

Differential Susceptibility  
to an Early Literacy Intervention

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**Differential Susceptibility  
to an Early Literacy Intervention**

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# Chapter 1

## General introduction

Parts of the introduction were published in: Van der Kooy-Hofland, V.A.C., Kegel, C.A.T., & Bus, A.G. (2011). Evidence-based computer interventions targeting phonological awareness to prevent reading problems in at-risk young students (pp. 214-227). In S.B. Neuman & D.K. Dickinson (Eds.), *Handbook of early literacy research*, Volume 3. New York: The Guilford Press.





There are various ways for young children to come into touch with written language in their home environment. Book sharing is often considered one of the most important activities parents can do to promote young children's early literacy skills (Bus, van IJzendoorn, & Pellegrini, 1995; Mol & Bus, 2011). However, literacy experiences in literate homes may also include reading and writing of words whereby children initially demonstrate an emotional bond with names: the proper name, 'mama', 'papa', and the name of a friend or pet. Almost three decennia ago, the Argentinean researchers Emilia Ferreiro and Ana Teberosky (1982) reported research that underscores the importance of the early years for developing the foundation for future literacy. This report had a strong impact on the research community and since then a spate of articles has appeared to explain early learning processes. As research in the field of early literacy emphasizes the importance of the early years for developing the foundation for future literacy, the interest in early interventions has strongly increased as well.

We explore new roles that computers can play to assist and support teachers who practice good literacy teaching for emerging readers and writers. Because 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 pupils, additional computer programs that focus on a wide range of early literacy skills (e.g., letter knowledge, concepts of print, vocabulary, and story structure) may be attractive tools for providing additional home-like experiences with literacy, especially for advancing delayed kindergarten children. However, there is a dearth of evidence regarding computer programs as tools to provide young children with relevant additional practice while there is increasing interest in computer programs in support of instruction in early stages of becoming literate. In the Netherlands, the number of computers in kindergarten classrooms has grown from 1 computer per 17 pupils in 1999 to 1 computer per 5 pupils in 2010. Moreover 90% of the computers have internet connections nowadays (Kennisnet, 2010).

The current thesis examines a Web-based program that was created to compensate for homes where early literacy experiences are sparse. The target program aims at familiarizing children with the alphabetic principle, i.e., understanding that letters represent sounds in spoken words and can be used to create an infinite number of words. As a result of this basic understanding, children may benefit more from new experiences with letters and words at home and in school as well as from beginning reading instruction in grades 1 and 2. Understanding, that units of print map onto units of sounds (the alphabetic principle) is not obvious as is clearly demonstrated by a three-year-old boy's reaction to a picture storybook entitled "O van Opa [G of granddad]" (Bus, 1995). A recurring theme in the booklet is the first letter /o/ of opa. For instance, the main character in the booklet notices that when granddad smokes his cigar he produces circles like his letter O. After having heard the storybook several times

the three-year-old boy wondered what the letter of *his* opa [granddad] would be now that O had been taken by the granddad of the boy in the booklet.

## Early literacy training in literate homes

Alphabetic knowledge is one of the early-developing pillars of learning to read that is rather strongly correlated with standardized reading tests in higher grades (e.g., Snider, 1995; Byrne, Fielding-Barnsley, & Ashley, 2000). Understanding the alphabetic principle enables children to gain access to decoding procedures that are taught in grade 1 and beyond (Silva & Alves-Martins, 2002). To advance children from homes where early literacy skills are sparse we took into account how learning about the alphabetic principle starts in literate homes and designed a Web-based computer program for kindergartners that boosts similar learning processes.

*The proper name as starting point.* In literate homes children develop an interest in writing the proper name. Children are exposed to the written form of their name on such personal possessions as their bedroom door, their drinking glass, or their artwork. As a result of that, children start to copy their names and to write them on their own. Given these experiences and children's interest in their own name, it is not surprising that children's knowledge of their name develops before any other word. Children's writing of their own names is identifiable as writing prior to other words (Levin, Both-de Vries, Aram, & Bus, 2005). From studies in which words were dictated to young children, it appeared that name writing is the first stable written form with meaning that children can write conventionally (Levin & Bus, 2003).

As the name is the first stable written form with meaning, it may fulfill a very special function in the psychogenesis of alphabetic skills and represent a singularly important benchmark in early literacy development (Ferreiro & Teberosky, 1982; Welsch, Sullivan, & Justice, 2003). Even though writing the proper name may not automatically imply understanding of the alphabetic principle – i.e., understanding that letters of printed language stand for sounds in spoken words – the proper name may be a pathway through which children develop alphabetic knowledge thereby influencing reading and spelling of other words (Byrne, 1998). This reasoning is in line with Badian's finding (1982) that name writing is one of the top three predictors of both first and second grade reading achievement, using the Stanford Achievement Test Total Reading Score as outcome measure.

*Early invented spellings.* It seemed a plausible assumption that familiarity with the written form of the name may affect young children's letter knowledge and invented spellings of untrained words. In a first attempt to test effects of the name, Both-de Vries and Bus (2008) reanalyzed the writings of young children,

all at the age of four, who mostly produced strings of conventional letters when they were asked to write words (Levin & Bus, 2003). The least advanced children not yet writing phonetically were compared to more advanced children who had just started to produce some phonetic spelling. The two groups differed in name writing. Of the more advanced group, 65% wrote almost all letters of their name correctly whereas 76% of the less advanced children wrote only one or two letters correctly. Consistent with Bloodgood's (1999) finding, about half of the letters used to write dictated words were letters from the child's proper name. The least advanced children had a strong preference for the first letter of the name whereas the advanced group used other letters from the name as often as the first letter. More importantly, the first letter of the name was the one to be written phonetically by the more advanced group. They used the first letter of the name significantly more often in words that actually included the letter than in words without the letter, indicating that it is not merely chance that children use the first letter of the name phonetically. Other letters were rarely used phonetically. The group that mainly produced random letter strings often used the first letter of the name in their writings but as often in words that included the letter as in words that did not include the letter, which implies that their use of the letter is random instead of phonetic. In other words, it seems that the first letter of the child's name is the one and only letter that is written phonetically at the very start of phonetic writing.

In a follow-up study, Both-de Vries and Bus (2010) dictated the same number of words including the first letter of the child's name as words not including this letter. Dictations thus differed to some extent for the participants in this study. The majority (65%) of the 4- to 5½-years olds in this sample wrote their name readably, i.e., they produced at least invented spelling (for instance, Slva instead of Silva). The rest (35%) wrote the first letter and one or more other letters (for instance, jT instead of Juliet) or made strings composed of pseudo-letters or pseudo-cursive writing. This study demonstrated again that, if children were able to write their name, they selected the first letter of the name more often for words that actually included this letter (in 5 out of 8 words) than for words without this letter (in 3 out of 8 words). In the group yet unable to write the name, the first letter occurred in two out of eight words, whether the word included the name letter or not.

*Mediators between name writing and phonetic spelling.* Adult feedback to children's attempts to write the proper name may explain learning to spell. (Levin & Aram, 2004; Robins & Treiman, 2011). The name may elicit teaching of the sound of the first letter and phonetic sensitivity about the first letter of the name. Due to this knowledge, phonetic spelling arises (Ehri & Wilce, 1985; Frost, 2001). By focusing children's attention on letter units and how they sound in the name – adults may for instance say: “It's /pi/ of Peter” – they provide children with fairly substantial amounts of direct instruction about letters as symbols for sounds (Molfese, Beswick, Molnar, & Jacobi-Vessels, 2006). They thus stimulate phonetic

sensitivity, i.e., the ability to identify the sound of the first letter of their name in a spoken word, and alphabetic-phonetic writing that goes beyond imitation of the form. According to this line of reasoning, we expected that invented spelling with the first letter of the name is mediated by familiarity with the letter name and how it sounds in words.

Of those children who wrote their names readably, most children (80%) were able to name the first letter of the proper name (Both-de Vries & Bus, 2010). A small minority (19%) of the children who could not write the name readably was able to name or sound out the first letter of the name. When testing children's ability to identify the sound of the first letter and other letters in spoken words, Both-de Vries and Bus (2010) found that children identified the sound of the first letter of their name more often correctly than other sounds. The contrast between the name and non-name sound was significant when children wrote the name readably but not when they were unable to write the name.

Further analyses were commensurate with the hypothesis that name writing affects phonetic spelling through knowing the first letter's name and phonemic sensitivity to this letter (Both-de Vries & Bus, 2010). This appeared from a hierarchical multiple regression analysis on the ability to use the first letter of the name phonetically. Ability to write the proper name was a strong predictor ( $\beta = .41$ ). Yet, after familiarity with the first letter of the name and the ability to identify this letter in spoken words were entered, effects of the proper name were no longer significant. The finding that phonemic sensitivity explains variance beyond the variance explained by familiarity with the letter name, and vice versa, means that learning is not modulated by either prior phonemic sensitivity or letter knowledge (Castles, Coltheart, Wilson, Valpied, & Wedgwood, 2009).

## **A Web-based intervention program**

Researchers, including Labbo and Reinking (1999), hold the opinion that well-founded computer programs that, in contrast to many commercial programs, balance edutainment with instruction and practice could make a substantial contribution to the learning environment of young learners at home and in classrooms. In particular programs that are modeled on the early literacy training in literate homes and that take account of which activities boost young children's learning may compensate for homes where early literacy experiences are sparse. The target program in the studies presented hereafter is modeled to learning in real life. The computer program uses young children's emotional bond with the proper name and the pleasure they have in recognizing their own name to draw attention to the first letter of the name and how this letter sounds in the name and other words.

*A Web-based program for young children.* Living Letters was developed and installed by a private company in schools across the Netherlands. Unlike popular educational computer programs such as Daisy Quest and Daisy's Castle (Foster, Erickson, Forster, Brinkman, & Torgesen, 1994), Living Letters is tailored to a child's knowledge by using the name of the child to draw attention to phonemes in spoken words (Bus & van IJzendoorn, 1999; Ehri, Nunes, Willows, Schuster, Yaghoub-Zadeh, & Shanahan, 2001).

The program Living Letters was developed in close collaboration with computer experts, designers, and experts in the field of education. The program encompasses three different layers. After a series of games in which children identify their proper name among other words, the program instructs children in naming the first letter and how the name's first letter sounds in other words. Figure 1 presents screenshots that illustrate each layer:

- All children start with games in which they are asked to recognize the proper name or 'mama' among other words (e.g., find your name; Figures 1a - 1d). The program uses the child's proper name unless the spelling is inconsistent with Dutch orthography (e.g., Chris or Joey). The program then switches to 'mama', another high-frequency name known by young children.
- These games are followed by games with the first letter of the name. Figure 1e illustrates a game in which children have to find the first letter of mama ('which one is the /m/ of mama?').
- Games to identify pictures that start with the same sound as the child's name or 'mama' or with this sound in the middle. In Figure 1f Tom should click on 'tent' and ignore 'ball' or 'rake'.

In all, the program is composed of seven sets of games each including 4-6 different games. Each set starts with an attractive animation using two main characters to explain the upcoming games; for instance, the two main characters, a boy and a girl named Sim and Sanne, discover that their names start with the same sound.

*Feedback loops in the Web-based program.* Apart from games, the program has built-in feedback loops that imitate the adult responses. Where feedback encourages children to try again, feedback facilitates repetition. However, the program also provides children with strategies to solve the tasks by listening carefully thus enabling engagement in similar tasks independently. The oral feedback promotes letter-sound knowledge as well as phonemic sensitivity to the sound of the letter. For instance, where they have to click on the picture that starts with the same sound as the proper name, they receive as feedback: "the /p/ of peter sounds just as /p/ in pear." Summarizing, errors are followed by increasingly supportive feedback:

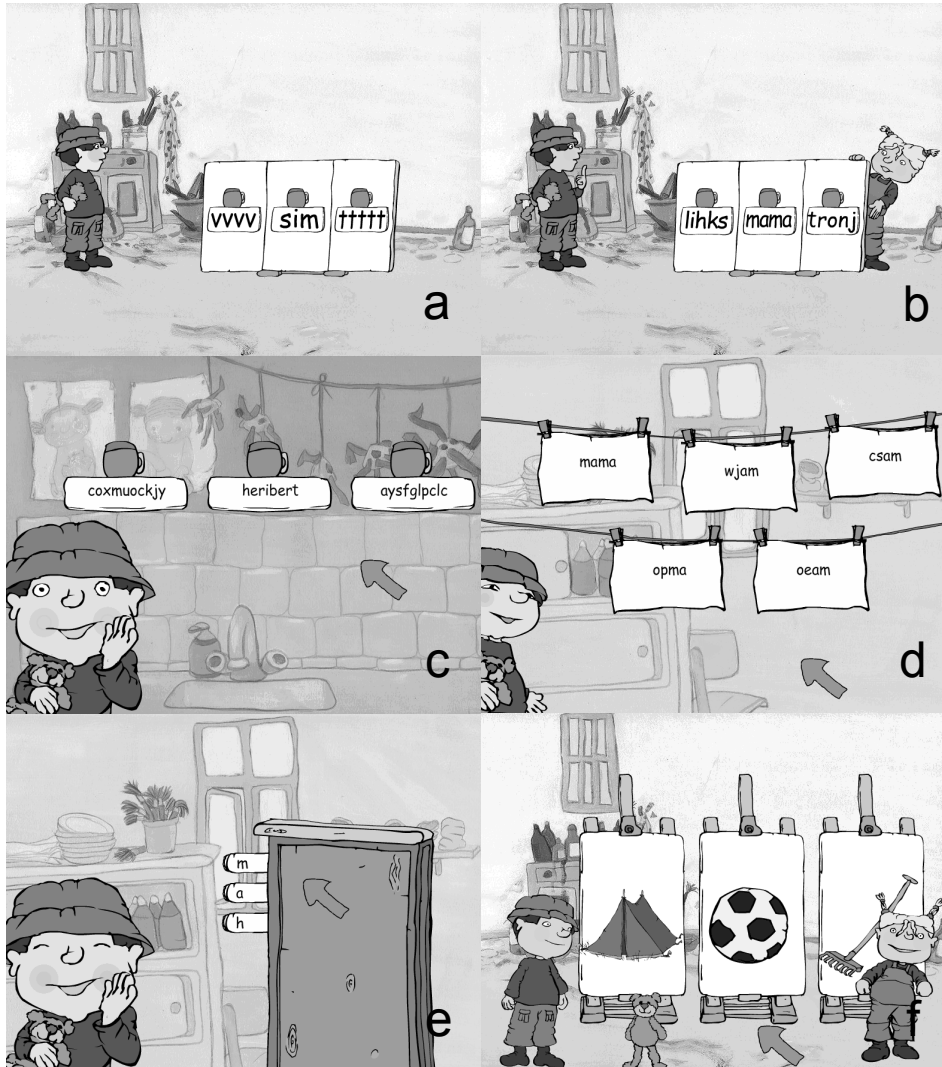


Figure 1. The screenshots have been derived from six different games: selecting the proper name (a and c), selecting 'mama' (b and d), selecting the first letter of 'mama' (e), and selecting the painting that starts with the letter of the child's own first name (e.g., tom-tent) (f). When the mouse skims a picture, the computer names the words.

- The task is repeated when children do not solve the task the first time;
- After two errors in a task, clues are given: for instance when they do not succeed in finding which words starts with the sound of their name they receive a clue tailored to the child's name (e.g., "in which word do you hear /k/ of Koen");
- The correct solution is demonstrated and confirmed by adding a verbal explanation tailored to the child's name ("The /t/ of 'Tom' is also the /t/ of 'tent'").

The program facilitates routines where children operate through repetition of tasks and introduces variations on those tasks so that the child internalizes not only the task but also the ability to engage in similar tasks independently. Computer pals personalize the interaction between child and computer by looking the child in the eyes while asking a question as is illustrated in Figure 1c. To make the feedback less intimidating to the child, corrective feedback is not given by age mates, Sim or Sanne, but by Sim's stuffed bear as is illustrated by Figure 1f.

### **Long-term effects**

Research findings contradict the theory that the initiation of formal reading instruction in primary school equalizes the skill base across children (Juel, 1988). Formal beginning reading instruction does not appear to produce unified outcomes; it may actually lead to a further differentiation of good and poor readers in the early grades (Fischel et al., 2007). Children face significant challenges in learning to read when they lack essential early literacy skills and they may not acquire adequate decoding skills in the first years of school (Torgesen, 1998). They have an increased chance of remaining a poor reader at the end of second grade: Good readers have experienced many more words in running text at school and at home by that time than poor readers, with the result that differentiation between readers increases rather than decreases. The rich-getting-richer and the poor-getting-poorer seems a proper description of this differential effect of reading instruction (Stanovich, 1986; Spira, Bracken, & Fischel, 2005; Vaughn, Wanzek, Woodruff, & Linan-Thompson, 2007). Stanovich (1986) was the first to apply this bootstrapping mechanism that attributes major individual differences to the differential development of reading skills, referring to the Gospel according to Matthew: "For unto every one that hath shall be given, and he shall have abundance: but from him that hath not shall be taken away even that which he hath" (XXV: 29, KJV).

In this line of argumentation, programs in support of the kindergarten curriculum that practice important precursors of reading seem to be helpful to decrease disparity in reading skills in the first grades of primary education

(Bowyer-Crane et al., 2008; Byrne, Fielding-Barnsley, & Ashley, 2000; Silva & Alves Martins, 2002; Snider, 1997). In so far experimental tests have been carried out they support the importance of interventions prior to formal reading instruction (Bus & van IJzendoorn, 1999; Ehri et al., 2001). However, most studies have been carried out in languages with an opaque orthography. About two-third of all experiments concerned English-speaking preschoolers and kindergartners (Ziegler, Perry, Ma-Wyatt, Ladner, & Schulte-Körne, 2003). Share (2008) hypothesized that in particular basic insights in letter-sound relations prior to the start of formal reading instruction may be more important in opaque languages than in transparent languages. If letter-sound knowledge is easy to acquire there is no need to extend the period for learning basic reading skills by starting earlier. The period of formal reading instruction provides ample opportunity to acquire letter-sound knowledge. If Share's hypothesis holds, we may expect that pre-reading skills are less important in the Dutch language that is characterized by a rather transparent orthography, and that initial effects of a treatment in kindergarten fade away in the first months of formal reading instruction.

### **Susceptibility factors**

In evaluating experimental interventions in the domain of emotional and physiological development researchers have found differential effects of their manipulations (Belsky, 1997; Belsky, Bakermans-Kranenburg, & Van IJzendoorn, 2007; Ellis, Boyce, Belsky, Bakermans-Kranenburg, & van IJzendoorn, 2011). Children with a fearful temperament appear to suffer most from persistent family conflict or low quality of day care but also to benefit most from supportive environments. Blair (2002), for instance, found that a comprehensive early education program significantly lowered the level of internalizing and externalizing behaviors of three-year-old children with more negative emotionality but not in children with less negative emotionality. Such findings suggest that fearful temperament or temperamental emotionality is a 'risk' under less supportive conditions but a susceptibility factor in a supportive environment.

As a critical test of differential susceptibility in the cognitive domain, the study in chapter four explored the effects of Living Letters on pupils who differ in susceptibility to instruction. Target pupils in this study were children with perinatal adversities. They are known to suffer from elevated stress reactivity and, probably because of that, easily shut themselves off for learning experiences, which may explain their poor academic achievements. The literature (e.g., Chyi, Lee, Hintz, Gould, & Sutcliffe, 2008; Nomura, et al., 2009; Van Baar, Vermaas, Knots, de Kleine, & Soons, 2009) emphasizes the incidence of learning problems in this sub-sample of children who are full term but small for gestational age (SGA) or



late preterm (LP). Compared to full term children, late preterm children have lower reading scores (Kirkegaard, Obel, Hedegaard, & Henriksen, 2006; Chyi et al., 2008; Lee, Yeatman, Luna, & Feldman, 2010) and adults born near-term have an increased risk of learning disabilities and lower educational achievement (Johnson & Breslau, 2000; Nomura et al., 2009). In all, this group encompasses about 20% of all pupils.

Due to elevated stress reactivity, perinatal adversities may be a 'risk' under less supportive conditions but a susceptibility factor in a supportive environment (e.g., Obradović, Bush, Stamperdahl, Adler, & Boyce, 2010). That is, for children with perinatal adversities the mainstream classroom environment may be an unsatisfactory environment. Overcrowded early literacy settings are likely to challenge these students, while they may outperform their classmates without perinatal adversities when they receive intensive, closely monitored and individualized practice. Unlike common experiences for development enhancement, however, special programs such as Living Letters may arouse their interest and increase their willingness to practice which may result in the highest achievements. Outcomes of differential susceptibility may therefore differ from a more common model - the protective factor model. According to the latter model, successful interventions counteract the negative effects of risk behavior which means that children with perinatal adversities learn as much as their peers without perinatal adversities in a supportive learning environment. However, according to this model children with perinatal adversities are not expected to outperform children without perinatal adversities as the differential susceptibility model predicts.

Most educational studies target main effects of early literacy interventions (Al Otaiba & Fuchs, 2002). So far no evidence is available on the differential effectiveness of enriched educational environments created for children with delays in early literacy skills. Investigators of educational programs that aim at explaining differential effects of interventions in education have mainly focused on the aptitude treatment interaction (ATI) model this far (Cronbach & Snow, 1977). ATI assumes that all children are susceptible to instruction but that not all children benefit from similar forms of instruction. However, this model does not explain for why educational interventions have proven both variable and generally modest across studies (e.g., Bus & van IJzendoorn, 1999). Differential susceptibility thinking, however, might be an adequate explanation for these findings, because samples may have varied in the proportion of more and less susceptible pupils in their samples.

If the finding that children differ in their susceptibility to environmental influence in a "for better and for worse" manner (Belsky, 1997; Belsky et al., 2007; Ellis et al., 2011) applies to academic learning it leads to the following hypotheses:

1. Systematic, intensive programs such as Living Letters may be supportive to a priori defined eligible children but not to all.
2. More susceptible individuals are likely to experience sustained change in academic skills, not just transient fluctuations in functioning, in response to programs such as Living Letters.
3. Effects of Living Letters may be underestimated when we consider whole groups only, instead of susceptible sub-groups as a priori defined.

### **The studies reported in this dissertation**

This dissertation reports the potential benefits of an individualized Web-based program, *Living Letters*, in support of teacher-delivered literacy training in kindergarten. The studies targeted kindergarten children who had not yet begun to develop code-related skills as appeared from a screening on fifteen participating schools in the second year in kindergarten. Experimentation takes place in a digital environment, which is a formidable advantage (Battro, 2010). There is maximum control of exposure to the program since children's activities and the unfolding of the learning skills can be observed online.

