Nina L. Saine

On the Rocky Road of Reading

Effects of Computer-assisted Reading Intervention for At-risk Children

JYVÄSKYLÄ LONGITUDINAL STUDY OF DYSLEXIA

JYVÄSKYLÄ STUDIES IN EDUCATION, PSYCHOLOGY AND SOCIAL RESEARCH 400

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UNIVERSITY OF JYVÄSKYLÄ

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ABSTRACT

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The study focused on the reading development of at-risk children and their non-at-risk peers (N = 166) in a longitudinal setting chosen intentionally to represent the natural learning environment of children in Finland. The lowest achieving 30% of children in school entrance examinations were randomly assigned into one of two intervention groups, a regular (RRI; n = 25) and a computer-assisted phonics-based remedial reading intervention (CARRI; n = 25), or into mainstream instruction (n = 116). The reading and spelling achievements of these children were followed from school entry to Grade 3. Further, three predictors, letter knowledge, phonological awareness and rapid automatized naming (RAN), were used to predict the future reading performance of these children.

The interventions comprised 4 x 45-min sessions per week over 28 weeks. The only difference between the intervention groups was the training used during first 15 min of each remedial session: the CARRI group used computer-assisted instruction while the RRI group used regular remedial methods to train letter-sound-connections and phonological awareness. Otherwise the reading program was identical between the RRI and CARRI groups.

The aims were, first, to investigate whether a computer application designed for remedial reading training can enhance letter knowledge, reading accuracy, fluency and spelling in at-risk children and their peers, and, second to predict the intervention outcomes for three contrastive reading groups.

In letter knowledge, reading accuracy, fluency and spelling the CARRI group reached the level of the mainstreamers. Most importantly, the children in the CARRI group made gains during the study and continued to progress on equality with the mainstreamers in the post-intervention follow-ups at 12 and 16 months, indicating both short- and long-term intervention effects in primary literacy skills. Similar progress was not seen in the RRI group.

Pseudo individual analyzes were used, in order to find out how different deficit combinations in pre-reading skills influence later reading abilities. The computer-assisted intervention indisputably yielded the best results independent of the initial level of one or more deficits in the three core pre-reading skills: letter knowledge, phonological awareness and RAN.

Keywords: remedial reading intervention, computer-assisted, letter knowledge, phonological awareness, rapid automatized naming, random assignment

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Asko; he has given me an opportunity to benefit from his considerable expertise in the area of statistical analyses. No matter whether a day or two before Christmas or on a hot summer day, tirelessly, and with boundless enthusiasm Asko has tutored me in the wonders of statistics.

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Jyväskylä, April 2010 Nina L. Saine

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II Saine, N.L., Lerkkanen, M.-K., Ahonen, T., Tolvanen, A., & Lyytinen, H. (submitted). Long-term intervention effects for children with different profiles of compromised pre-reading skills.

III Saine, N.L., Lerkkanen, M.-K., Ahonen, T., Tolvanen, A., & Lyytinen, H. (2010). Predicting word-level reading fluency outcomes in three contrastive groups: regular and computer-assisted remedial reading intervention, and mainstream instruction. *Learning and Individual Differences,* 2010, 20, 404-414.

ABBREVIATIONS

ALLU	Ala-asteen Lukutesti *[ALLU – Graded Comprehensive School Reading Test]*
ARMI	Luku- ja kirjoitustaidon arviointimateriaali 1. luokalle *[ARMI – Materials for evaluating reading and writing skills in Grade 1]*
ARMI 2	Luku- ja kirjoitustaidon arviointimateriaali 2. luokalle *[ARMI 2– Materials for evaluating reading and writing skills in Grade 1]*
C	Consonant
CAI	Computer-assisted instruction/intervention
CARRI	Computer-assisted remedial reading intervention
CV	Consonant-vocal
CVV	Consonant-vocal-vocal
D	Decoding
IQ	Intelligence quotient
JLD	The Jyväskylä Longitudinal Study of Dyslexia
LC	Listening comprehension
LD	Learning disability
MA	Master of Arts
RAN	Rapid automatized naming
RC	Reading comprehension
RD	Reading disability
RRI	Remedial reading intervention
RTI	Response to intervention
V	Vocal
VC	Vocal-consonant
WISC-III	Wechsler Intelligence Scale for Children-III

1 INTRODUCTION

Literacy skills, that is, reading and spelling are essential cross-cultural skills. When a child begins school, reading becomes step by step a primary way of learning. Learning to read builds on cognitive, linguistic, and social skills that have developed from the earliest age. The most important among these is the child's competence in language, which provides the basic foundation of reading (Rayner, Foorman, Perfetti, Pesetsky, & Seidenberg, 2001). To read, the child must learn how to connect the abstract lines and circles (i.e., letters) on a page with spoken language. Put differently, learning to read is learning how to use the conventional forms of printed language to obtain meaning from words. This definition separates learning to read from other aspects of cognitive development.

The holistic phenomenon of reading is rather complex. Many lower-level psychological processes (e.g., phonemic awareness, phonological decoding, ability to process stimuli rapidly and automatize this process, memory, ability to recognize words) contribute to a single act of reading (Grigorenko, 2001). Those who master reading skills successfully and those who have difficulties doing so differ in across a wide range of reading-related processes.

Literacy skills are among the most essential skills that children need to master. However, literacy skills take years to fully develop. According to Rayner et al. (2001) the starting point for literacy is reading skill. During the first school years, rapid progress in reading and spelling skills takes place (de Jong & van der Leij, 2002; Juel, 1994; Näslund & Schneider, 1996; Vellutino & Scanlon, 1991). The need for young children to gain accurate and fluent word-level skills has been emphasized by many researchers during past years (see e.g., Adams, 1990; Blachman, Schatschneider, Fletcher et al., 2004; Ehri, 1991; Lyytinen, Erskine, Kujala, Ojala & Richardson, 2009; Perfetti, 1985; Pressley, 2002; Share & Stanovich, 1995; Vellutino, Scanlon, & Tanzman, 1994; Williams, 1994). Children who struggle to acquire alphabetic principle[1] fail to develop early, successful

[1] Alphabetic principle refers to alphabetic writing systems in which each speech sound or phoneme of a language has its own distinctive graphic representation.

word reading skills (Stanovich, 1986). Moreover, children who get off to a poor start in reading rarely catch up (Torgesen, 1998). For these children, learning to read can be arduous and frustrating, if they do not receive sufficient intervention to compensate for their poor pre-reading skills.

Researchers have suggested that it is essential to ensure that children learn to decode in Grade 1 (e.g., Blachman et al., 2004). If decoding skills are not acquired then, it may be hard to change the direction that reading achievement takes (Gough & Juel, 1991). Several studies have shown that the poor first-grade reader almost invariably continues to be a poor reader later in life (see e.g., Francis, Shaywitz, Stuebing, Shaywitz, & Fletcher, 1996; Torgesen & Burgess, 1996). Moreover, individual differences between children's reading performances are generally quite stable (Smith, 1997; Torppa, Tolvanen, Poikkeus et al., 2007), but may decrease in magnitude across the first five years of formal schooling (Parrila, Aunola, Leskinen, Nurmi, & Kirby, 2005). However, without early intervention, at-risk children may never achieve adequate reading skills and end up as dyslexics[2].

The best solution to the problem of reading failure is to allocate resources for early identification and prevention (Torgesen, 1998). However, it has been reported that remedial reading intervention[3] may not be sufficient to support children at risk for or with reading disabilities (henceforth RDs) (see e.g., Bentum & Aaron, 2003; Hatcher, Hulme, & Snowling, 2004; Kennedy, Birman, & Demaline, 1986; Moody, Vaughn, Hughes, & Fischer, 2000; Puma, Karweit, Price et al., 1997; Snow, Burns, & Griffin, 1998; Torgesen, 2005). Once children fall behind, the preventive model of intervention turns out to be a remedial model of intervention, which is more expensive, more extensive, less effective, and more difficult (see e.g., Torgesen, 1998). Therefore, school or school district-based preventive efforts should be engineered to maintain growth in critical word reading skills throughout the early school years. The present study was designed to contribute to understanding of the intervention conditions that need to be in place to prevent reading disabilities in at-risk children.

Reading is a complex cognitive skill that improves only with practice (see e.g., Rayner et al., 2001). The latest tool for helping struggling readers is computer-assisted intervention (see e.g., Fawcett, Nicolson, Moss, Nicolson, & Reason, 2001; Magnan & Ecalle, 2006; Nicolson, Fawcett, Moss, & Nicolson 1999; Nicolson, Fawcett, & Nicolson, 2000; Regtvoort & van der Leij, 2007; Torgesen, Wagner, Rashotte, Herron, & Lindamood, 2009). Bringing new technology into the arena of reading instruction is one attempt to catch at-risk children before they fall. A computer-assisted remedial reading intervention also occupies a central role in this thesis the aim of which was to investigate the short- and long-term effects of a computer-assisted remedial reading intervention for at-

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2 A dyslexic is a person with a specific learning disability that is neurological in origin and is characterized by difficulties with accurate and/or fluent word recognition, and by poor spelling and decoding abilities.

3 Remedial reading intervention refers to a special educational program designed to supplement or substitute for the reading instruction of at-risk children and/or children with learning disabilities such as dyslexia.

risk children as compared to the outcomes of a regular remedial intervention and mainstream instruction.

1.1 Theories of literacy skill development

The main focus in theoretical accounts of literacy skill development has been on word recognition because of its central role in beginning reading. Word reading skill is the visual recognition of words or a process primarily relying on alphabetic knowledge and letter-sound correspondences (e.g., Ehri & Wilce, 1985). Progress in learning to read has often been viewed as series of stages (Chall, 1983; Ehri, 1991; Frith, 1985; Gough & Hillinger, 1980; Gough & Juel, 1991; Gough & Walsh, 1991; Marsh, Friedman, Welch, & Desberg, 1981). Process-oriented theories in turn share the idea of a continuum: each stage of development builds upon earlier experiences and provides the foundation for later ones (e.g., Ehri, 1987, 1989a; Ehri & McCormick, 1998; Ehri & Wilce, 1983, 1985; Frith, 1985 see also Duncan & Seymour, 2000; Seymour, 2005; Seymour & Evans, 1994, 1999). The alternative theoretical accounts emphasize the acquisition of individual word representations (see e.g., Perfetti, 1992). The phonological approach to reading (Stuart & Coltheart, 1998) is based on the idea that the main mechanism available to the child is *phonological recoding*, recoding of spellings into pronunciations. A model of how this mechanism works is given in Share (1995), who emphasized the role of self-teaching in learning to read words. An important focus in Share's model is children's attempts to phonologically recode words. Share's (1995) self-teaching model emphasizes the child's acquisition of individual word representations, rather than stages of development (see e.g., Harm & Seidenberg, 1999; Perfetti, 1992; Share, 1995, 2008).

According to the stage theories of reading, all normally progressing readers pass through various stages from pre-reading to skilled reading. In these theories, a point of divergence is the importance attached to letter-sound knowledge when children begin to read and spell. Snowling and Hulme (2005) explain that the term "stage" is a misnomer; in almost all of these theories there is overlap between the stages and the "phase" has come to be preferred to convey this notion. One of the most frequently used models of decoding skill acquisition and reading achievement is Ehri's phase model (e.g., Ehri, 1987, 1989a, 2002; Ehri & McCormick, 1998). In this model, the acquisition of alphabetic knowledge and facility with letter-sound relationships is of pivotal importance in the process of learning to read and spell. Ehri's model was refined on the basis of the early work of Frith (1985). In comparison to Frith (1985), Ehri worked from a knowledge-based perspective, but ending up with similar stages (i.e., phases) to those identified by Frith.

The Frith model. Frith (1985) proposed a *three-stage model of reading*. Each of the three stages includes the development of word identification skills that lead to enhanced word knowledge, furthering reading development. The first stage in the Frith model is called the *logographic stage*, and is deeply visually oriented.

In this stage words are learned by rote memory and any visually graphic link to a word is exploited so that its recall is automatically bound up with the graphic (i.e., logographic) representation of the word. The second stage in the Frith model is called the *alphabetic stage*. That is a more analytical stage than the *logographic stage*. During the *alphabetic stage*, the alphabet system is identified, element by element, in a word. In the *alphabetic stage* sounding out words is paramount and the rules for representing spoken language (i.e., English) are important. Some visual representation is also present to augment the learning of segmentation skills. The third and final stage in the Firth model is *the orthographic stage*, where readers are skilled enough to analyze words from much larger units. Letter groupings and word structure become critical here for processing word knowledge.

The Ehri model. There are five phases in the model of Ehri (Ehri, 1987, 1989a, 2002). Each of the five phases characterizes the learner's understanding and use of the alphabetic system in word reading (Ehri & McCormick, 1998). During the *pre-alphabetic phase* the child acquires oral language skills and begins to identify printed signs from the environment, learning the shapes and names of letters. Transition to the *partial-alphabetic phase* is thus signaled when the child starts attending to specific letter-sound relationships, usually word initial or final letters and sounds, to aid word recognition. In the *full-alphabetic phase* the child is able to fully recognize the connections between the letters and sounds they encounter in words, and also to decode unfamiliar words. In the *consolidated-alphabetic phase* child begins to operate with multi-letter units in words like affixes, onsets, or syllables, and store the orthography and spelling patterns in the word memory. The sight vocabulary grows and words are recognized automatically as a whole, without the need for letter-sound processing. In the *automatic phase*, words are read proficiently with increasing automaticy and speed.

In principle, Ehri (1989b) reported that reading and spelling develop hand in hand. Ehri's (1987, 1989b, 2002) theory on learning to spell thus corresponds to her postulated reading phases. In the *pre-communicative phase*, the child generates spellings that resemble print using randomly selected letters or numbers. In *the semi-phonetic phase*, the child learns the names or sounds of letters, selects letters for words on the basis of letter names or letter sounds of letters, and uses this knowledge in spelling. However, most of the spellings are incorrect and memory for correct spelling is unstable. In the *phonetic phase*, the child's spelling contains letters for all of the sounds in words and knowledge of grapheme-phoneme correspondence is demonstrated. As the child's experience of words upgrades s/he reaches the *transitional phase*. At this point, the child becomes aware of the visual features of words and begins to combine understanding of how a word sounds with knowledge of how the word looks. The child's fluency in reading and spelling thus increases.

The Seymour model. Seymour, with his co-workers, Duncan and Evans developed a *process-orientated dual foundation literacy model* for beginning reading. This model is similar to the model of Ehri (Duncan & Seymour, 2000; Seymour, 2005, Seymour & Evans, 1994, 1999). In the model of Seymour and colleagues

letter-sound knowledge mediates the transition into the foundation phase (phase 1), which is similar to that in the model of Ehri (1983, 1985, 2002). The foundation phase comprises of two parallel processes: *a logographic process*, which consists of visual word-level recognition and storage of familiar words, and *an alphabetic process*, where word recognition occurs through decoding words on the basis letter-sound correspondences. The subsequent phases are then developed according to the foundation processes. *An orthographic literacy* process constitutes phase 2, and requires competence with full complexity of the spelling system using abstract generalisable format. In phase 2, *a morphological literacy process* is required for the understanding of meanings and semantic dimensions within the text.

1.2 Sub-skills of reading and spelling

Reading and spelling sub-skills can be identified through reading models. Learning to read is a combination of sub-skills that are constructed on the basis of earlier skills. In fact, the development of reading sub-skills begins long before formal education. For example, environmental factors, cognitive and linguistic skills among others affect reading development (Grigorenko, 2001; Rayner et al., 2001). Furthermore, literacy consists of knowledge and attitudes, which are developmental precursors to reading and writing (Whitehurst & Lonigan, 1998). The present study focused on the development of letter knowledge, decoding, reading accuracy, fluency and spelling.

Decoding, is what children do when they analyze the graphic symbols in words to break the reading "code". Further, decoding words requires blending skill to transform graphemes into recognizable words (see e.g., Ehri et al., 2001). At a basic level children recognize that letters represent the sounds of spoken words (see e.g., Foorman, Francis, Shaywitz, Shaywitz, & Fletcher, 1997; Torgesen, 2000). As children master each letter of the alphabet, they map these letters to the sounds they represent. This mapping enables children to begin to decipher whole words. By breaking up words into their component sounds, phonemes, children can sound words out. With practice, decoding becomes automatic for the normally progressing reader. Children see words and read them without struggling, even if they do not know the meaning of every word. At this point, children may appear, some would say, to be ”barking at print” without fully understanding what they are reading. According to Torgesen and Barker (1995) children with RDs are not likely to receive sufficient opportunities to practice decoding skills to a level of fluency that will enable them to read adequately. Decoding is the first step on the pathway to reading skill that children need to master in order to read accurately and fluently.

Reading accuracy refers to the ability of students to develop efficient mastery in reading isolated words correctly. Automatic mastery of decoding is the accuracy with which students are able to accomplish this task. Word reading accuracy is mainly dependent on phonological decoding skills (see e.g., Adams,

1990; Foorman et al., 1997; Torgesen, 2000). Quite obviously, problems and mistakes in working out the correct pronunciation of a certain grapheme string will have a strong negative influence on reading accuracy. Torgesen, Rashotte, and Alexander (2001) found that the most common characteristic of poor readers was a difficulty in reading words accurately and instantly. In order to read words accurately and instantly students need good skills in decoding. If children fall behind in the growth of critical word reading skills, very intensive interventions may be needed to bring them up to adequate levels of reading accuracy (Allington & McGill-Franzen, 1994; Vaughn, Schumm, & Sinagub, 1996). Reading accuracy is a corner stone in learning to read. Reading accuracy directly affects the next component of reading, which is reading fluency.

Reading fluency. Definitions of reading fluency are complex and they often stress specific features of reading. One of the most used definitions refers to a level of accuracy and rate where decoding is relatively effortless; where oral reading is smooth and accurate with correct prosody; and where attention can be allocated to comprehension (e.g., Wolf & Katzir-Cohen, 2001). Others define fluency as the ability to read text quickly, accurately, and with proper expression (National Reading Panel, 2000), while Kuhn and Stahl (2003) documented three central components of fluency: (1) accuracy in decoding, (2) automaticy in word recognition, and (3) the appropriate use of prosodic features, intonation, and duration that contribute to expressive reading. Torgesen, Rashotte and Alexander (2001) emphasize the contribution of automaticy to fluent reading, while Allington (2006) stresses the role of prosody. According to Rayner et al. (2001) practice in reading brings about an increasing facility with words; it increases the quality of lexical presentations. It turns low-frequency words into high-frequency words; the result is commonly called reading fluency. Difficulty in reading fluency is one of the major problems in children with reading deficits: their reading is slow, hesitant, and sometimes extremely laborious. Furthermore, students who score low on assessments of fluency tend latter to score low on measures of reading comprehension (Armbruster, Lehr, & Osborn, 2001). Constructing meaning is the main goal of any literacy experience (Cooper, 2000; McGuinness, 2004). Further, it is reading practices that support comprehension and vocabulary growth as well as spelling skill (Rayner et al., 2001).

Spelling. The spelling process requires that a person can connect phonemes with corresponding letters and apply language-specific spelling rules (see e.g., Berninger, 1999; Graham, 1999). Basically, spelling is the reverse process of decoding (see e.g., Ehri, 1989, 1997). That is translating written words into the sounds and meanings of spoken words. The skills used in spelling are usually developed along side decoding skills and reflect similar learning. Successful spelling performance involves the process of segmenting the spoken word into phonemic components and then selecting the appropriate graphemes to represent the phonemes (e.g., Ball & Blachman, 1988). Even if two sides of the same coin, as Ehri (1989, 1997) stated, Lerkkanen, Poikkeus, Ahonen, Siekkinen, Niemi, & Nurmi (2010), in their Finnish language study found that accurate spelling developed more slowly than accurate reading during the first two

years of school. Furthermore, spelling requires greater precision than decoding (Perfetti, 1997). Spelling also requires production whereas reading requires recognition; therefore success in reading does not lead automatically to success in spelling (Rayner et al., 2001).

In some languages with opaque orthographies, spelling has been taught as a separate subject, or separately from reading, whereas in transparent orthographies, such as Finnish, reading and spelling are taught parallel, due to the high level of consistency between the spoken and written language (see e.g., Lerkkanen, 2007; Lerkkanen, Rasku-Puttonen, Aunola, & Nurmi, 2004a). In the more opaque orthographies, spelling problems often persist (e.g., Berninger, Nielsen, Abbott, Wijsman, & Raskind 2008; Rose, 2009; Spear-Swerling, 2005). Individuals with challenges in spelling may require explicit instruction focusing on spelling, including awareness and coordination of phonological, orthographic, and morphological word forms and their parts (Berninger et al., 2008).

