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

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ABSTRACT

The aim of the longitudinal intervention study was to build a model of predictive values of reading fluency in three contrastive reading groups: remedial and computer-assisted remedial reading intervention, and mainstream instruction, to identify the most effective type of intervention for children with different profiles of compromised pre-reading skills. The participants were 7-year-old Finnish school beginners ($N = 166$). Two remedial interventions took place in four weekly sessions of 45 min over a period of 28 weeks in Grade 1. For a child with deficits in the core pre-reading skills (letter knowledge, phonological awareness or rapid automatized naming), the computer-assisted remedial intervention would be the most successful in remediating reading fluency in the transparent Finnish language. Furthermore, children in the computer-assisted intervention were able to reach the average level of the mainstream children by the end of Grade 2.

Differences in the reading fluency distinguish competent from poor readers (e.g., Stanovich, 1991). Dysfluent reading performance is an outcome of difficulties in word recognition systems; such as phonology and orthography (Breznitz, 2006). The inability to read fluently constitutes a problem for struggling readers as they tend to read in a labored, disconnected manner with a focus on decoding at the word level that challenges reading comprehension (Compton & Carlisle, 1994; Hudson, Lane, & Pullen, 2005; Lyon & Moats, 1997; Torgesen et al., 2001; Torgesen, Rashotte, Alexander, Alexander, & MacPhee, 2003; see also Johns, 1993; Samuels, 1988; Schreiber, 1980). This inability to read fluently has been attributed to a slow and serial phonological decoding process as shown by a greater sensitivity to the number of letters in a word, commonly labeled as the word length effect (Martens & de Jong, 2006; Ziegler, Perry, Ma-Wyatt, Ladner, & Schulte-Körne, 2003; Zoccolotti, De Luca, Judica, & Spinelli, 2008). In an effort to extend the finding of the existing the reading fluency studies, the main goal of the present study was not only to follow the effectiveness of the remediation but at the same time, investigate the predictors of word-level reading fluency. The former intervention studies have concentrated mainly on remediating fluency itself, that is, basically on rate (see e.g., Mastropieri, Leinart, & Scruggs, 1999; Yap & van der Leij, 1993). The present paper investigated a quite new area covering; what effects early intervention on letter knowledge and phonological skills has on future word-level reading fluency skills. In the present study the word-level reading fluency outcomes were assessed in three contrastive reading groups. More specifically, two reading interventions implemented in Grade 1 were observed and contrasted to the development of the mainstream group. This was done to find out whether a reading intervention targeted at phonological awareness and letter–sound connections, would have an impact on the future word-level reading fluency outcomes.

The early phases of learning to read are considerably influenced by the orthography of the language the child is exposed to. Orthographic consistency may determine the rate of reading acquisition across different languages (Ziegler & Goswami, 2005). The syllabic complexity and orthographic depth of a language have strong effects on word reading skill during the literacy foundation phase: word reading skills are easier to acquire in the shallower orthographies (e.g. Seymour, Aro, & Erskine, 2003; Ziegler & Goswami, 2005; Ziegler et al., 2010). Among the languages spoken in Europe, the Finnish language has the shallowest orthography (full symmetric consistency between graphemes and phonemes) and the simplest syllabic structure (Seymour et al., 2003). When a Finnish-speaking child has acquired the names of the letters and systematic letter–sound rules, s/he can easily read and spell all Finnish words (e.g. Lyytinen, Leinonen, Nikula, Aro, & Leiwo, 1995). In the Finnish language context one-third of

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children can read at the time they enter school, at the age of seven. Most of the remaining children in the same age cohort acquire their basic word reading skills during the first year of formal schooling (Holopainen, Ahonen, & Lyytinen, 2001; Lerkkanen, Rasku-Puttonen, Aunola, & Nurmi, 2004a; Niemi, Poskiparta, Vauras, & Mäki, 1998; Seymour et al., 2003).

The current longitudinal investigation focused on the word-level reading fluency development and its predictors in the highly transparent Finnish language. The study was formed on reading accuracy and speed in word level reading. Rasinski (2003) proposed that accuracy, or accurate decoding of words in text, automaticity, or decoding words with minimal use of attentional resources, are among pivotal components of reading fluency. Consequently, dysfluent reading relates to three linguistic levels each of which incorporates aspects of fluency: (1) word level, (2) syntactic level and (3) meaning level (Meyer & Felton, 1999). Automaticity in the fluency context refers to the quick and effortless identification of words in or out of context (Ehri & McCormick, 1998; Kuhn & Stahl, 2000a,b); whereas reading rate is quantified in terms of reading speed (Hudson et al., 2005). Yap and van der Leij (1993) pointed out that word reading fluency — the rate of identification of single words — is defective in children with reading disabilities. This 'automatic decoding deficit' has received substantial support (Breznitz, 2002; Van den Bosch, Van Bon, & Schreuder, 1995; Van der Leij & Van Daal, 1999; Wimmer, Mayringer, & Landerl, 1998). According to Mastropieri et al. (1999) reading intervention programs generally focus on increasing the reading rate, as slow reading rate can lead to weakened comprehension.

In turn, Wolf and Katzir-Cohen (2001) strongly argue for a definition of fluency that is developmental- and component-based, where rate and speed are characteristics of the components and subskills of reading, and where accuracy and automaticity are assessable outcome stages of reading and reading fluency. This type of processing frees reader's conscious attention to comprehend or construct meaning from the text (e.g., LaBerge & Samuels, 1974; Perfetti, 1985). In sum, the ultimate goal of reading is to allow reader to focus on content.

The theories presented above have had a profound impact on the design of remedial intervention programs for improving reading fluency. Recent research has found that both repeated oral reading and continuous oral reading increase reading fluency (O'Connor, White, & Swanson, 2007). According to the review by Chard, Vaughn, and Tyler (2002) reading fluency research has focused almost entirely on repeated-reading interventions. Moreover, the most effective interventions in enhancing fluency for children with learning disabilities are often teacher-modeled (Chard et al., 2002). Chard, Vaughn, and Tyler (2002) also argue for the importance of repeated reading of the same text, and also the reading of increasingly difficult text accompanied with feedback and correction. Kuhn and Stahl (2003) also reported on the effectiveness of fluency instruction through repeated reading in their review. However, Kuhn and Stahl (2003) also noted that positive effects found may have been due to the increased amount of reading rather than repeated reading in itself. In the present paper, however, focus is on a reading intervention targeted at phonological awareness and letter–sound connections, and what impact this early intervention has on reading fluency outcomes of at-risk children in the end of Grade 1 and 2.