Summarizing, our aims were four-fold:

1. To evaluate the efficacy of the Web-based computer program Living Letters to promote early literacy skills, directly after working with the program as well as in the long-term at several moments during the first two years of formal reading instruction.
2. To compare development of initially delayed children with the mainstream group (not delayed according to the screening test in kindergarten) throughout the first two years of formal reading instruction.
3. To test whether a sub-sample with mild perinatal adversities (small for gestational age or late preterm) is susceptible to intervention in a "for better and for worse" manner.
4. To discuss opportunities and challenges that must be considered when Web-based computer programs are implemented.

The main focus of chapter 2 is on the effects of the computer program Living Letters in a group of kindergarten children who are delayed in code related skills. It is tested if practice with the initial name letter that primes for attending to the sound-symbol relationship in the proper name benefits the development of children's code-related skills. We present short-term (directly after finishing the computer program) and long-term results (after 18 months of formal reading instruction in primary education).

Chapter 3 focuses on the long-term effects of the computer program Living Letters. It is experimentally tested whether improvements in code-related knowledge as a result of a 15-week computer program that primed for attending to the sound-symbol relationship in a familiar word, can reduce the gap between the initially delayed children and the mainstream group throughout the process of learning to read in the first two grades.

In chapter 4, it is examined whether short- and long-term intervention effects are moderated by mild perinatal adversities. This study is one of the first tests of the differential susceptibility hypothesis in the domain of academic learning; that is, it is studied whether children differ in their susceptibility to educational influences in a “for better and for worse” manner.

The final chapter summarizes the findings presented in the previous chapters and discusses the limitations and implications of the findings for practice of early interventions and future research.



## Chapter 2

### **Effects of a brief but intensive remedial computer intervention in a sub-sample of kindergartners with early literacy delays**

This chapter will be published as: Van der Kooy-Hofland, V.A.C., Bus, A.G., & Roskos, K. (in press). Effects of a brief but intensive remedial computer intervention in a sub-sample of kindergartners with early literacy delays. *Reading and Writing*.

## **Abstract**

Living Letters is an adaptive game designed to promote children's combining of how the proper name sounds with their knowledge of how the name looks. A randomized controlled trial (RCT) was used to experimentally test whether priming for attending to the sound-symbol relationship in the proper name can reduce the risk for developing reading problems in the first two grades of primary education. A web-based computer program with more intensive practice than could be offered by teachers affords activities that prompt young children to pay attention to print as an object of investigation. The study focused on a sub-sample of 110 five-year-old Dutch children from 15 schools seriously delayed in code-related knowledge. Outcomes support the need for early remedial computer programs, and demonstrate that, without a brief but intensive treatment, more children from the at-risk group lack the capacity to benefit from beginning reading instruction in the early grades. With an early intervention in kindergarten, children with code-related skills delays gained about half a standard deviation on standardized tests at the end of grade 2.

## **Introduction**

Most kindergartners have a nascent awareness of the sound-symbol relationship in printed words and have begun to accrue baseline knowledge of a small assemblage of letters and sounds as is demonstrated in their invented spelling attempts (Sulzby, Barnhart, & Hieshima, 1989; Treiman & Kessler, 2003). A sub-sample of children in each kindergarten classroom is already, by 5 years of age, lacking in competencies fundamental to learn to read (Duncan et al., 2007) due to sparse experiences in the early years or inability to take advantage of their environment (Shonkoff & Phillips, 2000; Stipek & Ryan, 1997) and as a result their capacity to benefit from beginning reading instruction may be compromised (Byrne, Fielding-Barnsley, & Ashley, 2000; Duursma, Augustyn, & Zuckerman, 2008; Silva & Alves-Martins, 2002; Snider, 1995). In this line of argumentation, our study tests whether an early intervention creates a better starting position for learning to read in primary education (e.g., Byrne et al, 2000; see for meta-analytic evidence: Bus & van IJzendoorn, 1999; Ehri et al., 2001). Therefore, in addition to short-term effects of the program long-term effects are assessed after 18 months of formal reading instruction.

In contrast to many early intervention programs that target whole or small groups, this program targets only a sub-sample that is in need of an additional or more intensive program in preparation for reading instruction in primary education. We modeled, therefore, an individualized remedial computer program for young children with early literacy delays to pay attention to print as an object of investigation. In this report we present effects of this program in a sub-sample of kindergartners with code-related skills delays. Results of this educational intervention show that delayed children achieve higher gains in beginning reading instruction in the first grades of primary education when they receive computer-assisted instruction in support of the kindergarten curriculum.

## **Considerations underlying the computer program's design**

Typically, many children begin to understand how letters relate to sounds when they learn how to read and write their name or some portion thereof. Name writing is commonplace in young children's everyday life resulting in the proper name being the first word that many children learn to read and write (Levin & Bus, 2003; Levin, Both-de Vries, Aram, & Bus, 2005). Close inspection of children's emerging letter name knowledge, phonemic awareness, and invented spellings supports the hypothesis that the initial letter of the proper name serves as an early decoder illuminating how sounds relate to letters (Bloodgood, 1999; Levin & Bus, 2003; Molfese, Beswick, Molnar, & Jacobi-Vessels, 2006). Most children can name

the initial letter of the proper name earlier than other letters; most can locate the sound of the first letter in other words preceding other sounds; and most can use the first letter of the proper name first of all in their invented spellings (Both-de Vries & Bus, 2008; 2010). These results suggest that children's playful experiences with the proper name offer a framework that anchors code-related skill instruction and practice in a personally motivating context.

Years spent from ages 2 to 5 offer many opportunities to learn the name, the first letter of the name, how it sounds in words, and how word spellings can be created using this letter-sound knowledge (Levin & Aram, 2004). Replicating the home literacy environment at school to remedy the sparse print exposure for children in some families is challenging and leads to an approach that fundamentally differs from more common early interventions that practice with a range of phonemes in generic tasks (Ehri et al., 2001; Borstrom & Elbro, 1997; Byrne et al., 1998). In classrooms, there is no real match for the long stretch of early literacy experiences with cumulative effects across the preschool years, although the at-school curriculum can attempt to build in some salient features of the home environment (e.g., teachers can play games using the first letter of the name). Since at risk kindergarten children do not have the luxury of time that a print rich home literacy environment affords in the preschool years, a computer program may offer the opportunity to practice frequently with the first letter of the child's name, affording far more exposure and instruction than from the teacher alone (Heuston, 1996). Computer speech, interactions, along with interesting graphics and animation has permitted the development of programs that are highly motivating to children (Mayer & Moreno, 2002). Moreover many software programs do not require large investments in professional development for purposes of differentiating instruction (Chera & Wood, 2003).

The *Living Letters* web-based program, developed in close collaboration among computer experts, designers, and experts in the field of education, took into account how learning about the alphabetic principle starts in literate homes and used the child's proper name as a stimulus that primes children for understanding the alphabetic principle. It is a series of adaptive games intended for kindergarten children not yet demonstrating an awareness of the sound/letter relationship in an alphabetic language. Its instructional framework is modeled on the aforementioned name writing research and emphasizes three successive skill areas: (1) recognizing the proper name in print; (2) associating the initial name letter with its sound; and (3) identifying the sound of the initial name letter in other orally presented words. The web-based software program automatically adapts to the child's proper name and provides the child with targeted instruction on sound-letter relationships modeled after parental instruction (Anderson, Boyle, & Reiser, 1985). The program registers the child's immediate responses to tailor the program to individual differences—a design advantage over traditional



classroom instruction and stand alone computer software programs (Greasser, Conley, & Olney, in press). For instance, when children produce one or more erratic responses to an assignment, the assignment is repeated one to three times, thus promoting more practice when children fall behind.

As with all computer-aided instruction, there may be drawbacks to Living Letters as an intervention for achieving code-related skill outcomes. Based on our observations, young children can indeed use a computer mouse without adult aid and can complete online educational programs independently (Bus, Verhallen, & Van der Kooy-Hofland, 2009; De Jong & Bus, 2002; 2004; Verhallen, Bus, & De Jong, 2006; Verhallen & Bus, 2010). Yet, as we have observed, the *blind eye* of computer-aided instruction can leave children to their own devices, opening the door to *free play* rather than playful engagement with the content (De Jong & Bus, 2002). Children can complete the computer assignments without seriously attempting to solve the problems they pose with the result that the potential benefits of computer-aided instruction are reduced (Kegel, Van der Kooy-Hofland, & Bus, 2009). This may explain why adaptive computer-assisted learning systems that prevent the incidence of random responses have been demonstrated to significantly increase phoneme awareness in low-performing preschoolers (Mitchell & Fox, 2001), at-risk preschoolers and kindergartners (Lonigan et al., 2003), and typical preschoolers (Foster, Erickson, Forster, Brinkman, & Torgesen, 1994) compared to a control group not utilizing any computer-assisted learning systems. We are mindful of the possible weakness of Living Letters in that children play the games by just responding randomly despite the built-in feedback loops and expect that errors are negative predictors of learning from the Living Letters intervention.

## **This study**

To test the theory that kindergarten children who have not yet begun to develop code-related skills are more at risk for developing reading problems this study tests the long-term benefits of the individualized web based program, Living Letters, in support of teacher-delivered literacy training in kindergarten. Research suggests that cueing children to sound-letter information in the proper name, particularly the initial name letter, primes the insights that (a) letters represent sounds and (b) letter-sound information can be used to make words. Once they have grasped these insights as appears from the short-term effects of the program, at risk children may benefit more fully from classroom practice in code-related skills in kindergarten as well as in the first years of reading instruction. Despite the short duration of the program (2½-3 hours), high intensity practice with the first letter of the name is expected to help kindergarten children understand

that letters in written words relate to sounds in spoken words and may enable them to make a start with invented spelling, phonemic awareness, and decoding skills (Silva & Alves-Martins, 2002). The present study is also a critical test of the universal need for early literacy interventions. Share (2008), for instance, argued that grasping basic insights in letter-sound relations prior to the start of formal reading instruction may be important in English where letter-sound relations are difficult to fathom but not so relevant in transparent languages as Dutch because letter-sound knowledge is easy to acquire. The study also probes the degree of predictability between error levels in completing program activities and code-related outcome measures, which provides an additional test of the role of the actual program as an incentive of children's learning.

The study used a randomized controlled trial (RCT) to research the instructional effects of Living Letters on a sample of at risk kindergarten children performing in the lower quartile on pre-reading assessments. Eligible children from the same kindergarten classrooms were randomly assigned to either (a) Living Letters (LL); (b) a treated control program entitled *Living Books* (LB), which focuses on story comprehension (Bus et al., 2009), or (c) a combined program consisting of Living Letters (LL) and Living Books (LB). In the present report, we only discuss the contrast between sub-sample of children at risk who were exposed to the intervention program Living Letters (alone or combined with the control program) and the control group (sub-sample of children at risk who were exposed to Living Books alone (effects of Living Books is not discussed in this paper). The target program is supplementary to an estimated hour per week of classroom practice in code-related skills by practicing letters and playing games with words and sounds per the Netherlands kindergarten curriculum. We tested the following hypotheses:

1. Participation in the computer program Living Letters alone or in combination with Living Books significantly improves at risk kindergarten children's code-related skills, including (i) letter knowledge, (ii) phonological awareness, (iii) word spelling, and (iv) decoding; a basic assumption is that practice with the initial name letter stimulates and re-organizes attention to sounds and letters in printed words toward understanding that letters relate to sounds.
2. Child gains in code-related skills accrued from participation in the computer program Living Letters are sustained beyond the kindergarten year—an assumption based on the expectation that delay in code-related skills, if not addressed in the early years, may lead to an ongoing knowledge gap, given that some code-related knowledge at the start of reading instruction enables practicing reading and spelling proficiency with success in primary school years (Juel, 1988). We opted for assessing reading and spelling skills after about two years of reading instruction because by then basic reading and

spelling skills can be reliably assessed without floor or ceiling effects (e.g., Paris, 2005).

3. A low error threshold on the computer program, defined as successful completion of a majority of tasks, is required to realize optimal benefits from participation in the program although we can not exclude in advance that children learn from errors, especially if they sooner or later stop committing them, and errors may have a positive impact on outcomes. Registrations of errors can serve as level of success indicator since number of errors yields objective data about success and/or error rates that may impact program efficiency.

## **Method**

### *Participants*

The intervention sample was drawn from 15 schools in the Western part of the Netherlands. From these schools, 404 senior kindergarten children speaking Dutch as their first language and between 60 to 72 months old were screened upon kindergarten entry over a three-week period on early literacy skills in fall 2006. An estimated 12% of all pupils did not participate in the screening, due to illness or absence for other reasons or failure of parental consent. Those students scoring among the 30% lowest on the early literacy screening composite measure were selected as eligible candidates for the intervention, totaling 110 children. The 30% cut-point for the sample was based on the finding that this group demonstrated weak code-related skills. As shown in Table 1, on name writing and rhyming all students scored close to ceiling, however the lowest scoring children differed from the average or above average scoring group on three other indicators: letters ( $t = 18.13$ ,  $df = 377$ ,  $p < .001$ ), writing 'mama' [*mom*] ( $t = 15.16$ ,  $df = 326,520$ ,  $p < .001$ ), and writing other words ( $t = 13.63$ ,  $df = 274,502$ ,  $p < .001$ ). Overall the lowest scoring children did not write phonetically (i.e., they mostly produced conventional symbols, however the symbols did not represent sounds in the word) as is indicated by mean scores on the scale slightly beyond 2 whereas the highest scoring group (beyond 3) produced phonetic writing (B or BT for BOAT). Moreover, in the lowest scoring sub-sample boys were overrepresented,  $X^2=6.70$ ,  $df = 15$ ,  $p < .01$ , and mothers were lower educated,  $t = 3.42$ ,  $df = 377$ ,  $p < .001$ .

Table 1

Mean scores (and standard deviations) on gender, age, maternal education and the screening tests (including letter knowledge, rhyming and writing) for total group, highest scoring 70% and lowest scoring 30%.

|                    | Max | Total group<br>(n = 404)<br>M (SD) | Highest 70%<br>(n = 269)<br>M (SD) | Lowest 30%<br>(n = 110)<br>M (SD) |
|--------------------|-----|------------------------------------|------------------------------------|-----------------------------------|
| Gender m / f       |     | 200 / 204                          | 122 / 147                          | 66 / 44                           |
| Age                |     | 64.95 (3.59)                       | 65.12 (3.76)                       | 64.67 (3.19)                      |
| Maternal education | 8   | 5.28 (1.89)                        | 5.52 (1.84)                        | 4.80 (1.88)                       |
| Letter knowledge   | 8   | 5.62 (2.07)                        | 6.65 (1.53)                        | 3.62 (1.35)                       |
| Rhyming            | 10  | 9.07 (1.78)                        | 9.40 (1.48)                        | 8.32 (2.21)                       |
| Writing Name       | 6   | 5.63 (0.86)                        | 5.78 (0.69)                        | 5.32 (1.10)                       |
| Writing Mom        | 6   | 3.67 (1.74)                        | 4.35 (1.64)                        | 2.29 (0.96)                       |
| Writing words      | 6   | 3.04 (1.07)                        | 3.44 (0.98)                        | 2.21 (0.69)                       |

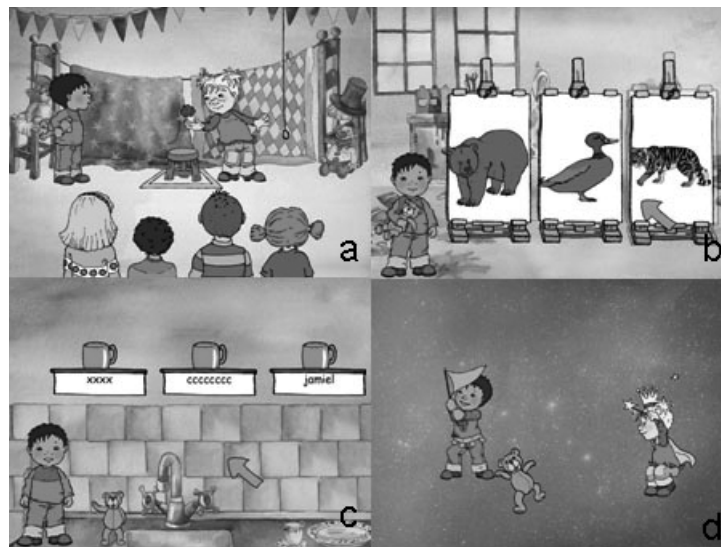
The selected sample varied from 3 to 15 children per school (17.6% - 51.7%). Eligible children were randomly assigned to Living Letters-only, Living Books-only, or Living Letters+Living Books, stratified for school and gender. No child attrition occurred during the kindergarten year; during the follow-up two years later seven children from the treatment group and five from the control group were lost due to removal ( $n = 8$ ), repeating ( $n = 3$ ) or placement in special education ( $n = 1$ ).

#### Description of Treatment Conditions

Children assigned to the intervention condition participated in a series of games of increasing difficulty in the following order:

- 22 games providing practice in recognizing the proper name (see for instance, Figure 1C); as the program adapts to the child's name tasks are unique for each child.
- 6 games focusing on recognition of the first letter of the proper name; children are asked to identify their name letter among three or more other letters; the computer pronounces the letter ("yes that is your letter, /t/").
- 12 games providing practice in identifying pictures that start or end with the first letter of the child's name. Criteria for selecting words were familiarity and transparency of words. For every child the program provides a unique selection of words attuned to the first sound in the child's name.

All sessions start with an attractive animation to explain the upcoming games (e.g., main characters, *Sim* and *Sanne*, discuss their names and discover that they begin with the same sound). Errors when solving the games are followed by increasingly supportive audio feedback in the following order: (1) repetition of the task (*Find the word that starts with the same sound as your name*); (2) a clue (*Tom starts with /t/*), and (3) demonstration of the correct solution (*You hear /t/ in tom and tent*). Apart from increasingly supportive feedback errors imply one to three repetitions of the same assignment. Tasks as well as oral feedback are adapted to the child's name. Figure 1a shows a screenshot from the instruction at the start of the last set of games; *Sanne* is the magician who finds words that start with the /s/ of *Sanne*. Figure 1b is one of the assignments in the last set of games. *Tom* has to find the word that starts the same as his name. Figure 1c shows that bear provides a cue when the child has not succeeded two times to find his or her name among the three alternatives. Figure 1d is a screenshot from the scene at the very end of each game. In the current study the six games focusing on recognition of the first letter of the proper name and the 12 games providing practice in identifying pictures that start or end with the first letter of the child's name were always repeated in a subsequent session, these games thus constituting two-thirds of the total computerized program.



*Figure 1.* The screenshots have been derived from four different elements of the games: the animation at the start of a new set of games (a), one of the assignments (b), bear provides a cue after an error, and (c) the scene at the very end of each game (d).

Children assigned to the control condition listened to five age-appropriate electronic books that consisted of oral narration, but no printed text, thus allowing the child to *read by listening*. In each 10-minute session, children *read* one book and responded to four follow-up questions among which two about difficult words (e.g., *What are paving stones?*) and two about story events (e.g., *Is dad happy or angry?*) by choosing one out of three pictures. Each book was repeated three times across the 15 sessions. In each repeated reading, children responded to four new questions, totaling 12 questions per book.

### **Assessment measures**

*Background.* As a control for factors that may influence the beneficial effects of the computer program, indicators for intelligence and SES were assessed. The Dutch version of Raven's Colored Progressive Matrices (Van Bon, 1986), a measure of nonverbal intelligence, was administered in the pre-assessment phase of the study (fall of the kindergarten year). To survey maternal education mothers ticked their highest level of education: 1 (primary school), 2 (preparatory secondary vocational education), 3 (preparatory middle-level vocational education), 4 (senior secondary vocational education), 5 (senior secondary education), 6 (pre-university education), 7 (professional higher education), and 8 (university).

*Literacy Screening to select the 30% lowest scoring children (Fall).* As a measure of invented spelling children were asked to write the *proper name* (name writing task), *mama* (mom), and four other words (e.g., *boot* [boat]). We selected words which are familiar to children (Schrooten & Vermeer, 1994) but not practiced in invented spellings. Each word was double-coded on a scale from 1 (writing-like scribbles) to 6 (conventional spelling) by trained master students (Levin & Bus, 2003). The intra-class correlation coefficient for 20 double-coded assignments was high ( $r = .99$ ). The rhyming task included 10 items asking children to select the picture among three alternatives that rhymed with a target picture. In the receptive letter knowledge task, children were asked to point to one of eight target *letters*, each presented on a card between four other letters. Alpha reliabilities for the tests were satisfactory; see Table 2. Scores on invented spelling and letter knowledge were standardized and averaged to form an early literacy composite measure to select the 30% lowest scoring children. Name writing and rhyming were not included due to ceiling effects.

*Pre/post assessments (Winter; Spring).* A more extensive set of pre/post assessments was applied to assess effects of the intervention. *Letter knowledge:* On pre-test children were asked to identify by sound or name eight high frequency letters on

a chart. To avoid placing unreasonable demands on children, only a selection of letters was given. On post-test, 14 more letters were added to the letter knowledge test. Awarding both letter sound and letter name the maximum score on the pretest was 8 and on posttest 22. *Phonological skills* (pre- and post-tested) were assessed in a 5-task series: (1) identifying among three words the one that starts with a sound different from the other two words; (2) selecting among four words two words with the same initial sound; (3) selecting from four words two words with the same final sound; (4) naming the first sound of words; and (5) naming all sounds of words. To reduce examiner bias, all picture names were pronounced by a computerized voice. All target sounds ( $n = 20$ ) were consonants; all words were monosyllabic (CVC or CVVC). Each correct response was awarded one point (maximum = 25). *Invented spelling* (pre/post-tested): Children were asked to write five randomly chosen words: *papa* (dad), *kaas* (cheese), *been* (leg), *jurk* (dress), and *duim* (thumb) that were scored on a 1-6 scale. *Word recognition* (post-tested only): Children were asked to identify the depicted target word among four printed words. The (incorrect) alternatives differed in 1, 2, or 3 letters from the target word. For instance, distracters for /*raam*/ were /*room*/, /*rat*/, and /*been*/. Correct responses were rewarded with a score of 3 (raam); a match of the first and last letter (room) with a score of 2; a match of the first letter only with a score of 1 (rat); and no match (been) with 0. *Decoding* (post-tested only): Children were tutored in decoding four vowel-consonant (VC) and four consonant-vowel-consonant (CVC) nonsense words. If children failed to pronounce the nonsense word in the first five seconds after presentation of a word, they were prompted to sound out the separate letters. If this did not elicit correct decoding, the experimenter pronounced the separate sounds and stimulated the subjects to blend the sounds. If they did not succeed, the experimenter repeated the separate sounds, blended them, and had subjects repeat the naming and blending. The list of eight words was repeated five times in different sequences. Scores per word varied from 5 (successful first attempt) to 1 (non-completion of item). Alpha reliabilities were satisfactory (see Table 2).