1.3 Predictors of reading and spelling

Phonological awareness[4] has been documented to be one of the most important predictors of successful reading in several languages (see e.g., Ball & Blachman, 1988; de Jong & van der Leij, 1999, 2002; Grigorenko, 2001; Seymour & Evans, 1994; Wimmer, Mayringer, & Landerl, 1998; Ziegler, Bertrand, Toth et al., 2010). However, based on the meta-analysis by Bus and van Ijzendoorn (1999) programs combining a phonological and letter training were more effective than purely phonological training. Based on their meta-analysis, experimentally manipulated phonological awareness explained about 12% of the variance in word-identification skills (Bus & van Ijzendoorn, 1999).

Both theoretically (Ehri, 1987, 1989a, 1989b, 2002) and empirically previous studies (e.g., Byrne, 1998; Gallagher, Frith, & Snowling, 2000; de Jong, & Olson, 2004; Elbro et al., 1998; Elbro & Petersen, 2004; Hatcher, Hulme, & Snowling, 2004; Lonigan, Burgess, & Anthony, 2000; Lyon, Shaywitz, & Shaywitz 2003; Lyytinen et al., 2004; Scarborough, 1990, 1998, 2001; Snow et al., 1998; Snowling et al., 2003; Stanovich & Siegel, 1994; Vellutino, Fletcher, Snowling, & Scanlon, 2004) have confirmed that letter knowledge[5], letter-sound relationships and correspondences[6] and phonological awareness are of pivotal importance in beginning reading and spelling. Also, rapid automatized naming (henceforth RAN)[7] has been shown to predict reading, especially reading fluency (see e.g., Badian, 1993; de Jong & van der Leij, 1999; DiFilippo Brizzolara, Chilosi et al., 2006; Kir-

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4 Phonological awareness or phonemic awareness refers to knowledge of the internal sound structure of spoken words.

5 Letter knowledge refers to knowledge of exact letter names and ability to name them fluently and accurately.

6 Letter-sound correspondences refer to ability to sound out phonemic sounds of letters fluently and accurately.

7 Rapid automatized naming refers to ability to name objects automatically, fluently and accurately.

by, Parrila, & Pfeiffer, 2003; Parrila, Kirby, & McQuarrie, 2004; Wimmer, Mayringer & Landerl, 1998, 2000; Wimmer & Mayringer, 2002). In the Finnish language context, phonological awareness (e.g., Holopainen, Ahonen, Tolvanen, & Lyytinen, 2000; Lerkkanen, Rasku-Puttonen, Aunola, & Nurmi, 2004b; Puolakanaho, Poikkeus, Ahonen, Tolvanen, & Lyytinen, 2003) and letter knowledge have been demonstrated to be important predictors of reading skills (see e.g., Lepola, Salonen, & Vauras, 2000; Lerkkanen et al., 2004a; Lyytinen et al., 2009; Lyytinen, Ronimus, Alanko, Poikkeus, & Taanila 2007; Poskiparta et al., 1999; Torppa et al., 2007), while a connection between rapid automatized naming and reading speed has been reported by Torppa et al. (2007).

A competent spelling process requires a sufficient mastery of letter knowledge and phonological awareness (see e.g., Berninger et al., 2008). On this premise, reading (e.g., decoding, reading accuracy and fluency) and spelling would seem to be based on the same pre-reading skills, i.e., letter knowledge and phonological awareness, while rapid automatic naming has been shown to be a predictor of responding to spelling instruction (Amtmann, Abbott, & Berninger, 2008). Moreover, spelling is affected by independent reading and exposure to text, viz. avid readers see more words in print and have more opportunities to learn the spellings of specific words (Spear-Swerling, 2005).

Furthermore, letter knowledge, phonological awareness and rapid automatized naming have been shown to be indicators of RDs. For example, this has been reported in the Jyväskylä Longitudinal Study of Dyslexia (JLD) (for a review see e.g., Lyytinen, Aro, Holopainen, Leiwo, Lyytinen, & Tolvanen, 2006). Familial risk for dyslexia, that is, the incidence of developmental dyslexia among close relatives, has been shown to be an important predictor of RDs in offspring (e.g., Gilger, Pennington, & DeFries, 1991; Grigorenko, 2001; Lyytinen et al., 2006; Pennington, Gilger, Pauls, Smith, Smith, & DeFries, 1991; Scarborough, Dobrich, & Hager, 1991; Snow et al., 1998; Snowling, Gallagher, & Frith, 2003). However, the familial risk was not included in the present study.

1.4 Features of the Finnish orthography

The early phases of learning to read are heavily influenced by the orthography of the language in question. Studies conducted among English speakers have traditionally dominated literacy research; however recently the focus of attention has shifted towards orthographical differences between languages, and how orthography impacts on literacy acquisition (see e.g., Seymour, Aro, & Erskine, 2003; Ziegler & Goswami, 2005; Ziegler et al., 2010). The syllabic complexity and orthographic depth of a language have strong effects on word reading skill. That is, word reading skills are easier to acquire in the more transparent orthographies where the connections between spoken and written language are consistent in both directions at grapheme-phoneme level (Grigorenko, 2001; Lyytinen et al., 2006; Seymour et al., 2003; Ziegler & Goswami, 2005).

Truly productive reading, that is, the ability to read novel words comes from an increase in knowledge of how orthography relates to phonology (Rayner et al., 2001). A likely reading strategy for children acquiring reading ability in a transparent orthography, such as Finnish, would be phonological reading. Synthetic phonics-based instruction emphasizes the relationship between graphemes and phonemes. Contrastively, in whole-word instruction (also called the "look-say method"), a sight vocabulary of 50-100 words is initially taught. However, Finnish beginning readers do not have the advantage of sight words because of two idiosyncrasies of their language. Finnish has only about 50 monosyllabic words. Finnish words also tend to be extremely long because of the agglutinative nature of the Finnish language, for these reasons synthetic phonics is commonly used in Finnish schools.

In Finland primary school begins when children become seven years old, which is quite late compared to other countries. As stated above, in Finnish schools, reading and spelling are taught through phonics-based instruction, in which the learning of sound-symbol correspondences is important (Lerkkanen, 2007), for the reason that the orthography of Finnish is almost perfectly transparent. This means that reading and spelling acquisition are parallel processes i.e., spelling a phoneme is as consistent as pronouncing a grapheme. Reading and spelling instruction in general, and also in the classrooms observed for this thesis, includes learning of letter names as well as listening, segmenting, and blending phonemes and syllables. After a few letters and sounds have been mastered in Grade 1, they are combined into CV/VC syllables and CV/VC – CV/VC words. The Grade 2 literacy curriculum focuses on the further development of fluency and reading comprehension (see e.g., Lerkkanen, 2007).

Beginning Finnish readers have been documented to decode words and non-words equally well. Holopainen et al. (2000) found a correlation of .93 between these two measures among Grade 1 readers. When the ability to decode has been assessed cross-linguistically, English-speaking first-graders have shown error rates between 40% and 80% (Juel, Griffith, & Gough, 1986; Treiman, Goswami, & Bruck, 1990), as compared to error rates of below 25% in their Finnish (e.g., Holopainen, Ahonen, & Lyytinen, 2001) and German (e.g., Wimmer & Hummer, 1990) peers.

1.5 Reading interventions for at-risk children

Considerable attention has been paid recently to the benefits of early intervention for children who are struggling to learn to read (e.g., Snow et al., 1998; Linan-Thompson, Vaughn, Prater, & Cirino, 2006; Torgesen, 2002; Vaughn, Linan-Thompson, & Hickman-Davis, 2003). It has been demonstrated that the most efficient reading intervention programs combine explicit training in phonological awareness with highly structured reading instruction (Hatcher, Hulme, & Ellis, 1994; Hatcher, Hulme, & Snowling 2004; Hatcher, Hulme, Miles et al., 2006; Hulme, Snowling, Caravolas, & Caroll, 2005; Iverson & Tunmer, 1993;

Lyytinen et al., 2007, 2009). Further, there is compelling evidence that early reading programs that emphasize the connections between the phonological structure of spoken words and the alphabet can help close the gap between children who are struggling to learn to read and those who learn to read easily (Blachman, 2000; Ehri et al., 2001; Liberman & Liberman, 1990; Vellutino, 1991).

The evidence to date indicates that reading under-achievement in children at risk for reading failure is preventable by explicit instruction in letter-sound correspondences (Foorman, Francis, Fletcher, Schatschneider, & Mehta, 1998). For example, Lovett, Barron and Benson (2003) emphasized the necessity of direct remediation of phonological awareness deficits, systematic and explicit instruction in letter- and letter cluster-sound mappings, and reinforcement of word identification and learning through text reading practice by using a controlled decodable reading vocabulary. Despite the existing knowledge on the basic elements of reading acquisition, the mainstream approach often fails to support at-risk children (see e.g., Hatcher et al., 2004). It has been demonstrated that at-risk children require a more individualized approach (Torgesen, 2005) to acquire sufficient letter knowledge and to develop accurate and fluent reading and spelling ability. Therefore, the mainstream reading approach is an obviously unsatisfactory environment for at-risk children. However, it has also been reported that remedial reading practices may not be sufficient either in supporting children at risk for or with reading disabilities (e.g., Bentum & Aaron, 2003; Hatcher et al., 2004; Kennedy, Birman, & Demaline, 1986; Moody et al., 2000; Puma et al., 1997; Snow et al., 1998; Torgesen, 2005). Current recommendations for good-quality remedial settings suggest that highly structured explicit and systematic research-based reading interventions that emphasize the phonologic and orthographic connections in words are especially important for children at risk (see e.g., Fletcher, Lyon, Fuchs, & Barnes, 2007; Hatcher et al., 1994; Hatcher et al., 2004; Hatcher et al., 2006; Hulme et al., 2005; Iverson & Tunmer, 1993; Lyytinen et al., 2007, 2009; Swanson, Harris, & Graham, 2006). The present remedial reading intervention study was designed to contribute to understanding of the intervention conditions that need to be in place to prevent reading disabilities in at-risk children.

It has been hypothesized that a computer-assisted remedial reading intervention would be a more powerful instrument in training literacy skills than regular remedial reading intervention methods. Computer-assisted reading instruction has currently been explored as an individual-orientated, scientific-based, intensive and viable method of training reading skills (McCormick, 1999; Torgesen, 2002). Previous studies have recognized that computer-assisted reading intervention can be effective in training at-risk children (e.g., Fawcett et al., 2001; Magnan & Ecalle, 2006; Nicolson et al., 1999, 2000; Regtvoort & van der Leij, 2007; Torgsen et al., 2009). In like vein, computer applications have been acknowledged to be useful instruments in training the literacy skills of children with reading disabilities (e.g., Elbro, Rasmussen, & Spelling, 1996; Hurford & Sanders, 1990; Jiménez et al., 2003, 2007; Lynch, Fawcett, & Nicolson, 2000; van Daal & Reitsima, 2000; Wentink, van Bon, & Schreuder, 1997; Wise, Ring, & Ol-

son, 1999). The meta-analyses by Soe, Koki, and Chang (2000), The National Reading Panel (2000) and the review by Blok, Oostdam, Otter and Overmaat (2002) also support these findings. Research-based computer applications may provide individually adjusted learning environments with active, individually targeted reading support i.e., productive drill and practice in pre-reading and reading skills. Moreover, computer applications are able to provide immediate visual and audio feedback to both correct and incorrect choices, which is of paramount importance when learning such cognitive tasks as reading. In the present study we used GraphoGame to train pre-reading skills of at-risk children.

1.6 Aims of the empirical studies

The present study was designed to contribute to understanding of the intervention conditions that need to be in place to prevent reading disabilities in at-risk children. The study focused on short- and long-term intervention outcomes of letter knowledge, reading accuracy, fluency and spelling in two groups of at-risk children and their non-at-risk peers (Mainstream group) in the Finnish language context. In a longitudinal setting, children were followed from school entry to Grade 3. An attempt was made to predict intervention outcomes for three contrastive reading groups: regular (henceforth RRI) and computer-assisted remedial reading intervention (henceforth CARRI), and mainstream instruction. The development of letter knowledge, reading accuracy and fluency were predicted with two growth components (slope and final level) of letter knowledge, phonological awareness and rapid automatized naming.

Study I examined the benefits of a regular and a computer-assisted remedial reading intervention. The aim of the randomly assigned comparative study was to investigate whether the computer-assisted remedial reading application can enhance letter knowledge, reading accuracy, fluency and spelling in children with low pre-reading skills and risk for RDs. The progress of the two remedial reading groups: the regular and computer-assisted remedial reading intervention, were compared with the progress of a Mainstream group. Six assessments along with two follow-ups were included to determine changes in reading and spelling abilities. In addition, effect sizes were calculated to assess the effectiveness of the programs.

In Study II, the development of letter knowledge and reading accuracy were the foci of interest. The aim was to build a model of the predictive value of the development of letter knowledge and reading accuracy in three contrastive reading groups: a remedial and a computer-assisted remedial reading intervention, and mainstream instruction, and further to identify the short- and long-term intervention effects for children with different profiles of compromised pre-reading skills, i.e., phonological awareness, letter knowledge and rapid automatized naming.

In Study III, the main goal of the study was to build a model of the predictive value of reading fluency in three contrastive groups whose reading acquisition has been supported differently. Children with the most typical risk profiles were selected for the study and assigned to either the RRI or CARRI intervention groups, or to mainstream instruction. Intervention outcomes were predicted with three risk factors: (1) low letter knowledge, (2) poor phonological awareness and (3) slow automatized naming, and combinations of these. A second aim was to compare the most effective types of intervention for children with different profiles of compromised pre-reading skills at the beginning of school. For this purpose, the development of reading fluency between pre-and post-intervention assessments for each of the three types of instruction was followed.

2 METHOD

2.1 Participants

The data form a part of an ongoing Prevention Game Research -project in the Centre of Excellence and Department of Psychology in University of Jyväskylä. The aim of the project is to identify effective research-based and peer-reviewed intervention methods for children at risk for reading failure, and for those diagnosed with RDs or dyslexia[8]. The Prevention Game Research -project was derived from the Jyväskylä Longitudinal Study of Dyslexia (JLD). The GraphoGame software (used in this thesis) was developed as an application of the results of the JLD in the Centre of Excellence for Learning and Motivation Research and is intended for use outside as well as in Finland (see e.g., Lyytinen et al., 2004, 2006, 2008). The overall aim of the project is to help prevent developmental reading disabilities among children at risk for reading failure or with RDs (for further details see Lyytinen et al., 2007, 2009).

The data used for the present thesis were drawn from two successive age cohorts (n = 88 and n = 83) of 7-year-old (M = 87.6, SD = 4.2) school beginners screened in the province of Western Finland. All the schools participating in the experiment were from the same school district. The district was in a middle-class suburban area with consistent socio-economic status and population density. Five children were excluded due to failure to obtain parental consent to participate (2 children) or changes of schools (3 children). Thus 166 children from the two cohorts (n = 85 and n = 81; 88 girls and 78 boys) participated in the study. Of these children, one male student had diagnosed specific language impairment.

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8 Dyslexia, also known as specific reading disability, is a common, cognitively and behaviorally heterogeneous developmental condition, characterized primarily by serious difficulty in the mastery of reading despite average intelligence and adequate education (see e.g., Grigorenko, 2001).

2.2 Procedure and measurements

The pre-reading skills of all the 166 participating children were tested at school entry. The screening included (1) letter knowledge, (2) six phonological subtests of the nationally norm-referenced test battery (ALLU; Lindeman, 1998) and (3) the norm-referenced Rapid Automatized Naming Test (RAN; Ahonen, Tuovinen, & Leppäsaari, 1999). After that maneuver, the lowest achieving 30% of these children (the lower tail), in two screening assessments out of three, were offered remedial reading intervention by randomly dividing them into two intervention groups (n = 25 and n = 25; 20 girls and 30 boys). This cut-point was based on statistics compiled by the Finnish Central Statistical Office (2009) according to which 26-30% of Finnish children receive remedial reading training in Grades 1 and 2. Consents for the remedial reading intervention and research protocols were obtained at the time of the parental interview (N = 50). After that procedure the remaining 116 children (48 boys, 68 girls) were assigned to the mainstream reading group. All the participating children were native Finnish speakers and had no mental, physical, or sensory handicaps. Their cognitive abilities were estimated by the vocabulary, similarities, digit span and block design tests of the WISC-III (Wechsler, 1999) in the spring term of Grade 2. There was no attrition. Six children moved or changed schools after Grade 2. However, they were willing to complete the last assessment at the beginning of Grade 3.

Basic academic skills in reading and spelling were assessed using various tests (see Table 1) during each measurement point (see Figure 1). Table 1 describes the measures and assessment phases of Studies I-III. In all studies the design was random assignment in a longitudinal setting (N = 166 in each of the studies).

Letter knowledge. Progress in letter knowledge was assessed five times during the ten-month period in Grade 1. On each occasion the 29 letters of the Finnish alphabet were presented to the participants in mixed order. Each correctly named letter scored one point, with a maximal score of 29.

Reading accuracy. The two subtests of the nationally normed reading test battery (ALLU; Lindeman, 1998) were used to assess progress in reading. These two subtests were used as a measure of word-level reading accuracy in context. The first-grade subtest was completed in January. The test was based upon the total number of words read and connected correctly to the right object within the space of two minutes. The subtest for the third graders was administered in August (Follow-up 2). The test was based upon the total number of sentences read and connected correctly to the right object within the space of two minutes. According to the test manual (Lindeman, 1998), the Kuder-Richardson reliability coefficient was 0.97 in Grade 1, and 0.82 in Grade 3.

Fluency. A time-limited fluency test (Lukilasse Graded Fluency Test; Häyrinen, Serenius-Sirve, & Korkman, 1999) was constructed to assess reading fluency and accurate decoding. The fluency test consists of 90 Finnish words rang-

ing from VCV to multisyllabic word forms. Scoring was based upon the relevant age norms and the total number of words read aloud correctly within the space of two minutes. The fluency test was carried out twice: at the end of the experiment (Post test) and 12 months later (Follow-up 1). According to the test manual (Häyrinen et al., 1999), the reliability of the test was .979 in Grade 1 and .968 in Grade 2.

Spelling. The Lukilasse Graded Word Spelling Test (Häyrinen et al., 1999) was used to measure spelling ability. In Grades 1 and 2, the test consists of 20 dictated Finnish words ranging from CVV to multisyllabic word forms. The scoring, maximum 40 points, was based upon the relevant age norms and the number of words written correctly. The Grade 3 spelling test consisted of words and sentences, including punctuation and capital letters at the beginning of the sentences. The spelling test was carried out at the end of the experiment (May, Grade 1, post test) and in both follow-ups. According to the test manual (Häyrinen et al., 1999), the reliability of the test was .979 in Grade 1, .968 in Grade 2 and .972 in Grade 3.

2.3 Interventions

The study was designed to assess the effectiveness of an intervention that would be viable in a resource room setup. The idea was to apply the existing research-based knowledge in practice. Consequently, the training regimes were designed for children working in groups of five, in four weekly sessions of 45 minutes, over a period of 28 weeks. The difference between the intervention groups concerned the nature of the instruction given during the first 15-min of each remedial lesson. The CARRI group practised with the computer-assisted GraphoGame while the RRI group trained with more traditional methods (for a review see Figure 2). These interventions were incorporated in the Grade 1 literacy curriculum.