Since the seminal work of Frederiksen (Frederiksen, Warren, & Rosebery, 1985), the beneficial effects of flashed presentations on phonological decoding and word identification were demonstrated by several studies (e.g., Das-Smaal, Klapwijk, & Van der Leij, 1996; Kappers, 1997; Van den Bosch et al., 1995). According to Snellings, van der leij, de Jong, and Blok (2009) it is important to note that these studies focused on the sublexical level to generate transfer effects and not on the repeated-word level, which affects only word-specific knowledge (i.e., the overlearning of trained words, not affecting new words; Van Daal & Van der Leij, 1992). Consequently, the focus of the flashed presentation studies, have been on single word reading. Breznitz (2006) argued that reading rate manipulation was beneficial for reading sentences both among adult readers with reading disabilities and among normally achieving readers. More recently Huemer, Landerl, Aro, and Lyytinen (2008) found that a focus on sublexical items increased reading fluency of the trained consonant clusters; however, the generalization effects were small.

The study presented here was based on the earlier findings that assessments carried out before direct exposure to reading instruction seem to be valuable predictors for further success in reading (McGuinness, 2004). The intervention model used in the present study was loosely derived from the Response to Intervention (RTI) model (for review see e.g., Fuchs & Fuchs, 2006; Gertsen & Dimino, 2006; Linan-Thompson, Vaughn, Prater, & Cirino, 2006; Vaughn, Linan-Thompson, & Hickman-Davis, 2003; Vellutino, Scanlon, Small, & Fanuele, 2006) commonly used in the United States. Further, the measurements used in the study are very similar to the American fluency measures such as DIBELS (for review see e.g., Good, Gruba, & Kaminski, 2001).

Phonological awareness, letter knowledge and rapid automatized naming have been shown to play a pivotal role in pre-reading skills (e.g., Adams, 1990; Elbro, Borstrøm, & Petersen, 1998; Gallagher, Frith, & Snowling, 2000; Lonigan, Burgess, & Anthony, 2000; Pennington & Lefly, 2001; Scarborough, 2001; Vellutino, Fletcher, Snowling, & Scanlon, 2004; Wimmer, Mayringer, & Landerl, 1998; 2000; Wimmer & Mayringer, 2002). The speed with which text is translated into spoken language has been identified as a major component of reading proficiency (Adams, 1990; Fuchs, Fuchs, Hosp, & Jenkins, 2001; Hasbrouck & Tindal, 1992; Samuels, Schermer, & Reinking, 1992). A recent study of five European languages by Ziegler et al. (2010), indicated that phonological awareness was the main factor associated with reading in each language. However, once struggling readers learn sound–symbol relationships through intervention and become accurate decoders they are well on their way to reading proficiency (e.g., Hudson et al., 2005; Torgesen et al., 2001, 2003). Naming skills have also been found to be connected with both early reading acquisition and later reading abilities (e.g., Badian, 1993; de Jong & van der Leij, 1999; DiFilippo et al., 2006; Kirby, Parrila, & Pfeiffer, 2003; Parrila, Kirby, & McQuarrie, 2004; Wimmer, 1993). Ziegler et al. (2010) however reported that the influence of rapid naming was rather weak and limited only to reading speed.

1. Finnish language and GraphoGame

A reading strategy for children acquiring reading ability in a transparent orthography would likely be phonological reading. Finnish beginning readers do not have the advantage of sight words because of two idiosyncrasies of language. First, the number of monosyllabic word is only about 50. Words also tend to be excessively long because of agglutinative nature of the Finnish language. Beginning Finnish readers have been found to decode words and nonwords equally well. Holopainen, Ahonen, Tolvanen, and Lyytinen (2000) found a correlation of 0.93 between these two measures among their preschool readers. When assessing cross-linguistically the ability to decode English-speaking first-graders show error rates between 40% and 80% (Juel, Griffith, & Gough, 1986; Treiman, Goswami, & Bruck, 1990), whereas in Finnish (e.g., Holopainen et al., 2001) and German (e.g., Wimmer & Hummer, 1990) error rates were below 25%.

In Finland primary schools begin when children become seven years old. In Finnish schools reading and spelling is taught through and phonics-based instruction, in which the learning of sound–symbol correspondences is important (Lerkkanen, 2007). This emphasis is explained by the fact that the orthography of Finnish is almost perfectly transparent, which makes reading and spelling acquisition parallel processes: spelling a phoneme is as consistent as pronouncing a grapheme. Reading and spelling instruction in general, and also in the classrooms of this particular study, includes learning of letter names as well as listening, segmenting, and blending phonemes and syllables. After a few letters and sounds have been mastered, they are combined into CV/VC syllables and CV/VC-CV/VC words.

In the Finnish language context, phonological awareness has been widely investigated (e.g., Holopainen et al., 2000; Lerkkanen, Rasku-Puttonen, Aunola, & Nurmi, 2004b; Lyytinen et al., 2006; Puolakanaho, Poikkeus, Ahonen, Tolvanen, & Lyytinen, 2003) and letter knowledge has been demonstrated to be an important predictor of reading skills (see e.g., Lepola, Salonen, & Vauras, 2000; Lerkkanen et al., 2004a; Lyytinen, Ronimus, Alanko, Poikkeus, & Taanila, 2007; Lyytinen, Erskine, Kujala, Ojanen, & Richardson, 2009; Torppa et al., 2007; Poskiparta, Niemi, & Vauras, 1999), while a connection between rapid automatized naming and reading speed has been reported by Torppa et al. (2007).

Previous study by the present research project examined reading subskill outcomes in a regular remedial reading intervention and computer-assisted remedial reading intervention (Saine, Lerkkanen, Ahonen, Tolvanen, & Lyytinen, in press). In the present study, the word-level reading fluency outcomes were predicted with two growth components of letter knowledge, phonological awareness and rapid automatized naming. Furthermore, the intervention outcomes were predicted for three contrastive reading groups: remedial and computer-assisted remedial reading intervention, and mainstream instruction. The goal of the present study was to shed new light on what kinds of interventions produce the best results in the area of reading fluency. In other languages it has been argued that remedial programs are not effective enough (see e.g., Bentum & Aaron, 2003; Hatcher, Hulme, & Snowling, 2004; Kennedy, Birman, & Demaline, 1986; Moody, Vaughn, Hughes, & Fischer, 2000; Puma et al., 1997; Snow, Burns, & Griffin, 1998; Torgesen, 2005).