*Post-post measures* were conducted after 18 months of reading instruction, as follows: *Word reading fluency* was tested by administering the Een-Minuut-Test (one minute test), a standardized test to determine how many words from a list can be read during one minute (Brus & Voeten, 1973). *Klepel*, a standardized nonsense word reading test, assesses how many words are read accurately in 2 minutes (Van den Bos, Lutje Spelberg, Scheepstra, & de Vries, 1994). *Spelling*: For fifteen dictated words, well-known, with two or three syllables (including more complex letter-sound rules), the correctly spelled words were scored. Schools did not allow us to use a standardized test for spelling to avoid interference with regular progress monitoring. *Compound measure for reading and spelling*: The measures

Table 2  
 Mean scores (and standard deviations) on age, gender, maternal education, nonverbal intelligence, screening tests, pre-tests, and post-tests for intervention group (LL) and control (LB).

| Measure                             | $\alpha$         | Timing      | LL <sup>c</sup><br><i>n</i> = 73 | LB <sup>d</sup><br><i>n</i> = 37 |
|-------------------------------------|------------------|-------------|----------------------------------|----------------------------------|
| Gender M / F                        | -                |             | 45 / 28                          | 21 / 16                          |
| Age at the screening in months      | -                | Fall K      | 64.89(3.28)                      | 64.41(3.24)                      |
| Maternal education (max = 8)        | -                | Winter K    | 4.79 (1.98)                      | 4.81 (1.70)                      |
| Nonverbal intelligence              | .92 <sup>a</sup> | Winter K    | 4.97 (1.84)                      | 5.18 (1.94)                      |
| Number of errors in games           | -                |             | 13.16 (7.31)                     | --                               |
| Letter knowledge (max = 8)          | .73 <sup>b</sup> | Fall K      | 3.66 (1.32)                      | 3.54 (1.43)                      |
| Rhyming (max = 10)                  | .82 <sup>b</sup> | Fall K      | 8.55 (2.03)                      | 7.86 (2.49)                      |
| Writing Proper Name (max = 6)       | -                | Fall K      | 5.37 (1.12)                      | 5.22 (1.06)                      |
| Writing Mom (max = 6)               | -                | Fall K      | 2.24 (.83)                       | 2.39 (1.18)                      |
| Writing words (max = 6)             | .87 <sup>b</sup> | Fall K      | 2.27 (.67)                       | 2.08 (.73)                       |
| Letter knowledge (max = 8)          | .66 <sup>b</sup> | Winter K    | 3.63 (2.10)                      | 3.03 (1.80)                      |
| Letter Knowledge (max = 22)         | .90 <sup>b</sup> | Spring K    | 10.93 (6.00)                     | 9.46 (4.43)                      |
| Phonological skills (max = 25)      | .81 <sup>b</sup> | Winter K    | 8.05 (5.05)                      | 7.35 (4.22)                      |
| Phonological skills (max = 25)      | .87 <sup>b</sup> | Spring K    | 13.58 (5.89)                     | 11.11 (5.69)                     |
| Invented spelling (max = 6)         | .85 <sup>b</sup> | Winter K    | 2.45 (.65)                       | 2.15 (1.03)                      |
| Invented spelling (max = 6)         | .79 <sup>b</sup> | Spring K    | 3.27 (.81)                       | 2.91 (.63)                       |
| Word Recognition (max = 45)         | .80 <sup>b</sup> | Spring K    | 28.42 (7.58)                     | 26.32 (5.76)                     |
| Decoding (max = 40)                 | .98 <sup>b</sup> | Spring K    | 25.10 (8.09)                     | 22.26 (5.17)                     |
| Word reading fluency <sup>c</sup>   |                  | End Grade 2 | 44.38 (15.47)                    | 39.66 (13.23)                    |
| Klepel <sup>c</sup>                 |                  | End Grade 2 | 40.29 (18.03)                    | 32.81 (17.16)                    |
| Spelling <sup>c</sup>               | .85 <sup>b</sup> | End Grade 2 | 6.00 (3.83)                      | 3.94 (2.84)                      |
| Reading and Spelling (factor score) |                  | End Grade 2 | .15 (1.03)                       | -.31 (.86)                       |
| Reading Comprehension               | .85 <sup>b</sup> | End Grade 2 | 10.41 (4.18)                     | 8.45 (4.09)                      |

Notes. <sup>a</sup> Guttman's split-half reliability. <sup>b</sup> Cronbach's alpha. <sup>c</sup> (*n*=66). <sup>d</sup> (*n*=32).



for word reading, non word reading, and spelling showed high correlations (> .55). Principal Component Analysis revealed one component explaining 85% of variance with test loadings ranging from .87 to .95. This new variable was normally distributed. *Reading comprehension* was assessed with a cloze test. This test on paper consists of a 142 words text with 21 words removed, where the child is asked to write the missing words. Children completed the test on their own.

*Error registration in the target program.* To determine the frequency of child appeals for feedback while engaged in the intervention program, the position and location of the mouse onscreen were recorded every 10th second. How successful children were at solving the computer assignments immediately or after one or more repetitions can be derived from these registrations.

## **Procedure**

The training regimes, consisting of one weekly session, held over a period of 15 weeks, were incorporated into the kindergarten curriculum. Children receiving one program spent 10-15 minutes a week on the intervention while those assigned to the condition that combined the control and intervention program spent an estimated 15-30 minutes per week playing computer games. Sessions occurred during the morning either in classroom or computer room conditional upon the school routines. Children wore headphones to reduce noise and distractibility. University students at the master's level were present but did not provide any guidance while children solved the computer tasks even when children asked for support. It was the students' task to prevent and solve technical problems. They logged children in on the website and provided supervision and assistance to ensure that children could complete all sessions. When the supervisor entered the child's name and the system had identified the child, the correct game appeared on screen and the system was programmed in a way that the session automatically discontinued after four games. An off-site helpdesk was available for emergencies. Failed or missed sessions were repeated within one week.

In fall (screening), one month before the 15-week intervention (winter 2006), directly after the intervention (spring 2007), and after 18 months of instruction (April 2009) master's level university students, blind to treatment, tested the children. Assessments were delivered in a fixed order to all participants. Examiners were extensively trained in administration procedures. With the exception of the invented spelling task, pre/post assessment was videotaped.

Table 3  
Correlations among pre- and posttest measures and number of errors in computer tasks

|                               | Time        | 1 <sup>a</sup> | 2 <sup>a</sup> | 3 <sup>a</sup> | 4 <sup>a</sup> | 5 <sup>a</sup> | 6 <sup>a</sup> | 7 <sup>a</sup> | 8 <sup>a</sup> | 9 <sup>b</sup> | 10 <sup>b</sup> | 11 <sup>c</sup> |
|-------------------------------|-------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|-----------------|-----------------|
| 1. Letter knowledge           | Winter K    | -              | .78**          | .42**          | .56**          | .20*           | .51**          | .58**          | .58**          | .34**          | .41**           | -.42**          |
| 2. Letter Knowledge           | Spring K    |                | -              | .44**          | .65**          | .28**          | .63**          | .65**          | .78**          | .38**          | .45**           | -.58**          |
| 3. Phonological skills        | Winter K    |                |                | -              | .50**          | .27**          | .36**          | .47**          | .59**          | .13            | .29**           | -.41**          |
| 4. Phonological skills        | Spring K    |                |                |                | -              | .22*           | .54**          | .59**          | .80**          | .29**          | .46**           | -.46**          |
| 5. Invented spelling          | Winter K    |                |                |                |                | -              | .34**          | .24*           | .24*           | .25*           | .28**           | -.21            |
| 6. Invented spelling          | Spring K    |                |                |                |                |                | -              | .68**          | .69**          | .30**          | .44**           | -.40**          |
| 7. Word recognition           | Spring K    |                |                |                |                |                |                | -              | .69**          | .37**          | .48**           | -.39**          |
| 8. Decoding                   | Spring K    |                |                |                |                |                |                |                | -              | .29**          | .47**           | -.57**          |
| 9. Reading & spelling         | End Grade 2 |                |                |                |                |                |                |                |                | -              | .63**           | -.42**          |
| 10. Reading Comprehension     | End Grade 2 |                |                |                |                |                |                |                |                |                | -               | -.32**          |
| 11. Number of errors in tasks | Spring K    |                |                |                |                |                |                |                |                |                |                 | -               |

Notes. \*\*  $p < .01$ . \*  $p < .05$ . <sup>a</sup>  $n = 110$ . <sup>b</sup>  $n = 98$ . <sup>c</sup>  $n = 73$ .

## **Results**

This study examined the effects of the computer-based intervention Living Letters on at risk kindergarten children's code-related skills within the context of the kindergarten curriculum. Although the correlations between dependent measures were rather high, as can be seen in Table 3, outcome measures were analyzed separately to determine those skills specifically influenced by the program and those that were not. Because intra-class correlations (ICC) ranging from .03 to .24 indicated interdependence of observations within schools, we adapted standard errors within schools with the Huber-White sandwich estimator (cf. Hatcher et al., 2006; Miles, 2006). We used Complex Samples Analyses (General Linear Model) to test the contrast intervention versus control group while we controlled for differences associated with gender, maternal education, nonverbal intelligence, and, when available, pre-intervention levels of performance on the same task.

*Hypothesis 1: The treatment group outperformed the control group in the acquisition of code-related skills in kindergarten.* Pre-test early literacy skills were a significant covariate when assessed whereas maternal education level and gender caused significant effects on invented spelling, word recognition, and decoding and non-verbal intelligence on phonological skills. Table 4 reports effects of the treatment on all dependent measures after controlling for the covariates. A Cohen's  $d$  that equals 1.0 represents a difference of 1  $SD$  between treatment and control group and is equivalent to a strong effect size if  $d$  equals .8, moderate if  $d$  equals .5, and small if  $d$  equals .2 (Cohen, 1988). As is shown in Table 4, effects sizes were small to moderate. They were strongest for word recognition ( $d = .48$ ), followed by phonological awareness ( $d = .47$ ), invented spelling ( $d = .46$ ), and decoding ( $d = .39$ ). For three out of five assessments, namely those tapping invented spelling, phonological awareness skills, and word recognition, the difference between treatment and control group reached significance; however, for decoding the effect was marginally significant ( $p < .07$ ) and for letter knowledge non-significant.

Table 4  
*Intervention effects on short term (spring K) and long term (Grade 2), after controlling for background variables and pretest if available.*

| Measure               | Timing   | Estimate (SE) | 95%CI B  | <i>t</i>          | <i>p</i> | Cohen's <i>d</i> <sup>c</sup> |
|-----------------------|----------|---------------|----------|-------------------|----------|-------------------------------|
| Letter knowledge      | Spring K | .02 (.06)     | -.11,.16 | .38 <sup>a</sup>  | .71      | .01                           |
| Phonological skills   | Spring K | .18 (.08)     | .02,.38  | 2.42 <sup>a</sup> | .03      | .47                           |
| Writing               | Spring K | .18 (.08)     | .02,.35  | 2.38 <sup>a</sup> | .03      | .46                           |
| Word recognition      | Spring K | .16 (.07)     | .02,.30  | 2.50 <sup>a</sup> | .03      | .48                           |
| Decoding              | Spring K | .21 (.10)     | -.01,.42 | 2.01 <sup>a</sup> | .07      | .39                           |
| Reading and Spelling  | Grade 2  | .22 (.09)     | .03,.42  | 2.43 <sup>b</sup> | .03      | .50                           |
| Reading Comprehension | Grade 2  | .23 (.08)     | .06,.40  | 2.89 <sup>b</sup> | .01      | .53                           |

Notes. <sup>a</sup> *n* = 110, *df* = 14. <sup>b</sup> *n* = 98, *df* = 14. <sup>c</sup> For calculating Cohen's *d* we used the formula  $2t/\sqrt{n-2}$  (Thalheimer & Cook, 2002).

*Hypothesis 2: Gains in code-related skills after the computer treatment sustained beyond the kindergarten year.* The treatment effect was tested for reading and spelling and comprehension after 18 months of reading instruction while controlling for differences associated with gender, maternal education, and nonverbal intelligence. For both reading and spelling, and comprehension skills, the difference between treatment and control group reached significance. Effect sizes (*d*'s) for reading and spelling, and for comprehension were moderate equaling .50 and .53, respectively (see Table 4).

*Hypothesis 3: Low error rate predicted code-related skill acquisition in the treatment group.* On average the 73 children in the treatment group made errors in 8 out of 40 games. In particular the last set of games - identifying words with the sound of the first letter of the proper name - revealed more errors than the games that included recognition of the written form of the name and recognition of the first letter of the proper name between alternatives. The percentage of errors in the last set (48%) was much higher than the percentage in the first two sets (10%). Table 3 shows that correlations with pre-tested scores were moderate; those with post-tested scores ranged from moderate for invented spelling, phonological skills, and word recognition to strong for letter knowledge and decoding; and those with post-post tested scores were moderate as well. After estimating robust standard errors for the dependent measures Complex Samples Regression Analyses were carried out with gender, maternal education, nonverbal intelligence, and number of errors as covariates. As more errors were made children's skills improved less.

As Table 5 shows, the number of errors explained substantial variance, ranging from 7% for phonological awareness to 30% for decoding at post-tests and from 13% for reading and spelling to 21% for comprehension at post-post tests.

Table 5  
*Effects of computer behavior on short term (End-K) and long term (Grade 2) posttest scores, expressed as estimates (SE) and increase in explained variance of the model ( $\Delta R^2$ ).*

| Measure             | Timing  | Estimate (SE) | 95%CI B   | p-value | R <sup>2</sup> | $\Delta R^2$ |
|---------------------|---------|---------------|-----------|---------|----------------|--------------|
| Letter knowledge    | End-K   | -.33 (.08)    | -.50,-.17 | .001    | .619           | .076         |
| Phonological skills | End-K   | -.32 (.12)    | -.57,-.06 | .02     | .323           | .066         |
| Writing             | End-K   | -.35 (.10)    | -.57,-.13 | .004    | .177           | .114         |
| Word recognition    | End-K   | -.37 (.10)    | -.59,-.16 | .002    | .124           | .176         |
| Decoding            | End-K   | -.62 (.10)    | -.84,-.41 | .000    | .104           | .300         |
| Reading & Spelling  | Grade 2 | -.44 (.12)    | -.70,-.18 | .003    | .037           | .206         |
| Comprehension       | Grade 2 | -.28 (.15)    | -.61,.04  | .085    | .080           | .126         |

*Note.* R<sup>2</sup> = explained variance of a model including background variables (gender, maternal education, nonverbal intelligence) and pretest if available.

## Discussion

This is one of the few randomized controlled trials testing effects of a remedial computer program at the kindergarten age. In a child sub-sample with code-related skills delays, treated children seemed to thrive on the remedial program. They outperformed an equally delayed treated control group in phonological skills, invented spelling, and decoding of words and nonsense words directly after the intervention period. Children's skill gains are considerable—on the order of a half a standard deviation on average. Effect sizes (Cohen's *d*'s), ranging from .39 for decoding to .48 for word recognition, approximate those reported in an earlier meta analysis of phonemic awareness training programs (overall *d* = .44); see Bus & Van IJzendoorn (1999). More importantly, this study is one of the first showing that an effective and efficient intervention targeted toward gaps in early literacy skills in kindergarten-age is essential to the developmental success of children in the first two grades of primary education. The group at-risk who received the remedial computer program at kindergarten-age scored on average half a standard deviation higher on reading and spelling tests and on reading comprehension after about two years of beginning reading instruction. The program seems to narrow in noticeable way the skills gap by about 8%.

To account for effects comparable to those in more comprehensive and lengthier interventions, we argue that by combining children's understanding of how the proper name sounds with knowledge of how the name looks the computer program acts as a catalyst that stimulates the young child's attention to the grapheme-phoneme relationship in printed words. Once children have accrued baseline knowledge of a small assemblage of letters and sounds they benefit more from the kindergarten curriculum in so far it focuses on training of phonological skills, and they show progress on tests that encompass a set of code-related skills beyond those targeted by the computer program. Yet, experimental and control children were on par in letter knowledge after the intervention period which may indicate that baseline knowledge as promoted by the computer program, is not required for learning associations between letters and sounds/names (National Early Literacy Panel, 2008).

As a result of a program that helps children to combine their understanding of how the name looks with knowledge of how the name sounds in kindergarten-age the treated group seems better prepared to benefit from the reading curriculum in the first two grades of primary education whereas the non-treated group is more vulnerable to a phenomenon referred to as the Matthew effect (Stanovich, 1986). That is, early delays persist until the end of second grade when no interventions are carried out to stem achievement gaps (Juel, 1988). An appropriate program may help to avoid the consequences of these early delays in the learn-to-read process. Compared to children with similar code-related skills delays in kindergarten-age the treated children scored half a standard deviation higher on standardized reading and spelling tests at the end of grade 2, thus narrowing the achievement gap. To account for the long-term effects of a brief intervention, we argue that Living Letters creates a vital *opportunity to learn* how reading works, how letters and words work, and how literacy learning can be applied to new situations (Castles, Coltheart, Wilson, Valpied, & Wedgwood, 2009).

Apart from the computer treatment, there were no differences between treatment and control condition that might explain the treatment group's advantage at the end of grade two; the treated control group and treatment groups were taught by the same teachers and children in both conditions received the same general classroom instruction, in kindergarten and beyond, for about the same amount of time. We can also be confident that the computer program was applied with high implementation fidelity. Due to the storage of children's mouse behavior during the computer sessions the principal researcher immediately noticed when children had skipped one or more sessions. Moreover, the presence of a researcher during the sessions served to monitor that children used the materials as intended and on each occasion completed all aspects of a given activity.

Not all children participating in the treatment, however, realized the full benefits of the software program; those with high task completion on first

attempts outperformed their peers after the training and in second grade. This result is another indicator that the computer program itself and not its side effects explain the short- and long-term effects. This finding makes it less plausible that experimental children outperformed control children because their teachers saw children practice these skills on the computer and therefore decided to offer more practice in code-related skills in classroom. It becomes also less plausible that children assigned to the treatment program practiced more on other occasions stimulated by the computer program.

So far we can only theorize about the causes of these differential effects of the program. The present findings refute the hypothesis that poor prior literacy skills cause more errors and thereby lower performance on outcome measures after the intervention. The relation between errors and outcome measures still exists after controlling for pre-tested skills. It may be more plausible to assume that in particular a sub-sample of children with under-developed regulatory skills profit less from computer programs as described here compared to same-age children with appropriate regulatory skills because they are unable to stay attentive and focused without continuous adult support (Kegel et al., 2009).

## **Limitations**

The current study is, of course, not without limitations. The first is that we assumed that the name is the best pathway through which children develop code-related knowledge, without testing this assumption. Because the name provides surface perceptual features that help children discover sound-symbol relationships between the first letter of the name and its sound in the spoken name, we gave the name a very special function in the program (Ferreiro & Teberosky, 1982). However, the critical test of comparing a program that uses the name as a starting point for code-related knowledge with an alternative program using other words remains to be done.

Second, we did not compare individualized early computer interventions with additional classroom instruction provided by a teacher. The computer format has pivotal qualities that might make it superior to teacher-led interventions (Vernadakis, Avgerinos, Tsitskari, & Zachopoulou, 2005). For instance, the computer program individualizes opportunity to learn and practice around someone's own proper name, the most familiar word to young children. Furthermore, the program not only enables more individual tuition than teachers can provide, it also enables fine-tuning of instruction to the child's skills and it provides a better match for the long stretch of early literacy experiences in literate homes than teachers could realize given instructional demands. Another plus-point of a computer program is that it allows for individual variations, such as

skipping tasks or an increased number of repetitions. However, to prove that a well-founded computer program could make a substantial contribution to the learning environment, other experiments are warranted.

Lastly, when children make relatively many errors in the program's assignments, they benefit less from playing the games. However, a sound explanation for making comparatively many errors in computer assignments resulting in differential effects of the computer program is so far missing.

## **Conclusions**

This study supports the need for remedial programs at the kindergarten-age, and demonstrates that a brief, intensive treatment can improve the capacity to benefit from beginning reading instruction in the early grades (Raudenbush, 2009). Unlike previous long-term studies (Henning, McIntosh, Arnott, & Dodd, 2010), the evidence obtained here indicates that pre-emptive measures in kindergarten can effectively interrupt a potentially downward spiral at an early stage in the learn-to-read process (Stanovich, 1986) although not all eligible children may be susceptible to the intervention to the same extent (Kegel, Bus, & Van IJzendoorn, 2011). A personalized remedial computer intervention with an individualized and consistent feedback loop seems better equipped than whole or small group interventions to prevent reading problems (Byrne et al., 2000; Henning et al., 2010). But this hypothesis awaits further research.



## Chapter 3

### **Long-term effects of a computer intervention to narrow the code-related knowledge gap in young children**

This chapter is based on: Van der Kooy-Hofland V. A. C., & Bus A. G. Long-term effects of a computer intervention to narrow the code-related knowledge gap in young children. Manuscript submitted for publication.

## **Abstract**

Living Letters is an adaptive computer program designed to improve code-related skills of delayed kindergarten children. We tested its effectiveness using a randomized controlled trial (RCT) in a sample of 135 five-year-old Dutch children scoring among the lowest 30% on code-related skills. The current study experimentally tested whether improvements in code-related understanding as a result of a 15-week program that primed for attending to the sound-symbol relationship in a familiar word - the proper name or 'mama' - can reduce the risk of reading problems in the first two grades. The study shows that initially low-performing children, who had a chance to catch up in kindergarten, make significantly more progress in word reading fluency throughout the first two years of formal reading instruction than initially low-performing children without a chance to catch up. Adaptive early computerized interventions in support of the kindergarten curriculum can reduce the risk of a delayed reading performance in the first two grades of primary education.