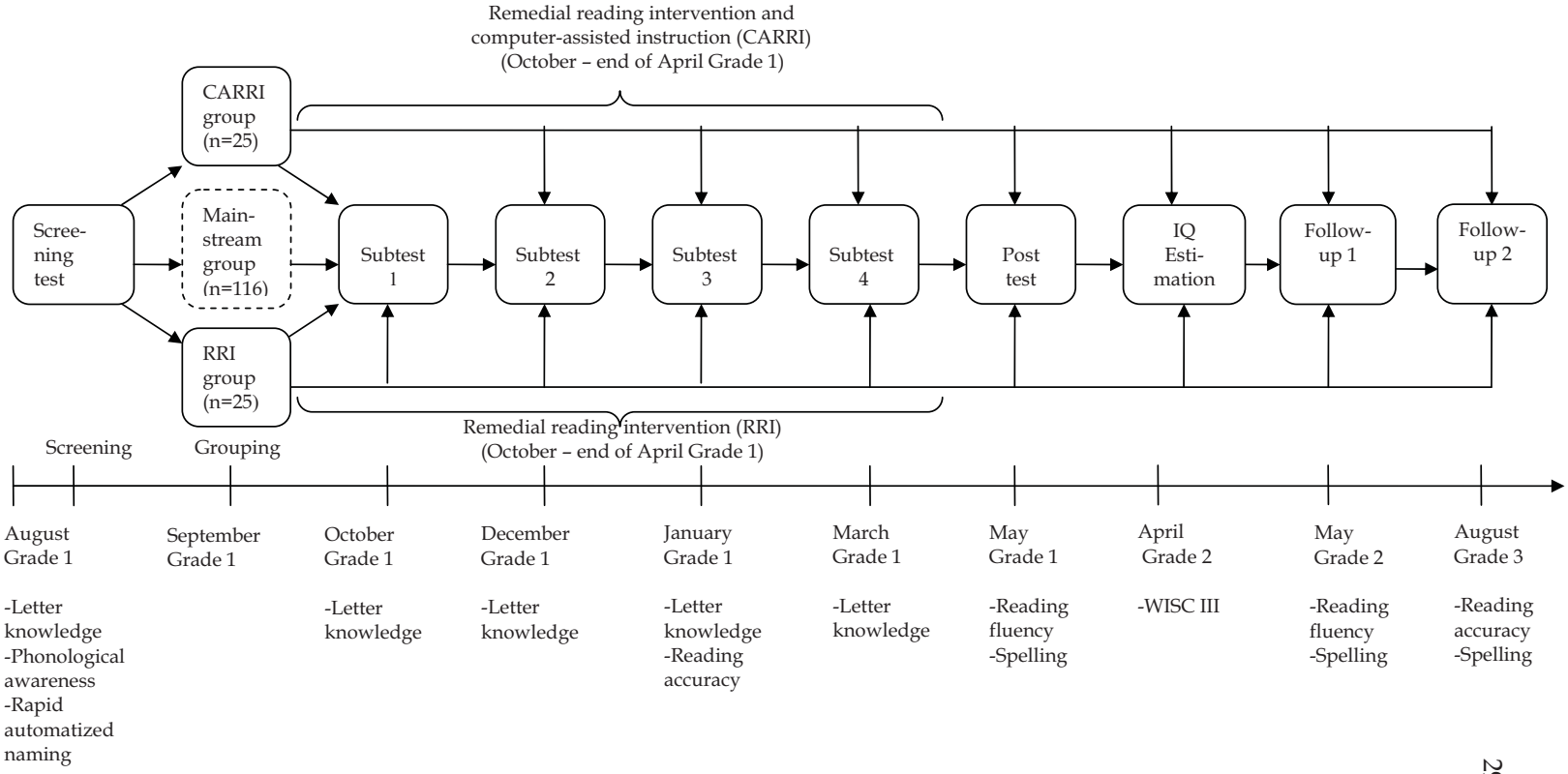
After six weeks of formal schooling the interventions began. The times of the day that the children were taught in the experimental condition during Grade 1 varied. The average period of time the children spent in the resource room was 66 hours. The intervention time varied according to absences and extracurricular conditions such as field trips or public holidays. Both experimental groups were implemented by a remedial reading specialist[9] who had a Masters degree in special education. The same remedial reading specialist carried out both experiments in order to exclude trainer effects. The training protocols were monitored by keeping written records for each intervention session, and through observation and discussions. The fidelity of treatment was monitored in the intervention groups by the remedial reading specialist, written

[9] A remedial reading specialist in the Finnish context is a special teacher or special educator specialized in remedial reading intervention, and has a Masters degree in special education.

records, and also by the game server in the CARRI group. During the intervention period described in the present thesis, the participating 166 children did not receive any other interventions or any additional provision from the research team or other sources.

Four elementary schools participated in the study. Both treatment conditions took place in each school. The participants were taught by nine class teachers altogether. Each teacher taught the class for two years – Grades 1 and 2 were included in the study. All the teachers (eight female and one male teacher) had master's degrees

FIGURE 1 The assessments of the children's reading and spelling skills



Note. RRI = Regular Reading Intervention, CARRI = Computer-assisted Remedial Reading Intervention, Mainstream = Mainstream Reading Group.

TABLE 1 Assessment phases and methods used in the studies of the thesis

Measures	Time of Assessment	Study I	Study II	Study III
IQ estimation	IQ Estimation; April, Grade 2	X	X	X
Letter-knowledge	Screening; August, Grade 1	X	X	X
	Subtest 1; October, Grade 1	X	X	X
	Subtest 2; December, Grade 1	X	X	X
	Subtest 3; January, Grade 1	X	X	X
	Subtest 4; March, Grade 1	X		
Phonological awareness	Screening; August, Grade 1	X	X	X
Rapid automatized naming	Screening; August, Grade 1	X	X	X
Reading accuracy	Subtest 3; January, Grade 1	X	X	
	Follow-up 2; August, Grade 3	X	X	
Reading fluency	Post test; May, Grade 1	X		X
	Follow-up 1; May, Grade 2	X		X
Spelling	Post test; May, Grade 1	X		
	Follow-up 1; May, Grade 2	X		
	Follow-up 2; August, Grade 3	X		

in education and at least 5 years experience in teaching reading to school beginners. Generally, the class teachers performed all the basic teaching activities in their classes apart from music, art and crafts, physical education and the remedial reading intervention described in the present thesis.

The regular phonics-based remedial reading intervention package in the RRI group was implemented by using regular remedial procedures for first graders. Each 45-min remedial intervention period was divided into four sections. Each section
consisted of activities which varied in teaching mode, cognitive task, and level of stimulus difficulty. Criteria were specified by the use of training strategies. The package progressed from easier to more challenging activities (see Figure 2).

The first section, lasting 15-min, was based on activities linking reading, spelling and phonology. These activities included practising letter-sound associations, sound synthesis into syllables and words, and fluency. Reading and spelling were also related to sounds using plastic or magnetic letters, flash cards, self-made memory cards, Logigo® – and LUKO® game boards.[10]

The second 10-min section consisted of basal remedial reading training comprising word segmentation into sounds, identification and manipulation of syllables, identification and discrimination of sounds within words, identification and supply of rhyming words, and omission of sounds from words, sound substitutions within words, e.g. in word endings, and identifying words as units within sentences.

The third 10-min section was spent on primer usage. The training units were decoding, orthographical processing, and actual reading and spelling practice; including writing words while paying attention to letter-sound relationships, recoding, decoding, fluency, reading and writing in context. Pseudoword tasks and writing words while paying attention to letter-sound relationships were also practised. Each of the sections with the primer followed the same format, which consisted of the aims of the tasks, the materials needed, and instructions for doing the tasks. The fourth 10-min section consisted of multisensory vocabulary training to expand the participants' vocabulary by using improvisation cards, mimicry, pantomime, acting and illustrating charades on a blackboard, or tale telling.

The training strategies were set out in the sections covering letter-sound relations, decoding, writing letters and syllables, reading and writing words, reading and writing pseudo-words and reading and writing in context. Each section consisted of activities which varied in teaching mode, cognitive task, and level of stimulus difficulty. The package progressed from easier to more challenging activities.

The phonics-based remedial reading intervention enriched with the GraphoGame computer-assessed reading intervention program used in the CARRI group comprised the same reading package as in the RRI group, except for the first section

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10 Logigo® and LUKO® are plastic game boards that are used along with the exercise books. The idea is to build reading skills in a mechanical game-like environment by reading and changing the location of the plastic pieces.

which was replaced by the GraphoGame application. In the CARRI group the training package consisted of 15-min of individual time with the GraphoGame computer-assessed reading program at the beginning of every remedial session. Mean time-on-task was 4 hours 53 minutes.[11] The remedial lessons were divided into four sections, the last three of which were the same as those in the RRI group (see Figure 2).

Three PC computers with Windows XP and an Internet connection were allocated to each group of five participants. Computer-assisted training and regular remedial reading training overlapped in the first section. Two to three participants at a time practised with the computer application, while the others completed the regular remedial reading tasks in the second section. This was due the lack of a sufficient number of computers. After 15-min practice the participants changed over.

The primary purpose of the GraphoGame application used in the CARRI experimental condition is to provide productive drill and practice in pre-reading and reading skills; such as integration of letter-sound relations and phonemic awareness, decoding skills and further practice in accuracy and fluency. GraphoGame addresses the development of phonological awareness as a pre-reading skill in direct connection with letter-sound-correspondence. The application delivers context-free practice on specific syllable and word identification skills. Further, GraphoGame delivers supportive practice in fluency. The GraphoGame computer-assisted intervention has been developed for children at risk for and with learning disabilities (LD) and at risk for dyslexia. The software was developed within the Jyväskylä Longitudinal Dyslexia Study (see e.g., Lyytinen et al., 2004, 2006, 2008) and was strictly grounded in research-based practices. The overall aim of the GraphoGame computer application is to prevent developmental reading disabilities among children at-risk for reading failure (for more details see Lyytinen et al., 2007, 2009).

GraphoGame includes the basic components that are needed in the acquisition of basic reading skills in the orthographically consistent Finnish language. The graphics of the GraphoGame application include falling balls that contain an orthographic stimulus. Simultaneously with the falling balls an auditory stimulus is given via headphones. Choices among the falling balls are made by clicking the mouse on the orthographic target. From 2 to 9 orthographic items fall as balls on the screen, one of which matches the given auditory stimulus. The initial requirements of GraphoGame begin at a low level of demands with exercises in letter-sound correspondence. The training of phonemic awareness is implemented by immediate exposure to letters and sound relations. After acquisition of the target letter-sound correspondence, GraphoGame progresses

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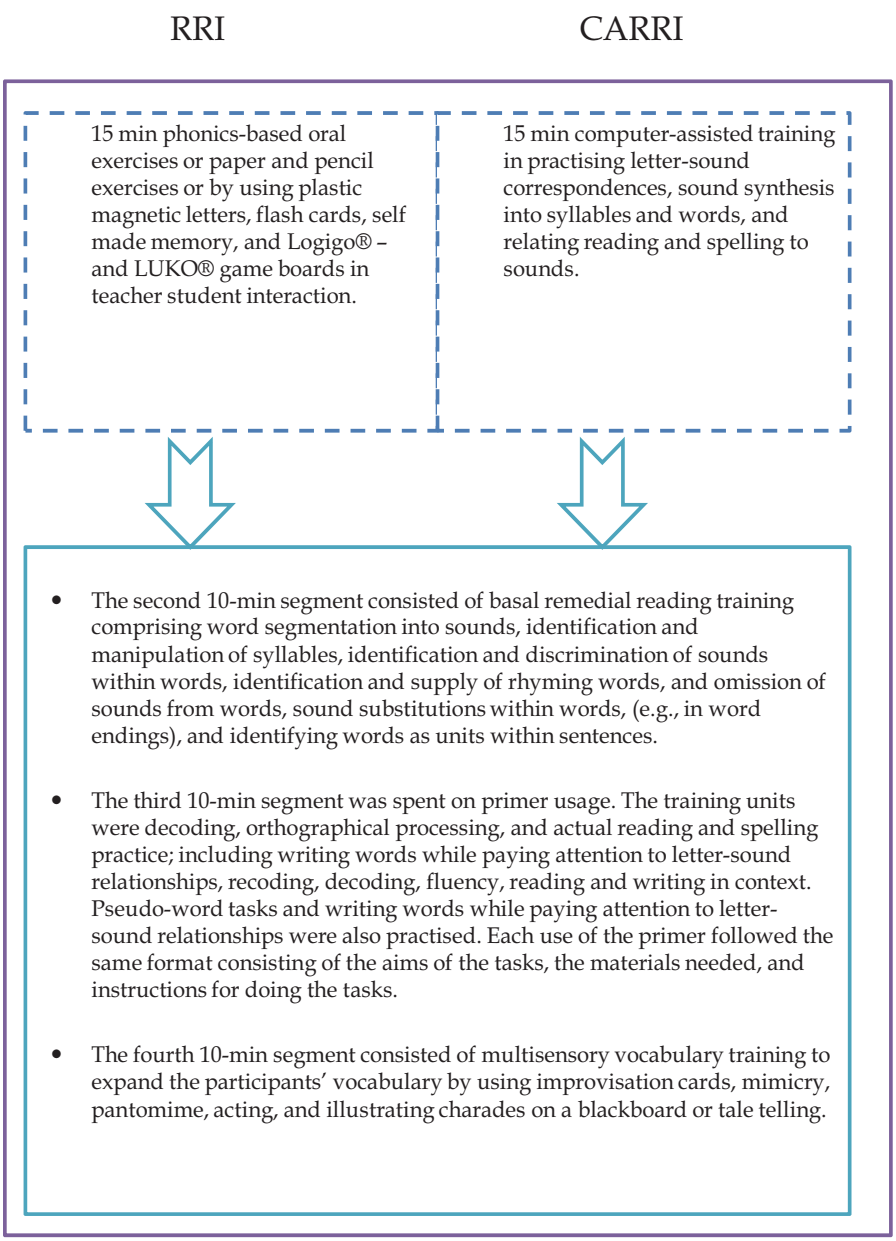
11 The time spent on-task during the letter-sound connection, word accuracy and fluency training, or time spent practising with the GraphoGame application. Time spent attending to instructions, receiving rewards, and moving between screens were all subtracted from exposure time.

gradually in stages to sound synthesis in syllables, words and pseudo-words, aiming at acquisition of the alphabetic principle.

GraphoGame is programmed to support the individual rate of acquisition via adaption to the level of personal achievement. The ultimate aim is an automatized connection between the auditory and orthographic stimulus. The application is automatized to adjust its responses to the actions and abilities of each individual.

FIGURE 2 Description of the remedial practices studied.



Participants who make progress are assigned new, more complicated tasks. Intervention data and logs are recorded on the server at the University of Jyväskylä, Finland. Online recordings have made it possible for researchers to monitor the responses of each individual, and for automatic adjustment of the application to meet the special needs of an individual child. GraphoGame is currently available to Finnish- and Swedish-speaking children in Finland free of charge via the support of the Finnish Ministry of Education.

The essential difference between the two intervention groups was the instrument used during the first 15-min of the remedial training. There were also some minor differences in the training protocols between the two experimental groups. In the RRI group training was clearly divided into four different segments while in the CARRI group segments one and two overlapped each other due to the limited number of computers available. However, in both groups the exercises were carefully planned to meet the specific requirements of each. The CARRI group used computer-assisted training in practising letter-sound correspondences, sound synthesis into syllables and words, and relating reading and spelling to sounds, while more regular reading instruction was used by the RRI group to acquire the same skills. Both experimental settings involved individualized, highly structured training, embodying many current recommendations for good remedial practice (see e.g., Fletcher et al., 2007; Swanson et al., 2006). The entire group of 166 first graders in the study was receiving phonic-based reading instruction in classroom.

The mainstream reading instruction group (the Mainstream group) was included in the study to assess the developmental variation in the acquisition of literacy skills in at-risk and not-at-risk children. These children received their regular classroom teaching without any additional provision from the research team. The mainstreamers were introduced by class teachers to phonics-based reading. Their progress in reading and spelling skills was measured in the same manner as in the two experimental groups. The extent of the instruction showed no systematic differences between the three study groups.

2.4 Analytical strategies

In Study I, the main interest was in the progress made by the two remedial reading intervention groups, i.e., the regular and computer-assisted groups in relation to each other. The development of these two experimental groups was then compared to the development of the mainstream group. The mainstream group was included in the study to assess the developmental variation in the acquisition of literacy skills in at-risk and not-at-risk children. Literacy scores for letter knowledge, reading accuracy, fluency, and spelling were obtained for all participants and included in the analyses.

Letter knowledge was measured on five successive occasions (screening test, Time 1, Time 2, Time 3 and Time 4). Development in letter knowledge was compared by means of a latent growth model within an SEM framework. These

analyses were performed with the Mplus statistical package (Version 5.1; Muthén & Muthén, 1998-2007). The estimation method was maximum likelihood with robust standard errors and chi-square test value MLR). The fit of the model was evaluated with a scaling-corrected (Δ) chi-square test (χ^2), CFI (comparative fit index), TLI (Tucker-Lewis index) RMSEA (root mean square error of approximation) and SRMR (standardized root mean square residual). The non-significant chi-square test results, values higher than .95 for the CFI and TLI and smaller than .06 for the RMSEA (Muthén, 1998-2004) indicate good fit of the model. The tested measurement models were compared via the Satorra-Bentler scaled difference chi-squared test (Satorra & Bentler, 1999). For other variables, which were measured on two successive occasions, repeated measures ANOVA was used to test whether each of the trained groups differed from each other and whether these groups differed from the Mainstream group. These analyses were performed separately using pairwise comparisons. Similarly, single measurements were tested using the t-test. Cohen's *d* (Cohen, 1988) was used in comparing the mean values of the difference scores to the standard deviation of the mainstream group in the pretest. The reliability sum scales were then calculated by Cronbach's alpha, where possible.

In Study II, the development of letter knowledge and reading accuracy were examined in the RRI, CARRI and Mainstream groups. The analyses were performed using the Mplus 5.1 program (Muthén & Muthén, 1998 – 2007). The method of estimation was the full information maximum likelihood with robust standard errors and adjusted chi-square test (MLR), both of which correct bias due to skewed distributions. The group of 116 mainstream students was used as the normative group (the Mainstream group) when building the reading accuracy model by means of the structural equation modeling technique. The intervention groups were dummy coded, forming two new variables regular remedial reading intervention (RRI; n = 25) and computer-assisted remedial reading intervention (CARRI; n = 25). The observed variables as well as latent factors were regressed on the dummy variables based on the large modification index and this procedure confirmed that the coefficient was statistically significant. These effects were the main effects of the regular and computer-assisted remedial reading intervention groups. To be able to test the paths between the intervention groups and the normative Mainstream group, the interaction variables were formed and tested in the same way as was done for main effects. A statistically significant coefficient indicates a difference between the Mainstream and intervention group. The equality of main or interaction effects between the intervention groups were tested using the Satorra-Bentler scaled difference chi-square test (Satorra & Bentler, 2001).

First, in the latent growth curve model letter knowledge was used to build a comprehensive model. Instead of the initial level and slope, the final level and slope were used to estimate the developmental features of letter knowledge. This was done for the following reasons: (1) to determine the effect of selection criterion on the development of the level achieved in letter knowledge, and (2) to control for achieved letter knowledge as a predictor of later reading. Second,

reading accuracy was predicted with the growth factors of letter knowledge and the goodness-of-fit of final model evaluated by χ^2, with a non-significant p-value indicating a good fit. The other fit indices used were the root mean square error of approximation (RMSEA) with values of 0.06 or less and a comparative fit index (CFI) and Tucker-Lewis Index (TLI) with values of 0.95 or above indicating a good fit (Muthén & Muthén, 1998–2004). ANOVA was used to test whether each of the trained groups differed from each other and whether these groups differed from the mainstream group. The analyses were performed separately using pairwise comparisons. Cohen's *d* (Cohen, 1988) was used in comparing the mean values of the difference scores to the standard deviation of the mainstream group in the pretest.

In Study III the development of reading fluency was assessed in the RRI, CARRI and Mainstream groups. Study III followed the same pattern as Study II except that, instead of letter knowledge and reading accuracy achievements, reading fluency was predicted. The goodness-of-fit of the final model was evaluated by using the χ^2 test, in which a non-significant p-value indicates a good fit. The other fit indices used were the root mean square error of approximation (RMSEA), with values of 0.06 or less, and a comparative fit index (CFI) and Tucker-Lewis Index (TLI) with values of 0.95 or above indicating a good fit (Muthén & Muthén, 1998–2004).

In sum, following by the ANOVA group-based difference analyses in Study I, Study II took a closer look at the development of letter knowledge and reading accuracy and Study III investigated reading fluency. The effects of early intervention on letter-sound knowledge and phonological skills on future reading fluency skills, was investigated in the Study III. This procedure breaks new ground in reading intervention research. Predictors of these reading sub-skills were studied by using latent growth models consisting of final level and slope. Moreover, pseudo individual profiles were applied to clarify the most suitable intervention that would assist children with specific compromised pre-reading profiles to attain proficient letter knowledge, reading accuracy and fluency skills.