In the study the mainstream condition was applied along with two different intervention conditions to assess developmental variation in the acquisition of letter knowledge and word-level reading fluency. The two intervention conditions were: 1) regular remedial reading intervention (hereafter RRI) and computer-assisted remedial reading instruction (henceforth CARRI) which was the RRI complemented with the GraphoGame computer program. The GraphoGame program (Lyytinen et al., 2007) was used to enrich the regular type of remedial reading intervention by providing an intensive individual learning environment with individualized repetition. GraphoGame applies two key alphabetic principles: phoneme awareness and letter knowledge. The GraphoGame application gives both visual and audio feedback to both correct and incorrect choices of letter–sound correspondences. Moreover, GraphoGame progresses from letter–sound relations to the stage of phonological recoding and decoding, covering the basic areas needed for fluent and accurate reading.

GraphoGame was developed to harness the cognitive operations that constitute reading a word. These include the visual operations of putting individual letters into an orthographic unit (visual word form) and their transformation into an internal sound (input phonology) and its articulation (output phonology). Earlier studies (e.g., Seidenberg & McClelland, 1989; Poshner & Rothbart, 2007) have also based their theories of decoding on cognitive operations. In GraphoGame letters and words appear at an accelerating rate on the screen and might improve automatized naming and visual recognition more effectively than in more regular environments (e.g., when using flash cards). Further, a computer-assisted reading environment can be described as attention catching, while play-like features with immediate rewards and individualized instruction in a fun format make decoding practices less formidable and motivate the child to complete tasks.

2. Aims

The main goal of the study was to build a model of the predictive value of word-level reading fluency in three contrastive groups whose reading acquisition has been supported differently, that is, via participation in remedial reading intervention (RRI), or computer-assisted remedial reading intervention (CARRI), or mainstream instruction. A second aim was to identify the most effective types of intervention for children with different profiles of compromised pre-reading skills before school age. For this purpose, the development of word-level reading fluency post intervention for each of the three types of instruction was followed.

Longitudinal studies have convincingly shown that letter knowledge, phonological awareness and rapid automatized naming (RAN) are all predictors of reading fluency development and indicators of early risk for reading disability (e.g. Gallagher et al., 2000; de Jong & Olson, 2004; Lonigan et al., 2000; Pennington & Lefly, 2001; Scarborough, 2001; Wagner, Torgesen, & Rashotte, 1994; Wimmer et al., 1998). The participants of the present study were followed from the school entry to Grade 2. Those with the most typical risk profiles were selected for examination using either remedial reading intervention (RRI), computer-assisted remedial reading intervention (CARRI), or mainstream instruction.

Three types of pre-reading risk profiles were of interest: (1) children with low performance in all three core pre-reading skills (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. That was done by regressing the final level and slope of letter knowledge and word-level reading fluency on the three core pre-reading skills (letter knowledge, phonological awareness and rapid automatized naming).

3. Methods

3.1. Participants

Seven-year-old native Finnish-speaking children were selected for participation in the study by means of a screening process. Two cohorts ($n = 88$ and $n = 83$) of school beginners were screened in the province of Western Finland. 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) finally participated in the study. All of these children where followed from school entry to the beginning of Grade 3.

3.2. Procedure

All the schools in the experiment were from the same school district. The district is in a middle-class suburban area with consistent socio-economic status and population density. The pre-reading skills of all the seven-year-old school beginners participating in the study ($N = 166$) were tested during first two weeks of Grade 1. The screening included (1) letter-knowledge, (2) six phonological subtests of the nationally normed reading test battery (ALLU; Lindeman, 1998) and (3) the Rapid Automatized Naming Test (RAN; Ahonen, Tuovinen, & Leppäsaari, 1999). In the letter-knowledge examination the 29 letters of the Finnish alphabet were presented in mixed order individually to each child. The examiner pointed to the letter and the child was asked to name it. Responses were accepted as correct if the child produced the appropriate name or phonetic sound of the letter. The six phonological subtests (ALLU; Lindeman, 1998) measuring the children's phonological abilities, such as identification of rhyming words, building words by syllable sounds, word fragmentation, deletion of initial sounds, letter–sound relations, and deletion of final sounds were administered in groups. The Rapid Automatized Naming test (RAN; Ahonen et al., 1999) was used to assess automatized naming speed. IQ was estimated by the vocabulary, similarities, digit span and block design tests of the WISC-III (Wechsler, 1999) in the spring term of the Grade 2 in both cohorts.

The lowest achieving 30% of these children, in two screening assessments out of three, were offered remedial reading intervention. 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. After that the target group participants were randomly divided, i.e., by being assigned random numbers, into two groups. Thus each participant had a 50% chance of ending up in either of the two equivalent intervention conditions. Consents for the remedial reading intervention and research protocols were obtained at the time of the parental interview. After these procedures the fifty (30 boys, 20 girls) lowest achieving children with possible risk for RD were randomly divided into two experimental groups of twenty-five while the remaining 116 children (48 boys, 68 girls) formed the mainstream reading group.

A questionnaire was administered to parents ($N=50$) of the children requiring remedial reading intervention. These children's family background, including parents' level of education, parental marital status, size of family, child's birth order, and information about family risk for RDs were covered. The representativeness of the children's family background with respect to the general Finnish population was good. Among the children's mothers in the RRI 16% and in the CARRI 24% had a Master's degree or higher, 72% (RRI) and 60% (CARRI) had a BA or vocational school degree, 12% (RRI) and 16% (CARRI) had no education beyond comprehensive school. Among the children's fathers, 20% in both intervention groups had a Master's degree or higher, 56% (RRI) and 64% (CARRI) had a BA or vocational school degree, and 24% (RRI) and 16% (CARRI) had no education beyond comprehensive.