## **Introduction**

The relationship between pre-reading skills, which children possess upon entering school, and their later academic performance is strikingly stable (e.g., Duncan, et al., 2007; Fischel, et al., 2007; Spira, Bracken, & Fischel, 2005). It is a well-known fact in the literature that as foundational knowledge lacks children may not be able to take advantage of the learning opportunities in the classroom (Stanovich, 1986). When, for instance, children know that letters in written words relate to sounds in spoken words they have a better starting position for learning to decode in first and second grade (e.g., Byrne, Fielding-Barnsley, & Ashley, 2000; see for meta-analytic evidence: Bus & van IJzendoorn, 1999; Ehri, et al., 2001). Especially if achievement at older ages is the product of a sequential process of skill acquisition, then strengthening skills prior to school might lead children to master more advanced skills at an earlier age and perhaps even increase their ultimate level of achievement (Duncan et al., 2007). Although such findings have engendered early intervention programs to enhance early literacy skills prior to school entry longitudinal evidence for effects is scarce. The current study tests whether an intervention in kindergarten that addresses the essentials of beginning reading (Hindson et al., 2005), can improve the beneficial effect of beginning reading instruction, while children without intervention may increasingly fall behind resulting in a lower level of reading achievement after two years of instruction. The focus here will be confined to early reading education, although even stronger arguments can be made with respect to other academic skills such as mathematics because those skills are more hierarchical (e.g., LeFevre, et al., 2010).

## **The need for supplemental instruction in kindergarten-age**

Since Ferreiro & Teberosky's (1982) finding in the seventies of the last century that literacy development starts before schooling there has been a growing interest in preschool literacy. A plethora of studies has shown that children's capacity to benefit from instruction expands as children's academic ability grows early in life. It is a lot easier for children to obtain new information when they pay attention to the informative aspects and ignore the trivia. For instance, learn to read simple words is more complex when phonological skills are underdeveloped. Juel (1988) found that good readers had seen an average of more than 18.000 words in running text in their school by the end of first grade, whereas poor readers averaged about half that. A pioneering article by Stanovich (1986) about the Matthew effect in learn-to-read has made reading experts more aware of the annoying effects of early delays as a motivational multiplier. Children who start to read words later because they lag behind in phonological skills when they enter first grade may easily loose

interest in reading and find themselves in a downward spiral (Stanovich, 1986).

In this line of argumentation, individual differences would be mitigated across the course of schooling when they are reduced as a result of an early intervention while without early interventions differences may increase rather than decrease. An alternative outcome could be that the initiation of formal reading instruction in first grade equalizes the skills base across children. All benefit from the normal “dose” of instruction especially in a transparent orthography such as Dutch where reading acquisition is relatively straightforward and can be accomplished in a rather brief period (Leppänen, Niemi, Aunola, & Nurmi, 2004). Preliteracy skills may therefore be less vital for reading success in transparent orthographies. The emphasis on early literacy skills might be a product of English spelling-sound inconsistency which makes the learn to read process a complex and long-lasting process (Share, 2008)

Intervention research should shed light on the importance of adopting evidence-based approaches in the preschool period by testing whether early treatments are associated with better adjustment in the long run. However, long-term studies are scarce and in so far available outcomes are inconsistent (Ball & Blachman, 1991; Bentin & Leshem, 1993; Bianco, et al., 2010; Byrne & Fielding-Barnsley, 1991; Cunningham, 1990; Elbro & Petersen, 2004; Henning, McIntosh, Arnott, & Dodd, 2010; O'Connor, Notari-Syverson, & Vadasy, 1996; Segers & Verhoeven, 2005; Torgesen & Davis, 1996). For instance, Byrne and colleagues (1991) showed enhanced literacy one year after successfully teaching phoneme awareness to children from average socioeconomic backgrounds. In contrast, Henning and colleagues (2010) found no significant differences between children who had received intervention in preschool and those who had not. Moreover, studies have rarely tested that optimal preparation for success in formal reading instruction normalizes development in primary education by contrasting the development of initially delayed children to the progress of mainstreamers (for an exception see Saine, Lerkkanen, Ahonen, Tolvanen, & Lyytinen, in press).

The capacity of intervention programs for young children to promote early literacy skills before entering first grade according to meta-analytic findings (Bus & van IJzendoorn, 1999; Ehri et al., 2001), has promoted that these programs have become part of the kindergarten curriculum in the last decades. However, as a substantial proportion of children does not benefit from practicing the identification of sounds in words in the classroom program (Torgesen, 2002), additional programs are developed for the lowest achieving kindergarten children who despite kindergarten curricula lag behind in early literacy skills. Living Letters - a remedial program - appeared to have effect on increasing children's code-related knowledge beyond the effects gained in classrooms using the regular type of the kindergarten curriculum, (Van der Kooy - Hofland, Kegel, & Bus, 2011; Van der Kooy - Hofland, Bus, & Roskos, in press). In the current study we test effects of

supplemental practice offered by a one-to-one, computer-child focused learning environment with individualized repetition. Unlike mainstream programs (e.g., Borstrom & Elbro, 1997; Byrne et al., 1998; Ehri et al., 2001; Fuchs et al., 2002), this supplemental program does not emphasize a range of phonemes in generic tasks but targets one letter with a special meaning for young children – the first letter of the proper name (Levin, Both-de Vries, Aram, & Bus, 2005).

The program imitates activities in literate homes with familiar words such as the proper name and the first letter of the name – activities that stimulate the development of foundational literacy skills (Justice, Pence, Bowles, & Wiggins, 2006; Levin et al., 2005; Levin, Shatil-Carmon, & Asif-Rave, 2006). By promoting children's understanding that the first letter of the proper name not only relates to sounds in the proper name but also to sounds in other words, the program may have effect on increasing children's code-related knowledge. The program may thus compensate for reading-related experiences as normally occur in literate families.

## **This study**

The current study tests a number of hypotheses related to how school-entry literacy skills are associated with later reading achievement. A randomized control trial (RCT) was carried out to demonstrate effects of an individualized computer program in support of the kindergarten curriculum in the second half of the year. In kindergarten, students scoring among the 30% lowest on an aggregate measure composed of three screening assessments (letter knowledge, writing 'mama' and writing other words), were randomly assigned to an intervention or control condition. The cut-point of 30% was based on the finding that this selection encompassed all children who were unable to represent any letter phonetically. The intervention group was offered a computer treatment targeting children's understanding that letters relate to sounds and the control group another computer program not focusing on early literacy skills during the same amount of time. Contrasting the intervention with the treated control group revealed that differences between the two groups have increased in favor of the intervention group just after the program had ended (Van der Kooy - Hofland et al., 2011, in press).

In the current study two word reading tests along with three or four follow-ups were included to determine changes in word reading fluency in the first two grades of primary education. Main aim of this study is to test that intervention children outperform control children in the first two years of reading instruction. In seeking a better understanding of the extent to which an early intervention is associated with reading achievement in the first two grades, it is important that

groups do not systematically differ apart from the intervention. The randomized control trial (RCT) guarantees that effects are outcomes of the early intervention and not outcomes of other unintended external factors, such as quality differences between teachers. All participating classrooms included children from the control and experimental group. Moreover the progress of the treatment group and the treated control group were contrasted to progress of mainstreamers (the 70% of children not included in the kindergarten experiment). This design enables to test whether development of initially delayed children who received an intervention prior to the start of beginning reading instruction is more similar to the mainstream group than development of the group that was not exposed to the target intervention.

Not all children participating in the treatment, however, realized the full benefits of the software program; those with high task completion on first attempts outperformed their peers at the post-test directly after the training. This result indicates that the ones who made few errors in computer tasks improved most in basic understandings as a result of the computer intervention. In the same vein, we may expect that among the initially delayed children who received an intervention prior to the start of beginning reading instruction the ones who made few errors in the computer assignments were better prepared for instruction in the primary grades.

This study aimed to determine whether the gains made by delayed kindergartners after a remedial one-to-one, individualized computer program in kindergarten transferred to word reading proficiency in grade 1 and 2. In the light of the above explained theory it was expected that:

1. After a remedial intervention in kindergarten children with early delays in code-related skills profit more from instruction during the first two years of primary education than children who are not exposed to remedial interventions.
2. Interventions in kindergarten may narrow the gap between the initially delayed group and the mainstream group throughout the process of learning to read in the first two grades.
3. Children who successfully participated in the remedial program as can be derived from the number of errors in computer assignments in the remedial program in kindergarten make more progress in the primary grades than children who relatively often failed the computer tasks and who showed less progress in basic reading skills at post-tests directly after the program.

## Method

### *Child sample selection and design*

In autumn of 2006, 404 kindergarten children attending 15 full-day schools in the Western part of the Netherlands, speaking Dutch as their first language and between 60 to 72 months old were screened over a three-week period on early literacy skills. The screening included name writing, invented spelling, and alphabet letter-naming. Approximately 12% of the sample ( $N = 459$ ) did not participate in the screening, due to absence for illness or other reasons or because parents/guardians did not return consent for their children's participation within due course. Students scoring among the 30% lowest on the screening measures were selected for participation in the intervention, totaling 135 children. The selected sample varied from 4 – 17 children per school (19.0% - 54.8%). The 135 children were randomly assigned to one of three conditions (Living Letters, Living Books, or both programs) stratified for school and gender. Pre- and post testing before and directly after the intervention revealed significant effects of Living Letters on phonemic awareness, invented spelling, and decoding (reported in Van der Kooy - Hofland et al., 2011, in press). Both students scoring low on the screening measures or scoring high ( $N = 269$ ) were post-post tested in grades 1 and 2. The current study reports about the complete group's development in the long run in the first two grades of primary education contrasting intervention and control group with each other and initially delayed children with and without intervention with mainstreamers (70% highest on the screening test). Because of the longitudinal design, there has been some subject attrition. In grade 1 we lost twelve children in the treatment groups due to removal (5 children), doubling a classroom (6 children) or referral to special education (1 child). In grade 2, four more children were lost due to removal. Concerning the conditions, the dropouts were part of Living Letters ( $n = 9$ ) and Living Books ( $n = 7$ ). In the non treatment group ( $n = 269$  in kindergarten), 29 children were lost in grade 1 and five in grade 2, all due to removal.

## Description of computer intervention in kindergarten

*Living Letters* (LL) uses the child's proper name to draw attention to phonemes in the spoken name and other words unless the spelling of the name is inconsistent with Dutch orthography (e.g., Chris or Joey). In those cases, the program switches to 'mama' (mom), the spelling of which is also highly familiar to many kindergartners though less than the spelling of the proper name (Both-de Vries & Bus, 2008; 2010). Living Letters is composed of 40 personalized games to be played individually in sessions of about 10 minutes across a period of 15 weeks:

(1) the first 22 games provide practice with recognition of the proper name and 'mama'; (2) 6 games focus on recognition of the first letter of the name or 'mama'; and (3) 12 games provide practice in identifying pictures that start with the first letter of the child's name or 'mama' or with the first letter in the middle of a word. The last 18 games appeared to be most difficult and were therefore always repeated in a subsequent session, thus constituting two-thirds of the total computerized program. All sessions start with an attractive animation to explain the upcoming games; for instance, the two main characters, *Sim* and *Sanne*, discuss their names and discover that they start with the same sound as an introduction to games in which children have to find words that start with the same letter as their name. Errors in the 40 computer assignments are followed by increasingly supportive oral feedback. First the task is repeated (*Which one is your name?*), next a clue is given (*Tom starts with /t/*), and lastly the correct solution is demonstrated (*You hear the first sound of your name, /t/ of tom, in tent*).

*Living Books* (LB) consists of five age-appropriate computer books that include oral narration, but no printed text, thus allowing the child to *read by listening*. In each 10 minute session, children *read* one book interrupted for four question prompts about difficult words or story events. Errors are followed by increasingly supportive oral feedback: (1) The question is repeated; (2) a clue is given (*Do you remember what dad said to Tim?*); and (3) the correct answer is explained. Each book was repeated three times across the 15 sessions. In each repeated reading, children responded to four new questions, totaling 12 questions per story, 60 questions in all.

#### *Error registration in the target program.*

To determine the child appeals for feedback while engaged in the intervention program, the position and location of the mouse onscreen were recorded every 10th second. How successful children were at solving the computer assignments the first time can be derived from these registrations and was used in the current study as indicator of children's success in solving computer assignments.

#### *Post-Post measures*

*Word reading fluency.* Fluency in reading words was tested by administering a standardized word reading test, the 'Een-Minuut-Test' [one minute test], which assesses how many words from a list can be read accurately within one minute (Brus & Voeten, 1973). *Klepel* is a standardized pseudo-word reading test that assesses how many words from a list can be read accurately in 2 minutes (Van den Bos, Lutje Spelberg, Scheepstra, & de Vries, 1994).



## **Procedure**

Assessments were individually administered after 4 and 8 months in first grade and 4 and 8 months in second grade (one school year equals 10 months). Assessment was conducted by master's level university students blind to children's results on the screening test and their treatment in kindergarten. The word reading test was conducted at all four points of measurement while the pseudo-word reading test was first conducted after 8 months of instruction in first grade because of its complexity.

## **Statistical analysis**

First, a descriptive analysis was conducted on the assessments of (pseudo-) word reading throughout the first two years of primary education. To examine differences in the level and rate of change among individuals, we used individual growth modeling to analyze the word and pseudo-word measures. As participants had three data points each for pseudo-word reading and four points for word reading, a linear model was used (Singer & Willett, 2003; Willet, Singer, & Martin, 1998). To arrive at a final model that best predicted development in word reading, we built taxonomy of theoretically motivated individual growth models. In the first stage, we fitted an unconditional means model that included no predictors to describe variation in the outcomes (Singer & Willett, 2003). We then fitted an unconditional growth model, in which we examined within-person change by fitting growth trajectories for each child over time. We measured time in terms of points of measurement. For the pseudo-word reading test: 0 for the score after 8 months of instruction, 1 for the score after 14 months of instruction, and 2 for the score after 18 months. For word reading: 0 for the score after 4 months of instruction, 1 for the score after 8 months of instruction, 2 for the score after 14 months of instruction, and 3 for the score after 18 months. In light of the variation across children, we looked at between-person variation and added predictors to investigate whether they affected individual changes in the word reading measures. We included age, gender, maternal education, school, and group membership. Group membership (mainstream, initially delayed with intervention or initially delayed without intervention) was kept in the model even if it was not significant, as it was key predictor. School was kept in the model to control for differences between schools. The estimated coefficients for most schools tended to be around zero for pseudo-word reading and word reading, indicating that most schools had similar levels at the first assessment. Maternal education was a significant predictor of pseudo-word and word reading and was included in the final model to control for SES. Predictors such as age and gender that were not statistically

Table 1

*Characteristics of participants including gender, age and maternal education and mean scores (and standard deviations) on three screening tests in kindergarten (Fall).*

| Measure                        | $\alpha$         | Mainstream<br><i>n</i> =269 | Delayed Treated<br><i>n</i> =90 | Delayed Control<br><i>n</i> =45 |
|--------------------------------|------------------|-----------------------------|---------------------------------|---------------------------------|
| Gender M / F                   |                  | 122 / 147                   | 53 / 37                         | 25 / 20                         |
| Age at the screening in months |                  | 65.12 (3.76)                | 64.63 (3.18)                    | 64.58 (3.33)                    |
| Maternal education (max = 8)   |                  | 5.52 (1.84)                 | 4.88 (1.98)                     | 4.69 (1.78)                     |
| Letter knowledge (max = 8)     | .73 <sup>a</sup> | 6.65 (1.53)                 | 3.64 (1.34)                     | 3.42 (1.42)                     |
| Writing Mom                    |                  | 4.35 (1.65)                 | 2.23 (.83)                      | 2.39 (1.10)                     |
| Writing Words                  | .87 <sup>a</sup> | 3.44 (.98)                  | 2.27 (.73)                      | 2.15 (.75)                      |

<sup>a</sup>Cronbach's alpha; writing scores beyond 3 indicate the use of phonetic letters

Table 2

*Mean scores (and standard deviations) on post-post tests on word reading and non word reading, in grade 1 and 2 for the mainstream, initially delayed treatment, and initially delayed control group.*

| Measure             | Months of instruction | Mainstream    | Treatment     | Control       |
|---------------------|-----------------------|---------------|---------------|---------------|
| Word Reading        | 4                     | 18.69 (7.62)  | 12.27 (5.09)  | 11.64 (4.30)  |
| Word Reading        | 8                     | 30.97 (13.44) | 23.33 (11.81) | 20.31 (8.41)  |
| Pseudo-Word Reading | 8                     | 28.70 (14.58) | 22.45 (12.77) | 19.62 (9.87)  |
| Word Reading        | 14                    | 41.97 (14.89) | 34.26 (13.87) | 30.24 (11.70) |
| Pseudo-Word Reading | 14                    | 38.22 (17.18) | 31.74 (15.93) | 27.08 (14.17) |
| Word Reading        | 18                    | 51.44 (15.23) | 44.20 (14.80) | 38.84 (13.83) |
| Pseudo-Word Reading | 18                    | 44.95 (18.47) | 39.90 (17.48) | 31.92 (16.88) |

Note: 4 and 8 months: Mainstream (*n*=241); Treatment (*n*=84); Control (*n*=39). 14 and 18 months: Mainstream (*n*=236); Treatment (*n*=81); Control (*n*=38)

significant were kept out of the final model. Because we were comparing models that differ in their fixed effects but not their variance components, we used full maximum-likelihood estimation (see Willet, et al., 1998).

Combining the within-person and between-person models yielded the following model:

$$\text{Word reading} = [\beta_{00} + \beta_{01} \text{ Group} + \beta_{02} \text{ School} + \beta_{03} \text{ SES} + \beta_{10} \text{ TIME}_{it} + \beta_{11} \text{ Group} * \text{TIME}_{it}] + [u_{0i} + u_{01} \text{ TIME}_{it} + r_{it}]$$

The parameters in the above model represent the effect of the kindergarten intervention on the *level* of word reading at the first assessment ( $\beta_{01}$ ) and the effect of group (mainstream, initially delayed with intervention and initially delayed without intervention) on the *rate of change* in word reading ( $\beta_{11}$ ).

## Results

Characteristics of the sub-samples assigned to mainstream (non treatment), treatment and control group are summarized in Table 1. Gender and age were similar across groups, but maternal education and screening results differed between the initially delayed children and the mainstream group favoring the mainstreamers (maternal education,  $t = 3.58$ ,  $df = 402$ ,  $p < .001$ ; screening,  $t = 21.24$ ,  $df = 322.925$ ,  $p < .001$ ). Descriptive statistics for all measures at post-post tests are presented in Table 2. Average scores for word reading outperformed those for pseudo-word reading. Note that the score on word reading represents how many words are read per minute and for pseudo-word reading how many words per 2 minutes. The mainstream group continued to outperform the groups that were delayed in kindergarten, however the delayed group that received treatment in kindergarten outperformed the delayed group that was assigned to the control condition at all assessments.

*Did delayed kindergartens assigned to an intervention in the second half of kindergarten outperform the control group in primary education?*

From the unconditional means model without predictors appeared that the child's word reading skills varied over time and that the children differed from each other. The intraclass correlation coefficient describing the proportion of the total outcome variation that lies *between* people (Singer & Willett, 2003, p. 96) equaled .19 for words and .63 for pseudo-words. Comparison of the variance component in the unconditional and unconditional growth model shows that 80.2% of the within person variation in words and 60.6% of the variation in pseudo-words

Table 3  
*Multilevel regression growth equation for pseudo-word and word reading carried out in the initially delayed groups*

|                | Estimate (Std.Error)  |                |
|----------------|---|----------------|
|                | Pseudo-words  | Words          |
| Fixed effects  |   |                |
| Intercept      | Intervention group<br>23.30(1.46)***                              | 12.90(.69)***  |
| Slope          | Difference between control and intervention group<br>-3.34(2.31)  | -1.48(1.12)    |
|                | Intervention group<br>8.51(.56)***                                | 10.43(.45)***  |
|                | Difference between control and intervention group<br>-2.39(1.00)* | -1.24(.80)     |
| Random effects |   |                |
| Residual       | 12.69(3.20)***  | 20.15(1.84)*** |
| Intercept      | 116.52(18.05)***  | 18.05(4.31)*** |
| Slope          | 13.35(3.69)***  | 12.84(2.21)*** |
| Akaike's       | 2646.82   | 3254.47        |

was associated with linear time. Table 3 reports main results for the long-term effects of the intervention in kindergarten. The initially delayed group without intervention in kindergarten scored on average 3.34 words lower than the intervention group on pseudo-words at the first measurement in grade 1 after 8 months of instruction. The intervention group outperformed the control group but the difference was not significant. At follow-up assessments the difference in pseudo-word reading rather increased than decreased. Each new assessment the intervention group scored about 2.5 words beyond the control group. This difference in growth was statistically significant. After 18 months the intervention group read on average 40 pseudo-words per two minutes and the control group 32 which indicates that the treatment group needed about 700 milliseconds less per word. For word reading we found a similar pattern of results; however, the differences between intervention and control group were not significant.

*Did treatment in kindergarten have effect on narrowing the gap between the initially delayed groups and the mainstream group throughout the process of learning to read in the first two grades?*

The intraclass correlation coefficient describing the proportion of the total outcome variation that lies *between* people (Singer & Willett, 2003, p. 96) equaled .27 for words and .66 for pseudo-words. Comparing the variance component in the unconditional and unconditional growth model shows that 82% of the within person variation in words and 71% of the variation in pseudo-words was associated with linear time. Next we contrasted the two initially delayed groups (with and without intervention) with the mainstream group. Table 4 shows that the mainstream group scored on average higher on pseudo-words than initially delayed children. After 8 months of instruction the intervention group lagged slightly less than 6 words behind and the control group about 8 words. The differences were statistically significant. The gap between the mainstream group and the intervention group slightly narrowed in the next 10 months but a decrease of .28 words per assessment was not statistically significant. On the other hand, the gap between mainstream group and control group rather increased than decreased. Every assessment the control group lagged 2 more words behind the mainstream group. After 18 months of reading instruction the mainstream group read about 45 words per 2 minutes, the intervention group 40, and the control group 33. The mainstream group outperformed both initially delayed groups but the gap with the control group was far largest. Differences between mainstream and treatment group and between mainstream and control group were 350 and 1.000 milliseconds, respectively.