3 AN OVERVIEW OF THE ORIGINAL STUDIES

3.1 Study I: Computer-assisted remedial reading intervention for school beginners at risk for reading disability

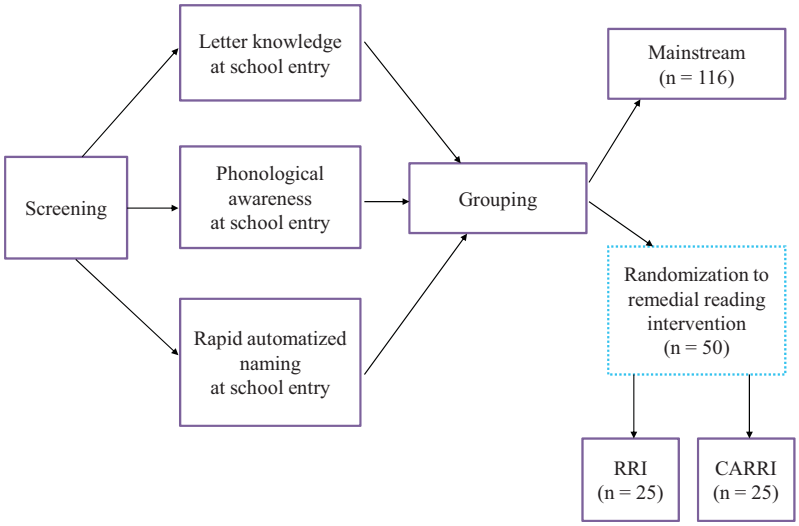
Based on the earlier research literature, it was hypothesized in Study I that the computer-assisted intervention (CARRI) would be a more powerful instrument in training the literacy skills of children at risk for reading disabilities than the RRI, due to the intensive individual-orientated learning environment with individualized repetition that it enables. In Study I, the benefits of a regular remedial reading intervention (RRI) and computer-assisted remedial reading intervention (CARRI) were scrutinized in school beginners with compromised pre-reading skills. The goal of the study was to investigate whether a research-based computer application designed for remedial reading training can enhance letter knowledge, reading accuracy, fluency and spelling among children with low pre-reading skills. Equally of interest were achievement levels: can children at risk for reading disabilities attain the level of mainstreamers? Figure 3 depicts the associations investigated.

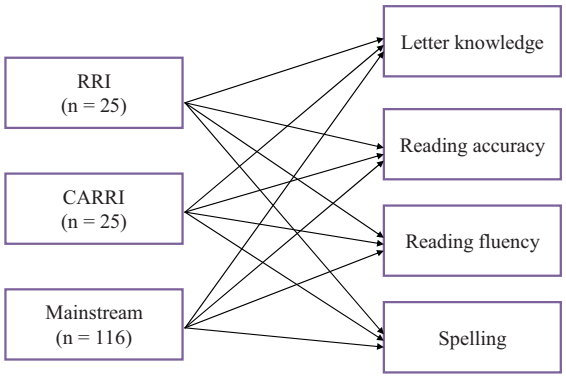
Results: The children in the computer-assisted remedial reading intervention group made gains during Grade 1 and continued to progress similarly in the follow-ups conducted 12 (Grade 2) and 16 months (Grade 3) after the intervention had ceased. The at-risk children in the RRI group also gained, but to lesser extent than the computer-assisted group. More specifically, the overall gains in the CARRI group were significant, not only in letter knowledge, decoding and accuracy, but also in fluency and spelling. Furthermore, the children in the CARRI group reached the average level of the mainstreamers, whereas similar achievements were not seen in the RRI group.

Key findings: (1) The results indicated that children at risk for developmental reading failure would benefit from a remedial reading intervention enriched with a computer application such as GraphoGame. (2) The remedial reading intervention enriched with GraphoGame seemed to reduce the risk of later RDs among at-risk children. (3) The reading and spelling attainment of such children

should nevertheless be carefully followed till Grade 3, to ensure that those who continue to lack success have acquired fluent reading and spelling skills. (4) Children still failing to succeed in reading and spelling should be provided with active, individually targeted reading support. (5) In general, the findings of the study were in line with earlier studies conducted in the field of computer-assisted remedial reading (e.g., Fawcett et al., 2001; Nicolson et al., 1999, 2000).

FIGURE 3 Depicts the associations investigated in Study I





Notes. RRI = Regular Reading Intervention, CARRI = Computer-assisted Remedial Reading, Mainstream= Mainstream Reading Group.

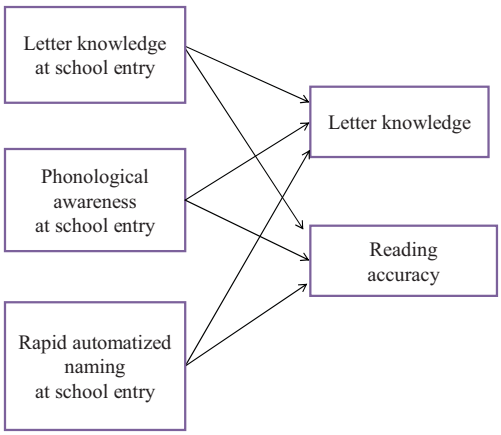
3.2 Study II: Long-term intervention effects for children with different profiles of compromised pre-reading skills

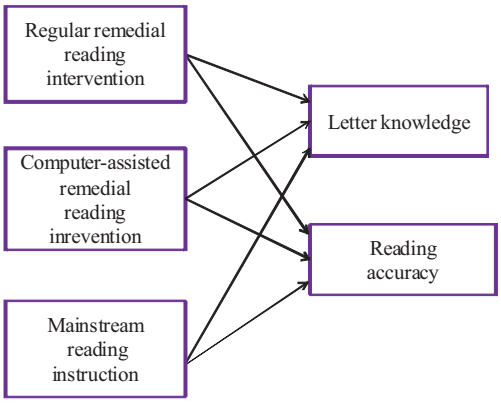
This study was conducted to learn more about what kinds of interventions produce the best results in the reading development of at-risk children, and about their responsivity to different types of treatment according to the characteristics of delayed development. The aim was first to build a model of the predictive values of the development of letter knowledge and reading accuracy. The second aim was to investigate to what extent two types of interventions can help children who show delayed development in areas known to be associated with compromised reading acquisition – phonological awareness, letter knowledge and slow automatized naming – assessed at school entry. Figure 4 depicts the associations investigated.

The participants of the present study were followed from school entry to Grade 3. The purpose was to identify the most effective types of intervention for children with different profiles of compromised pre-reading skills at school entry. Three pre-reading risk profiles were of interest: (1) children with low performance in all three core pre–reading skills of letter knowledge, phonological awareness and rapid automatized naming, (2) children with low performance in any two of the core pre-reading skills, and (3) children with low performance in one of the core pre-reading skill. These three profiles were chosen to analyze the relative strength of the possible associations between the three different reading groups (RRI, CARRI and Mainstream) regressing the final level and slope of letter knowledge and reading accuracy (in Grade 1 and Grade 3) on the core pre-reading skills (letter knowledge, phonological awareness and rapid automatized naming).

Letter knowledge. The latent growth model was used in analyzing letter knowledge development. The observed letter knowledge variables were standardized by using the means and standard deviations of the January measurement. This gave a meaningful reference point for interpreting the level of letter knowledge achieved during the intervention, since by the end of January Grade 1 the whole alphabet has typically been learnt in Finnish schools. Further, the latent growth model, consisting of the post intervention level of letter knowledge, and the two components final level and the slope, was estimated (for more details see Study II). The CARRI group began at a lower level than the RRI group in letter knowledge. Furthermore, both experimental groups were lower than the normative group (i.e., Mainstream group). In general, the results indicated that development in letter knowledge was more than two standard deviations faster in the intervention groups compared to the normative Mainstream group from August Grade 1 to January Grade 1, (i.e., at the time when basic reading skills are most typically learnt in Finnish schools). Presumably, this is due to the ceiling effect of letter knowledge in the Mainstream

FIGURE 4 Description of Study II





group (December, Grade 1). Notably, the Mainstream group knew approximately 21 out of the 29 letters in the Finnish alphabet at school entry. Based on the findings, it was obvious that the at-risk children acquired the letter knowledge needed for proficient reading faster in either of the treatment groups than if they received only mainstream instruction. However, 24% of the children in the RRI group reached the level of the Mainstream group in letter knowledge by the end of Janyary Grade 1; in contrast, 92% of the children in the CARRI group, i.e., 68% more than in the RRI group, reached the level of the mainstreamers. Cohen's *d* was 2.08 in favour of the CARRI group, which revealed a strong intervention effect (see Table 2).

Reading accuracy. After six months of schooling, in January Grade 1, both intervention groups remained at a markedly lower level than the typically developing children in the Mainstream group. Children who at the beginning of Grade 1, were at acknowledged risk for reading failure, had not by that measurement point (January Grade 1), developed the requisite skills for reading accuracy. Thus, they had an obvious need for proactive and intensive remedial reading training. Reading accuracy observed in August Grade 3 was predicted to the same extent by pre-intervention letter knowledge in all three groups. Furthermore, reading accuracy was substantially predicted by phonological awareness only in the RRI group. Notably, reading accuracy measured at the mid-point of Grade 1 in January no longer predicted reading accuracy in the Grade 3 measurement. In reading accuracy 76% of the children in the RRI group and 92% of the children in the CARRI group reached the level of the Mainstream group. This finding revealed that even most at-risk children learn to read fairly accurately in the Finnish orthography during Grade 1. Nevertheless, 16% more of the children in the CARRI group reached the level of the mainstreamers, indicating that the remedial reading intervention enriched with the GraphoGame computer application was more effective than regular remedial reading support. Correspondingly, Cohen's *d* was 1.07 in favour of the CARRI group, indicating a large effect (see Table 2).

Conclusion: the results showed differences in the effectiveness of the different types of intervention for children with different profiles of compromised pre-reading skills. The results revealed first, that the pre-intervention level of phonological awareness predicted the development of the letter knowledge differently in the three groups, with the computer-assisted group showing the most enhanced letter knowledge development. Moreover, children receiving the computer-assisted remedial reading (CARRI) intervention had a better chance to achieve the level of the Mainstream group in letter knowledge than those receiving the more regular type of intervention. Placement in the CARRI group resulted in faster reading development than placement in either of the other two groups. The computer-assisted intervention during Grade 1 predicted the fastest development in both letter knowledge and reading accuracy until Grade 3. The computer-assisted intervention clearly yielded the best results independent of the initial level or combination of deficits in the three core pre-

reading skills. Thus at-risk children with a combination of compromised pre-reading skills would also profit from computer-assisted remedial reading training. Children who had low letter knowledge and/or slow automatized naming skills would in particular benefit from computer-assisted remedial reading training. In the long term, mainstream instruction would not sufficiently support at-risk children

TABLE 2 Effect sizes for intervention attainment measures of letter knowledge, reading accuracy, reading fluency and spelling in three groups (N = 166)

Measures	CARRI versus RRI *d*	RRI versus Mainstream *d*	CARRI versus Mainstream *d*
Letter- knowledge:[1,2]			
Subtest I – Screening	0.32*	0.57**	0.89***
Subtest II – Subtest I	0.13	0.58**	0.71**
Subtest III – Subtest II	-0.05	0.58**	0.53**
Subtest IV – Subtest III	-0.24	0.59**	0.35*
Subtest IV	2.08***	-1.77	0.30*
Reading Accuracy:[1,2]			
Subtest III	0.23*	-1.69	-1.46
Follow-up II	1.07***	-0.82	0.25*
Reading Fluency:[1,3]			
Follow-up I – Post test	0.22*	0.36*	0.57**
Follow-up I	1.01***	-1.31	-0.30
Spelling:[1]			
Follow-up I – Post test	0.90***	-0.80	1.70***
Follow-up II	1.68***	-1.88	-0.20

Notes. RRI = Regular Reading Intervention, CARRI = Computer-assisted Remedial Reading, Mainstream = Mainstream reading group; *Cohen's *d* 0.1-0.4 small effect; **Cohen's *d* 0.5-0.7 medium effect; ***Cohen's *d* 0.8 > large effect; [1] Study I, [2] Study II; [3] Study III.

who have low phonological awareness in the beginning of the school. However, if an at-risk child had average phonological awareness, regardless of the level of letter knowledge and rapid automatized naming, mainstream instruction would support that child's reading development children better than the RRI group.

Key findings: (1) Children in the computer-assisted remedial reading intervention (CARRI) not only reached the average level of the mainstreamers but surpassed the latter in both letter knowledge (March, Grade 1) and reading accuracy (in Grade 3). The results revealed that the regular remedial reading

group (RRI) was not enough, which sharpens the findings of earlier studies (e.g., Bentum & Aaron, 2003; Hatcher et al., 2004; Torgesen, 2005). (2) Letter knowledge, phonological awareness and rapid automatized naming were indicated to be valuable tools in evaluating pre-reading skills of school beginners. (3) School entrance assessments should be regarded as valuable predictors of future letter knowledge and reading accuracy outcomes. Screenings or school entrance assessments can help class teachers, remedial reading specialists (i.e., special educators) and school psychologist to decide which students require remedial reading training, and more distinctively what kind of remedial practices are likely to support an individual child with specific pre-reading profiles. Furthermore, individual risk profiles based on core pre-reading skills may provide valuable knowledge both about children's future reading development, and about where remedial reading intervention resources can most efficiently be applied. (4) School beginners, at risk for reading failure, benefited from a remedial reading intervention that was enriched with computer-assisted reading training application, GraphoGame. Drilling in the computer-controlled learning environment, 15-min at a time was required to boost the acquisition of letter knowledge and reading accuracy.

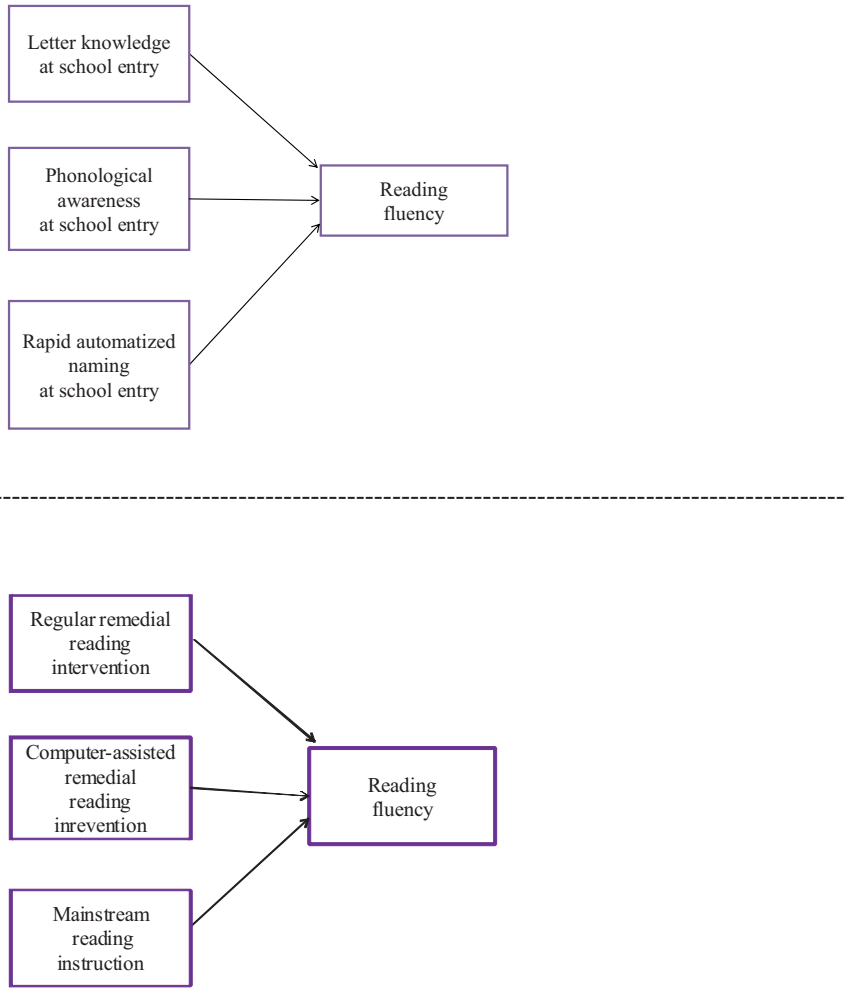
3.3 Study III: Predicting word-level reading fluency outcomes in three contrastive groups: a remedial and a computer-assisted remedial reading intervention, and mainstream instruction

Study III investigated what effects early intervention in letter knowledge and phonological skills has on future reading fluency skills. The main goal of the study was to build a model of the predictive value of reading fluency in three contrastive groups whose reading acquisition has been supported differently, that is, via participation in a regular remedial reading intervention (RRI), or in a computer-assisted remedial reading intervention (CARRI) or in Mainstream instruction. A second aim was to identify the most effective types of intervention for children with different profiles of compromised pre-reading skills at school entry. For this purpose, reading fluency outcomes were assessed in the three contrastive reading groups described above. More specifically, the outcomes of two reading interventions implemented in Grade 1 were observed and contrasted to the progress of a Mainstream group, to find out whether a reading intervention targeted at phonological awareness and letter-sound connections would later on have an impact on reading fluency.

The participants of the present study were followed from school entry to the end of Grade 2. This was done to identify the most effective types of intervention for children with different profiles of compromised pre-reading skills at school entry. Three types of pre-reading risk profiles were of interest: (1) children with low performance in the three core pre–reading skills of letter knowledge, phonological awareness and rapid automatized naming, (2) children

with low performance in any two of the core pre-reading skills, and (3) children with low performance in one of the core pre-reading skills. These three profiles were chosen to analyze the relative strength of the possible associations between the three different reading groups regressing the final level and slope of letter knowledge and fluency (Grade 1 and Grade 2) on the core pre-reading skills (letter knowledge, phonological awareness and rapid automatized naming). Figure 5 depicts the associations investigated.

FIGURE 5 Description of Study III



In reading fluency, high letter knowledge at the midpoint of Grade 1 (i.e., January, Grade 1) predicted fluent reading in May Grade 1. Furthermore, a high

phonological awareness measured at school entry predicted fluent reading in all three contrastive research groups in May Grade 1. Instead, slow automatized naming at school entry predicted fluent reading in the CARRI group in May Grade 1. Some may interpret this finding as exceptional, as rapid automatized naming has been seen as a valuable predictor for reading fluency in the Finnish language context (see e.g., Torppa et al., 2007) as well as in other languages (see e.g., de Jong & van der Leij, 1999; Liao, Georgiou, & Parrila, 2008; Wimmer, Mayringer, & Landerl, 2000). However, the findings of a recent study undertaken by Ziegler et al. (2010) on five European languages revealed that rapid automatized naming may not be as strong a predictor of reading fluency outcomes as hitherto thought.

Moreover, high phonological awareness at school entry, high letter knowledge measured in Grade 1 (January), and a small change in letter knowledge predicted good reading fluency outcomes in all groups, in May Grade 1. However, it seemed that some at-risk children in the RRI group were rather stable in reading fluency from Grade 1 till the end of Grade 2. More specifically, their reading fluency skills did not develop from Grade 1 to Grade 2. The reading fluency scores were 56% for the RRI group and 88% for the CARRI group. This revealed the difference of 32% in favour of the CARRI group. The effect size in turn was *d* 1.01 in favour of the CARRI group (see Table 2), indicating a large effect.

Conclusion: the results revealed that the computer-assisted reading intervention (CARRI) was the most effective of the three methods used, and caused permanent improvements in the reading fluency of the children at risk for reading failure. It may be that children with phonological insensitivity do not receive sufficient amounts of repetition, drill and practice via the regular type of intervention. At-risk children seem to need intensive and focused letter-sound training to help them to read fluently. The children in the CARRI group received more stimulation in this key area and therefore showed a higher level of achievement than the others. The computer-assisted remedial reading training seemed successfully tackle basic reading skills at the roots level, which in turn seemed also to influence the future development of reading fluency. The children in the CARRI group, presumably received more systematic remedial training, and therefore reached the level of the Mainstream group by the end of Grade 2. It was somewhat alarming that the RRI group did not boost the reading fluency outcomes of at-risk children any better than the mainstream approach. This confirmed the findings of earlier studies (e.g., Bentum & Aaron, 2003; Hatcher et al., 2004; Torgesen, 2005), which have documented that the existing remedial programs are not effective enough.