In RRI 60% of children and in CARRI 56% of children came from nuclear families, 24% (RRI) and 20% (CARRI) were from single parent families, 8% (RRI) and 8% (CARRI) from blended families, and 8% (RRI) and 16% (CARRI) from families where the parents were divorced and the child has two homes. Four percent of the children in both intervention groups came from families with two members and 20% of the children in both intervention groups were from families with three members. Moreover, 32% (RRI) and 24% (CARRI) of children came from families with four members, 36% (RRI) and 40% (CARRI) from families with five members, and 8% (RRI) and 12% (CARRI) from families with six members. In RRI 24% and in CARRI 32% of the children were firstborns, 48% (RRI) and 36% (CARRI) were secondborns, 20% (RRI) and 24% (CARRI) were thirdborns, and 8% of the children in both intervention groups were born as forthborns.

Parents answered questions about whether they or the child's biological siblings had encountered difficulties in learning literacy at school age. Among the mothers 40% (RRI) and in the 49% (CARRI) responded “yes”, and among the fathers responded “yes” 32.3% (RRI) and 57.7% (CARRI) of fathers, and 28% (RRI) and 62% (CARRI) of siblings were indicated to have had or continually have problems in reading and/or writing. However, no reading disability diagnoses were available.

Nine classrooms in four elementary schools participated in the study. Both treatment conditions RRI and CARRI were administered in each school. There was no statistical difference in pre-reading skills between the RRI and CARRI groups (see Table 1). The remedial training was spread over a 28-week period between October and

Table 1
Variable means and standard deviations in three groups ($N=166$).

Variable	RRI ($N=25$)			CARRI ($N=25$)			Mainstream ($N=116$)		
	Mean (SD)	Min	Max	Mean (SD)	Min	Max	Mean (SD)	Min	Max
Gender									
Number of boys	13			17			48		
Number of girls	12			8			68		
Age in months	87.40 (4.43)	81	101	86.20 (5.76)	77	102	88.00 (3.72)	80	98
IQ Estimation									
WISC-III[a]	101.44 (11.80)	85	126	102.68 (11.45)	78	122	103.15 (12.70)	75	136
April, Grade 2 (*IQ estimation*)									
Phonological awareness[b]									
August, Grade 1 (*Screening test*)									
Identification of rhyming words	3.24 (1.54)	1	6	2.96 (1.90)	0	8	9.34 (1.11)	2	10
Building words by syllable sounds	3.92 (1.15)	2	6	3.96 (1.72)	0	6	9.27 (1.04)	3	10
Word fragmentation	3.40 (1.08)	2	5	3.52 (1.33)	0	6	8.33 (1.39)	2	10
Deletion of the initial sound	4.20 (1.29)	2	7	5.40 (2.04)	2	8	8.69 (1.39)	2	10
Letter sound connection	4.96 (1.77)	2	7	5.04 (1.57)	2	7	8.45 (1.57)	4	10
Rapid automatized naming[c]									
August, Grade 1 (*Screening test*)	66.38 (7.11)	55.6	78.4	69.74 (6.80)	58.7	82.4	56.26 (5.18)	47.8	71.4
Letter knowledge[d]									
August, Grade 1 (*Screening test*)	6.64 (2.41)	3	12	7.60 (2.29)	4	12	21.22 (5.46)	8	29
October, Grade 1 (*Subtest I*)	11.28 (3.04)	7	20	14.60 (3.56)	8	24	23.44 (4.59)	12	29
December, Grade 1 (*Subtest II*)	17.60 (3.18)	13	23	20.88 (3.23)	12	26	25.38 (3.51)	15	29
January, Grade 1 (*Subtest III*)	22.16 (3.64)	15	28	24.64 (2.86)	18	28	26.62 (2.53)	17	29
March, Grade 1 (*Subtest IV*)	27.24 (1.74)	22	29	28.88 (0.44)	27	29	28.64 (0.79)	25	29
Reading fluency[e]									
May, Grade 1 (*Post test*)	26.44 (10.86)	6	50	35.80 (11.42)	6	50	47.51 (14.10)	12	78
May, Grade 2 (*Follow-up I*)	48.28 (12.14)	24	70	60.68 (11.97)	24	74	64.32 (12.27)	31	88

Notes. RRI = Regular Reading Intervention, CARRI = Computer-assisted Remedial Reading, Mainstream = Mainstream reading group.
[a] IQ was estimated by the vocabulary, similarities, digit span and block design tests of WISC-III.
[b] Maximum score 10.
[c] Time used in automatized naming.
[d] Maximum score 29.
[e] Items read correctly in 2-min time-limited test.

late-April in Grade 1. The only difference between the two conditions was the type of remedial reading instruction given during the first 15-min of the remedial reading class. The mainstream group received phonics-based reading instruction in regular classroom teaching with no special form of additional provision from the research group. The participants were taught by nine class teachers altogether. Each teacher taught their class for two years. All the teachers (eight female and one male) had a Master's degree in education and were qualified primary school class teachers with at least 5 years experience in teaching reading to school beginners. The class teachers performed the all basic teaching activities in their classes.

3.3. Word-level reading fluency measures

3.3.1. Fluency

A 2-min time-limited word-level fluency test (Lukilasse Graded Fluency Test; Häyrinen, Serenius-Sirve, & Korkman, 1999) was constructed to assess word-level reading fluency and accurate decoding. The word-level reading fluency test consists of 90 Finnish words ranging 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 2 min. The word-level reading fluency test was carried out twice: at the end of the experiment (Post test) and 12 months later (Follow-up 1). The reliability of the test in the Grade 1 test was 0.979. In the Grade 2 test reliability was 0.968.

3.4. Interventions

The study was designed to assess the effectiveness of an intervention that would be viable in a resource room setup. Consequently, the training regimes, consisting of four weekly sessions of 45 min, held over a period of 28 weeks were designed for children working in groups of five, and were incorporated into 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 the Grade 1 varied. The average period of time the children spent in the resource room was 66 h. The intervention time varied according to absences and extracurricular conditions such as field trips or public holidays. Both experimental groups were trained out by the same remedial reading specialist, to exclude trainer effects. The training protocols were monitored by keeping written records for each intervention session, and through observation and discussions with the special education team. In each group the exercises were carefully planned to meet the participants' specific requirements and each involved individualized, highly structured training, embodying many current recommendations for good remedial practice (e.g., Fletcher, Lyon, Fuchs, & Barnes, 2007; Swanson, Harris, & Graham, 2006). Meanwhile, all 166 first graders in the study received phonic-based reading instruction in their classrooms.

