADHD enjoy watching television more and have greater involvement in television-related activities when compared to typically developing children. We expected therefore to find a cross-over Gene × Environment interaction, showing that carriers of the 7-repeat allele of the DRD4 gene may profit most from both computer programs and even outperform their less susceptible peers without this DRD4 7-repeat allele.

Results so far were mixed. A study by Kegel, Bus, and Van IJzendoorn (2011) was the first experiment in which genetic differential susceptibility for *Living Letters* was tested. From this study, which included typical four-year-olds, it appeared that in particular children with the 7-repeat allele of the DRD4 gene were susceptible to the educational computer intervention *Living Letters*. Carriers of the 7-repeat allele fell behind in early literacy skills in comparison to their peers without the extra input of *Living Letters*, but outperformed their peers when they did work with *Living Letters*. Plak, Kegel, and Bus (2015) tested both the educational computer programs, *Living Letters* and *Living Books*, in a group of five-year-olds delayed in early literacy skills. They could not replicate the differential effects for *Living Letters* but did find differential effects of *Living Books*. Non-carriers of the 7-repeat allele did not benefit from *Living Books* but carriers did substantially. Teachers suggested that *Living Letters* was too easy and too boring for five-year-olds, which might explain results so far. In the current study, we therefore complicated the program by dropping the easiest games.

1.1. Current study

In a large countrywide randomized controlled trial, we provided 5-year-olds, just before their transition from kindergarten to first grade, with the computer programs that trained important precursors for learning to read in first grade. We targeted children from 136 different schools whose early literacy skills were delayed or rather low according to their teacher and their scores on a national standardized literacy test. In total, 583 5-year old kindergarten children were randomly assigned to one of two early literacy computer programs, *Living Letters*, *Living Books*, or a control condition, *Clever Together* that practiced visual-spatial skills. They practiced with *Living Letters*, *Living Books* and *Clever Together* for a brief period, ranging between 160 and 220 min and over the course of about 12 weeks. The researchers assigned the children randomly to one of the three programs and provided online access but were not involved in the implementation or testing. A standardized test for literacy administered by teachers in January and June in the senior kindergarten year provided pre- and posttest scores. We tested (1) main effects of literacy programs on the standardized literacy test, (2) whether there was evidence for a Gene × Environment interaction and carriers of the 7-repeat DRD4