Key findings: (1) If risk for RDs was identified, it was possible to avoid the compromised development of reading skills, including fluency. (2) School entrance assessments should be regarded as valuable predictors of future reading fluency outcomes. Screening or school entrance assessments can help class teachers, remedial reading specialists (i.e., special educators) and school psychologist to decide which students require remedial reading training, and more

distinctively what kind of remedial practices are likely to support an individual child with specific pre-reading profiles. Furthermore, individual risk profiles based on core pre-reading skills may provide valuable knowledge both about children's future reading development, and about where remedial reading intervention resources can most efficiently be applied. (3) Children in the computer-assisted remedial reading intervention (CARRI) reached the average level of the mainstreamers by the end of Grade 2. On the other hand, results revealed that the reading fluency performance in the regular remedial reading group (RRI) was stable and that the at-risk children in the RRI group did not develop in reading fluency from Grade 1 till the end of Grade 2. (4) School beginners, at risk for reading failure, benefited from a remedial reading intervention that was enriched with computer-assisted reading training GraphoGame. Drilling in the computer-controlled learning environment, 15-min at the time was required to boost the acquisition of the reading fluency skills. In sum, computer-assisted intervention programs such as GraphoGame are important instruments in the remedial teaching of children at risk for reading failure and, furthermore in contributing to successful and cost-effective remedial practices.

4 GENERAL DISCUSSION

The present thesis focused on literacy intervention for children at risk for reading disabilities and their non-at risk peers in a longitudinal setting. The study was designed to contribute to understanding of the intervention conditions that need to be in place to prevent reading disabilities in at-risk children. The lowest 30% (the lower tail) of the children in school entrance assessments were randomly assigned into one of two intervention groups while the rest of the children formed the Mainstream group. The reading and spelling achievement of these children were followed in a longitudinal setting from school entry to Grade 3. Further, three well-known predictors – letter knowledge, phonological awareness and rapid automatized naming – were used to predict the future reading performance of these children.

The present thesis was an attempt: (1) to predict the reading development of at-risk children under conditions that they are supported by regular remedial teaching or with intervention which uses a computer-based learning game to drill and practice intensively the core pre-reading skills needed for learning to read, and (2) to assess the short and long-term intervention outcomes in three contrastive reading groups: a regular type of remedial reading intervention (RRI) and a computer-assisted (CARRI), and Mainstream instruction. Moreover, a wide variety of normative reading and spelling skill measurements were used to study the achievements of these three groups. In addition the aim was to design research-based peer-reviewed remedial reading practice in the context of Finnish special education.

The results indicated that children at risk for developmental reading failure would benefit from remedial reading intervention that was enriched with the computer application such as GraphoGame. Moreover, remedial reading enriched with GraphoGame seemed to reduce the risk of later RDs, whereas the regular remedial reading intervention was less successful. At-risk children with a combination of compromised pre-reading skills would also greatly profit from computer-assisted remedial reading training. In particular, children who had

low letter knowledge and/or slow automatized naming skills would benefit considerably from such training.

While it has been widely reported that the regular type of remedial reading training is often ineffective (e.g., Bentum & Aaron, 2003; Hatcher et al., 2004; Kennedy, Birman, & Demaline, 1986; Moody et al., 2000; Puma et al., 1997; Snow et al., 1998; Torgesen, 2005), studies comparing different intervention methods and technologies are scarce (for an exception see e.g., Torgesen et al., 1999; Hatcher et al., 2006). The first peer-reviewed intervention study training phonological skills in the Finnish context was the study conducted by Korkman and Peltomaa (1993) over fifteen years ago. The focus of their study was on children with speech and language delays in kindergarten and therefore not comparable with the present research program. In the Finnish special educational context intervention studies have continued to remain virtually non-existent. The sole experiment undertaken in this context and reported in a peer-reviewed scientific journal is the Turku study conducted by a research team led by Professors Niemi and Vauras (for reviews see e.g., Niemi, Poskiparta, Vauras, & Mäki, 1998; Poskiparta et al., 1999) over a decade ago. The Niemi and Vauras study used pair-wised matched controls, while a randomly controlled trial was used in the present study. The Niemi and Vauras group studied the achievements of 26 at-risk children receiving training in linguistic awareness, 11 at-risk receiving training by normal special educational methods (i.e., regular remedial reading intervention) and 15 at-risk children receiving general classroom education (i.e., mainstream approach). There is thus a serious shortage of research-based and peer-reviewed intervention programs in Finland that are capable of reducing risks for RDs. The research database of peer-reviewed intervention studies has been meager in Finland. The present study was an attempt to bridge the existing research based knowledge of good remedial reading practices to the Finnish resource room contexts.

Although computer-assisted instruction (CAI) has arrived in the area of reading intervention, longitudinal intervention studies with follow-ups that include both an experimental and control condition along with a mainstream condition are very few (for an exception see Regtvoort & van der Leij, 2007). Moreover, random assignment has not been much favored in remedial reading intervention research. According to Seethaler and Fuchs (2005) randomized controlled trials are "a drop in the bucket" in the field of reading intervention, although such trials are particularly suitable in areas where well-developed theoretical and empirical support exists for a particular intervention. Random assignment designs also seem to provide the best evidence for the effectiveness of an intervention (see e.g., Harrington, Cartwright-Hatton, & Stein, 2002; Torgerson & Torgerson 2001). Moreover, the present study was conducted in real-word relevance as a part of primary school reading program and the participants were an unselected group of school beginners from a randomly selected school district. Consequently, the thesis represents additions to the research literature that draw on longitudinal data covering predictors of literacy skills, literacy skill development and computer-assisted remedial reading intervention.

The aim of the present experiment was to gather empirical data on at-risk children and their non-at-risk peers in a natural school environment. In the data-analysis, an attempt was made to address the complex development of literacy skills and how these can be predicted by pre-reading skills (i.e., letter knowledge, phonological awareness and rapid automatized naming) measured at school entry. As the traditional statistical research tools – focusing on group averages and variances – do not always provide the best fit with developmental research questions and phenomena (Torppa, 2007), a wide selection of measures of at-risk children and their non-at-risk peers were included in the present studies (for an overview see Studies I-III). Special effort was invested in isolating the best fitting analytical strategies for each research question. This led to the wide use of statistical modeling.

4.1 The predictors of literacy sub-skill development

Overall, the findings of the thesis were in line with the previous research revealing that low pre-reading skills, that is, phonological awareness, letter knowledge (e.g., Byrne, 1998; Gallagher et al., 2000; Elbro et al., 1998; Elbro & Petersen, 2004; Hatcher et al., 2004; Lonigan et al., 2000; Lyon et al., 2003; Lyytinen et al., 2004; Scarborough, 1990, 1998, 2001; Share, 2008; Snow et al., 1998; Snowling et al., 2003; Stanovich & Siegel, 1994; Vellutino et al., 2004; Wagner, Torgesen, & Rashotte, 1994) and slow serial naming (see e.g., Badian, 1993; de Jong & van der Leij, 1999; DiFilippo et al., 2006; Kirby et al., 2003; Parrila et al., 2004; Wimmer et al., 1998, 2000; Wimmer & Mayringer, 2002) at school entrance, are valuable predictors of reading disabilities. The associations between pre-reading skills and reading achievement seemed to be strong. Children with acknowledged risk for reading failure gathered reading sub-skills more slowly than their normally developed peers.

More specifically, reading sub-skills (i.e., letter knowledge, reading accuracy and fluency) seemed to be predicted by pre-reading skills measured at the time of school entry, which is in line with previous findings (see e.g., Bradley & Bryant, 1985; Bryant & Bradley, 1983; Catts, Fey, Zhang, & Tomblin, 2001; de Jong & van der Leij, 1999; Elbro & Petersen, 2004; Goswami & Bryant, 1992; Hatcher et al., 2006; Hulme, Snowling, Caravolas, & Carroll, 2005; McCormick, 1999; Torgesen & Wagner, 1994). The analyses underlined the complex interaction both between pre-reading skills and between the achieved literacy skills. The thesis supports the findings of earlier studies conducted in the Finnish language environment that phonological awareness and letter knowledge are predictors of future reading achievement (see e.g., Holopainen et al., 2000; Lepola, Vauras, & Mäki, 2000; Lerkkanen et al., 2004a; Lerkkanen et al., 2004b; Leppänen, 2006; Lyytinen et al., 2006; Poskiparta et al., 1999; Puolakanaho et al., 2003, 2008; Torppa et al., 2007). Instead, rapid automatized naming seemed not to affect reading fluency in the data of the present study as strongly as reported by Torppa et al. (2007).

Moreover, the computer-assisted remedial reading training turned out to be a powerful tool for training phonological skills, letter-sound connections and decoding in children at risk for reading failure, which is in line with earlier findings in the area of computer-assisted reading intervention (e.g., Fawcett et al., 2001; Magnan & Ecalle, 2006; Nicolson et al., 1999, 2000). The findings of the present thesis revealed that early intervention based on the alphabetic principle, phonological skills, letter-sound connections and decoding can help close the gap between children who struggle to learn to read and those who learn to read easily. This is consistent with the findings of Blachman (2000), Ehri, Nunes, Willows, Schuster, Yaghoub-Zadeh and Shanahan (2001), Liberman and Liberman (1990) and Vellutino (1991).

4.2 The benefits and pitfalls of two comparative interventions

The present study utilized randomly assigned intervention groups and focused on group level differences in reading and spelling attainment. The only difference between the intervention groups was the training used during the first 15-min of each remedial session. Brooks (2007) has suggested that intervention needs to be ”little and often” and time must be allowed for reinforcement. According to him 20-min of phonics intervention per day is recommendable. For example, in a US study undertaken by Torgesen, Wagner, Rashotte, Rose, Lindamood, Conway et al. (1999) the reading intervention was implemented 20-min a day, 4 days a week over a period of 2 years. In the present study 15-min of phonics-based computer-assisted intervention in parallel with 30-min of regular remedial practice 4 times a week for 7 months, was enough to produce significant group level differences in children at-risk for reading failure. In contrast to the present study, Torgesen et al. (1999) investigated the relative effectiveness of three different instructional approaches to prevent reading disabilities in young children. As in the present study, their study was designed to contribute to understanding of the instructional conditions that need to be in place to prevent reading disabilities in at-risk children. In the study by Torgesen et al. (1999), at-risk children received 88 hrs of one-on-one instruction from the second semester of kindergarten till the end of the second grade. Children were randomly designed to one of four conditions: (1) non-treatment, (2) regular classroom support, (3) embedded phonics, and (4) phonological awareness and synthetic phonics. The findings indicated that the phonological awareness and synthetic phonics condition was the most effective as it was the only regimen that produced reliable effects on word-level reading.

In the present study the benefits of a regular remedial reading intervention (RRI) and a computer-assisted remedial reading intervention (CARRI) were scrutinized in school beginners with compromised pre-reading skills. A Mainstream group was included in the study along with the remedial groups to reflect developmental variations. It was expected that at-risk children would acquire letter knowledge, reading accuracy, fluency and spelling slower than their

non-at-risk peers, and would be able to reach the level of the Mainstream group with a sufficient amount of remedial reading intervention that was enriched with the computer application GraphoGame.

The main focus was on letter knowledge, reading accuracy, fluency and spelling development. More specifically, the progress of the two remedial reading groups, RRI and CARRI, were contrasted to the progress of the mainstreamers. Six assessments along with two follow-ups were included to determine changes in reading and spelling abilities. In addition effect sizes were calculated in order to assess the effectiveness of the intervention programs. The effect size estimation revealed that the CARRI group was the most beneficial in supporting at-risk children.

First of all, the computer-assisted remedial reading intervention proved to be beneficial in the acquisition of letter-sound association. This is in accordance with the findings of Elbro and Petersen (2004), who argued that training letter-sound connections may also activate phonological skills. Furthermore, there was also consistency with the findings of Hatcher et al. (2004), who argued that children at risk for reading failure may benefit from additional training in phoneme awareness linked to letter-sounds. Similarly, in the meta-analysis by Bus and van Ijzendoorn (1999) programs combining phonological and letter training were more effective than purely phonological training.

In the present study both remedial reading groups received additional training in phoneme awareness that was linked to letter-names and letter-sounds. However, training letter-sound correspondence with the GraphoGame application proved to be beneficial to the children at risk for reading failure. This was most likely due to intensive training in letter-sound correspondences, phonology and decoding in the individually adjusted computer-assisted environment during the first 15-min of each remedial lesson. The intervention in the RRI group may also be consistent with the findings of Hatcher et al. (2004) and Bus and van Ijzendoorn (1999). However, the level of achievement of the RRI group was not as high as in the CARRI group. It can be assumed that the children in the CARRI group received more focused and intensive drilling in the computer-assisted environment than the children in the RRI group in the regular remedial environment. This finding in the CARRI group is consistent with the finding by Beech, Pedley and Barlow (1994). In their experiment a group of children who followed the computer tracing of letters and named the letters seemed to make better progress than children instructed in a more regular remedial environment. Magnan, Ecalle, Veuillett and Collet (2004) in turn suggested that phonological representations can be specified by training involving both phonological and orthographic units; this suggestion is borne out by the findings of the present thesis.

In the present study, seven months was required for the CARRI group to reach the ceiling level of letter knowledge, i.e., all 29 letters of the Finnish alphabet, while the children in the mainstream group already knew 21 letters at school entry. In other words, the at-risk children needed more time to acquire letter-names and letter-sound connections than children who did not have de-

lays in phonological awareness or in letter-naming skills at school entry. These findings may well confirm the claim of Lyytinen et al. (2007) that children who do not acquire reading skills as expected during early school instruction need greater and more intensive exposure for learning letter names and letter-sounds, and also more training in phonemic awareness, and decoding in enjoyable practicing context (e.g., with computer-assisted GraphoGame). The study by Torgesen (2005) demonstrated that at-risk children require a more individualized approach. Moreover, it may be typical that at-risk children require more training and practice to reach the level of mainstreamers (see e.g., Thompson, 1984; Torgesen, 2005). The present study supported the findings of Thompson (1984) and Torgesen (2005).

Second, both remedial groups lagged behind the mainstreamers in the decoding and accuracy tasks in the mid-term of Grade 1 (i.e., January). However, when the reading accuracy test in Grade 3 was carried out the CARRI group outperformed both groups. Likewise, in the study conducted by Elbro and Petersen (2004) the long-term training effects on reading were manifested in the follow-ups. Based on these findings it can be concluded that children with low pre-reading skills require more time for learning to decode than their not-at-risk peers with well developed phonological awareness and letter knowledge. However, in the CARRI group, with the appropriate early intervention, the achievement level was maintained and progress steady and cumulative after the intervention ceased.

Third, there were clear delays in the acquisition of reading fluency as well as in decoding and accuracy skills. After nine months training (in May Grade 1) both experimental groups had gained, but were still behind the mainstreamers. However, within a year the CARRI group achieved the level of the mainstream group. An equal achievement span was not seen in the performance of the RRI group. The gradual gains during the follow-ups testify to the fact that children at-risk for RDs can reach the level of mainstreamers. However, they require more training and practice than children with adequate reading skills. The findings presented here favor the GraphoGame intervention. These findings are particularly significant in the area of fluency, and moreover consistent with those reported in the study undertaken by Wise et al. (1999).

Fourth, the CARRI group had reached the level of the mainstreamers in spelling skills by Grade 3, whereas similar progress was not seen among the children in the RRI group. Interestingly, the GraphoGame computer application also affected the spelling outcomes. This may confirm the findings of Ehri and McCormick (1998) that reading and spelling develop parallel or even reciprocally. Earlier studies in the Finnish context have also produced similar findings (see e.g., Lerkkanen et al., 2004a; Puolakanaho et al., 2007). In general, the gains made by the CARRI group were progressive in both reading and spelling; however, the development of these skills was delayed in these children compared to the non-at-risk children.

In the study undertaken by Torgesen et al. (1999) neither the group receiving regular classroom support nor the embedded phonics group showed

growth in word-level reading skills that was reliably different from that of the children in the non-treatment condition. This finding is in accordance with the findings of the present study. Moreover, Torgesen et al. (1999) argued that one-on-one instruction may not have a significant impact on the word-level reading of at-risk children unless it is very explicit and includes phonemic-awareness and phonemic decoding training. The present study indicated that one-on-one instruction or intervention is not needed if computer-assisted training constitutes part of the remedial reading training. In addition to phonemic-awareness and phonemic decoding training, letter name and letter-sound connection training was also required to for the at-risk children to reach the level of the mainstreamers in the present study. Based on the present study, if computer-assisted remedial reading training formed part of the resource room activities in Grade 1, at-risk children could become skillful readers by the beginning of Grade 3.

The present thesis raised a number of issues relevant to development of reading skills, such as the extent to which phonological skills should be trained simultaneously with letter-sound connections, and to what extent phonology and reading need to be made explicit in the teaching of reading. Notice should be taken of the extent to which children differ in the ease with which they acquire decoding. As well as differing in their ability to acquire decoding skill children may also differ in their propensity and ability to acquire accuracy and fluency, and spelling. Furthermore, research should consider the extent to which reading and spelling should be taught simultaneously, at least in transparent orthographies.

It is apparent that individual differences also exist in reading accuracy and fluency development. However, a focus on decoding alone may not be sufficient to ensure that at-risk children have comparable reading skills. It seemed that an intensive and individual training was required for at-risk children to become adequate readers in the Finnish language context. Moreover, an integrated package of reading and phonological training in the computer-assisted environment seemed to improve both reading and spelling skills. Thus, these findings confirmed the phonological linkage hypothesis of Hatcher et al. (1994), revealing that combining phonological awareness training with instruction in letter-sound knowledge has more powerful effects on subsequent literacy achievement than phonological awareness training alone.

The technology used in the CARRI group is familiar to today's children via the wide variety of PC and video game consoles on the market. The magnitude of the gains achieved in the CARRI group makes the present remedial reading intervention educationally significant. In the present thesis, the long follow-up period along with steady and cumulative results indicated educational effectiveness and long-term effects. In line with a number of earlier studies, computer-assisted reading instruction and intervention have been considered to be both an educationally and economically efficient way of training early literacy skills (see e.g., Fawcett et al., 1999; Nicolson et al., 1999, 2000), which is also in line with the present thesis. In previous computer–assisted intervention studies, such as Nicolson et al. (1999, 2000) some children appeared not to profit as

much as others. In similar vein, about 13% of the children investigated in the present thesis needed remedial reading support in Grade 2. However, only two children in the CARRI group were among those requiring continuous reading intervention. These results are consistent with the suggestions and findings of the Response to Intervention (henceforth RTI) model (see e.g., Burns & Coolong-Chaffin, 2006; Fletcher et al., 2007; Fuchs & Fuchs, 2006) used commonly in the US. Moreover, the findings revealed, that remedial practices should be based on research-based methods that use assessment data to identify and respond to student needs.

Key findings of the group comparisons: (1) at-risk children may well reach the level of mainstreamers with an adequate individually adjusted remedial reading program that is enriched with a computer application such as GraphoGame. (2) A training duration of 15-min four times a week for 28 weeks was required to treat the at-risk children. (3) At-risk children need a clearly structured research-based training schedule, as well as intensive drill and practice to acquire the pivotal reading and spelling skills within the remedial reading intervention. Thus, the CARRI approach (i.e., regular remedial reading program enriched with the computer application GraphoGame) proved to be a feasible learning environment to gather the core reading sub-skills required for proficient reading. (4) The merely regular type of remedial intervention (i.e., that used in the RRI group) was not sufficient enough. (5) Children in the computer-assisted remedial reading intervention (CARRI) had reached the average level of the mainstreamers by the end of Grade 2 in reading fluency, and moreover surpassed the average level of the Mainstream group in letter knowledge in March Grade 1 and in reading accuracy by August Grade 3, while similar achievements were not seen in the RRI group. (6) Most importantly, the children in the CARRI group made gains during the study and continued to progress steadily in the follow-ups conducted 12 and 16 months after the intervention had ceased, which argues for the long-term effects of steady and cumulative progress in the primary literacy skills. This was also consistent with the findings of Elbro and Petersen (2004), who reported that the training effects on reading were also manifested in the follow-up tests. Similarly, in the study undertaken by Hatcher, Goetz, Snowling, Hulme, Gibbs, & Smith (2006) it was found that children receiving intervention made significant gains in reading and spelling that were maintained at follow-up. In sum, an important benefit of the present study was that it was conducted in the real school context, following procedures which can be easily applied as such to any Finnish school.