3.4.1. RRI

The regular phonics-based remedial reading intervention package in the RRI group was administrated by using regular remedial procedures for Grade 1 students in groups of five. Each 45-min remedial intervention period was divided into four segments: (1) pre-reading activities linking reading, spelling and phonology (lasting 15-min), such as, games of letter–sound associations and sound synthesis into syllables and words, and fluency by using flash cards, Logigo® and LUKO® plastic game boards,[1] (2) activities of word segmentation (lasting 10-min), for example, identification and manipulation of syllables and sounds within words, rhyming words, and omission of sounds from words, sound substitutions within words, and identifying words as units within sentences; (3) activities of decoding and spelling (lasting 10-min), such as writing words/pseudo-word while paying attention to letter–sound relationships, recoding, decoding, fluency, reading and writing in context; and (4) vocabulary training (lasting 10-min) by using improvisation cards, mimicry, pantomime, acting, and illustrating charades on a blackboard or tale telling. The intervention package progressed from easier to more challenging activities.

3.4.2. CARRI

The CARRI group used the same phonics-based remedial reading package as the RRI group with the difference that the GraphoGame application was used during the first segment instead of the pre-reading activities described above. Thus the students had 15 min individual time with GraphoGame at the beginning of each session. The mean time-on-task was 4 h 53 min.[2]

Three PC computers with Windows XP and an Internet connection were allocated to each group of five participants. The computer-assisted training and regular remedial reading training overlapped in the first segment. Two to three participants at a time with the computer application, while the others completed the regular remedial reading tasks allowed to the second segment. At the end of the 15-min the participants changed over.

The GraphoGame computer-assisted intervention has been specially developed for children with learning disabilities and risk for dyslexia. The software was developed within the Jyväskylä Longitudinal Dyslexia Study (see e.g., Lyytinen et al., 2004) with the overall aim of preventing developmental reading disabilities among children at-risk for reading failure (for further details see Lyytinen et al., 2007, 2009). The GraphoGame application provides productive drill and practice in pre-reading and reading skills; such as the integration of letter–sound relations and phonemic awareness, decoding skills and further practice in accuracy and fluency.

The application delivers context-free practice on specific syllable and word identification skills. The graphics used in the GraphoGame include falling balls which contains an orthographic stimulus. Simultaneously with the falling balls an auditory stimulus is given via headphones. The ball, which matches the auditory stimulus, is selected from among the 2–9 falling balls on the orthographic target. From 2 to 9 orthographic items fall as balls on the screen. 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 gradually in stages to sound synthesis in syllables, words and pseudo-words, aiming at acquisition of the alphabetic principles of the Finnish language.

GraphoGame is programmed to support the individual rate of acquisition by adapting task difficulty to the level of personal achievement. The ultimate aim is an automatic connection between the auditory and orthographic stimulus. 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 enable researchers to monitor the responses of each individual, while the application makes automatic adjustments to meet the special needs of each individual.

In the present study, 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 on 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 reading

[1] Exposure time is the time spent on task, during the letter–sound connection or word accuracy and fluency training, or time spent practicing with the GraphoGame application. Attending to instructions, receiving rewards, and moving between screens were all subtracted from exposure time.

[2] 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.

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 study, adherence was assessed through the written reports of a reading specialist and through the GraphoGame game server reports and graphs. Thus the research team was able 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, Brannigan, Falco, & Hansen, 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 engagement 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 reading specialist had an MA in education and was specialized in training children with reading disabilities. Furthermore, the GraphoGame intervention used in the CARRI group, which was based on the Jyväskylä Longitudinal Study of Dyslexia (see e.g., Lyytinen et al., 2004), 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.

The children were also taught in their own classrooms by their regular primary school teacher during the intervention period (seven months). During the present interventions, the participating 166 children did not receive any other interventions. Later on, in Grade 2, the 22 lowest achieving children in the RRI ($n=20$) and CARRI groups ($n=2$) received a regular reading intervention based on reading fluency that was not enriched with any CAI applications. The rest of remaining children were placed into the mainstream reading groups in their home classes and they did not receive any intervention after Grade 1. In the Finnish school system the Grade 2 literacy curriculum focuses on fluency and reading comprehension, as nearly every child learns to decode in Grade 1 (see e.g., Lerkkanen, 2007).

4. Statistical analysis

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 a normative 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 RRI ($n=25$) and CARRI ($n=25$). The observed variables as well as latent factors were regressed on the dummy variables utilizing a large modification index. The resulting effects were the main effects of the RRI and CARRI groups. To be able to test the paths between intervention groups and the normative Mainstream group, the interaction variables were formed and tested in the same way as was done for the main effects.

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 the intervention to the development of the level of letter knowledge achieved and (2) to control for the level of letter knowledge achieved as a predictor of later reading.

Second, word-level reading fluency was predicted with the growth factors of letter knowledge and the final model goodness-of-fit 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, 1998–2004). For other variables, 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.

5. Results

To build a model of the word-level reading fluency development, pre-intervention letter knowledge, phonological awareness and rapid automatized naming were used as predictors in all three contrastive reading groups. The differences in this development and in the predictions between the two experimental intervention group, and the mainstream training group were taken into account on the basis of the modification index. In the first step, the paths from the dummy-coded variables were added to the model, if needed, to observe and latent variables. This yields the prediction related directly to the effects of the interventions. In the second step, the regression paths between the dependent and interaction variables were added to the model if needed. This path explains the statistically significant differences in the regression coefficients between the groups. The final model (see Fig. 1) fitted the data well $\chi^2(58)=59.13$, $P=0.43$, TLI = 1.0, CFI = 1.0, RMSEA = 0.011, SRMR = 0.024.

5.1. Predictors of reading word-level reading fluency in Grade 1

Word-level reading fluency in Grade 1 was predicted by the final level (regression coefficient 0.15, the same for all three groups) and the slope (regression coefficient −0.59, the same for all three research groups) of letter knowledge (see Fig. 1). Also, phonological awareness (0.28, the same for all three groups) and rapid automatized naming (a regression coefficient of 0.33 was needed only for the CARRI group) predicted the word-level reading fluency outcome. A higher level letter knowledge in Grade 1, January and a low change in letter knowledge predicted more fluent reading in Grade 1, May.