Results for word reading were similar but less pronounced. After 4 months of reading instruction, the mainstream group outperformed the intervention and

Table 4  
*Multilevel regression growth equation for pseudo-word and word reading contrasting  
 mainstream and delayed groups*

|                | Estimate (Std.Error)                            |                  |                |
|----------------|---|------------------|----------------|
|                | Pseudo-words                                    | Words            |                |
| Fixed effects  | Intercept                                       | 28.73(.87)***    | 19.03(.53)***  |
|                | Mainstream group                                |                  |                |
|                | Difference between control and mainstream group | -7.98(2.29)***   | -7.03(1.40)*** |
|                | Difference between intervention and mainstream  | -5.73(1.69)***   | -6.05(1.03)*** |
|                | Slope   | 8.25(.35)***     | 10.91(.28)***  |
|                | Difference between control and mainstream group | -2.12(.93)*      | -1.74(.74)*    |
| Random effects | Difference between intervention and mainstream  | .28(.69)         | -.47(.54)      |
|                | Residual  | 25.41(1.91)***   | 23.25(1.25)*** |
|                | Intercept                                       | 146.55(12.54)*** | 46.72(4.84)*** |
|                | Slope   | 15.88(2.36)***   | 13.56(1.41)*** |
|                | Alkaike's                                       | 7911.17          | 9952.35        |

control group with 6 and 7 words, respectively. These differences were statistically significant. The gap between mainstream and initially delayed children increased for the control group but not for the intervention group. Each assessment, the control group lagged 1.74 words further behind the mainstream group. After 18 months the mainstream group needed 1.160 milliseconds per word (52 words per minute), the initially delayed intervention group 1.277 milliseconds (47 words per minute), and the initially delayed control group 1.500 (40 words per minute).

*Did children who successfully participated in the remedial program as can be derived from number of errors in computer assignments in the remedial one-to-one, individualized computer program make more progress than children who relatively often failed the computer tasks and had made less progress on the post-test directly after the intervention?*

These analyses only encompassed the initially delayed group who received an intervention (about 90 children). The intraclass correlation coefficient describing the proportion of the total outcome variation that lies *between* people (Singer & Willett, 2003, p. 96) equaled .14 for words and .64 for pseudo-words. Comparing the variance component in the unconditional and unconditional growth model shows that 79% of the within person variation in words and 49% of the variation in pseudo-words was associated with linear time. Table 5 shows that the intervention group scored 28 pseudo-words per 2 minutes after 8 months of instruction if the number of errors was zero. However, if they failed all assignments the first time scores were about 15 words lower. On average children improved 12 words per assessment but, if they failed all assignments the first time, growth per assessment was only about 1.5 words (11.71-10.21). Findings for the word reading test were very similar; see Table 5.

Table 5

*Multilevel regression growth equation for pseudo-word and word reading in the initially delayed intervention group testing numbers of errors in the treatment program as moderator of intervention effects*

|                |   | Estimate (Std.Error) |                |
|----------------|---|----------------------|----------------|
| Fixed effects  |   | Pseudo-words         | Words          |
|                | Intercept without errors                              | 27.69(2.78)***       | 16.21(1.30)*** |
|                | Decrease of intercept due to highest number of errors | -15.36(7.86)***      | -11.13(3.59)** |
|                | Slope without errors                                  | 11.71(1.04)***       | 12.17(.86)***  |
|                | Decrease of slope due to highest number of errors     | -10.21(2.89)***      | -5.54(2.35)*   |
| Random effects | Residual  | 25.33(3.98)****      | 22.35(2.47)*** |
|                | Intercept   | 137.43(25.14)***     | 21.86(6.12)*** |
|                | Slope   | 9.33(4.02)*          | 11.91(2.67)*** |
|                | Akaike's  | 1767.86              | 2215.66        |

## Discussion

The present study investigated whether development of pseudo-word and word reading can be normalized by successful stimulation of code-related knowledge in kindergarten. The study shows that when initially low-performing children had a chance to catch up in kindergarten they make significantly more progress throughout the first two years of formal reading instruction than low-performing children without a chance to catch up. The differences between intervention and control group at the first assessments in grade 1 were not statistically significant probably because variation in scores on word reading fluency was limited at that time of testing due to bottom effects (Paris, 2005). Throughout the first two years effects of the treatment in kindergarten were most pronounced for pseudo-word reading probably because the intervention targeted code-related skills.

When initially delayed children had a chance to catch up by means of an additional computer program in kindergarten they continue to lag behind the mainstream group at the start of first grade. However, the gap has not increased by the end of second grade. On the contrary, the gap tends to narrow in the intervention group especially for pseudo-word reading. In so far students scoring among the 30% lowest on early literacy skills did not receive a supplemental training in code-related skills in kindergarten, they fall further behind during the first two



years of primary education. A lag of 2.5 words after four months has increased to 6 words after 18 months. This means that initially delayed children without treatment in kindergarten read words on average about 380 milliseconds slower than the mainstream group. The intervention group reads slower as well but not so much (about 200 milliseconds per word). Results for pseudo-words are similar. The current study thus demonstrates that an individual computer intervention program in support of the kindergarten curriculum can be an effective measure to prevent gaps in word reading fluency.

We did not find evidence for the hypothesis that children delayed at the end of kindergarten easily catch up throughout the first two grades. Our findings thus refute the hypothesis that in a relatively transparent orthography such as Dutch gaps in early literacy skills will close without interventions because reading acquisition is relatively straightforward and almost all pupils acquire basic reading skills confidently as a consequence of beginning reading instruction (Share, 2008). The present results are consistent with the theory that children benefit less from instruction and reading practice in the first two grades of primary education when they lag behind in early literacy skills. The study clearly indicates that children with delays in phonological skills at school entry fail cognitive and motivational multipliers for intensive practice of word reading. They need more time to acquire letter-sound connections and decoding skills than children without delays. Due to an additional training in kindergarten, however, children can catch up and benefit more from formal reading instruction as appears from the finding that the intervention group's gains in word reading skills were similar to those of the mainstreamers throughout grade 1 and 2.

However, not all children benefited from the intervention in kindergarten to the same extent. Actually, we found evidence that only children who successfully solved the games in the supplemental computer program benefited from the program and achieved similar to the mainstream group in the first two grades. Children who made relatively many errors in the games demonstrated a lower starting level and they increasingly lagged behind in word reading during the first two years of primary education. Although the present results reveal some evidence for differential effects of an early computer intervention it is a limitation of the present study that a sound explanation for making comparatively many errors in computer assignments is so far missing. A plausible explanation may be that pupils are distracted by details and less focused on the core problem. In line with this hypothesis a prior study revealed that pupils with low regulatory skills produced more errors in the computer assignments and benefited less from the program (Kegel, Van der Kooy-Hofland, & Bus, 2009). Future studies must be designed to explore this hypothesis and alternative explanations. Whatever may explain errors, the finding that beneficial effects of the computer program were only manifest when children were successful in playing the games demonstrates

that children's reading development was influenced by the computer program and not by any side effects of the program such as teachers or parents paying more attention to phonological skills elicited by the program.

## Conclusions

This study adds significantly to the literature in its test of the long-term effects of preschool literacy interventions. Despite limitations, this study supports the need for preventive / remedial programs at kindergarten-age, and demonstrates that a brief but intensive one-to-one individualized treatment can improve the capacity to benefit from beginning reading instruction in the early grades (Raudenbush, 2009). Unlike previous long-term studies (Bianco et al., 2010; Hatcher, Hulme, & Snowling, 2004; Henning et al., 2009; Whitehurst et al., 1999), the evidence obtained here indicates that pre-emptive measures in kindergarten, in support of the regular curriculum, can effectively interrupt a potentially downward spiral at an early stage in the learn-to-read process (Stanovich, 1986). Targeting children who lag behind in early literacy skills and offering them intensive, closely monitored and individualized practice may be part of the intervention's success. An individualized remedial intervention may be better equipped than whole or small group interventions to prevent later reading problems (Byrne et al., 2000; Henning et al., 2009). But these hypotheses await further research.

## Chapter 4

### **Differential susceptibility to early literacy intervention in children with mild perinatal adversities: short and long-term effects of a randomized control trial**

This chapter is based on: Van der Kooy-Hofland V. A. C., Van der Kooy, J., Bus A. G., Van IJzendoorn, M. H., & Bonsel, G. J. Differential susceptibility to early literacy intervention in children with mild perinatal adversities: Short and long-term effects of a randomized control trial. Manuscript submitted for publication.

## **Abstract**

In a randomized control trial we test whether short- and long-term effects of an early literacy intervention are moderated by mild perinatal adversities in accordance with differential susceptibility theory. One-hundred five-year-old children (58 percent male), who scored at or below the 30th percentile on early literacy measures were randomized to a web-based remedial early literacy program *Living Letters* or a treated control group. Parents gave written informed consent to access the perinatal data of their children at the Perinatal Register in the Netherlands. Twenty-one children were at birth small for gestational age but full term (SGA) or late preterm (LP). In the group with mild perinatal adversities, intervention children outperformed the control group immediately after the intervention and after eight months of formal reading instruction, but a similar effect of the computerized literacy program in children without mild perinatal adversities was absent. In line with the theory of differential susceptibility children with mild perinatal adversities seem to be more open to environmental input, for better *and* for worse.

## **Introduction**

Mild perinatal adversities such as being small for gestational age or being born late preterm (SGA or LP) are usually considered to be risk factors for subsequent child development, including cognitive development (Chyi, Lee, Hintz, Gould, & Sutcliffe, 2008; Nomura, et al., 2009; Van Baar, Vermaas, Knots, de Kleine, & Soons, 2009). Here we present experimental data supporting a radically different view, derived from the theory of differential susceptibility (Belsky, Bakermans-Kranenburg, & van IJzendoorn, 2007; Boyce & Ellis, 2005; Ellis, Boyce, Belsky, Bakermans-Kranenburg & Van IJzendoorn, 2011). We suggest that mild (but not severe) perinatal adversities may have programmed children to be more susceptible than other children to the environment, for better *and* for worse.

Children who are small for gestational age or born late preterm may acquire poorest early literacy skills in unfavorable environments but they might perform at the highest literacy level if delays in early literacy development are addressed at an early stage. Children may profit more from beginning reading instruction when they have received an early literacy intervention in kindergarten that prompted them to pay attention to print as an object of exploration – an important precursor of the beneficial effects of reading instruction (Byrne, Fielding-Barnsley, & Ashley, 2000; Duursma, Augustyn, & Zuckerman, 2008; Silva & Alves Martins, 2002; Snider, 1997; Van der Kooy - Hofland, Kegel, & Bus, 2011). For kindergarten children with early literacy-related delays we tested in the current randomized control trial (RCT) whether after the intervention and at the end of first grade children with mild perinatal adversities were differentially susceptible to an early computer-based literacy intervention.

The impaired neuromotor, medical, social and cognitive development of very preterm children (< 32 weeks) and children who are extremely SGA (< 2.5<sup>th</sup> percentile) has been extensively documented (Aarnoudse-Moens, Weisglas-Kuperus, van Goudoever, & Oosterlaan, 2009; Anderson & Doyle, 2003; Bhutta, Cleves, Casey, Craddock, & Anand, 2002; Rodrigues, Mello, & Fonseca, 2006). For children with mild perinatal adversities fewer studies on their later development have been conducted. However, most available evidence supports the conventional assumption that children with mild perinatal adversities are at risk for medical and neurocognitive problems as well. Compared to full term children LP children had lower reading scores (Kirkegaard, Obel, Hedegaard, & Henriksen, 2006; Chyi et al., 2008; Lee, Yeatman, Luna, & Feldman, 2010), a two times higher risk for special education at all grade levels (Van Baar, et al., 2009), and a greater risk for developmental delays and school-related problems (Morse, Zheng, Tang, & Roth, 2009). Cognitive development of mild SGA children has also been shown to lag behind, with increased risk of learning disabilities and impaired learning-related abilities in childhood, and lower educational achievement among adults born

near-term (Johnson & Breslau, 2000; Kirkegaard et al., 2006; Nomura, et al., 2009). No evidence is available however on the effectiveness of enriched educational environments created for children with previous mild perinatal adversities.

In developmental psychopathology the concept of 'biological sensitivity to context' or more general 'differential susceptibility' has emerged to acknowledge the accumulating evidence that some children with a specific neurobiological, temperamental or genetic make-up seem to suffer most from negative environments but at the same time appear to profit most from positive environments, for better *and* for worse (Belsky, et al., 2007; Belsky & Pluess, 2009; Boyce & Ellis, 2005; Ellis et al., 2011; Pluess & Belsky, 2011). Core idea is that not every child seems equally susceptible to the same parental, educational or environmental influences. Temperament has been one of the differential susceptibility factors central in the first wave of studies pioneered by Belsky and colleagues (Belsky, Hsieh, & Crnic, 1998). For example, an intervention that provided both high quality child care and parenting support showed a moderating effect of infant negative emotionality with respect to subsequent cognitive functioning and externalizing behavior (Blair, 2002). A reactive temperament seems not a 'risk' but a susceptibility factor. Genetic differential susceptibility has been introduced by a Leiden group (Bakermans-Kranenburg & Van IJzendoorn, 2006) who documented the potential role of dopamine-system genes for differential susceptibility. For example, children with the DRD4 7-repeat allele and unresponsive mothers displayed more externalizing behavior problems than children without the DRD4 7-repeat variant (irrespective of maternal responsiveness); but children with the DRD4 7-repeat allele and responsive mothers showed the lowest levels of externalizing problem behavior (Bakermans-Kranenburg & Van IJzendoorn, 2007).

Physiological factors (i.e., biological reactivity) have been introduced by Boyce and his team (Boyce, et al., 1995). In a pioneering study on biological sensitivity to context Boyce et al. (1995) showed that 3-5 year old children with low cardiovascular or immune reactivity to stressors had approximately equal rates of respiratory illnesses in both low and high adversity settings. Highly biologically reactive children exposed to high adversity child care settings or home environments had substantially higher illness incidences than all other groups of children. Unexpectedly, they also found that highly sensitive children living in more supportive child care or family settings had the *lowest* illness rates, lower than even low reactivity children in comparable settings (see Ellis et al., 2011, for an extensive review of converging evidence). Here we suggest that mild perinatal adversities may have been associated with physiological changes such as higher cardiovascular reactivity to context, which according to the study of Boyce and colleagues would make children more sensitive to context, for better *and* for worse. Because of their stress reactivity children with mild perinatal adversities may easily shut themselves off for learning experiences in a less optimal learning

environment, whereas they might be most eager to learn from positive feedback in a supportive learning environment.

We present the first educational intervention study using a randomized control trial to demonstrate the short- and long-term, high learning potential of children with mild perinatal adversities in an optimal educational environment. The study targets a literacy intervention developed as a remedial program for children who lag behind in early literacy skills and who therefore are at risk not to benefit optimally from beginning reading instruction (Shonkoff & Phillips, 2000; Stipek & Ryan, 1997). *Living Letters*, a computer-based educational program, compensates for a lack of environmental experience that promotes early literacy skills and once children have acquired these competencies that are fundamental for learning to read they are better able to benefit from formal reading instruction in second grade (Van der Kooy-Hofland et al., 2011). In line with the theory that mild perinatal adversities are not a 'risk' but a susceptibility factor we expect that children with mild perinatal adversities will outperform the children without adversities when they receive the program but lag further behind without program. Due to an early, preventive remedial program at kindergarten, children with mild perinatal adversities may be better prepared for further reading instruction, and because of the hierarchical nature of the reading process early interventions may reveal long-term effects on their school achievements as well (Heckman, 2006).

The intervention program in this study uses the proper name to provide surface perceptual features of letters that help children discover sound-symbol relations between the first letter of their name and its sound in its spoken counterpart (Van der Kooy - Hofland, et al., 2011). There is compelling evidence showing that name writing is commonplace in young children's everyday life and that the proper name is one of the first perceptually familiar words to young children (Levin, Both-de Vries, Aram, & Bus, 2005; Levin & Bus, 2003). By calling children's attention to sounds of letter units in the written name (e.g., "It's /pi/ of Peter") children receive a substantial amount of direct instruction about letters as symbols for sounds in the name. Most kindergarten children begin to combine understanding of how a word sounds with knowledge of how a word looks by using opportunities for development enhancement in daily life (Levin & Aram, 2005; Molfese, Beswick, Molnar, & Jacobi-Vessels, 2006). An individualized remedial computer program, *Living Letters*, was modeled after literate home activities with the proper name as a crucial prompt to stimulate children to explore print. The computer program is especially created for children lacking in competencies fundamental to reading success who easily shut themselves off for learning experiences at home and in school. We expect the program to be more successful in holding these children's attention by providing constructive feedback immediately following an error (Corbett & Anderson, 2001) as well as by being adaptive to characteristics of the user or to the user's interaction with the system (Vasilyeva, 2007). For instance,

the program offers more feedback (more cues for solving the task) when a child fails the task and help is reduced when the learner is more competent and solves problems after a few attempts.

### **Aims and hypotheses**

In the current randomized control trial we include 100 five-year-olds who scored at the lowest level of early literacy skills in the fall of the senior kindergarten year. Our central question is whether mild perinatal adversities moderate effects of a remedial intervention program targeting kindergarten children lacking in competencies fundamental to their school success – notably in the area of literacy. Findings so far show that the overall effects of Living Letters are moderate immediately after the intervention as well as on the long-term (Van der Kooy-Hofland et al., 2011). Such a pattern of findings may manifest itself because the intervention increases learning only for those children who are most susceptible to their environment and need systematic instruction and support to explore print.

Children with mild perinatal adversities may be more susceptible to the environment including compensatory educational intervention in kindergarten and outperform children with mild perinatal adversities who do not receive the compensatory educational intervention as well as children without mild perinatal adversities who received the intervention. This differential intervention effect would emerge not only directly after the intervention but also a year later. Due to a better starting position as a result of the intervention the children with mild perinatal adversities benefit more from beginning reading instruction in first grade. Without a timely enriched environment, literacy performance of these children is expected to remain at a lower level because they, in contrast to their peers without perinatal adversities, are less receptive to influences in their daily environment. In line with differential susceptibility theory we expect therefore that the majority of children without perinatal adversities are less susceptible to compensatory education in kindergarten. On the long-run they remain at roughly the same level whether or not they received a remedial computer program in kindergarten, and they will be outperformed by their peers with mild perinatal adversities who participated in the enriched literacy environment. The predicted differential effectiveness of Living Letters should be independent of possible contaminating systematic SES, IQ or executive function differences between the groups.

The current study aims therefore at testing the following hypotheses: (1) Children with mild perinatal adversities are most susceptible to early compensatory interventions in kindergarten and show the strongest beneficial effects directly after the intervention. (2) Beneficial effects stretch to the period of beginning



reading instruction that builds on early literacy skills. Short-term positive effects assessed directly after the intervention in the mild perinatal adversities group are predicted to be maintained for reading tests at the end of grade 1 almost one year after the end of the intervention.

## **Method**

### *Participants*

The intervention sample was drawn from 15 regular public schools with a “normal” population. Eligible for participation were pupils speaking Dutch as their first language and between 60 to 72 months old. An estimated 12% of 459 pupils did not participate in the screening, due to illness or absence for other reasons or failure of parental consent. The lowest scoring 30% ( $N = 135$ ) on an aggregate measure composed of three screening assessments (letter knowledge, writing ‘mama’ and writing other words) was selected to participate in the experiment. The cut-point of 30% was based on the finding that this selection encompassed all children who knew very few letters and were unable to represent letters phonetically in their writings. The selected children were randomly assigned (ratio 2:1) to the intervention program (Living Letters) or treated control group (Living Books) stratified for school and gender.

One-hundred parents (74%) gave written informed consent to access the perinatal data of their children at the Perinatal Register in the Netherlands (PRN, 2010). The children (58 percent male) were at the start of the study 60 to 71 months old ( $M = 64.16$  months,  $SD = 2.99$ ). Almost all schools (14 out of 15) were represented in the subsample. Children were assigned to the group with mild perinatal adversities a priori defined as birth weight ranging between the 2.5th and 10th percentile for the gestational age (full term small for gestational age, SGA), or being late preterm (LP) that is a gestational age at birth of 34-37 weeks + 6 days. Twelve children (eight in intervention program, see Table 1) were at birth SGA and nine late preterm (five in intervention program).

The children ( $N = 100$ ) participating in the current, perinatal part of the intervention study did not significantly differ from the total sample ( $N = 135$ ) on educational level of the father, verbal intelligence, regulatory skills, pretest early literacy skills, and outcome measure for early literacy skills. In grade 1 we lost seven children in the no mild adversities group (three in intervention program), because families moved ( $n = 3$ ) or children duplicated senior kindergarten classroom ( $n = 4$ ).

### *Study design*

A randomized pretest-posttest control group design was used to examine the

differential effects of a remedial intervention (*Living Letters*) in kindergarten. Control subjects were assigned to another computer program not focusing on early literacy skills (*Living Books*). Eligible children were randomly assigned to intervention and control group, stratified for school and gender.

To examine whether randomization had been successful, we applied t-tests with experimental group (*Living Letters* and control group) as factor and with mild adversities versus no mild adversities as factor to test whether they were similar on paternal education, verbal and non-verbal intelligence, regulatory skills and pretest early literacy skills (Tables 1 and 4). There were no significant differences between the experimental groups on paternal education, verbal and non-verbal intelligence, regulatory skills, and pretest early literacy skills.

Children of fathers with lower educational level were overrepresented in the mild adversities group ( $M = 5.56$ ,  $SD = 2.17$ ), compared to the no mild adversities group ( $M = 3.95$ ,  $SD = 2.13$ ),  $t = 3.03$ ,  $df = 98$ ,  $p < .01$  (Table 1). Also pretest early literacy skills showed a significant difference between the mild adversities group ( $M = -.45$ ,  $SD = .75$ ) and the no mild adversities group ( $M = .10$ ,  $SD = 1.06$ ),  $t = 2.23$ ,  $df = 98$ ,  $p < .05$  (Table 4). There were no significant differences on verbal or non-verbal intelligence and regulatory skills.