4.3 The predictors of reading achievement

The other central aim of the thesis was to build a model of the development of letter knowledge and reading accuracy (Study II), and reading fluency (Study III). Pre-intervention letter knowledge, phonological awareness and rapid automatized naming were used as predictors in all three contrastive reading

groups. The aim was to offer answers to the most typical questions educational psychologists face which intervention would be most suitable for an individual child they have assessed. At school entry, the mean delay of both intervention groups was -1.86 standard deviations behind the Mainstream group in phonological awareness (the Mainstream group served as a comparison group in the present study). In letter knowledge, measured at school entry, the RRI and CARRI groups were -2.56 and -2.51 standard deviations below the Mainstream group. In contrast to phonological awareness and letter knowledge the RRI and CARRI groups were 1.28 and 1.70 standard deviations above (meaning slower) the Mainstream group in rapid automatized naming.

4.3.1 Letter knowledge

The results revealed first that rapid automatized naming and phonological awareness predicted letter knowledge development. Second, development in the CARRI and RRI groups was faster than in the Mainstream group. However, development in the CARRI group was faster than in the RRI group. Third, the at-risk children showed the greatest benefit from the computerized letter-sound connection drilling during first two months of the intervention. In other words, it can be concluded that computer-assisted letter-sound connection training in at-risk children should start immediately at school entry. Similarly, Beech et al. (1994) advocated early training in letter-sound relations. Fourth, to start a proactive intervention, early screening tests are required in core pre-reading skills (i.e., letter knowledge, phonological awareness and rapid automatized naming) to identify those in need of remedial intervention. This is in line with the findings and suggestions reported by Burns and Coolong-Chaffin (2006), Fletcher et al. (2007) and Fuchs and Fuchs (2006). Well-designed intervention programs are based on scientific theories and recent knowledge of effective remedial practices. In the present study, the best chance of success for at-risk children seemed to be offered by the computer-assisted remedial reading intervention enriched with the GraphoGame application.

4.3.2 Reading accuracy

Based on the latent growth model, phonological awareness predicted reading accuracy most clearly in Grade 1, especially among normally developed children, but was a less successive predictor in the experimental groups. The children who were at acknowledged risk for reading failure in the beginning of Grade 1 seemed to develop slower than those in the Mainstream group in reading accuracy during Grade 1. However, during the first two years of schooling, at-risk children who received computer-assisted remediation reached the level of mainstreamers. This finding revealed that, independent of their risk profile at the beginning of Grade 1, children at risk for reading failure benefited from the computer-assisted remedial reading training.

In the Finnish language context, studies among normally developed children have found that reading accuracy skills are usually achieved during

Grade 1 (see e.g., Holopainen et al., 2001; Lerkkanen et al., 2004a). Moreover, differences between pre-readers and children learning to read during Grade 1 have tended to narrow later on (see e.g., Aunola, Nurmi, Niemi, Lerkkanen, & Rasku-Puttonen, 2002; Leppänen, 2006). According to Aunola, Leskinen, Onatsu-Arvilommi and Nurmi (2002) obvious was that initially poor readers caught up with others. Intervention studies on at-risk children and their long-term reading achievements were, until recently largely absent in the Finnish language context. However, the reading development of at-risk children has over the past few years been studied by Lerkkanen et al. (2010) and Torppa et al. (2006, 2007). Lerkkanen et al. (2010) found that the children in the at-risk group developed in their reading and writing skills and slightly caught up with the middle sub-group but did not reach the actual level of the middle sub-group. The studies Torppa et al. (2006, 2007) revealed that the at-risk children performed more poorly than the control children on most of the language and literacy skills assessed, starting with very early vocabulary development. Moreover, their letter knowledge development was delayed, and they were overrepresented in the sub-group of slow readers.

4.3.3 Reading fluency

Reading fluency in the Grade 1 measurement was predicted by the final level and slope of letter knowledge, phonological awareness and rapid automatized naming in all three contrastive research groups. In the present study, naming speed had only a slight effect on reading fluency via letter knowledge, which is a novel finding and in line with the results of Ziegler et al. (2010) who found, among five European languages, that rapid automatized naming is only a weak component in predicting reading outcomes. However, this finding requires further assessment. As there are also contrary findings to those presented in here (see e.g., Torppa et al., 2007).

Children who were at acknowledged risk for reading failure in the beginning of Grade 1 seemed to develop slower than the Mainstream group in reading fluency during Grade 1. Despite this, the CARRI group acquired fluency skills nearly a standard deviation ahead of the RRI group. This finding revealed that children at risk for reading failure, independent of their risk profiles at school entry, benefited from the computer-assisted remedial reading training.

A year after the first fluency measurement in May Grade 2, reading fluency was predicted by reading fluency in May Grade 1, revealing high stability in achievement. In the CARRI group high phonological awareness (at school entry, Grade 1), predicted better reading fluency in the Grade 2 measurement. It is noteworthy that the CARRI group caught up with the Mainstream group in reading fluency during Grade 2. From Grade 1 to Grade 2 the gap between the two experimental groups seemed accelerate rapidly, which is in line with the findings of Foorman, Schatschneider, Eakin, Fletcher, Moats and Francis (2006), who found that the gap between good and poor readers grows rapidly during the first school years. The earlier findings for normally developed Finnish school beginners (see e.g., Aunola et al., 2002; Leppänen, Niemi, Aunola, &

Nurmi, 2006; Lerkkanen et al, 2004a) do not support this phenomenon, which is known as a cumulative trajectory or the ”Matthew effect” in the research literature (Stanovich, 1986). However, intervention studies among at-risk children hardly exist in the Finnish language context.

In the present study, it seemed that some at-risk children in the RRI group were rather stable in reading fluency from Grade 1 till the end of Grade 2. In other words their reading fluency skills did not develop from Grade 1 to Grade 2. Based on the present study, while the gap between good and poor readers may grow fast, the reading performance of poor readers does not seem worsen. Therefore, the cumulative trajectory was not proven. Instead, this may support earlier findings in the Finnish orthographic context claim that nearly all children learn to decode accurately during Grade 1 (see e.g., Holopainen et al., 2001; Lerkkanen et al., 2004a), and further that after Grade 1 it is the speed of reading, rather than reading accuracy that results in individual differences in literacy development (Aro, Tolvanen, Poikkeus, & Lyytinen, 2006). Similarly, the study undertaken by Seymour et al. (2003) in 14 European countries revealed that reading accuracy seems to reach a ceiling very quickly in transparent orthographies, leaving reading speed as the primary useful dependent variable. Nonetheless, remedial support has the potential to reduce individual differences in reading (Parrila et al., 2005).

Interestingly, there were no longer differences in reading fluency between the CARRI and Mainstream groups at the end of Grade 2. That is, the development of reading fluency was slow in the RRI group, while the CARRI group developed rapidly, and was over one standard deviation above the RRI group in Grade 2 May. As mention earlier, the present thesis investigated the novel area of what effects early intervention on letter-sound connections and phonological skills have on future reading fluency skills. The results revealed that drill and practice in the computer-controlled remedial reading environment was needed to boost the acquisition of the reading fluency skills. The RRI group, whose participants received regular remedial reading training, remained in their compromised position in reading fluency outcomes from Grade 1 till the end of Grade 2. This was consistent with the findings of Torgesen et al. (2001) that remedial reading intervention in regular setting is not effective enough, and moreover that regular remedial programs are merely ”stabilizing the degree of reading failure”. This phenomenon was most clearly demonstrated by the results for reading fluency in which the RRI group did not accelerate from Grade 1 to Grade 2.

In sum, the children who were at risk for reading failure at the beginning of Grade 1 not only benefited in their letter knowledge and reading accuracy from the computer-assisted remedial reading intervention, this training also accelerated their fluency skills significantly so that they caught up with the level of the mainstreamers within the space of two years. Moreover, the effects of the training, manifested in the follow-up test, were consistent with those in the study by Elbro and Petersen (2004) where the training effects on reading were also manifested in the follow-up tests. Similarly, in the study by Hatcher et al.

(2006), it was found that children made significant gains in reading (and spelling) that were maintained at follow-up.

4.4 The pseudo individual analyses

The pseudo individuals were created on the basis of the data gathered to model the reading development of at-risk children with different deficits in their pre-reading skills. The idea of the pseudo individual analyses was derived from the pivotal predictors of reading and its underlining deficits. According to Grigorenko (2001), many lower-level psychological processes (e.g., phonemic awareness, phonological decoding, ability to process stimuli rapidly and automatize this process, memory, ability to recognize words) contribute to a single act of reading. Consequently, those who master reading skills successfully and those who have difficulties doing so differ in a wide range of reading-related processes (Grigorenko, 2001). In the present study, phonological awareness, rapid automatized naming and letter knowledge were included in the analyses.

An important objective in the present thesis was to determine what kinds of remedial practices are likely to support an individual child with a specific pre-reading profile. Pseudo individual analyses were used (Study II and Study III), in order to find out how different deficit combinations in pre-reading skills influence later reading abilities, that is, (1) a child with low performance in all three core pre–reading skills (letter knowledge, phonological awareness and rapid automatized naming), (2) a child with low performance in any two of the core pre-reading skills and (3) a child with low performance in one of the core pre-reading skills. The development of the pseudo individuals was calculated for all three groups. Letter knowledge, reading accuracy and fluency were predicted by using estimated model parameters for six pseudo individuals. These pseudo individuals were chosen to represent imaginable cases with low profiles in letter knowledge, phonological awareness and rapid automatized naming.

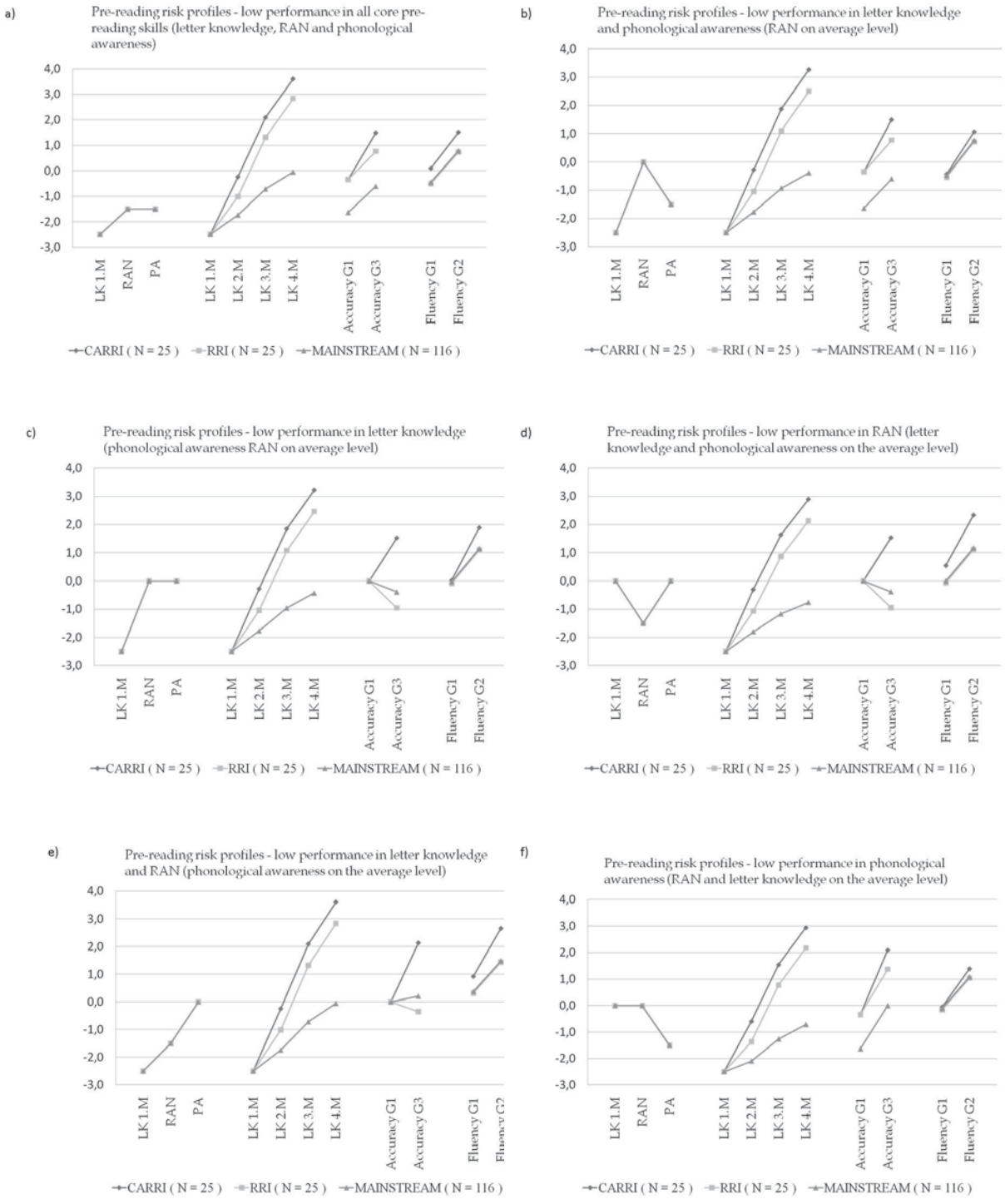
Based on the growth model, individual trajectories in reading development were produced for several risk types by using the pseudo individual profiles (see Figure 6). If a child from the Mainstream group had a low level of letter knowledge, this would lead to poor development in letter knowledge compared to a similar child receiving the CARRI or RRI intervention. Moreover, if a child received the computer-assisted intervention s/he would have a better chance of achieving the average level of the Mainstream group in letter knowledge than if placed in the RRI group. Although the regular remedial reading group would offer a more supportive educational environment for at-risk children than the mainstream approach, the CARRI group would produce better outcomes than the regular type of remedial reading support (i.e., RRI). In sum, children come to school with diverse pre-reading skills and develop differently. Therefore, early pre-reading skill assessments and individual interventions adjusted for the needs of each child are required.

If all three core pre-reading skills of phonological awareness, letter knowledge and rapid automatized naming (i.e., Figure 6a) were on a low level, the RRI group would be more beneficial than the Mainstream group in reading accuracy, but less so than the CARRI group. In reading fluency, in contrast, the RRI group along with the Mainstream group would yield the same learning achievement profile in reading fluency, whereas the CARRI group would perform nearly one standard deviation better. This means that children who have deficits in all three core pre-reading skills would be likely profit from the computer-assisted remedial intervention.

If letter knowledge and phonological awareness were low and rapid automatized naming average (i.e., Figure 6b), placement in the RRI group would be more beneficial than placement in the Mainstream group for improving reading accuracy. However, the CARRI group would still yield the most successful outcomes. With the same predictors, both the RRI group and Mainstream group would yield the same learning achievement profile in reading fluency, whereas placement in the CARRI group would be slightly more successful than placement in the other groups.

If letter knowledge was low and phonological awareness and rapid automatized naming were on the average level (i.e., Figure 6c), the Mainstream group would be more beneficial than placement in the RRI group for improving reading accuracy, but again, the CARRI group would offer the best chance for success. In comparison, with the same predictors the RRI group, along with the Mainstream group, would yield the same learning achievement profile in reading fluency. In turn, the CARRI group would be the most successful, outdistancing the other two groups by one standard deviation.

FIGURE 6 Description of the pseudo-individual analyses



If rapid automatized naming was low but phonological awareness and letter knowledge were average (i.e., Figure 6d), the Mainstream group would outperform the RRI group in reading accuracy, but not the CARRI group. In contrast, the RRI group along with the Mainstream group would yield the same learning profile in reading fluency. In turn, the CARRI group would perform over one standard deviation better than either of the two contrastive groups.

If letter knowledge and rapid automatized naming were low, but phonological awareness was average (i.e., Figure 6e), the Mainstream group would outperform the RRI group, but the CARRI would still be the most successful in improving reading accuracy. The RRI group, along with the Mainstream group, would once again yield the same learning profile in reading fluency, whereas the computer-assisted intervention group would perform over one standard deviation better than either of the other two contrastive groups.

If phonological awareness was low but rapid automatized naming and letter knowledge were average (i.e., Figure 6f), the RRI group would be more beneficial than the Mainstream group, but less beneficial than the CARRI group, for improvement in reading accuracy. The regular remedial reading group, along with the Mainstream group, would once again yield the same learning achievement profile in reading fluency, while the computer-assisted intervention group would be slightly more successful than the others.

The long-term intervention effects were examined in the present thesis. It is essential to find out what works with whom, by whom and in what context and how consistently (Klingner & Edwards, 2006). The computer-assisted intervention seemed indisputably to yield the best results independent of the initial level of one or more deficits in the three core pre-reading skills. Children with low letter knowledge and/or slow automatized naming skills would in particular, benefit considerably from computer-assisted remedial reading training in letter knowledge, reading accuracy and fluency (i.e., the computer-assisted intervention would produce a level of achievement in reading fluency about one standard deviation higher than would be produced by either of the other two contrastive groups, if a child had low letter knowledge and/or slow automatized naming).

Key findings: (1) the computer-assisted reading intervention (CARRI) was the most effective of the three methods studied, and caused permanent improvements in the reading performance of the at-risk children. (2) It seemed that the computer-assisted remedial reading training tackled the roots levels of reading sub-skills (i.e., letter knowledge, reading accuracy and fluency) and the children in the CARRI group reached the level of the mainstreamers within two years. (3) Interestingly, early intervention in phonological awareness and letter-sound connections markedly influenced the future development of reading fluency, as the at-risk children in the CARRI group reached the level of the mainstreamers by the end of Grade 2. Likewise, in letter knowledge and reading accuracy the at-risk children in the CARRI group not only reached the level of the mainstreamers, but surpassed them. (4) Most importantly, the children in the CARRI group made gains during the study and continued to progress steadily

in the follow-ups conducted 12 and 16 months after the intervention had ceased, which indicates the presence of long-term effects in primary literacy skills. These finding were consistent with the study undertaken by Elbro and Petersen (2004) in which the training effects on reading were also manifested in the follow-up tests. Similarly, in the study undertaken by Hatcher et al. (2006) it was found that children made significant gains in reading and spelling that were maintained at follow-up.

4.5 The fidelity of the treatment

The fidelity of the treatment administered is a key criterion in the field of intervention studies. Treatment fidelity refers to the methodological strategies used to monitor and enhance the reliability and validity of behavioral interventions, and incorporates five areas: (1) adherence, (2) dose, (3) quality of program delivery, (4) participant responsiveness and (5) program differentiation (Dusenbury, Brannigan, Falco, & Hansen, 2003). Monitoring of treatment fidelity ideally requires direct or indirect observations of sessions, which can be built into the study design to minimize costs in terms of time and resources. Monitoring treatment fidelity allows research teams to truly test interventions and to develop and implement interventions that ultimately improve the well-being of individuals (Resnick, Inguito, Orwig et al., 2005).

In the present thesis, three aspects of implementation fidelity were expected to have an impact on the extent to which the interventions produced the intended effects on the reading and spelling skill development of at-risk children: these were dosage, adherence, and quality of delivery. In the present study *dosage* (see O'Donnell, 2008) was assessed on the basis of the written reports of a reading specialist and the GraphoGame game server reports and graphs (the children were not permitted to finish the GraphoGame intervention until "game over") which enabled the research team to observe the frequency and length of specific parts of the intervention. *Adherence* is defined as the "degree to which program components were delivered as prescribed" (Greenberg, Domitrovich, Graczyk, & Zins, 2005). In the present thesis, adherence was assessed through the written reports of a reading specialist and through the GraphoGame game server reports and graphs. Thus it was possible to monitor that the remedial reading specialist followed the lesson scripts, used the correct intervention materials and the GraphoGame intervention as intended, and on each occasion completed all aspects of a given activity.

In contrast to these two aspects of implementation fidelity, which are fairly consistent in their conceptualization and measurement, there is little consensus in either educational or school-based prevention work about how to actually conceptualize and measure *quality of delivery* (Dusenbury et al., 2003; Greenberg et al., 2005; O'Donnell, 2008). Definitions range from "the quality of interaction and the degree to which interactive activities focus attention on desired elements" (Dusenbury et al., 2003, p. 244) to "the affective nature or degree of en-

gagement of the implementers when delivering the program" (Greenberg et al., 2005, p. 30). Researchers in the field of education have suggested that quality of delivery is synonymous with good teaching (O'Donnell, 2008). Good teaching was ensured in the present study by using the same remedial reading specialist in both intervention groups. The remedial reading specialist had an MA in special education and was specialized in training children with reading disabilities. Furthermore, the GraphoGame intervention used in the CARRI group, which was designed on the basis of the Jyväskylä Longitudinal Study of Dyslexia (see e.g., Lyytinen et al., 2004, 2006, 2008), was tested in a school environment, while the intervention in the RRI group followed the nation-wide literacy curriculum. Thus, it can be argued that in both cases the quality of delivery was good.