A higher level of phonological awareness predicted fluent reading in all three groups, while lower rapid automatized naming predicted fluent reading in the CARRI group. The predicted mean for letter knowledge in January was Mainstream (0), RRI (−2.89), and CARRI (−1.82). In Grade 1, the RRI and the CARRI were 3.66 and 2.30 standard deviations respectively below the Mainstream group. The predicted values in word-level reading fluency for the RRI and CARRI were 1.65 and 0.90 standard deviations (standard deviation 0.91 of the Mainstream group) lower than the mean value of the Mainstream group. These values were calculated by using the equation Index A (see Appendix A).

5.2. Predictors of word-level reading fluency in the Grade 2

Word-level reading fluency in Grade 2 was predicted by word-level reading fluency in Grade 1 (regression coefficient 0.85, was the same for all three groups) revealing high stability. The higher value of phonological awareness in the screening test (Grade 1, August), predicted the better word-level reading fluency outcome (regression coefficient was 0.29) in the CARRI group Grade 2.

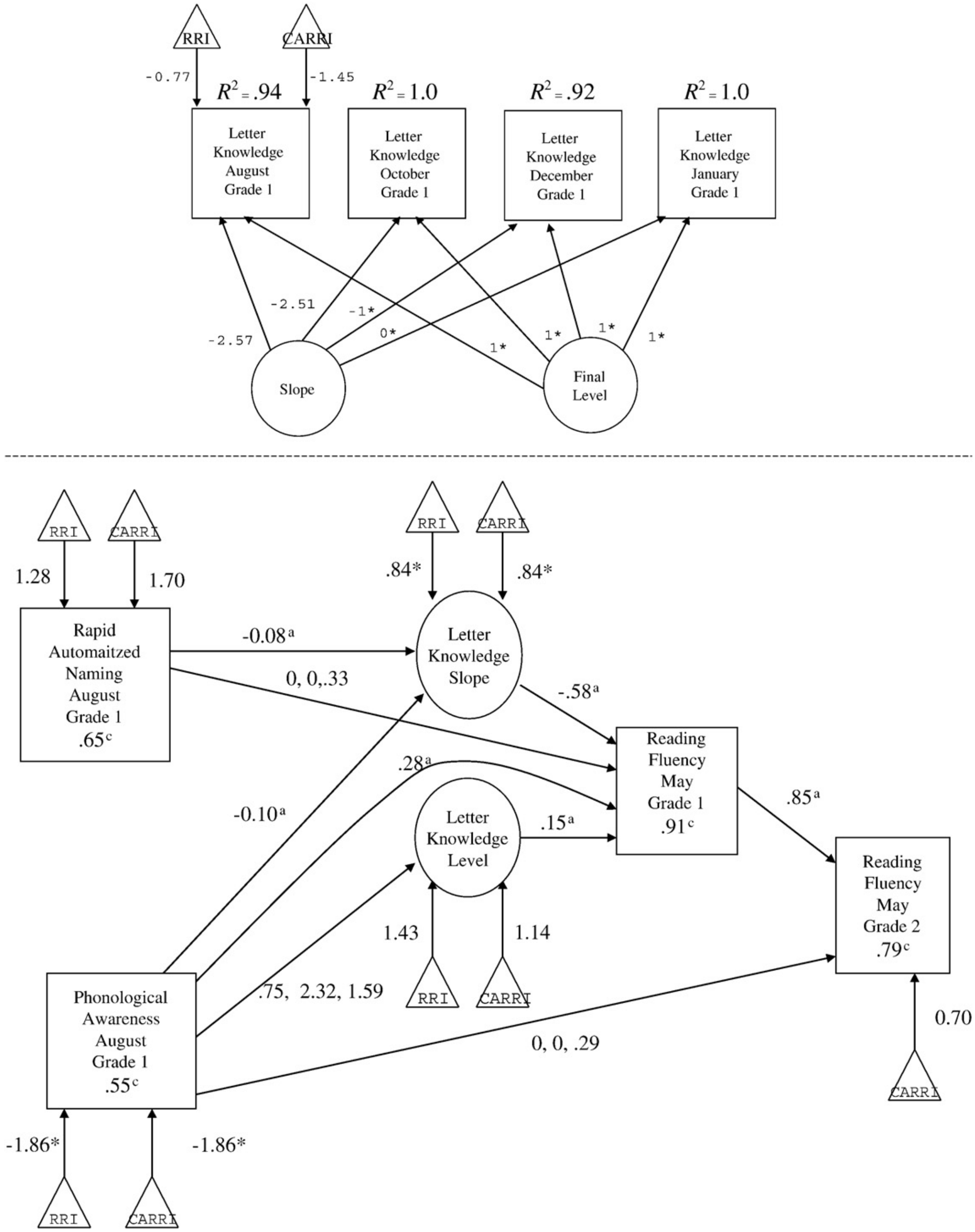

Fig. 1. The predictors of reading fluency. Notes. RRI = Regular Reading Intervention, CARRI = Computer-assisted Remedial Reading, Mainstream = Mainstream reading group; *Fixed equally between the RRI and CARRI groups; [a]Equal for all groups; [b]Fixed value; [c]Standard deviation of the Mainstream group.

The predicted values of word-level reading fluency for RRI (1.62) and CARRI (0.68) were lower than the mean value of the Mainstream group (0.79) in Grade 2. These values were calculated by using the equation Index B (see Appendix A).

5.3. Pseudo individual analysis

Based on the estimated model, individual trajectories in reading development were produced for several risk types by using pseudo individuals. Fig. 2 shows that if all the core pre-reading skills (phonological awareness, letter knowledge and rapid automatized naming) were on a low level (see Fig. 2a), the RRI group, along with the Mainstream group, would yield the same learning achievement profile in word-level reading fluency, whereas the computer-assisted intervention group (CARRI) would perform nearly 1.0 standard deviation better than the other two contrastive groups. If letter knowledge and phonological awareness were low and rapid automatized naming on average (see Fig. 2b), both the RRI group and Mainstream group would yield the same learning achievement profile in word-level reading fluency. However, placement in the computer-assisted intervention group (CARRI) would be slightly more successful than placement in the RRI or Mainstream group. If letter knowledge was low and phonological awareness and rapid automatized naming were on the average level (see Fig. 2c), the RRI