Table 1  
*Background variables as a function of experimental group and perinatal adversities*

|                                | Mild perinatal adversities<br>( $n = 21$ ) |                        | No mild perinatal adversities<br>( $n = 79$ ) |                         |
|--------------------------------|--|------------------------|---|-------------------------|
|                                | LL<br>( $n = 13$ )                         | Control<br>( $n = 8$ ) | LL<br>( $n = 52$ )                            | Control<br>( $n = 27$ ) |
| Gender (m/f)                   | 7/6  | 6/2                    | 30/22   | 15/12                   |
| Paternal education             | 4.31 (2.29)                                | 3.38 (1.85)            | 5.85 (2.19)                                   | 5.00 (2.04)             |
| PPVT <sup>a</sup>              | 77.23 (8.90)                               | 74.50 (13.59)          | 81.35 (12.13)                                 | 78.07 (11.28)           |
| Raven's CPM <sup>a</sup>       | 15.15 (4.20)                               | 18.00 (3.70)           | 16.92 (3.29)                                  | 16.85 (4.14)            |
| Regulatory skills <sup>b</sup> | -.08 (.76)                                 | -.76 (1.33)            | .17 (.99)                                     | -.07 (.95)              |

Note. <sup>a</sup> raw scores. <sup>b</sup> z-score

#### *Intervention program*

*Living Letters*. *Living Letters*, designed by a team of computer experts, designers, and experts in the field of education, and available for schools and parents via subscription, is aimed at training basic literacy skills. The child's proper name or another familiar name such as 'mama' [mom] (Levin, Shatil-Carmon, & Asif-Rave, 2006) is used to illuminate how letters in names relate to sounds (Bus &

van IJzendoorn, 1999; Ehri et al., 2001). Since the proper name is often the first word that young children can read and write, children received the program version with the proper name unless the name's spelling was inconsistent with Dutch orthography (e.g., Chris or Joey). In those cases, the program used 'mama', another often-known word, as target word (Both-de Vries & Bus, 2008; 2010). Of the 40 games 22 games provided practice in recognizing the proper name. Six games focused on recognition of the first letter of the proper name, and another 12 games provided practice in identifying pictures that start or end with the first letter of the child's name.

The sessions started with an attractive animation to explain the upcoming games; for instance, the two main characters, *Sim* and *Sanne*, discuss their name and discover that these names start with the same sound. Errors when solving the games are followed by increasingly supportive computerized oral feedback. Unlike most computer games, the program *Living Letters* gives adult-like feedback that goes beyond "great" or "not quite right, try again". First, the task is repeated (*Find the word that starts with the same sound as your name*), next a clue is given (*Which word starts with /t/ of Tom?*), and lastly the correct solution is demonstrated (*You hear the first sound of your name, /t/ of tom, in tent*). After a maximum of three trials per assignment, in both conditions, Sim, Sanne, and the teddy bear start dancing to mark the end of an assignment, whether or not the child has given the correct answer, after which the next game starts.

*Living Books*. The control group was given an alternative computer treatment however not targeting letter-sound knowledge: *Living Books*. This program consists of five age-appropriate computerized books that include oral narration and video representations of the scenes, but no printed text, thus allowing the child to *read by listening*. In each 10-minute session, children read one electronic storybook and responded to four follow-up questions among which two about difficult words (e.g., *What are paving stones?*) and two about story events (e.g., *Is dad happy or angry?*) by choosing one out of three pictures. Each book was repeated three times across the 15 sessions. In each repeated reading, children responded to four new questions, totaling 12 questions per book.

#### *Training procedure*

Training sessions were held over a period of 15 weeks. Children spent an estimated 10 minutes per session playing *Living Letters* or *Living Books*. Sessions occurred during the morning either in classroom or computer room conditional upon the school routines. Children wore headphones to reduce noise and distractibility. Because the intervention was the first tryout of *Living Letters* university students at the master's level were present to prevent or solve technical problems with the help of an off-site helpdesk. It was their task to log children in on the website and provide supervision and assistance to ensure that children could complete

all sessions. However, they did not provide guidance in explaining or solving the computer assignments. The system stored which assignments each child had completed and the correct game automatically appeared on screen when the supervisor entered the child's name. The system was also programmed in a way that the session automatically discontinued after four games so that sessions had the same duration and the program was held over a similar period. Each child thus played all games as often and in the same order. The system registered which assignments children had completed which enabled the main researcher to notify failed or missed assignments and repeat those within one week. Thanks to the computerized treatment, fidelity checks were maximal.

#### *Measures*

*Perinatal variables.* Data from the Netherlands Perinatal Registry (PRN, 2010) 2000–2001 were used. The PRN is a database that contains the linked data from three registries: the national obstetric database by midwives, the national obstetric database by gynaecologists, and the national neonatal/pediatric database (Méray, Reitsma, Ravelli, & Bonsel, 2007). The PRN registry contains comprehensive data on pregnancy, provided pregnancy care (interventions, referrals), and pregnancy outcomes. The coverage of the PRN is about 96% of all deliveries in the Netherlands. All variables were recorded by the health care provider during prenatal care, delivery and neonatal and lying-in period. The data are annually sent to the national registry office, where a number of range and consistency checks are conducted. Criteria for assignment to the group with mild perinatal adversities were birth weight between the 2.5th - 10th percentile for the gestational age (small for gestational age, SGA) or late preterm that is a gestational age at birth of 34 - 37 weeks + 6 days.

*Parental education* was surveyed using the following scale of highest form of education completed by the fathers and mothers: 1 (primary school), 2 (preparatory secondary vocational education), 3 (preparatory middle-level vocational education), 4 (senior secondary vocational education), 5 (senior secondary education), 6 (pre-university education), 7 (professional higher education), and 8 (university). Because the measures were strongly correlated but paternal education was more strongly associated with perinatal adversities we preferred this measure to maternal education as covariate.

*Intelligence.* To control for intelligence as a confounding factor we tested verbal and non-verbal intelligence with the Dutch version of the Peabody Picture Vocabulary Test (Schlichting, 2005) and the Dutch version of Raven's Colored Progressive Matrices (Van Bon, 1986).

*Regulatory Skills.* Because regulatory skills relate to learning via the computer (Kegel et al., 2009) we assessed regulatory skills at pre-test with four tasks: (1) Following the Stroop paradigm, children had to switch rules by responding with an

opposite, i.e., saying “blue” to a red dog and “red” to a blue dog (Beveridge, Jarrold, & Pettit, 2002). The task consisted of 96 trials distributed over four conditions, in which demands on working memory (remembering the name of one or two dogs) and inhibition of the most obvious response (e.g., saying “blue” to a red dog) varied. Incorrect naming and corrections were both scored as errors. (2) In a second Stroop-like task (opposites) children had to respond with the opposite to contrasting pairs of pictures [e.g., saying “fat” to thin] (based on Berlin, Bohlin, Nyberg & Janols, 2004). Incorrect naming and corrections were both scored as errors. (3) In a test called ‘same tapping’ the child copied the experimenter’s hammer taps on cubes (Schroots & Van Alphen de Veer, 1976). Each correct imitation in this working memory task was awarded one point with a maximum score of 12. (4) In the peg tapping test the child tapped twice with a pencil after one tap by the experimenter, and vice versa (Diamond & Taylor, 1996). The total score was the number of correct responses to 16 items. Intraclass correlation coefficients between two independent coders were high for all four tasks ( $r > .97$ ). PCA revealed one component with high loadings (.66 - .75) explaining 49% of the variance. The distribution of this aggregated measure (regulatory skills) was normal for both the intervention and the control group.

#### *Screening tests*

Screening tests aimed at identifying kindergarten children delayed in the basic understanding that letters relate to sounds. Rhyming did not discriminate in this age-group, however the following measures did:

*Early writing.* Children were asked to write familiar words like *mama* (mom) and four other words (e.g., *boot* [boat]) (Schrooten & Vermeer, 1994). Each word was double-coded on a scale from 1 (writing-like scribbles) to 6 (conventional spelling) (Levin & Bus, 2003). A score of 3 or higher indicates that one or more letters are represented phonetically. The intra-class correlation coefficient for 20 double-coded assignments was high ( $r = .99$ ).

*Receptive letter knowledge task.* Children were asked to point to one of eight target letters, each presented on a card between four other letters.

*Aggregated screening score.* Alpha reliabilities for the tests were satisfactory; see Table 2. Correlations among the tests were rather high ( $\geq .52$ ). Principal Component Analysis (PCA) on the measures revealed one component with high loadings (.83 - .87) that explained 74% of the variance. The lowest scoring 30% on the composite measure were selected as experimental group because they did not represent letters phonetically.

Table 2  
 Mean scores (SD) and reliabilities for child characteristics, screening-tests, pre-tests and post-tests.

|                          | Measure                              |                  | N   | M (SD)        | Skewness<br>(SE) | Kurtosis<br>(SE) |
|--------------------------|--------------------------------------|------------------|-----|---------------|------------------|------------------|
| Child<br>Characteristics | Paternal education                   |                  | 100 | 5.22 (2.25)   | -.04 (.24)       | -1.47 (.48)      |
|                          | Peabody Picture Vocabulary Test      | .94 <sup>b</sup> | 100 | 79.38 (11.70) | -.02 (.24)       | -.44 (.48)       |
|                          | Non-verbal intelligence              | .69 <sup>c</sup> | 100 | 16.76 (3.70)  | -.03 (.24)       | -.06 (.48)       |
|                          | Executive Functioning (factor score) |                  | 100 | .00 (1.00)    | -.46 (.24)       | .12 (.48)        |
|                          | - Stroop task dogs (max = 96)        | .94 <sup>a</sup> | 100 | 83.98 (8.60)  | -.89 (.24)       | -.17 (.48)       |
|                          | - Stroop task opposites (max = 48)   | .91 <sup>a</sup> | 100 | 31.16 (7.44)  | -.50 (.24)       | -.18 (.48)       |
|                          | - Peg Tapping (max = 16)             |                  | 100 | 13.35 (2.32)  | -.66 (.24)       | -.41 (.48)       |
|                          | - Same Tapping (max = 12)            | .80 <sup>c</sup> | 100 | 6.88 (2.40)   | -.10 (.24)       | -.45 (.48)       |
| Screening                | Screening (aggregated score)         |                  | 404 | .00 (.86)     | -.23 (.12)       | .04 (.24)        |
|                          | - Letter knowledge (0-8)             | .73 <sup>a</sup> | 404 | 5.62 (2.07)   | -.46 (.12)       | -.92 (.24)       |
|                          | - Writing 'Mom' (1-6)                |                  | 404 | 3.67 (1.74)*  | .18 (.12)        | -1.27 (.24)      |
|                          | - Writing words (1-6)                | .87 <sup>a</sup> | 404 | 3.04 (1.07)*  | .23 (.12)        | .82 (.24)        |
| Pretest                  | Phonological skills (max = 25)       | .81 <sup>a</sup> | 100 | 7.54 (4.86)   | 1.02 (.24)       | .19 (.48)        |
| Posttest                 | Early literacy skills (factor score) |                  | 100 | .00 (1.00)    | .44 (.24)        | -.73 (.48)       |
|                          | - Phonological skills (max = 25)     | .87 <sup>a</sup> | 100 | 12.41 (6.03)  | .04 (.24)        | -1.20 (.48)      |
|                          | - Word recognition (max = 45)        | .80 <sup>a</sup> | 100 | 27.29 (6.55)  | .32 (.24)        | -.10 (.48)       |
|                          | - Decoding (max = 40)                | .98 <sup>a</sup> | 100 | 15.08 (4.53)  | -.54 (.24)       | -.68 (.48)       |
| Post-posttest            | Reading Grade 1 (factor score)       |                  | 93  | .00 (1.00)    | .14 (.25)        | -.56 (.50)       |
|                          | - Word reading fluency               | .91 <sup>b</sup> | 93  | 22.52 (10.33) | .28 (.25)        | -.48 (.50)       |
|                          | - Pseudo-word reading test           | .88 <sup>b</sup> | 93  | 21.82 (11.94) | .71 (.25)        | -.39 (.50)       |
|                          | - Serial naming                      | .74 <sup>b</sup> | 93  | 40.73 (8.90)  | .78 (.25)        | -.05 (.50)       |

<sup>a</sup>Cronbach's alpha; <sup>b</sup>test-retest reliability; <sup>c</sup>split-half reliability; \*scores  $\geq 3$  indicates writing one or more phonetic symbols;

### *Early literacy skills*

To test whether the program stimulates and re-organizes attention to sounds and letters in spoken and printed words the following test battery was applied (NELP, 2008):

*Phonological skills* (pre- and post tested) were assessed in a series of 5 tasks: (1) identifying among three words the one that starts with a sound different from the other two words; (2) selecting among four words two words with the same initial sound; (3) selecting from four words two words with the same final sound; (4) naming the first sound of words; and (5) naming all sounds of words. To reduce examiner bias, all picture names were pronounced by a computerized voice. All target sounds ( $n = 20$ ) were consonants; all words were monosyllabic (CVC or CVVC). Each correct response was awarded one point (maximum = 25).

*Word recognition* (only post-tested). Children had to identify the depicted target word (e.g., raam) among four printed words. The (incorrect) alternatives differed in 1 (room), 2 (rat) or all letters (bon) from the target word. Correct responses were rewarded with 3 points (raam); correspondence of first and last letter (room) with 2 points; correspondence of first letter with 1 point (rat); and no correspondence (bon) with 0.

*Decoding* (only post tested). Children were trained in decoding four vowel-consonant (VC) and four consonant-vowel-consonant (CVC) nonsense words. If children failed to pronounce the nonsense word in the first five seconds after presentation of a word, they were stimulated to sound out the separate letters. If this did not prompt correct decoding, the experimenter pronounced the separate sounds and stimulated the subjects to blend the sounds. If they did not succeed, the experimenter repeated the separate sounds, blended them, and had subjects repeat the naming and blending. The list of eight words was repeated five times in different sequences. Scores per word varied from 5 (successful first attempt) to 1 (non-completion of item).

*Early literacy skills.* Alpha reliabilities for all tests were satisfactory; see Table 2. As is shown in Table 3 the three measures were strongly correlated ( $> .59$ ). Principal Component Analysis (PCA) on the posttest measures revealed one component with high loadings (.81-.77) that explained 77% of the variance. This component was labeled as 'Early Literacy Skills' and used as dependent variable. We used phonological skills measured at pretest as covariate (see Table 4).

### *Beginning reading skills*

In first grade, children were tested with measures that are used in Dutch schools to assess reading development after about 8 months of instruction. In a regular orthography such as the Dutch language, measures that target speed discriminate better than measures of accuracy (Share, 2008):

Table 3  
Bivariate correlations among measures

|                             | Time          | 1 <sup>a</sup> | 2 <sup>a</sup> | 3 <sup>a</sup> | 4 <sup>a</sup> | 5 <sup>b</sup> | 6 <sup>b</sup> | 7 <sup>b</sup> |
|-----------------------------|---------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| 1. Phonological skills      | pretest       | -              | .55**          | .51**          | .65**          | .25*           | .18            | -.25*          |
| 2. Phonological skills      | posttest      |                | -              | .54**          | .79**          | .32**          | .23*           | -.29**         |
| 3. Word recognition         | posttest      |                |                | -              | .64**          | .31**          | .30**          | -.16           |
| 4. Decoding                 | posttest      |                |                |                | -              | .28**          | .22*           | -.21*          |
| 5. Word reading fluency     | post-posttest |                |                |                |                | -              | .93**          | -.64**         |
| 6. Pseudo-word reading test | post-posttest |                |                |                |                |                | -              | -.57**         |
| 7. Serial naming            | post-posttest |                |                |                |                |                |                | -              |

\*\*  $p < .01$ . \*  $p < .05$ . Note: <sup>a</sup> $n = 100$ ; <sup>b</sup> $n = 93$

Table 4  
Means pretest and post test scores (z-scores) and SE's as a function of experimental group and perinatal adversities

|                                      | Mild perinatal adversities |            | $p$       | No mild perinatal adversities |            | $p$       |
|--------------------------------------|----------------------------|------------|-----------|-------------------------------|------------|-----------|
|                                      | $(n = 21)$                 |            |           | $(n = 79)^a$                  |            |           |
|                                      | LL                         | Control    |           | LL                            | Control    |           |
|                                      | $n = 13$                   | $n = 8$    |           | $n = 52^b$                    | $n = 27^c$ |           |
| <i>Pretest</i>                       |                            |            |           |                               |            |           |
| Phonological skills                  | -.39 (.22)                 | -.55 (.24) | <i>ns</i> | .14 (.15)                     | .03 (.20)  | <i>ns</i> |
| <i>Posttest</i>                      |                            |            |           |                               |            |           |
| Early literacy skills (factor score) | .64 (.25)                  | -.47 (.11) | <.05      | -.06 (.10)                    | -.06 (.16) | <i>ns</i> |
| <i>Post-posttest</i>                 |                            |            |           |                               |            |           |
| Reading Grade 1 (factor score)       | .42 (.21)                  | -.41 (.22) | <.05      | -.04 (.11)                    | .00 (.24)  | <i>ns</i> |

Note: <sup>a</sup>Grade 1,  $n = 72$ ; <sup>b</sup>Grade 1,  $n = 49$ ; <sup>c</sup>Grade 1,  $n = 23$



*Word reading fluency* was tested with the one-minute-test, a standardized test, to determine how many words from a list can be read during one minute (Brus & Voeten, 1973).

*Pseudo-word reading fluency*, a standardized pseudo-word reading test, assessed how many nonsense words were read accurately in 2 minutes (Van den Bos, Lutje Spelberg, Scheepstra, & de Vries, 1994).

*Serial naming of letters*. To assess how fast letters can be retrieved from memory children named 50 lowercase letters composed of five different letters (d, o, a, s and p) non-consecutively ordered as fast as possible (Van den Bos, Lutje Spelberg, Scheepstra, & de Vries, 2003).

*Aggregated measure for grade 1 reading*. Cronbach's and Guttman's alphas for the standardized tests were satisfactory; see Table 2. The measures for word reading, non-word reading and serial naming of letters showed high correlations (> .55). Principal Component Analysis revealed one component explaining 84% of variance with test loadings ranging from .87 to .95. This aggregated variable was normally distributed.

#### *Data collection and scoring procedure*

In fall (screening), one month before the 15-week intervention, directly after the intervention, and after 8 months of instruction master's level university students, blind to treatment, tested the children. Assessments were delivered in a fixed order to all participants. Examiners were extensively trained in administration procedures. Videotaped pre/post assessments were used to control the testing procedure. Master's level university students blind to treatment, scored tests under supervision of the main researcher.

#### *Analysis*

Because the subjects were recruited from 14 schools and observations within schools may be dependent we started with deriving the Huber-White estimates to correct for clustering of the measures (cf. Hatcher et al., 2006; Kegel, Bus, & Van IJzendoorn, 2011). We then included these estimates in the Complex Sample General Linear Model (CSGLM, SPSS 17) to carry out regression analyses with reading skills directly after the program in kindergarten and at the end of first grade as dependent or outcome variables, and pretest early literacy skills, paternal educational level, children's PPVT score (verbal intelligence), Raven score (non-verbal intelligence), regulatory skills, presence of mild perinatal adversities, and experimental group (Living Letters versus control group) as covariates (total  $N = 100$  children in 14 schools).

## Results

Paternal educational level, verbal and non-verbal intelligence and regulatory skills were non-significant predictors of beginning literacy skills in kindergarten and grade 1 reading skills. Experimental group and mild perinatal adversities group did not show significant main effects on early and beginning literacy skills. The interaction between experimental group and mild perinatal adversities, however, was significant not only immediately after the intervention,  $F(1, 13) = 8.25, p = .013$ , but also at the end of grade 1,  $F(1, 13) = 9.22, p < .01$ .

In order to examine the interactions between intervention and mild perinatal adversities, we repeated the CSGLM in the mild perinatal adversities and the no mild perinatal adversities groups separately. The significant effect of experimental group in the mild perinatal adversities group for posttest early literacy skills ( $F(1, 8) = 7.24, p < .05; n = 21$ ) was still present at the end of grade 1 reading ( $F(1, 8) = 5.79, p < .05; n = 21$ ), where children in the *Living Letters* group outperformed the control group (Table 2). However, the no mild perinatal adversities group was not susceptible for the early intervention as was demonstrated by the absence of a significant effect for end of kindergarten early literacy skills ( $F(1, 13) = .06, p < .82; n = 79$ ) and grade 1 reading skills ( $F(1, 13) = .01, p = .91; n = 72$ ). Outcomes were basically the same when the SGA and LP group were analyzed separately but for these post-hoc analyses statistical power was of course low due to the small number of subjects in the sub-groups.

Table 5

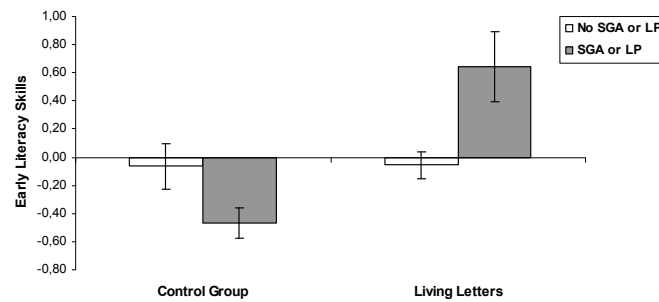
*Effects of treatment in the total group and in the subsample (mild perinatal adversities) directly after the intervention (posttest early literacy skills) and after one year reading instruction controlling for background (paternal education, PPVT, RCPM, regulatory skills and pretest)*

| Measure                    | n   | Estimate (SE) | 95%CI B  | t                 | p-value | Cohen's $d^d$ |
|----------------------------|-----|---------------|----------|-------------------|---------|---------------|
| <i>Total group</i>         |     |               |          |                   |         |               |
| Early literacy skills      | 100 | .12 (.07)     | -.04,.28 | 1.66 <sup>a</sup> | .12     | .34           |
| Reading Grade 1            | 93  | .08 (.13)     | -.19,.36 | .65 <sup>b</sup>  | .53     | .14           |
| <i>SGA or LP Subsample</i> |     |               |          |                   |         |               |
| Early literacy skills      | 21  | .36 (.13)     | .05,.67  | 2.69 <sup>c</sup> | < .05   | 1.24          |
| Grade 1 Reading            | 21  | .40 (.17)     | .02,.78  | 2.41 <sup>c</sup> | < .05   | 1.11          |

Note: <sup>a</sup> $n = 100, df = 13$ ; <sup>b</sup> $n = 93, df = 13$ ; <sup>c</sup> $n = 21, df = 8$ ; <sup>d</sup>For calculating Cohen's  $d$  we used the formula  $2t/\sqrt{n-2}$  (Thalheimer & Cook, 2002).

In Table 5 the effect sizes of the intervention for early literacy skills and grade 1 reading are presented. Although the overall effect of the computer intervention was low, the children with mild perinatal adversities benefited substantially from the intervention. The effect size for reading in first grade ( $d = 1.11$ ) was only slightly lower than the effect size for post test early literacy of  $d = 1.24$  directly after the intervention. Figure 1 illustrates the difference in effect size between experimental groups for post test early literacy and grade 1 reading scores. The dependent measure is the early literacy and grade 1 aggregate reading score residualized with the four covariates (paternal educational level, verbal intelligence, non-verbal intelligence, and regulatory skills) before computing means and standard deviations per sub-group. From Figure 1, it can be derived that the mild perinatal adversities group manifested the highest score on early literacy skills directly after the program and grade 1 reading after the *Living Letters* intervention, and the lowest in the control group.