4.6 Limitations

There are some limitations which should be taken into consideration in any attempt to generalize the results of the present study. First, this experiment was an attempt to bring new research-based and tested practices to the resource room. Therefore the results may not apply to all resource room practices in Finland, only to those following similar training schedules and program as those in the present study. Second, our subjects were middle-class children. Many interventions are for children from less advantaged backgrounds and our findings may not apply to them. Third, the sample size in the intervention groups was quite small and further replication, is warranted before the program can be adopted in practice. Fourth, the study was conducted in the transparent Finnish orthography in which with adequate teaching a child can learn to read and spell accurately very rapidly (within a year) compared to children in other languages with more opaque orthographies. Therefore, if the results are to be applied more widely, the CARRI intervention needs testing among children learning to read in a less regular orthography. Fifth, both the RRI and CARRI groups were taught by the same remedial reading specialist. This was to avoid possible trainer effects. However, the at-risk children along with the 116 mainstreamers were taught by same class teachers during lessons other than reading. This might have an effect on the reading acquisition of the at-risk children. The class teachers knew which children were taught in the remedial reading groups. Consequently, they may have devoted extra attention to these children during other classroom activities. On the other hand, there were 4-5 children in a remedial reading group in each home classroom. Therefore, individual attention from individual class teachers can hardly have been a priority. Also teachers were kept blinded to the research group setting and other research practices.

Moreover, motivational aspects may also affect results of the present study. Evidence of a bidirectional relationship between reading skills acquisition and motivation has been recognized as an important factor in reading development (see e.g., Cohen, Cohen, West, & Aiken, 2003; Kenny, 1979; Morgan & Fuchs, 2007). It has been acknowledged that at-risk children are most likely to benefit

from frequent practice but are often unmotivated to read (e.g., Chapman, 1988; Lepola et al., 2000). On the contrary, avid readers see more words in print and have more opportunities to learn their spelling (Spear-Swearling, 2005). Lack of motivation can usually be seen within a year or so of school entry (Chapman, Tunmer, & Prochnow, 2000; Lepola, Poskiparta, Laakkonen, & Niemi, 2005; Kenna, Kear, & Ellsworth, 1995), if at-risk children do not receive sufficient and motivating remedial reading support in time. This is an important motivational aspect for future studies on computer-assisted remedial reading interventions to tackle.

4.7 Practical implications

The regular type of remedial reading intervention (i.e., RRI) failed to provide the kind of intensive and individualized practice that at-risk children may need to attain proper literacy skills. This statement is in accordance with the findings of Bentum and Aaron (2003), Hatcher et al. (2004), and Torgesen (2005). Moreover, many children who receive remedial reading support in schools are reportedly making little or no progress (Bentum & Aaron, 2003). The children in the regular remedial reading intervention (RRI) progressed, but did not reach the level of mainstreamers, which can be interpreted to mean that the intervention was not sufficient enough. As in Torgesen et al. (2001) the results of the present thesis indicated that the regular remedial intervention did not remediate the at-risk children sufficiently. Therefore, one could claim that the regular remedial reading practices used in Finland require rethinking. Present remedial reading interventions in Finland, which are most commonly administered when an at-risk child has been observed to fail, should be replaced by a preventive intervention that seeks to identify and remediate at-risk children, as suggested by Torgesen (1998).

The early reading intervention for at-risk children should not only be beneficial but also persistent and progressive with steady and cumulative long-term effects. Notwithstanding, most children with RDs are not likely to receive sufficient opportunities to practice decoding skills to a level of fluency that will enable them to read adequately (e.g., Torgesen & Barker, 1995). Nonetheless, it is important to identify and target instruction at the weak areas of child's reading (see e.g., Aaron, 1997). The empirical evidence in the area suggests that prevention studies have generally been more successful. This has been demonstrated by larger effect sizes on reading and spelling measures in at-risk children in prevention studies than in children who have already experienced reading failure (Lyon & Fletcher, 2001; Torgesen, 2000). In this light, "wait to fail models" (for review see e.g., Dunn, 2007; Fletcher, Coulter, Reschly & Vaughn, 2004; Fuchs et al., 2003; Gersten & Dimino, 2006; Vaughn & Fuchs, 2003) are most unlikely to support children with RDs.

In the Finnish tradition, it has been more common to focus on children who have already experienced reading failure, although during the past few

decades knowledge on the reduction of reading failure has increased (Lyytinen et al., 2009; Stanovich, 1986; Torgesen, Wagner, Rashotte, Rose et al., 1999; Vellutino et al., 1996), and some empirical research has been conducted on preventing reading failure (see e.g., Lerkkanen et al., 2004a; Lyytinen et al., 2009; Puolakanaho et al., 2007; Snow et al., 1998; Torgesen, 2002; Torppa et al., 2006). In Finland the research results gathered in the course of reading and dyslexia research (e.g., the results of the JLD study and the studies noted above) seem to translate regrettably slowly into practice in the form of remedial reading intervention. As Dehaene (2009) states, there is a gap between educational programs and the most up-to-date findings in neuroscience. Moreover, Dehaene (2009) argued that the new science of reading is so young and fast moving that it is still relatively unknown outside the scientific community. In Finland, more cooperations would be required between reading researchers and departments of special education to bridge the gap between research results and resource room practices, while many more studies are required in the domain of reading intervention.

Epidemiological data has indicated that if their reading skills are not improved by the end of Grade 3, children will have considerable difficulty overcoming a slow and unsuccessful start in reading (e.g., Blachman et al., 2004, Torgesen, 1998). In the English language context, Shaywitz and Shaywitz (l996) found that 74% of children who were still poor readers at the end of Grade 3 were likely to be poor readers at the end of Grade 9 (see also Francis, Shaywitz, Stuebing, Shaywitz, & Fletcher, 1996; Juel & Leavell, 1988). Therefore, early preventive intervention is required, including the Finnish context. Remedial reading programs in Finland should be targeted at preventing reading failure in children at risk. According to Torgesen (2001) if children fall seriously behind in the growth of critical early reading skills, they will have fewer opportunities to practice reading. Moreover, these lost practice opportunities make it extremely difficult for children who remain poor readers during first three years of school to ever acquire the average level of reading fluency (Torgesen et al., 2001). Consequently, in languages with transparent orthographies, such as Finnish, it is reading fluency, especially reading speed, rather than accuracy, that results in individual differences (see e.g., Aro et al., 2006).

In the more transparent orthographies, such as Finnish, most children learn to decode accurately and fluently usually by the end of Grade 1 (e.g., Holopainen et al., 2001; Lerkkanen et al., 2004a; Lyytinen et al., 2006, 2008), and therefore the Grade 2 literacy curriculum focuses on the further development of fluency and reading comprehension (see e.g., Lerkkanen, 2007). In Finland, the instructional focus in reading changes rather drastically in Grade 3, putting children who are still poor readers at a considerable disadvantage, as from Grade 3 onwards, it is taken for granted that they are capable of ”reading to learn” and not learning to read. This change in instructional focus makes it less likely that Grade 3 children will routinely be exposed to explicit instruction in such reading sub-skills as decoding, accuracy and fluency. Spelling instruction

also receives less attention with the shift towards more productive writing after Grade 2.

Traditional regular type of remedial reading intervention may fail to provide the kind of intensive training environment that children at-risk may need to attain proper reading skills (see e.g., Bentum & Aaron, 2003; Hatcher et al., 2004; Torgesen, 2005). Many children who are receiving remedial reading support in schools are reportedly making little or no progress, or, as Torgesen et al. (2001) put it, these remedial programs are merely "stabilizing their degree of reading failure". This seemed to be the case in the RRI group studied in the present thesis. Also, the amount of time children actually spend in individualized, carefully supervised practice in reading skills has been indicated to be far from optimal (Torgesen & Barker, 1995; Torgesen, 2005; Hatcher et al., 2004). The lack of effectiveness of reading interventions provided in the resource room, have long been reported (Bentum & Aaron, 2003; Hatcher et al., 2004; Kennedy et al., 1986; Moody et al., 2000; Puma et al., 1997; Snow et al., 1998). Also the Finnish study by Poskiparta et al. (1999) claimed that special education was less effective, worse even, than the mainstream approach. Birman, Orland, Jung, Anson, Garcia, Moore et al. (1987) argued that any gains made are usually lost when children leave the program. Perhaps this is why, Berninger et al. (2008) stated that such children should not be dismissed from special education until their problems resolve. The present study was inline with most notions. The results of the present study argue strongly in favour of early identification and intervention for at-risk children.

An efficient way to increase the intensity of reading intervention for struggling readers is to provide remedial reading interventions in groups of 4-5 children (e.g., Nicolson et al., 2000; Rechly, 2003; Swanson, Trainin, Necoechea, & Hammill, 2003). This allows the intervention to be targeted at the specific needs of each child and further gives children more opportunities to respond and to receive feedback. Traditionally, one-on-one reading instruction has been considered optimal for students with RDs. However, Swanson (1999), in his meta-analysis of remedial reading practices, found that children who received reading instruction in small groups (e.g., in a resource room) experienced a greater increase in skills than did those who had individualized interventions (see also Swanson et al., 2006). Based on earlier studies one could also expect small group interventions to be more cost-effective than one-on-one interventions (see e.g., Nicolson et al., 2000). The present study was a mixed model of a small group and one-on-one remedial reading intervention, as in the beginning of each lesson at-risk children practised individually for 15-min either with the GraphoGame computer application (in CARRI group), or with more regular materials (i.e., plastic or magnetic letters, flash cards, self-made memory cards, Logigo® – and LUKO® game boards) in the RRI group.

Efficient interventions require skillful pedagogical methods and enthusiastic highly educated practitioners. Swanson (1999) pointed out in his meta-analysis that theoretically sound instructional practices include daily reviews, statements of an instructional objective, teacher presentations of new material,

guided practice, independent practice, and formative evaluations (i.e., testing to ensure the child has mastered the material). Torgesen (1998) added that the critical elements of an effective program for prevention of RDs are the right kind and quality of instruction delivered with the right level of intensity and duration to the right children at the right time. The RTI models (e.g., Burns, Dean, & Klar, 2004; Fuchs, 2003; Fuchs & Fuchs, 2006; Gresham, 2002) usually follow the problem-solving method, in which the assessment data gathering includes five steps: (1) identify the problem, (2) analyze the problem, (3) develop a plan, (4) implement the plan and (5) evaluate the plan. These practices are at the heart of any good reading intervention program and are reflected in several of the instructional components. It is essential that the intervention is well co-ordinated with the instruction mainstreamers are receiving in the classroom. Furthermore, the remedial reading specialist should meet regularly with the classroom teachers and school psychologists to discuss student progress in the resource room.

Although education is claimed to be resistant to change, it is important that in Finland remedial reading intervention should move away from the traditional "wait to fail" approach towards identification of children at risk and providing them with adequate intervention. Research should also be targeted at gathering information about what kind of identification and support systems are used in Finnish schools, as this has not yet been clarified. Moreover, resource room education ought to be based on pedagogical methods that are derived from research-based, well reported intervention studies. Ineffective one-on-one intervention should also be replaced by more powerful small group intervention that includes both group-based and individual practices.

In the area of mainstream education new, valuable research-based test materials (ARMI; Lerkkanen, Poikkeus, & Ketonen, 2006 and ARMI 2; Lerkkanen, Poikkeus, & Ketonen, 2008) have become available to the class teachers for evaluating the early reading development and pre-reading skills of all children. The ARMI packages include screening and follow-ups of reading and spelling development in Grades 1 and 2. At the same time there is a great need for new research-based assessment materials for remedial reading intervention, too. Some research-based test packages exist that remedial reading specialists (i.e., special educators) can use in different combinations to further assess the skills initially assessed by the ARMI package (ALLU; Lindeman, 1998; Lukilasse; Häyrinen et al., 1999; the Rapid Automatized Naming Test (RAN); Ahonen et al., 1999).

However, there is in Finland an evident lack of up-to-date research-based and norm-referenced evaluation packages for remedial usage (i.e., packages that would evaluate phonological abilities and reading sub-skill development more accurately than those currently available in ALLU (Lindeman, 1998)). Also more useful norm-referenced tests to assess early reading accuracy, that is, on the level of syllables, decoding and word recognition, would be required to monitor the progress of at-risk children in the Finnish language context. For any practitioner in the field of remedial reading intervention, it is important to bear

in mind that assessments are fundamental and foundational to well working intervention models (e.g., Burns et al., 2003; Gresham, 2002).

Conclusion, to develop quality instruction in the domain of early reading programs, all school beginners should be assessed for possible risk for reading failure. Class teachers should test their students with a norm-referenced screening test (ARMI; Lerkkanen et al., 2006), children considered to be at risk should be referred to remedial reading specialists followed by a remedial reading intervention that is built on well-formed research-based practices (i.e., practices using computer-assisted intervention as a part of the daily resource room routine). Moreover, intervention should take place in the groups of 4-5 children (e.g., Nicolson et al., 2000; Rechly, 2003; Swanson et al., 2006), 4-5 times a week during Grade 1 (Brooks, 2007). Furthermore, progress-monitoring data on all children should be gathered along with diagnostic information on how well at-risk children respond to the reading intervention. In this way, class teachers, remedial reading specialists (i.e., special educators) and school psychologists could obtain a more dynamic view of a student's progress. It ought to be after this early proactive intervention procedure that children showing signs of resistance to the intervention should be referred for more profound psychological evaluation (i.e., more profound skill and IQ assessments).

Class teachers, remedial reading specialists and school psychologists should work in close co-operation. Screenings or school entrance assessments can help class teachers, remedial reading specialists (i.e., special educators) and school psychologist to decide which students require remedial reading training, and more distinctively what kind of remedial practices are likely to support an individual child with specific pre-reading profiles. In the implementation of an intervention, the role of the school psychologist is in the area of assessment and data-based decision making. School psychologists are knowledgeable in various assessment systems and in which approaches would be best for particular students (Burns & Coolong-Chaffin, 2006). Once children are identified as struggling readers, the school psychologist should consult with remedial reading specialists and/or teachers about assessments to identify the most appropriate area for a small-group reading intervention; that is, what kind of intervention is required for an individual child with specific deficits. In the model presented in Figure 7 the idea is that children falling behind or showing intervention resistance in Grade 1 ought to be sent for cognitive assessments and consultation with the school psychologist in the spring term of Grade 1 before the transition to Grade 2.

4.8 The ideal model for remedial reading interventions

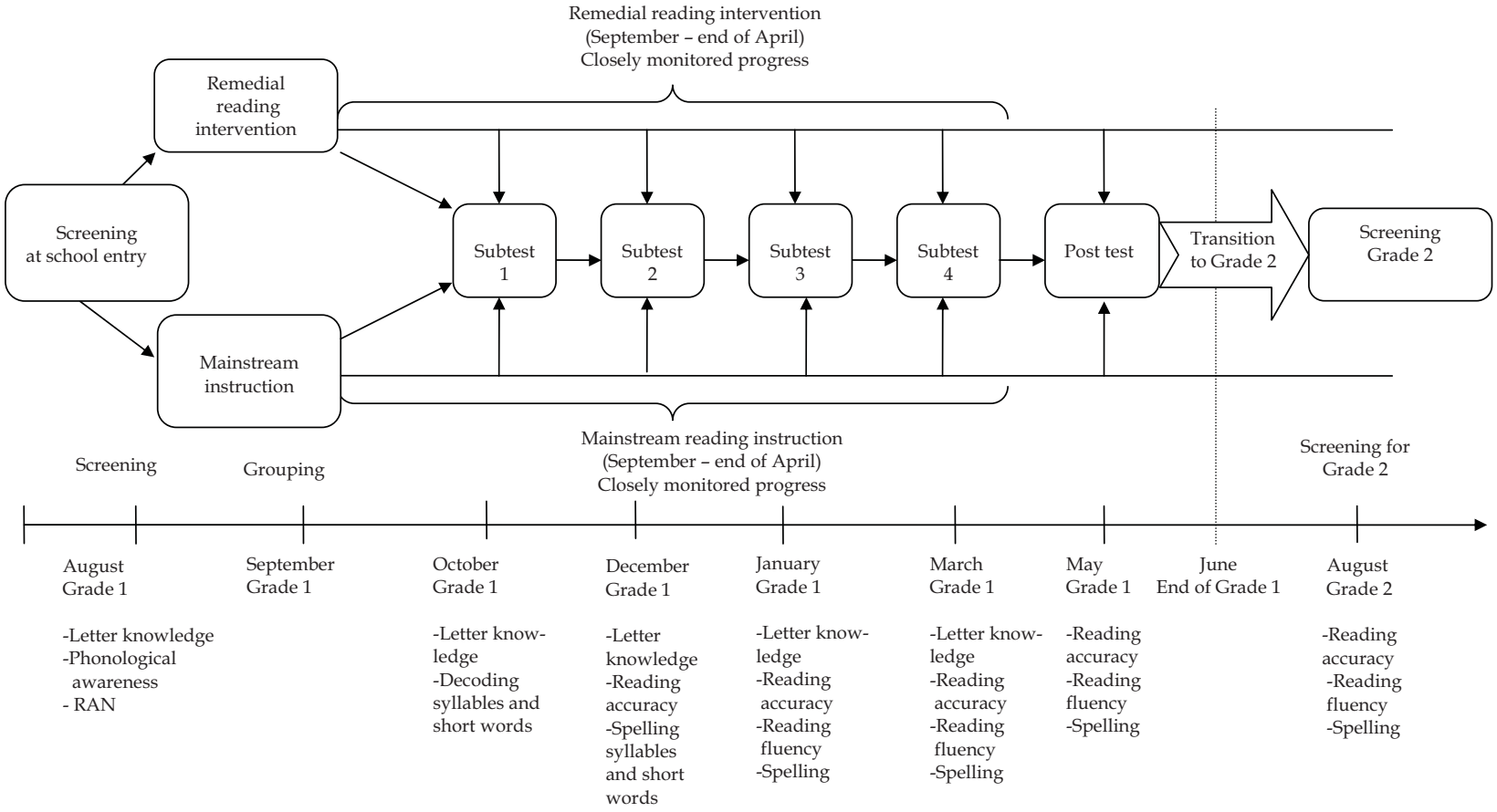
The lowest-scoring 30% should be offered remedial reading training (see e.g., Torgesen et al., 1999) in groups of 4-5 children, within the Grade 1 literacy block (see e.g., Swanson, 1999). The children should not be dismissed from remedial reading training until their problems are resolved (Berninger et al., 2008). In the

present thesis, seven months, four times a week, was required for the at-risk children to reach the level of mainstreamers. This result suggests that remedial reading intervention is not ”a quick cognitive therapy session” but a long-term process that requires research-based precise instruction, highly educated practitioners and persistency.

The training strategies in Grade 1 should be set out in segments covering letter-sound connections, phonological awareness, decoding, writing letters and syllables, reading and writing words, reading and writing pseudo-words and reading and writing in context. Each segment of the 45-min lesson should consist of activities which vary in teaching mode, cognitive task, and level of stimulus difficulty. The criteria should be specified by the use of training strategies, including individualized computer-assisted GraphoGame training for 15-min at a time. Furthermore, the training regimen ought to progress from easier to more challenging activities.

The reading attainments of at-risk children and their non-at-risk peers should be assessed with norm-referenced, research-based tests every two months during Grade 1. This is to keep a record of individual attainments (for further details see the Figure 7). The assessments described in Figure 7 ought to progress from letter-sound correspondence and phonological awareness to decoding of syllables and short

FIGURE 7 The ideal model for remedial reading intervention and reading achievement testing



words, and further to reading accuracy, fluency and spelling attainments. Children falling behind or showing intervention resistance should to be sent for cognitive assessments and consultation with the school psychologist in the spring term. This is to allow the early preventive intervention (beginning right after the school entry assessments) to take effect and give time for "late bloomers" to catch up. In the present study the fastest achievements in the at-risk children took place between January and March (and October and December if trained with the GraphoGame computer-application).