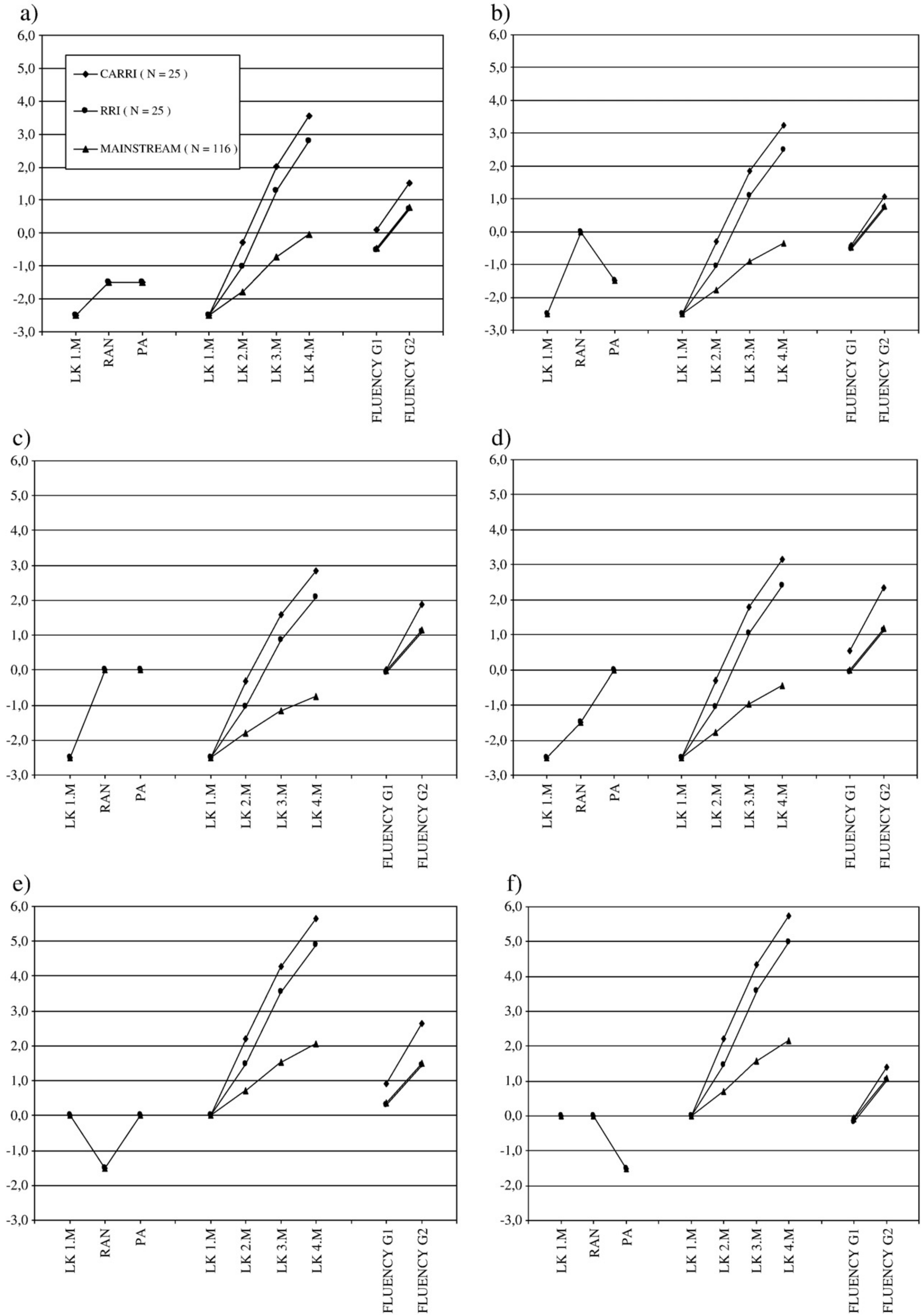

Fig. 2. The predictors of reading fluency for pseudo individuals. Note. RRI = Regular Reading Intervention, CARRI = Computer-assisted Remedial. Reading, Mainstream = Mainstream reading group.

group, along with the Mainstream group, would yield the same learning achievement profile in word-level reading fluency. In turn, the computer-assisted intervention group (CARRI) would be the most successful, outdistances in the other two groups by standard deviation of 1.0. If letter knowledge and rapid automatized naming were low, but phonological awareness was average (see Fig. 2d), the RRI group, along with the Mainstream group, would once again yield the same learning profile in word-level reading fluency, whereas the CARRI group would perform over 1.0 standard deviation better than either of the other two contrastive groups. If rapid automatized naming was low but phonological awareness and letter knowledge were average (see Fig. 2e), the RRI group along with the Mainstream group, would yield the same learning profile in word-level reading fluency. In turn, the CARRI group would perform over 1.0 standard deviation better than either of the two contrastive groups. If phonological awareness was low but rapid automatized naming and letter knowledge were average (i.e. Fig. 2f), the RRI group, along with the Mainstream group, would once again yield the same learning achievement profile in word-level reading fluency, while the CARRI group would be slightly more successful than the others.

It appeared that the CARRI group would produce a better level of achievement (about 1.0. standard deviation) in word-level reading fluency than either of the other two contrastive groups, especially if a child was slow in automatized naming and had low letter knowledge on school entry. If phonological awareness was low, the CARRI group would perform slightly better in word-level reading fluency outcomes than either of the other two groups. Even if all compromised pre-reading skills were low the CARRI group would perform nearly 1.0 standard deviation better than either of the other two contrastive groups.

5.4. Group differences

A further, the aim was to predict, whether word-level reading fluency of at-risk children can be boosted by a computer-assisted reading intervention program. ANOVA was used for measures. The mean value for word-level reading fluency in the groups differed in word-level reading fluency ($F(2,163)=31.18$, $p=<0.001$) in Grade 1, May. The Mainstream group had a higher mean and differed significantly from both experimental groups $p<0.001$, while the multivariate Bonferroni pairwise test indicated that the CARRI group did not differ statistically from the RRI group ($F(2,163)=7.17$, $p<0.01$). When measured 12 months later (in Grade 2, May), the RRI group differed significantly from the CARRI and Mainstream groups (Bonferroni pairwise test $p<0.001$). No statistical differences were found between the CARRI and Mainstream groups.