A



B

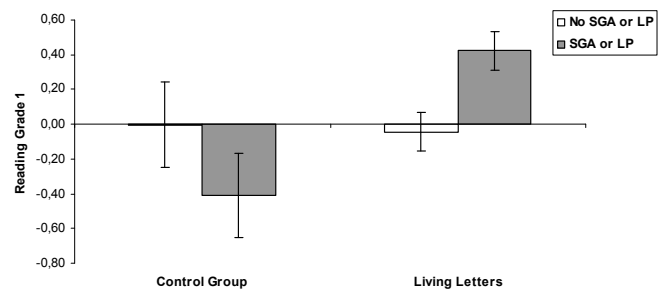


Figure 1. Estimated Means and SE's for Early Literacy Skills of Children with mild perinatal adversities (SGA or LP) and without (no SGA or LP) in Intervention Group (*Living Letters*) and in Control Condition (A) directly after the intervention ( $N = 100$ ) and (B) one year after the intervention ( $N = 93$ ).

## Discussion

In this randomized control trial we found that, without an adequate preventive intervention program, children who had experienced mild perinatal adversities (SGA or LP) performed at the lowest level at the end of grade 1. In line with differential susceptibility theory, however, we also found that children with mild perinatal adversities profited most from a computer-based remedial intervention with an adaptive feedback regime, and these susceptible children kept their advantage even at the end of grade 1, after one year of formal reading instruction without any further additional support. As children in intervention and control condition were taught by the same teachers and exposed to similar classroom curricula we can be certain that there were no differences apart from the computer-based literacy intervention in kindergarten to explain this finding. In particular the advantage at the end of grade 1 demonstrates how important it is to address early literacy delays at an early stage.

Remediation of early literacy skills at an early stage can enhance effects of systematic instruction in reading skills that in the Netherlands does not begin until children are in first grade. We also found that some children are more susceptible to early remedial interventions than other children. Children with mild perinatal adversities are vulnerable to develop persistent delays in literacy skills but they also seem to thrive and are quick in acquiring high levels of elementary literacy skills when they have a chance to catch up and outrun their peers prior to the start of beginning reading instruction by participating in an enriched, computer-based literacy environment in kindergarten. These susceptible children seem to have not only risk factors but also unexpected learning potentials when a rearing environment includes elements that make children attentive to the basic ingredients of reading. For the children who did not suffer from perinatal adversities the intervention did not result in short- or long-term elevated levels of literacy skills.

In the dominant paradigm of developmental psychopathology the cumulative nature of risk factors has been emphasized, and the diverging developmental pathways of children with specific vulnerabilities in challenging environments (Cicchetti, 1993; Sameroff, 1983). Most of the developmental studies of the past few decades have focused on children at risk for deviant development because of a combination of child-related and environmental risk factors. The prevailing tunnel view on risks prevented developmental researchers from paying equal attention to the other side of the coin, optimal development in supportive environments. Differential susceptibility theory draws attention to the possibility that in a wider view on environmental risks *and* positive contexts child-related risk factors might turn out to create greater susceptibility to positive environments. Reactive or difficult temperament has been one of the differential susceptibility factors central

in the first wave of studies pioneered by Belsky et al. (1998). The potential role of dopamine-system related genes for differential susceptibility has been introduced by Bakermans-Kranenburg and Van IJzendoorn (2006) for social-emotional and by Kegel et al. (2011) for cognitive development. Physiological factors (i.e., biological reactivity) have been introduced by Boyce and his team (Boyce, et al., 1995).

From this latter, pediatric perspective Boyce and Ellis (2005) used the metaphor of ‘dandelions’ to indicate the large number of children who are genetically or prenatally programmed in a way that they would survive and function rather robust within almost any environment. The smaller number of ‘orchids’ however would wilt quickly in neglecting circumstances but bloom in a spectacular way when raised in the most optimal environment. What seems to be a risk factor in an average or bad environment, e.g. biological reactivity to stress or a reactive temperament, turns out to promote optimal development in a nurturing context. The ‘orchid hypothesis’ (Dobbs, 2009) misleadingly suggests two distinctive classes of individuals instead of a continuum of more or less susceptibility to the environment. The orchid metaphor however brings also effectively home the surprising message that seemingly maladaptive but evolutionary enduring traits might have an important adaptive role in specific niches as they contribute to the indispensable variation in the human species. This is the evolutionary view on differential susceptibility Belsky (1997, 2005) was the first to articulate.

Why would mild perinatal adversities be susceptibility factors instead of only risk factors? In general, susceptibility to context is associated with characteristics that enhance the individual’s ability to monitor the environment and to extract most effectively its reward value. In Suomi’s (1997) studies on rhesus monkeys anxious, timid offspring would become anxious adults when they were reared in a harsh parenting environment but they would flourish and climb the hierarchy of the troop when they were raised by sensitive mothers who allowed them to use their anxious monitoring of the environment to elevate their access to resources. In a study of temperament and maternal discipline in relation to externalizing problems in early childhood, Van Zeijl et al. (2007) found that children with reactive temperaments were more susceptible to both negative and positive discipline than children of relatively easy temperament. On basis of their longitudinal studies Kochanska, Aksan, and Joy (2007) proposed that the ease with which stress and anxiety is induced in reactive children helps them to respond most favorably to gentle parental discipline but at the same time to be most vulnerable to the negative effects of harsh parenting.

Mild perinatal adversities may be associated with elevated levels of stress in the expectant mothers (Pluess & Belsky, 2011). Although the number of studies on the association between maternal stress as indexed by HPA-axis functioning and mild perinatal adversities is relatively small and findings are equivocal, a recent

large prospective cohort study suggested that larger cortisol awakening responses (CAR) in early pregnancy may be related to lower birth weight and higher SGA risk (Goedhart, et al., 2010; Kivlighan, DiPietro, Costigan, & Laudenslager, 2008). Mild perinatal adversities may lead to higher cardiovascular and HPA-axis reactivity to context, which according to the pioneering study of Boyce and colleagues (1995) would make children more sensitive to context, for better and for worse.

Low birth weight babies showed increased cortisol concentrations in umbilical cord blood and raised urinary cortisol excretion in childhood (Economides, Nicolaidis, Linton, Perry, & Chard, 1988). In adult life they have higher pulse rates, an index of sympathetic activity, and increased fasting cortisol concentrations (Phillips et al., 1998; 2000). Studies showed an enhanced plasma cortisol response to synthetic adrenocorticotrophic hormone (Levitt, et al., 2000; Reynolds, et al., 2001). An increased stress response was observed in low birth weight children (Jones, et al., 2006; Wust, Entringer, Federenko, Schlotz, & Hellhammer, 2005). Because of their elevated stress reactivity children with mild perinatal adversities may easily shut themselves off for learning experiences in a less organized and rewarding environment, whereas they might be most eager to learn from exposure to relevant experiences and positive feedback in a supportive learning environment (Pluess & Belsky, 2011).

The *Living Letters* interactive computer program has been designed to reflect the interactions of sensitive parents guiding their preschoolers into the world of written language. Before formal reading instruction children already are curious to know how written words convey meaning, and how the visual form relates to the spoken counterpart of words. In particular their proper name is focus of this search that mostly starts at an early age far before reading instruction begins. Sensitive parents reinforce the discovery of alphabetic writing by encouraging interest in the proper name and other frequently used names and helping their children to combine their understanding of how the name looks with knowledge of how the name sounds. They are quick to recognize and reward successful attempts to name the first letter of the proper name and recognize the letter in other words.

The computer program *Living Letters* creates a similar type of sensitive and stimulating environment for the acquisition of early literacy skills. For example, as the proper name provides surface perceptual features that help children to discover relations between letters of the name and sounds in spoken counterparts the program uses the child's own name to initiate the same discovery process. Errors when solving the games are followed by increasingly supportive computerized oral feedback of an adaptive and constructive nature. The feedback carefully scaffolds the children's trials and errors in their search for answers to the challenges of the games by repeating the task, giving clues, and finally demonstrating a correct

solution. This is the optimal learning environment in which children with mild perinatal adversities seem to learn most effectively while children without perinatal adversities gain as much whether experiences with print are specific or nonspecific.

An important limitation of the current study is randomization to treatment and control group without stratification to mild perinatal adversities. Although we ascertained that the bias introduced by this lack of stratification was minimal as children with and without mild adversities were almost equally divided among treatment and control group, in future studies participants should also be randomized on the basis of the susceptibility factor –a limitation of all differential susceptibility experiments to date. Another limitation is the lack of information on the mechanism of susceptibility of children with mild perinatal adversities to the intervention. We speculated about the elevated stress reactivity of these children but HPA-axis or cardiovascular responses to stress were not assessed in the current study, and elevated stress reactivity remains a hypothesis to be tested in a future, more comprehensive trial. Lastly, we included only one potential marker of differential susceptibility, namely mild perinatal adversities in the current study although another study on a different sample but with the same *Living Letters* intervention program revealed a strong differential susceptibility effect for carriers of the 7 repeat dopamine D4 receptor gene (DRD4-7R, Kegel et al., in press). To examine the associations between various susceptibility markers (temperament, regulatory skills, dopamine-related genes, perinatal adversities) in future studies these markers should be included simultaneously.

Our finding of enhanced susceptibility of children with mild perinatal adversities to the environment has at least two important implications. First, children with mild perinatal adversities have traditionally been viewed as being at risk for delays in later (cognitive) development. The current study shows that they may have a high potential for learning in enriched environments. What seems to be a risk factor turns out to be a potential asset which deserves our special attention in creating adequate educational environments. Second, experiments demonstrate that interventions might have only weak to modest effects on children's health or development across the board (for examples, see Van der Kooy - Hofland, et al., 2011; Kegel, Van der Kooy-Hofland, & Bus, 2009; NELP, 2008). Effect sizes in this study for the main effect of the interaction disregarding the susceptibility factor, for instance, remained below half a standard deviation. Yet the intervention appeared to be strongly effective for the specific, susceptible sub-group, as indexed by mild perinatal adversities. Even long-term effects of the intervention amounted to more than one standard deviation on an aggregate reading skills assessment that was in no way directly targeted in the computer-based early intervention program. For the majority the gap after 8 months of reading instruction was already present at enrollment in grade 1. In evaluating

experimental interventions researchers should take differential effects of their manipulations into account as predicted by differential susceptibility theory (Ellis, et al., 2011). The age-old intervention question of what works for whom might be fruitfully addressed from the perspective of differential susceptibility theory.

In sum, we found that children who experienced mild perinatal adversities might be at risk for early reading problems but in an enriched environment they may reach a high level of early reading skills, an advantage that still exists after one year of formal reading instruction. This provides unique experimental support for differential susceptibility theory in the cognitive domain and illustrates the double-edged nature of mild perinatal adversities as a risk factor for academic skills as well as a potential asset.



# Chapter 5

## General discussion

Parts of the discussion were published in: Van der Kooy-Hofland, V.A.C., Kegel, C.A.T., & Bus, A.G. (2011). Evidence-based computer interventions targeting phonological awareness to prevent reading problems in at-risk young students (pp. 214-227). In S.B. Neuman & D.K. Dickinson (Eds.), *Handbook of early literacy research*, Volume 3. New York: The Guilford Press.



The main aims in testing the effects of a web-based computer program on literacy development were three-fold:

- 1) Testing whether the Web-based computer program Living Letters, meant to promote foundational alphabetic understanding in support of teacher-delivered literacy training in kindergarten, narrows early gaps in literacy skills.
- 2) Testing the long-term effects of the Web-based computer program Living Letters assuming that successful programs enable initially delayed children to benefit from reading instruction in the first years of formal instruction and to narrow lags with the mainstream group.
- 3) Testing the hypothesis that some individuals are more susceptible than others to both the control (increasing delay) and treatment (learning-enhancing) conditions.

### **Effects of a web-based computer intervention**

The target program, Living Letters, is only meaningful for children who not yet understand that letters relate to sounds (alphabetic principle). Therefore, senior kindergarten children were screened at year entry with a test battery that consisted of assessments of writing (the proper name, 'mama,' and four other words) and letter knowledge (Van der Kooy-Hofland, Bus, & Roskos, in press). The experiment was carried out in fifteen primary schools in a western province of the Netherlands. Of a total of 404 pupils in the senior kindergarten year, 135 were eligible for the computer treatment. However, the percentage of eligible children per classroom varied from 19.1% to 54.8% with the highest percentages in classrooms in rural areas with mainly low-educated parents.

With a randomized pre-posttest-experiment it was tested whether alphabetic skills catch up as a result of exposure to the computer intervention. All eligible children played computer games 'teacher-free', i.e., without support from a teacher, peer, or other adult. Given that the program could be completed in 2½ to 3 hours, computer activities did not interfere with participation in the regular curriculum, which mainly includes teacher-guided instruction in rhyming and identifying sounds in names and other words during circle time for about 15 minutes per day in the Netherlands. To prevent research falling prey to the difficulty of valid comparison groups, the same number of eligible children was assigned per classroom to the control as to the experimental groups. We compared children from the Living Letters group with a group from the same classroom exposed to another computer program that stimulates other literacy-related skills. The program in the comparison group incorporated as key elements vocabulary learning and story comprehension. As the latter program, Living Books, does not

include written words or letters, the group exposed to Living Letters was expected to show advantages in early literacy skills over the group merely exposed to Living Books. Children were compared on such skills as identifying sounds in spoken words, creating invented spellings, and susceptibility for training in decoding. The two programs shared the same structure and were designed to run over a 15-week period, once a week for 10-15 minutes.

The present intervention is unique because young children were exposed to treatment without any direct adult support. Children sat alone at the computer screen in their classroom or the computer room, with a headset on. Researchers logged children in on the web site and made sure they completed all sessions, thereby guaranteeing that the program was used with high fidelity across all classrooms and that there was no variation in amount of time spent using the target software among students. When the system had identified the child who was logged in, the correct game appeared and the system discontinued the session automatically after four games. One area of investigation was whether children would make progress in skills that actually go beyond what is practiced by Living Letters (recognition of the proper name, naming the first letter of the proper name or identifying the sound of the first letter in spoken words). The expectation was that children can benefit more from their literate environment and teacher-delivered training in kindergarten when they have practiced with Living Letters and have developed a basic alphabetic understanding.

*Effects in support of the kindergarten curriculum.* This dissertation shows that a relatively short computer-based intervention can boost the ability to identify sounds in words (phonological skills), produce invented spellings, and make children more susceptible to instruction in decoding. After controlling for parent education, gender, age, and prior scores, the Living Letters group outperformed children from the same classrooms who scored equally low on the screening tests but were exposed to Living Books. A mean gain of 0.5 *sd* on the early literacy skills means that the group that scored among the 30% lowest scoring children at the start of the intervention would score just below the mean of a large sample from the same classes on literacy skills after being exposed to Living Letters. Though children have practiced their name, the first letter of their name and phonemic sensitivity to the first letter of the name, the benefits of the program accrued in a broader set of sounds. Compared to the Living Books group, the children in the Living Letters group appeared to better understand how reading works and how letters and sounds work in words. They also made better early attempts at reading real words. Once primed to the idea of phoneme-grapheme associations, children might become more susceptible to experiences with sounds and letters and benefit more from practicing with other sounds at school or in daily life. Because all dependent measures assessed skills beyond skills practiced in the program, the program apparently worked as a catalyst in early literacy development. Other

researchers have also reported significant and comparable gains on phonological processing tasks as a result of a computer program standing in for teacher-delivered instruction (e.g., Segers & Verhoeven, 2005; van Daal & Reitsma, 2000), however rarely as remedial program in a group of children who lag far behind (Macuruso & Walker, 2008).

*Fidelity.* One of the formidable advantages of a computerized environment for research is that treatment fidelity can be directly derived from computer registration logs (Battro, 2010). We had logged child responses to computer assignments to check whether children completed the assignments and to which extent they were successful. If children are less successful in completing the computer assignments they may not benefit to the same extent as children who are rather successful in completing the program. Our findings were in support of this hypothesis: When children made many errors, the program did not advance children's literacy skills.

*Executive functions.* Further research is required to explain why children made errors and whether the program can be improved in a way that all children benefit from the treatment. One reason for making errors may be that poor literacy skills cause random responses. Another explanation may be that the program insufficiently corrects children's regulatory skills that lay the foundation for errors while solving the computer tasks. The results refute the first hypothesis: After controlling for pre-tested phoneme skills the relation between computer behavior and errors still exists. There is, however, some direct evidence for the second explanation (Kegel, Van der Kooy-Hofland, & Bus, 2009): The group scoring lowest on regulatory skills made more mistakes. It seemed that the feedback loops built into Living Letters (e.g., providing cues to find the correct answer) were insufficient to counterbalance problems in planning and choosing the right steps. Given that the children with poor regulatory skills did not benefit from the intervention, there clearly is a need to further individualize games by adapting content (e.g., more games practicing the same) and providing appropriate feedback (e.g., after one or more errors starting each new task with a reminder of relevant steps).

### **Capacity to benefit from formal reading instruction.**

A main ground for early interventions is that as children's academic ability lags behind early in life, their capacity to benefit from reading instruction in later years falls short of the average group. The lags may increase rather than narrow down (Raudenbush, 2009). Hence, it is most important to test whether a computer intervention that is in support of the regular kindergarten curriculum plays a role in reading achievements in the first years of primary education. At best, intervention children run less risk to finding themselves in a downward spiral of

failing to comprehend instruction and complete assignments in school, leading to weaker achievements and increasing problems in completing assignments. There is, for instance, research demonstrating that children who can identify letter sounds or phonemes in spoken words, have a better starting position for learning to decode in first and second grade (Bus & van IJzendoorn, 1999; Ehri et al., 2001). According to this model, early interventions in preschool-age children should still be manifest in reading achievement at the end of grade two, when the stage of beginning reading instruction is complete and average Dutch pupils are assumed to read simple words fairly fluently.

Alternatively, a compensatory trajectory of development predicts that achievement gaps may narrow in first grade even without early interventions (Leppänen, Niemi, Aunola, & Nurmi, 2004). When letter-sound knowledge is rather transparent as in Dutch slow starters may easily catch up as a result of formal reading instruction that emphasizes the acquisition of code-related skills (Share, 2008). Furthermore, the development of initially precocious children may level off. Learning processes beyond basic reading skills require substantially more practice than is needed for the acquisition of basic skills, leading to a narrowing of individual differences in reading trajectories. After all, gaining reading fluency is a very time-consuming process.

*Effects in the long-term.* Even though both initially delayed groups show gains in word reading fluency in grade 1 and 2, the control group showed up unfavorably in comparison with the treatment group. When initially low-performing children had a chance to catch up in kindergarten- i.e., they participated in Living Letters- they made significantly more progress throughout the first two years of formal reading instruction than low-performing children without such a chance. The effect was most pronounced for pseudo-word reading probably because the intervention targeted code-related skills. In short, adaptive early computerized interventions can reduce the risk of a delayed reading performance in a transparent language such as Dutch. Since children in both groups were from the same classrooms and therefore, without doubt, received similar instruction in reading, exposure to Living Letters in kindergarten was the only stable difference. Taken together, the present outcomes strongly indicate that an early computer intervention simulating elements of early literacy training in literate homes reduces the risk of students entering first grade with poor literacy skills developing reading problems.

*Matthew effects.* The differences between the treatment and control group harmonize best with the so-called *cumulative model* (Leppänen et al., 2004). The control children encountered problems with benefiting from the early learn-to-read process as a result of less well-developed early literacy skills, consequently they read less in later stages, and without practice are more at risk of developing reading problems, as is demonstrated in this dissertation. In his classic article, Stanovich (1986) referred to this phenomenon as the Matthew effects, which posits

that early developmental differences in literacy ability are often maintained and may even be magnified over time as development proceeds and no interventions are carried out to compensate for achievement gaps. The findings suggest that children with delays in code-related skills at school entry fail cognitive multipliers for intensive practice of word reading. They need more time to acquire letter-sound connections and decoding skills than children without delays. Due to additional computer training in support of the kindergarten curriculum, however, children can catch up and benefit more from instruction in kindergarten and later years. The intervention group's gains in word reading fluency were similar to those of the mainstreamers (children without delay in kindergarten age) throughout grade 1 and 2 while the control group increasingly lagged behind.

*Computer behavior as predictor of progress over a two-year period.* The moderately high correlations between the number of errors in the computer tasks in kindergarten and the development of (pseudo-)word reading fluency throughout grade 1 and 2 indicates that long-term benefits were stronger when students succeeded in completing computer assignments. This finding corroborates the hypothesis that the additional program in kindergarten explains the long-term effects and not some side effect in later years.

## **Heterogeneous program effects across participants**

Although it is well established that early literacy interventions can reduce the risk for developing academic problems in later years (Bus & Van IJzendoorn, 1999; Ehri et al., 2001; NRP, 2000; NELP, 2008), there is striking variation in outcomes of experiments (e.g., Al Otaiba & Fuchs, 2002). In psychopathology, it has become increasingly clear that individuals with different characteristics vary not only in whether and how much they are negatively affected, but also in the extent to which they are positively influenced by environmental resources and support (Ellis, Boyce, Belsky, Bakermans-Kranenburg, & van IJzendoorn, 2011).

In recent years a few researchers have challenged the traditional view that high reactivity, whether measured at the emotional, behavioral, or biological level, does not invariably lead to maladaptation. That is, characteristics that make children vulnerable to adversity sometimes also make them likely to benefit from contextual support (Belsky, 1997; Belsky, Bakermans-Kranenburg, & van IJzendoorn, 2007). The research in this dissertation, showed a parallel result for academic learning when focusing on children who are late preterm or small for gestational age. It is well-established in the literature that these children may benefit less from instruction and develop problems in the academic skills domain in general (Chyi, Lee, Hintz, Gould, & Sutcliffe, 2008; Nomura, et al., 2009; Van Baar, Vermaas, Knots, de Kleine, & Soons, 2009) and reading problems in particular (Kirkegaard,

Obel, Hedegaard, & Henriksen, 2006; Chyi et al., 2008; Lee, Yeatman, Luna, & Feldman, 2010).