Post tests should take place in mid-May Grade 1 before the transition to Grade 2. The same kind of screening, intervention and achievement testing procedure should take place within the Grade 2 curriculum, but focusing more precisely on fluency and comprehension. This is to ensure that all children achieve proficient reading and spelling skills by Grade 3, and are reading to learn and no longer learning the essential reading sub-skills at Grade 3. As established in the present thesis, the computer-assisted intervention provided by the GraphoGame application along with other theoretically sound remedial practices, may help at-risk children to succeed on the rocky road of reading.

To implement such an intervention program, at least 4-5 modern computers with headphones and access to Internet should be available in the resource room. This is to ensure the learning outcomes described in the present thesis. The resource room should be designed on the principle of learning stations, where some children may practice in the computer-assisted environment, while others are doing pen and paper, or oral exercises, individually, in pairs or in a small group with teacher-student interaction. A well-constructed resource room makes transitions between learning stations flexible and easy to access. Moreover, if the learning outcomes are similar to those reported in this thesis, the initial investment in laptops or computers and reconstruction of the resource room, needed to enable a well-structured and theoretically sound reading intervention program based on ongoing evaluations, will soon be justified.

5 CONCLUSIONS

In general accord with the earlier research (e.g., Elbro et al., 1996; Fawcett et al., 2001; Hurford & Sanders, 1990; Jiménez et al., 2003, 2007; Lynch et al., 2000; Magnan & Ecalle, 2006; Nicolson et al., 1999, 2000; Torgesen et al., 2009; van Daal & Reitsima, 2000; Wentink et al., 1997; Wise et al., 1999) the present thesis concluded that a computer-assisted intervention can provide effective supplemental practice for at-risk children and children with RDs, if carefully monitored and delivered with enough regularity and frequency. However, computer programs are not yet well developed enough to be depended on as the major source of an intervention, despite the rather promising results reported here. It was not suggested that a computer-assisted reading training alone would work as the major source of an intervention for struggling readers. A well structured research-based remedial intervention, including regular monitoring of reading and spelling sub-skills, was also required to realize the achievements reported in the present study.

The GraphoGame computer-assisted reading intervention (15-min each time) along with more regular practice was an important contributor to the gains found in the present experiment. Consequently, the computer-assisted intervention such as GraphoGame is one instrument for raising the profile of the resource room intervention, which has been widely acknowledged to be ineffective (e.g., Bentum & Aaron, 2003; Hatcher et al., 2004; Kennedy et al., 1986; Moody et al., 2000; Puma et al., 1997; Poskiparta et al., 1999; Snow et al., 1998; Torgesen, 2005). GraphoGame proved to be an effective and beneficial instrument for individualized and effective reading intervention. The regular research-based intervention regimen, consisting of computer-assisted and other valuable remedial reading practices, should from an essential part of daily resource room routines, as at-risk children seem to require more time to "patch up" their poor pre-reading skills and catch up with their normally developing peers.

YHTEENVETO (FINNISH SUMMARY)

Lukemaan oppimisen kivisellä tiellä – Verkkopohjaisen Ekapeli -ohjelman kuntouttavat vaikutukset riskilasten lukemaan oppimisessa

Tutkimuksessa tarkasteltiin interventiotutkimuksen keinoin lukivalmiuksien kuntoutukseen kehitellyn Ekapelin vaikutusta riskilasten luku- ja kirjoitustaidon kehitykseen erityisopetuksessa.

Ekapeli on Jyväskylän yliopiston Psykologian laitoksen ja Niilo Mäki Instituutin monitieteellisenä yhteistyönä kehitelty verkossa pelattava interventiotietokoneohjelma. Ekapelin kehittäjinä ovat toimineet professori Heikki Lyytisen johdolla joukko psykologian, erityispedagogiikan, fonetiikan, matematiikan ja tietotekniikan asiantuntijoita. Ekapeli perustuu tieteelliselle tiedolle lukemisvalmiuksien kehityksestä ja lukivaikeuksista. Sen taustalla on Jyväskylässä toteutetun Lapsen kielenkehitys (LKK) pitkittäistutkimuksen tulokset.

Ekapeli harjoittaa lukemaan oppimisen perusteita. Se on suunniteltu lukivaikeuksien ennaltaehkäisyyn riskilapsilla, sekä lukilasten kuntotutukseen. Ekapeli alkaa grafeemi-foneemivastaavuuden harjoittelusta ja etenee kunkin pelaajan yksilöllisen taito- ja harjaantumistason mukaisesti tavu- ja sanatasoiseen lukutarkkuuden ja lukusujuvuuden harjoitteluun. Ohjelmaa käyttävien lasten harjoitustiedostot tallentuvat Jyväskylän yliopiston palvelimelle. Palvelin asettaa automaattisesti peliohjelman kunkin lapsen taitoja vastaavalle tasolle analysoimalla ja arvioimalla oppimistuloksia reaaliajassa.

Tutkimuksen tarkoituksena oli (1) selvittää missä määrin Ekapelitietokoneohjelmalla tehostetulla erityisopetuksella on lyhyt- ja pitkäkestoisia vaikutuksia riskilasten lukemaan ja kirjoittamaan oppimiseen sekä (2) ennustaa riskilasten ja heidän verrokkiensa lukutaidon kehitystä riskiprofiilien perusteella. Lisäksi tutkimustulosten ja tutkimuksessa käytettyjen pedagogisten menetelmien pohjalta pyrittiin hahmottamaan erityisopetusta palveleva luku- ja kirjoitustaidon interventiomalli.

Tutkimus koostuu kolmesta englanninkielisestä "The Prevention Game Research" – hankkeen (Saine, Lerkkanen, Ahonen, Tolvanen, & Lyytinen, 2007) artikkelista. Hankeen tutkimuksellisena tavoitteena oli osoittaa miten Ekapeli soveltuu täydentämään olemassa olevia lukiriskilasten tukirakenteita erityisopetuksessa. Tutkimukseen osallistui 166 ensimmäisen luokan oppilasta yhdeltä paikkakunnalta. Kaksi kohorttia (n = 85 ja n = 81) muodostivat tutkittavien lasten ryhmän. Koulun alkaessa oppilaiden keskimääräinen ikä oli 7 vuotta ja 3 kuukautta (M = 87.6 kk, SD = 4.2). Kaikki tutkimukseen osallistuneet lapset olivat äidinkieleltään suomenkielisiä ja lähes kaikki heistä olivat saaneet esiopetusta ennen koulun alkua. Tutkimukseen osallistuneiden lasten vanhempien koulutustaso vastasi suomalaisten keskimääräistä koulutustasoa.

Satunnaistamiseen perustuvan pitkittäistutkimuksen muodossa seurattiin 166 lapsen lukemaan ja kirjoittamaan oppimisen kehitystä ensimmäisen luokan alusta kolmannelle luokalle. Alkumittauksessa testattiin kaikkien tutkimukseen osallistuneiden (N = 166) lasten lukutaitoa ennustavat kielelliset valmiudet: kir-

jaintuntemus, fonologiset taidot (Allu; Lindeman, 1998) ja nopean nimeämisen taidot (Nopean sarjallisen nimeämisen testi; Ahonen, Tuovinen, & Leppäsaari, 1999). Lasten lukutaidon kehitystä seurattiin tiiviisti 1. luokan aikana kahden kuukauden välein (yhteensä kuusi mittausta). Toisen luokan lopussa lasten lukutaito ja kirjoitustaito testattiin Lukilasse – testillä (Häyrinen, Serenius-Sirve, & Korkman, 1999), lisäksi kognitiiviset taidot kontrolloitiin WISC-III–testillä (Wechsler, 1999) 2. luokan lopussa. Kolmannen luokan alussa lasten lukutaito arvioitiin vielä Allu–testillä (Lindeman, 1998) ja kirjoitustaito Lukilasse – testillä (Häyrinen et al., 1999).

Alkumittauksen tulosten perusteella heikoimpaan 30 % kuuluneet ns. riskilapset jaettiin satunnaistaen kahteen kuntoutusryhmään; perinteistä erityisopetusta saaviin (n = 25) sekä tietokonepohjaista Ekapeli – kuntoutusta ja erityisopetusta saaviin (n = 25) oppilaisiin. Loput tutkimukseen osallistuneista oppilasta (n = 116) muodostivat yleisopetusta saavan vertaisryhmän, joka ei saanut erityisopetusta. Riskilapset saivat tehostettua erityisopetusta neljä kertaa viikossa 45 minuuttia kerrallaan, 28 viikon ajan, viiden oppilaan ryhmissä. Ensimmäinen riskiryhmä (ns. RRI–ryhmä) sai perinteistä eritysopetusta, jossa harjoiteltiin kirjain-äännevastaavuutta, fonologisia taitoja sekä deekoodausta. Toinen riskiryhmä (ns. CARRI–ryhmä) sai perinteisen erityisopetuksen lisäksi tietokonepohjaista Ekapeli – harjoitusta erityisopetustunnin ensimmäisen 15 minuutin ajan.

Kukin oppitunti oli jaettu neljään osaan. Ensimmäisen 15 minuutin ajan harjoiteltiin kirjainäännevastaavuutta, fonologisia taitoja sekä deekoodausta pienryhmässä (RRI–ryhmä) tai Ekapelillä (CARRI–ryhmä). Seuraava 10 minuutin jakso harjoiteltiin molemmissa kuntoutusryhmissä kielellistä tietoisuutta mm. sanojen jakamista tavuihin, tavujen tunnistamista ja manipulointia, äänteiden ja tavujen erottelua sanoista, sanojen riimittämistä, äänteiden poistamista ja korvaamista sanoista, sanojen päätteitä ja päätteiden oikeaa käyttöä sekä sanojen tunnistamista ja ymmärtämistä lauseissa lukemisen ja kirjoittamisen keinoin. Tämän jälkeen harjoiteltiin 10 minuuttia aapisen päivän teeman mukaisia asioita mm. ääneen lukemista. Viimeinen 10 minuutin jakso harjoiteltiin sanavaraston multisensorista kehitystä apuvälineinä improvisaatio- ja sananselityskortit, tarinan kerronta, mimiikka, pantomiimi sekä vihjepiirtäminen. Erityisopetuksen sisältö oli suunniteltu viimeisimpien, tieteellisesti raportoitujen, kansainvälisten pedagogisten suositusten mukaisesti (mm. Burns & Coolong-Chaffin, 2006; Fletcher, Lyon, Fuchs, & Barnes, 2007; Fuchs & Fuchs, 2006; Swanson, Harris, & Graham, 2006). Samanaikaisesti kuntoutusryhmien kanssa yleisopetuksen vertaisryhmä (ns. Mainstream–ryhmä) sai luokanopettajan antamaa yleisopetusta kotiluokassa.

Tutkimustulokset osoittivat, että Ekapelillä rikastettu erityisopetus (CARRI) tuotti riskilasten ryhmässä kiistatta perinteistä erityisopetusta (RRI) paremmat kuntoutustulokset. Ekapeli-interventiota saaneiden lasten ryhmä kehittyi, jopa vertaisryhmää tarkemmaksi kirjaintuntemuksen ja lukutarkkuuden osa-alueella, sekä saavutti vertaisryhmän lukusujuvuudessa 2. luokan loppuun mennessä ja

kirjoitustaidossa 3. luokan alkuun mennessä. Yhtä nopeaa kehitystä ei ollut havaittavissa perinteistä erityisopetusta saaneessa ryhmässä.

Aiempien tutkimusten tavoin, myös tässä tutkimuksessa, kirjaintuntemus, fonologiset taidot sekä nopea nimeäminen osoittautuivat merkittäviksi lukemisen osataitojen (ts. dekoodaus, lukemisen tarkkuus ja sujuvuus) ennustajiksi sekä riskilasten että yleisopetuksen verrokkiryhmän osalta. Erityisesti painottui kirjaintuntemuksen ja fonologisten taitojen merkitys lukemisen tarkkuuden ja sujuvuuden kehityksessä sekä lyhyellä että pitkällä aikavälillä.

Lisäksi tutkimuksessa ennustettiin lukemaan oppimisen kehitystä riskitekijöiden funktiona. Riskimittareina käytettiin koulun alussa mitattua kirjaintuntemusta, fonologisia taitoja ja nopeaa nimeämistä, jotka viimeaikaisten kansainvälisten tutkimusten perusteella ovat tulevan lukutaidon parhaita mittareita. M-plus -mallinnuksen perusteella syntyi kolme riskiryhmää: (1) lapset, joilla oli haasteita yhdessä lukivalmiuksia mittaavassa taidossa, (2) lapset, joilla oli haasteita kahdessa lukivalmiuksia mittaavassa taidossa ja (3) lapset, joilla oli haasteita kaikissa kolmessa lukivalmiuksia mittaavassa taidossa. Saatujen profiilien perusteella mallinnettiin minkälaisia kirjaintuntemuksen, lukutarkkuuden ja -sujuvuuden tuloksia kunkin riskiprofiilin omaava lapsi saavuttaisi RRI–ryhmässä, CARRI–ryhmässä ja yleisopetuksessa.

Mallinnuksen perusteella parhaat oppimistulokset saatiin Ekapelillä rikastetussa erityisopetuksen ryhmässä (CARRI–ryhmässä) riippumatta siitä oliko lapsella haasteita yhdessä, kahdessa vai kolmessa lukivalmiuksia mittaavassa taidossa. Vain lukutarkkuus olisi kehittynyt RRI–ryhmässä yleisopetuksen vertaisryhmässä paremmin, mutta ei samassa mittakaavassa, kuin jos lapsi olisi sijoitettu Ekapelillä rikastettuun CARRI–ryhmään. CARRI–ryhmän hyödyt nousivat erityisesti esiin lukutarkkuuden ja -sujuvuuden osalta niiden lasten suorituksissa, joilla oli heikkoutta kirjaintuntemuksessa ja nopeassa nimeämisessä.

Mallinnuksen perusteella riskilasten fonologiset taidot osoittautuivat kirjaintuntemuksen ohella keskeisiksi tulevan lukutaidon ennustajiksi. Fonologisten taitojen osalta riskilasta tuki parhaiten CARRI–ryhmä. Jos lapsen fonologiset taidot olivat keskitasoa, riippumatta kuinka heikot lähtötaidot lapsella oli kahdessa muussa lukivalmiutta mittaavassa taidossa (kirjaintuntemuksessa ja nopeassa nimeämisessä) hän suoriutui sekä lukutarkkuutta että lukusujuvuutta mittaavista tehtävistä paremmin yleisopetuksessa kuin perinteisessä erityisopetusryhmässä (RRI). Perinteiset erityisopetuksen pedagogiset menetelmät fonologisten taitojen harjoittelussa eivät tämän tutkimuksen valossa näytä tukevan riskilasten lukutaidon kehitystä riittävässä määrin.

Erityisen huolestuttavia perinteisessä erityisopetuksessa (RRI) saadut tulokset olivat lukusujuvuuden osalta. Perinteisen erityisopetuksen ryhmässä lasten lukusujuvuudessa ei tapahtunut muutoksia 1. luokan keväästä 2. luokan kevääseen. Sen sijaan Ekapeli–kuntoutusta ensimmäisellä luokalla saaneet CARRI–ryhmän lapset, saavuttivat lukusujuvuudessa yleisopetuksen oppilaat 2. luokan kevääseen mennessä. Tutkimustuloksen tekee kiinnostavaksi se, että aiempi interventiotutkimus on keskittynyt lukunopeuden harjoittamiseen esim. toisto-

luennan ja nopeutetun luennan harjoituksilla. Tässä tutkimuksessa lukemisen sujuvuutta ei harjoitettu perinteisin lukusujuvuuden menetelmin, vaan Ekapeli–tietokoneohjelmalla. Ekapeli–kuntoutuksessa harjoitus kohdistuu ensin lukemisen esitaitoihin kuten kirjan-äännevastaavuuteen, ja sen kautta fonologisiin taitoihin, deekoodaukseen ja lukutarkkuuteen. Näiden taitojen säännöllisellä tietokonepohjaisella harjoittelulla, CARRI–ryhmän oppilaiden lukusujuvuus kehittyi toisen luokan kevääseen mennessä yleisopetusta saaneen vertaisryhmän tasolle. Sen sijaan perinteisessä erityisopetusryhmässä lukusujuvuudessa ei juuri tapahtunut muutosta 1. luokan kevään ja 2. luokan kevään välillä.

Tutkimuksen perusteella havaittiin, että perinteisen erityisopetuksen keinoin ei saavutettu yhtä hyviä tuloksia riskilasten luku- ja kirjoitustaitojen kehittämisessä kuin erityisopetuksella, jota oli tehostettu Ekapeli -harjoittelulla. Tulosten perusteella erityisesti varhaista erityisopetusta tulisi rikastaa Ekapeli–ohjelmalla säännöllisesti 15-minuutin ajan kullakin erityisopetuskerralla. Ekapeli–interventiolla tehostetun erityisopetuksen tulisi alkaa ensimmäisen luokan alusta ja jatkua riittävän pitkäkestoisena kunnes lapsi tavoittaa luku- ja kirjoitustaidossa muun ikäryhmänsä. Tutkimuksessa saatujen tutkimustulosten perusteella on perusteltua suositella riskilapsille Ekapelillä tehostettua lukutaidon erityisopetusta 4-5 oppilaan oppimisryhmissä vähintään neljä kertaa viikossa perinteisen yksilökeskeisen erityisopetuksen sijaan. Tulevaisuudessa Ekapeli–ohjelmaan tullaan sisällyttämään lukutaidon kehittymisen arvioinnin ja seurannan mahdollistavat komponentit, jotka helpottavat lasten luku- ja kirjoitustaidon oppimisen seurantaa.

Tutkimuksessa saatujen tulosten perusteella tulisi luoda pedagoginen interventiomalli, jonka perusteella riskilasten varhainen tunnistaminen on mahdollista jo ennen koulun alkua. Varhaisen tunnistamisen avulla, riskilasten kuntouttaminen voidaan aloittaa viimeistään koulun alkaessa – parhaassa tapauksessa jo esiopetuksessa. Riskilasten oppimistuloksia tulisi seurata sekä lyhyellä että pitkällä aikavälillä käyttäen luotettavia, tutkimukseen pohjautuvia arviointimenetelmiä, sekä yksilöllisten tarpeiden analysointia. Näin kullekin lapselle olisi mahdollista luoda yksilöllinen kuntoutussuunnitelma, joka tukee juuri hänen taitojaan ja oppimisvalmiuksiaan.

Tutkimuksen perusteella luodun, pedagogisen interventiomallin pohjalta riskilasten kuntouttavan erityisopetuksen, jonka yhtenä komponenttina on tietokonepohjainen Ekapeli–ohjelma, tulisi pohjautua jatkuvalle evaluoinnille. Evaluoinnin tulisi sisältää lukivalmiuksien alkuarvioinnin, riskilapsen ongelma-alueiden kartoituksen ja analysoinnin. Lisäksi lasten huoltajat tulisi haastatella ja selvittää mahdollinen suvussa esiintyvä alttius oppimisvaikeuksille, sekä muut mahdolliset lapsen kehitykseen ennen kouluikää liittyneet haasteet.

Olennaisena osana pedagogista interventiomallia tulisi olla lyhyen- ja pitkäntähtäimen yksilöllinen kuntoutussuunnitelma, joka perustuu jatkuvalle luku- ja kirjoitustaidon kehityksen, sekä käytettyjen interventiomenetelmien intensiiviselle arvioinnille. Kuntoutussuunnitelma voitaisiin tarvittaessa liittää osaksi lapsen HOPSia tai HOJKSia, mutta kuntoutussuunnitelma tulisi voida tehdä joustavasti myös ilman erityisopetukseen siirtopäätöstä. Lukemisen ja

kirjoittamisen erityisopetuksen tulisi pohjautua, nykyistä vahvemmin, tieteellisten menetelmien ja pedagogisten interventiomallien soveltamiseen ja kehittämiseen. Erityisesti uusien tieteellisten tutkimustulosten siirtämistä luku- ja kirjoitustaidon erityisopettajakoulutukseen ja erityisopetuksen käytänteisiin ja tulisi tehostaa.

Tutkimuksessa on luotu yksi esimerkki tieteelliselle pohjalle perustuvasta interventiomallista erityisopetuksen käyttöön. Jatkotutkimuksen haasteena on kehittää ja testata uusia pedagogisia menetelmiä, mittareita ja malleja riskilasten kuntouttamiseen erityisopetuksen keinoin. Erityisesti näitä mittareita ja malleja tarvitaan niiden lasten taitojen kehityksen ja kuntoutuksen arviointiin joilla on laaja-alaisia lukemisen oppimisen vaikeuksia.

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