In the group with mild perinatal adversities, intervention children outperformed the control group immediately after the intervention and after eight months of formal reading instruction, while in the group without perinatal adversities the intervention did not result in short or long term elevated levels of literacy skills. The current findings thus confirm that children with mild perinatal adversities are vulnerable to develop persistent delays in literacy skills. However, there is also evidence that these children seem to thrive and are quick in acquiring high levels of elementary literacy skills at school entry when they are exposed to an enriched, computer-based literacy environment in kindergarten. This susceptible group is also likely to experience sustained change in reading skills, as appears from their reading fluency scores in first grade, and not just transient fluctuations in functioning directly after Living Letters.

Which learning processes mediate the interaction between perinatal adversities and treatment has not yet been studied. One possibility is that, due to elevated stress reactivity, children with mild perinatal adversities may easily shut themselves off for learning experiences in a less organized and rewarding environment, whereas they might be more eager to learn from exposure to relevant experiences and positive feedback in a supportive learning environment (Blair, 2002; Pluess & Belsky, 2011). Findings seem to illustrate that biological reactivity to stress which is a risk factor in an average environment turns out to promote optimal development in a more positive context that is highly structured and provides feedback (Obradović, Bush, Stamperdahl, Adler, & Boyce, 2010). Therefore high reactivity may not merely be a pathogenic, risk-amplifying response to adversity but it can also promote adaptive functioning.

Our finding of enhanced susceptibility of children with mild perinatal adversities to the environment has at least the following important implications:

1. Features of Living Letters (systematic, personalized, adaptive, positive feedback) proved to be effective in a sub-sample with mild perinatal adversities. Apparently, for these children such an intervention was essential to narrow gaps in early literacy skills.
2. The finding that Living Letters caused long-term effects means that more susceptible individuals with perinatal adversities are likely to experience sustained developmental change as a result of exposure to treatment and not just transient fluctuations in functioning in response to environmental exposures.
3. Children with mild perinatal adversities have traditionally been seen as at risk for delays in later (cognitive) development, whereas they may have a high potential for learning in optimal environments. What was considered as a risk factor turned out to be a potential asset.



4. The current findings show that interventions may have only weak to modest effects on children's learning across the board; overall effect sizes in this study remained below half a standard deviation. However, the intervention appeared to be strongly effective for the more susceptible sub-sample characterized by mild perinatal adversities. Even long-term effects of the intervention amounted to more than one standard deviation on reading skills that were in no way directly targeted in the computer-based early intervention program.
5. The differential susceptibility perspective makes clear that the average effect of an intervention across all participants is not a valid index of the effectiveness of an intervention. To estimate the importance of a program it should be taken into account that some pupils are more susceptible to instruction, in a "for better and for worse manner".

### **Future directions and limitations**

*Value of early interventions.* The present studies support the opinion that there is a need for interventions that simulate the content of early literacy training in literate homes, and demonstrate that without early intervention, more pupils lack the capacity to benefit from beginning reading instruction in the first two grades (Raudenbush, 2009). Put differently, the step into conventional reading appears to be seriously impeded when children are not exposed to the kinds of early educational experiences found in literate homes. Timing of interventions may be important as well: Children who are unable to utilize new educational experiences in class because instruction tunes in to the mainstream group may benefit most from an additional training. In the long run, preemptive measures in kindergarten may prove more effective and less expensive than remediation in the future (Stanovich, 1986). The economist Heckman demonstrated in his 2006 paper that the financial return from an early literacy intervention may be much higher than the return from compensation later in a child's school career.

*Differential susceptibility.* Findings demonstrate that an average effect across all participants is not a valid index of Living Letters' effectiveness. Since intervention effects have not appeared to be homogeneous across all participants eligible for the intervention. Only a sub-sample characterized by perinatal adversities (about 20%) benefited from the treatment while the group without perinatal adversities did not benefit. A prior study demonstrated differential susceptibility in a sub-sample with specific genetic characteristics (Kegel et al., 2011). How perinatal characteristics are related to other genetic and behavioral characteristics may be a main theme in future research.

An obvious practical implication of the current finding - especially children with perinatal adversities benefited from the Living Letters - may be screening of

pupils in search of an optimal fit between computer intervention and individual. Increasing knowledge of factors that determine susceptibility for instruction may provide concrete guidance in identifying (a priori) subsets of pupils that benefit most from interventions such as Living Letters. It is an important area for future investigation to further specify behavioral characteristics of children who need intensive, closely monitored and individualized practice as in Living Letters. However, as long as realistic estimates of the effectiveness of preventive or curative programs cannot be made by practitioners, it seems prudent to address code-related knowledge of all kindergarten children who are delayed in these skills. Some children learn as much when they are exposed to the regular curriculum without any additional treatment in support of profiting from the regular curriculum. Given the promising outcome that a sub-sample's capability to benefit from formal reading instruction increases with about one standard deviation due to the additional program, it seems important to present Living Letters to all eligible five-year-olds.

*Promise of Web-based interventions.* Our speculations about Web-based interventions in support of classroom instruction are constrained by the limitations of our data. However, several features of Living Letters are common to other Web-based computer treatments; thus, we cautiously speculate on what our findings might have to say about using this kind of program for literacy instruction to young children who start school with less well-developed literacy skills. There is evidence that Web-based programs support the development of early literacy skills even though no evidence supports the claim that such programs are superior to teacher's using what have been deemed "best practices" in literacy instruction (Vernadakis, Avgerinos, Tsitskari, & Zachopoulou, 2005). Not only one-to-one interaction and the ability to use the program in support of the broader classroom curriculum, but especially tailoring the activities to children's interest and knowledge may be one of the crucial ingredients of Web-based programs, which implies that we would raise the effects of computer interventions above those of regular classroom instruction or stand-alone computer programs. Living Letters, for instance, uses the child's name and the first letter of the proper name to draw attention to letter- sound relations in spoken words. Follow-up research (Kegel & Bus, under review) demonstrated the importance of tutoring by providing cues and feedback.

In the Netherlands, and probably also in the rest of the world, there is a lack of promising Web-based programs that can help compensating for children from homes with sparse early literacy experiences. Dutch publishers are not keen on investing in platforms with evidence-based Internet programs for the youngest; they know that maintenance and overhauling are expensive. Having a sufficient number of schools subscribe to Internet sites with educational programs such as Living Letters might cover the costs, but as long as computer programs are

not part of daily routines in classrooms, schools adopt a reserved attitude, and earnings and costs are unbalanced. And in so far programs are free, schools may not succeed to find those on the Internet and / or not use them in appropriate ways.

*Computer behavior as predictor of learning.* Computer programs also become a valuable teaching aid. Our findings also suggest that Web-based programs can be used as diagnostic tools to detect poor problem solving skills that are barriers to learning about literacy. Registration of computer behavior, such as the time it takes children to solve the problems, random clicking and unnecessary mouse movements, and number of errors, seems to provide a valid tool for identifying children at risk for long-term reading difficulties (Vellutino, Scanlon, Zhang, & Schatschneider, 2008). Considering that computer behavior relates not only to academic skills but also to tests of regulatory skills, this finding supports the hypothesis that academic skills may not provide a complete picture of children's preparedness to meet the demands of the classroom. Computer behavior may predict later achievements because school success also depends on regulatory skills. Research in progress further explores this theory, as well as feedback loops that can be added to Web-based programs to improve young children's learning competence.

*Design and implementation of Web portals in classrooms.* It should be mentioned that availability of programs in classrooms does not guarantee that they are beneficial to pupils who need help. During the past year, we analyzed how often teachers logged in on the Web portal when their schools had a subscription to Living Letters. Teachers in only a small proportion of the approximately 150 schools used the program weekly. In a study in progress, teachers of 15 schools were asked to put particular pupils in their classroom to work with Living Letters once a week (Kegel, unpublished data). The program was rarely used the way it was meant to be used. Automatic registrations of log-in data revealed that pupils in some classrooms did not access the program for weeks, while on rare days it was continuously in use. Such observations indicate that we cannot take for granted that teachers are successful in integrating Living Letters into a broader curriculum of literacy instruction. As the availability of computer programs improves and the number of optional activities further increases, teachers may not realize which children in particular can benefit from regular access to a Web portal.

It may be helpful to incorporate algorithms in the Web portal to guide teacher decisions about children who need the programs (McDonald, Morrison, Fishman, Schatschneider, & Underwood, 2007). The computer program may provide recommendations, updated monthly, regarding the pupils for whom the programs should be invoked. Standardized test scores may be used to decide which pupils are most eligible for exposure to the program. Conditional upon the number of errors made while playing the games, tasks can be skipped or repeated. With the help of

built-in algorithms, fine-tuning of feedback to children may make the program even more effective. For instance, more reflective children may need different feedback than do children who mostly respond immediately, without taking any time for reflection between assignment and response. Further exploration of possible risk and protective factors is indispensable for the development of effective early literacy intervention programs. To teach all students to read means to meet each student's unique needs (Coyne, Kame'enui, & Simmons, 2004).

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**Samenvatting**

*Summary in Dutch*



De meeste jonge kinderen weten voor de start van formele leesinstructie dat letters verwijzen naar klanken in (gesproken) woorden. Zonder deze ontluikende alfabetische kennis lopen ze een groter risico op leesproblemen. Om te voorkomen dat kinderen met een achterstand de leesinstructie starten, is het remediërende computerprogramma *Letters in Beweging* ontwikkeld. Dit programma, gefinancierd door de Stichting Edict, heeft tot doel peuters en kleuters te laten ontdekken dat bekende woorden zoals de eigen naam uit letterklanken zijn opgebouwd. Het programma dat beschikbaar is via de Bereslim-website ([www.Bereslim.nl](http://www.Bereslim.nl)), is gemodelleerd naar de spontane activiteiten van kinderen die in een geletterde omgeving opgroeien. Naar analogie van wat er in de thuisomgeving gebeurt, begint het programma met de eigen naam omdat die in het dagelijks leven de eerste aanzet is tot alfabetische kennis en foneembewustzijn. In een longitudinaal onderzoek is de effectiviteit van *Letters in Beweging* getest in een groep vijfjarige kleuters met achterstanden in vroege alfabetische kennis.

Dit proefschrift zoekt in het bijzonder antwoord op de volgende drie vragen: (1) Draagt *Letters in Beweging* eraan bij dat kleuters beter presteren op voorlopers van lezen? (2) Zorgt een vroege interventie als *Letters in Beweging* ervoor dat kinderen minder problemen ervaren in het beginnend leesonderwijs? (3) Wie profiteren in het bijzonder van het programma?

## **Letters in Beweging**

Een belangrijke stimulans voor de vroege leesontwikkeling is het lezen en schrijven van de eigen naam, 'mama' en 'papa' of de naam van een vriendje of huisdier. *Letters in Beweging* bestaat uit een serie adaptieve spellen die gemodelleerd zijn naar vroege activiteiten in een geletterde omgeving waarvan gebleken is dat ze voor jonge kinderen een stimulans vormen om aandacht te besteden aan geschreven taal als object van onderzoek. Het programma oefent achtereenvolgens: (1) herkennen van de eigen naam in geschreven vorm, (2) associëren van de beginletter van de naam met de bijbehorende klank en (3) identificeren van de klank van de beginletter in andere woorden. Een niet bedreigend computermaatje - een teddybeer - bootst na hoe volwassenen reageren op pogingen van jonge kinderen om de computertaken op te lossen en bevestigt of corrigeert al hun reacties.

In hoofdstuk 2 wordt verslag gedaan van een gerandomiseerd experiment met 110 oudste kleuters. De op basis van een screening geselecteerde groep beschikt nog niet over de ontluikende alfabetische kennis die *Letters in Beweging* oefent. De studie toont aan dat de interventiegroep, in vergelijking met de controlegroep die even lang met een voorleesprogramma op de computer heeft geoefend, direct na afronding van het computerprogramma niet alleen beter presteert op alfabetische taken maar ook meer profiteert van instructie in decoderen. Het combineren van

de letters en klanken in de eigen naam lijkt als een katalysator te werken: het zet jonge kinderen op het spoor van klank - teken koppelingen in geschreven taal. Door met behulp van een computerprogramma te oefenen wat in de meeste geletterde gezinnen van jongs af aan spontaan gebeurt, profiteren kinderen meer van het curriculum in de kleuterklas en leren ze om ook andere klanken dan de eerste letter van de naam in woorden te identificeren. De voorsprong van de interventiegroep direct na afloop van de interventie blijft ook op lange termijn gehandhaafd. Eind groep 4 zijn de leesprestaties in de interventiegroep nog steeds significant hoger dan in de controlegroep.

Niet alle kinderen profiteren in gelijke mate van het computerprogramma. De negatieve correlatie tussen het aantal fouten in computertaken enerzijds en scores op beginnende leesvaardigheden en conventioneel lezen anderzijds kan betekenen dat kinderen minder profijt hebben van het programma. De computerspellen lijken nog te moeilijk zoals het betrekkelijk hoge aantal fouten suggereert. Het is ook mogelijk dat kinderen veel fouten maken vanwege de manier waarop ze de computertaken benaderen: omdat ze geneigd zijn te reageren zonder eerst na te denken, profiteren ze nauwelijks van de opdrachten. Om een verband tussen geringe effecten en zwakke executieve functies aan te tonen zou het experiment gerepliceerd moeten worden in groepen die vooraf als zwak of sterk in executieve functies zijn geïdentificeerd.

### **Preventie van Mattheus-effect**

In hoofdstuk 3 is getest in hoeverre Letters in Beweging van invloed is op de leesontwikkeling van kinderen in groep 3 en 4. Een eerste doel was te testen hoe een groep kinderen zich verder ontwikkelt als ze ondanks een grote achterstand in groep 2 geen interventie krijgen. Wordt de achterstand in de eerste twee leerjaren alleen maar groter zoals voorstanders van vroege interventies veronderstellen? Een tweede doel was te testen hoe kinderen zich verder ontwikkelden als ze het programma Letters in Beweging wel hebben gehad: Vallen ze na een aanvankelijke inhaalslag weer terug en presteren ze in groep 3 en 4 op het zelfde niveau als de aanvankelijke achterblijvers? Of zijn de leesvorderingen in groep 3 en 4 vergelijkbaar met de groep kinderen die bij aanvang van het onderzoek geen vroege achterstanden laat zien?

In de groep kinderen met vroege achterstanden laten zowel interventie- als controlegroep vooruitgang zien, maar de interventiegroep boekt snellere leesvorderingen dan de controlegroep. Dit effect is het duidelijkst bij de pseudowoorden. Kennelijk biedt het remediërende programma Letters in Beweging kinderen kans om meer te profiteren van formele leesinstructie. De interventiegroep ontwikkelt zich immers op dezelfde wijze als de groep kinderen

die bij aanvang van de studie niet achterloopt. De controlegroep die geen kans heeft gehad om beginnende leesvaardigheden te verbeteren, illustreert het 'Mattheus-effect': laag ontwikkelde alfabetische kennis aan het begin van leesinstructie resulteert erin dat kinderen minder profiteren van instructie in groep 3 en 4 en in vergelijking tot de kinderen die het interventieprogramma krijgen of kinderen die dat niet nodig hebben, verder terugvallen in leesprestaties. De vroege interventie maakt het blijkbaar mogelijk kleuters beter voor te bereiden op het leren lezen en zo een neerwaartse spiraal te doorbreken.

### **Differentiële gevoeligheid**

Uit diverse onderzoeken met kinderen die verschillen in temperament, blijkt dat de omgeving niet op alle kinderen in dezelfde mate invloed heeft. Kinderen met een negatief temperament hebben bijvoorbeeld meer te lijden onder een negatieve gezinsomgeving maar profiteren meer van een positieve omgeving. Of differentiële gevoeligheid - i.e., sommige kinderen zijn gevoeliger voor zowel een positieve als negatieve omgeving - eveneens optreedt in het cognitieve domein is getoetst door de effecten van Letters in Beweging te onderzoeken in een groep premature en dismature kinderen waarvan bekend is dat ze overgevoelig zijn voor stressvolle situaties. Voor veel kinderen biedt de dagelijkse omgeving voldoende prikkels om alfabetische kennis te exploreren en basisvaardigheden te ontwikkelen zonder enige systematische training. Dit zou in mindere mate het geval kunnen zijn bij kinderen die overgevoelig zijn voor een stressvolle omgeving waardoor ze onvoldoende profiteren van kansen om beginnende leesvaardigheden te oefenen en vaak lange tijd blijven onderpresteren. Een dergelijke groep kinderen zou, zo is beargumenteerd, afhankelijker kunnen zijn van een programma dat continue steun en feedback biedt en zo compenseert voor hun leerproblemen.

Om deze hypothese te toetsen is binnen de groep kinderen met vroege achterstanden een subgroep getraceerd met perinatale problemen. We vergeleken de effecten van Letters in Beweging in deze groep met die in een groep zonder perinatale problemen. Bij perinatale problemen kan sprake zijn van een 'late' vroeggeboorte (prematuur, geboren tussen de 34<sup>ste</sup> week en 37<sup>ste</sup> + 6 dagen) of van dismaturiteit (kinderen geboren vanaf 38 weken met een te laag geboortegewicht). Van deze premature en dismature kinderen is bekend dat zij meer kans hebben op specifieke leerproblemen, ook als zij een gemiddeld intelligentieniveau hebben. Perinatale problemen worden in verband gebracht met prenatale stress in de baarmoeder die kan leiden tot verhoogde postnatale stressreacties van kinderen op de omgeving. Als kinderen bijvoorbeeld om stress te omzeilen minder geneigd zijn het schrijven van hun naam te oefenen en daardoor minder instructie bij volwassenen uitlokken, zouden ze afhankelijker kunnen worden van een

programma dat niet alleen oefening in alfabetische basiskennis biedt maar dat ook hun aandacht stuurt en voortdurende persoonlijke, adaptieve feedback geeft. Kinderen met een spontane interesse in naamschrijven en daaraan gerelateerde activiteiten leren echter evenveel zonder programma en wellicht wordt een systematische training daardoor als minder stimulerend ervaren in deze groep leerlingen.

Uit de studie in hoofdstuk 4 blijkt dat de kinderen met perinatale problemen het meest profiteren van de interventie. Deze risicogroep blijkt met het programma veel betere prestaties te leveren dan de 'normale' groep. Ook laat de studie zien dat deze effecten niet tijdelijk zijn maar ook op lange termijn aantoonbaar blijven. Wellicht duidt dit verrassende resultaat erop dat het effect van Letters in Beweging niet zozeer afhangt van de extra oefening en instructie maar vooral van de wijze waarop het programma het leerproces ondersteunt. Als de computertaken de door kinderen ervaren stress bij het uitvoeren van taken verminderen, verdwijnt de belangrijkste oorzaak van onderpresteren en kunnen hun verborgen leermogelijkheden optimaal tot hun recht komen. Verder onderzoek moet verhelderen of en hoe Letters in Beweging het leergedrag van de risicokinderen beïnvloedt. Ook de niet-risicogroep gaat het alfabetisch principe steeds beter begrijpen maar hun vorderingen zijn veel geleidelijker en de continue feedback en hulp van het interventieprogramma resulteert niet in een versnelling van het leerproces zoals wel het geval is in de groep met perinatale problemen.

## Conclusies

In dit proefschrift is aangetoond dat een kort maar doelgericht computerprogramma in de kleuterleeftijd een nuttig hulpmiddel kan zijn bij de preventie van leesproblemen. Hoewel geen vergelijking is gemaakt met andersoortige interventies lijkt een adaptief computerprogramma een geschikt middel te zijn in een schoolomgeving waar individuele supervisie schaars is. Een korte intensieve behandeling in de tweede helft van groep 2 blijkt niet alleen effect te hebben op metingen direct na afloop van het programma maar draagt er ook aan bij dat kinderen meer profijt hebben van formele leesinstructie in groep 3 en 4. Niet alle achterblijvers profiteren echter van de interventie. In een kwetsbare subgroep blijken effectgroottes veel sterker te zijn dan in de totale groep achterblijvers, waar effectgroottes niet hoger zijn dan een halve standaarddeviatie. Vooralsnog lijkt de belangrijkste verklaring voor de sterk variabele effectgroottes dat programma's zoals Letters in Beweging vooral geschikt zijn voor jonge kinderen die door prenatale gebeurtenissen overgevoelig zijn voor stress en zich onder minder optimale condities aan leerervaringen proberen te onttrekken met als gevolg dat ze onderpresteren. Onderzoek naar fysiologische reacties tijdens het uitvoeren van



de computerspellen (bijv. hartslag, huidweerstand en concentratie van cortisol) moet hierover opheldering bieden. Uit verder onderzoek moet bovendien blijken of de bevindingen zoals in dit proefschrift gerapporteerd, generaliseerbaar zijn naar andere leeftijden en leerdomeinen en welke consequenties de bevindingen hebben voor de manier waarop remediërende programma's opgezet moeten worden. Vaststaat dat de effecten van programma's zoals Letters in Beweging bij kinderen met perinatale problemen en wellicht andere kwetsbare subgroepen veel sterker zijn dan de doorgaans matige effecten in de totale groep suggereren.



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# Curriculum Vitae





Verna A.C. van der Kooy – Hofland was born on March 15, 1959 in Rotterdam, the Netherlands. In 1976 she completed her secondary education at the Christelijk Lyceum Delft. After graduation from Teachers' Training College for Primary Education in Rotterdam, she worked as a teacher in primary education from 1979 to 1993 in Delft. In 1996 she received her M.A. degree in Education and Child Studies at Leiden University. From 1996 to 2002 she worked as staff developer and school psychologist at an Education Advisory Service (OnderwijsAdvies, Delft). From 2002 she worked as a lecturer in Education and Child Studies at Leiden University while (since 2005) completing her PhD research on the effects of an early literacy program.



## **List of Publications**



- Van der Kooy-Hofland, V. A. C., Van der Kooy, J., Bus A. G., Van IJzendoorn, M. H., & Bonsel, G. J., (submitted). Differential susceptibility to early literacy intervention in children with mild perinatal adversities: Short and long-term effects of a randomized control trial.
- Van der Kooy-Hofland, V. A. C., & Bus A. G. (submitted). Long-term effects of a computer intervention to narrow the code-related knowledge gap in young children.
- Van der Kooy-Hofland, V. A. C., Bus A. G., & Roskos K. (in press). Effects of a brief but intensive remedial computer intervention in a sub-sample of kindergartners with early literacy delays. *Reading and Writing*.
- Bus, A.G., Kegel, C.A.T. & Van der Kooy-Hofland, V.A.C. (2011). Interactief leesonderwijs voor kleuters. In: P. de Jong & H. Koomen (Eds.), *Interventie bij onderwijsleerproblemen*. Antwerpen – Apeldoorn: Garant.
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