The word-level reading fluency test was first completed nine months after formal schooling began (Post test, May, Grade 1). At the post test measurement the CARRI and RRI group differed significantly from each other ($t(48)=2.97$, $p\leq 0.005$). Furthermore, the CARRI and RRI group also differed significantly from the mainstream group ($t(139)=-3.88$, $p<0.001$, $t(139)=-7.03$, $p<0.001$). Improvement in the CARRI and RRI group was faster than that in the mainstream group ($F(1,139)=83.02$, $p<0.001$, $F(1,139)=26.17$, $p<0.001$, respectively). As shown in Table 2, the achievement level in effect size was 0.22 faster in the CARRI group than in the RRI group (and 0.57 faster than in the mainstream group).

At the Follow-up 1 (May, Grade 2) measurement the RRI group differed significantly from the CARRI and mainstream groups ($t(48)=3.64$, $p\leq 0.001$, $t(139)=-5.94$, $p<0.001$), whereas no statistical significant difference between the CARRI and mainstream group emerged (see Fig. 2). As shown in Table 2, the achievement level in effect size in the CARRI group was 1.01 higher than in the RRI group (and -0.30 lower than in mainstream group). When the achievement of the experimental groups was studied by using the cut-off value of the 10th percentile of the achievement in the mainstream group, the results for word-level reading fluency indicated (Follow-up 1, May, Grade 2) that 11 children (44%) from the RRI group and three children (12%) from the CARRI group were in the lowest 10 percentile. The cut-off value was set to as low as the 10th percentile because of the high transparency of the Finnish orthography. Some other studies have used higher cut-off values (see e.g., Allington & McGill-Franzen, 1994; Torgesen, 1998), but these studies have also been conducted in more opaque orthographies such as English, or their focus has been on younger children (e.g., Torgesen, 1998).

6. Discussion

The first aim of the study was to predict word-level reading fluency development with the two growth components of letter knowledge, phonological skills and rapid automatized naming, in a sample of native Finnish-speaking children who were at acknowledged risk for reading failure at the beginning of Grade 1. Word-level 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 (RRI, CARRI and Mainstream). Higher letter knowledge at the midpoint of Grade 1 predicted fluent reading in Grade 1, May. A high phonological awareness predicted fluent reading in all three contrastive research groups while lower rapid automatized naming predicted fluent reading in the CARRI group only. Overall, high phonological awareness measured at school entry, and high letter knowledge measured in Grade 1, January, (as well as a small change in letter knowledge) predicted a good word-level reading fluency outcome in all groups, in Grade 2, May. Thus, naming speed had only a slight effect on word-level reading fluency via letter knowledge. Additionally, in the CARRI group, a low score in pre-reading rapid automatized naming directly compromised the otherwise predicted better word-level reading fluency outcomes. In general, children who were at acknowledged risk for reading failure in the beginning of Grade 1 seemed to develop slower than the Mainstream group on word-level reading fluency during Grade 1. However, the CARRI group acquired the word-level reading fluency skills nearly one standard deviation ahead of the RRI group. This finding revealed that children who were at acknowledged risk for reading failure independent of their risk profile at the beginning Grade 1, benefited from the computer-assisted remedial reading training.

Word-level reading fluency in Grade 2, May, one year after the first measurement, was predicted by word-level reading fluency in Grade 2, May revealing high stability in achievement. Additionally, a higher

Table 2
Effect sizes for intervention attainment measures of letter-knowledge and, reading fluency in three groups ($N=166$).

Measures	CARRI versus RRI	RRI versus Mainstream	CARRI versus Mainstream
	d	*d*	*d*
Letter-knowledge			
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 fluency			
Follow-up I–Post test	0.22	0.36	0.57
Follow-up I	1.01	−1.31	−0.30

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

value in the screening test for phonological awareness (in Grade 1, August), predicted better word-level reading fluency at the end of Grade 2, in the CARRI group. Only the CARRI group caught up with the Mainstream group in word-level reading fluency during Grade 2. From Grade 1 to Grade 2 the gap between the two experimental groups seemed accelerate rapidly. In Grade 2, the RRI group was more than one and half standard deviations behind the Mainstream group, while a significant difference no longer existed between the CARRI and Mainstream groups. Moreover, development of word-level reading fluency was rather slow in the RRI group, while the CARRI group developed rapidly. The CARRI group was nearly one standard deviation above the RRI group in Grade 2 in May. The children in the CARRI group also seemed to have a higher level of word-level reading fluency than their peers in the RRI group in Grade 2, a year after the intervention ended. The RRI group, who received regular remedial reading training, remained in their compromised position in word-level reading fluency from Grade 1 to Grade 2.

It appeared that the training given to the CARRI group produced a better level of achievement (by about 1.0 standard deviation) in word-level reading fluency than the other two contrastive groups, especially among children with slow automatized naming and low letter knowledge at school entry. For children with low phonological awareness the CARRI would yield slightly better word-level reading fluency outcomes than either of the other two methods. On the other hand, for children whose pre-reading skills are all low CARRI would yield nearly 1.0 standard deviation better word-level reading fluency than either of the other two contrastive groups.

The results showed that the Mainstream group differed significantly from both experimental groups while the multivariate test indicated that the remedial groups did not differ from each other. The results indicated that the RRI group was statistically significantly at a lower level than the CARRI and Mainstream groups in the Grade 2 measurements, while no statistical differences were found between those latter two. The word-level reading fluency development of the CARRI group was boosted by the GraphoGame computer-assisted reading intervention program. The CARRI program rapidly increased the level of word-level reading fluency. 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 training (Saine et al., in press), but the same training also enhanced their word-level reading fluency skills.

The results indicated that the computer-assisted reading intervention (CARRI) was the most effective of the three methods used, and caused permanent improvements in the word-level reading fluency of the at-risk children for reading failure. It may be that children with phonological insensitivity do not receive sufficient amounts of repetition, drill and practice via the regular (i.e. RRI) type of intervention. At-risk children seem to need active letter–sound training to help them to read fluently and skillfully. The children in the computer-assisted remedial reading group (CARRI) received more stimulation in this key area and therefore showed a higher level of achievement. The computer-assisted remedial reading training seemed to have successfully tackled the root levels of basic reading skills. This may have influenced also to the development of word-level reading fluency. The results of the present longitudinal study reveal that the children in the CARRI group, by receiving more systematic remedial training, reached the level of the Mainstream group by the end of Grade 2.

Plausible 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 important factors in the reading development (see e.g., Cohen, Cohen, West, & Aiken, 2003; Kenny, 1979; Morgan & Fuchs, 2007). At-risk children are most likely to benefit from frequent practice but are often unmotivated to read (e.g., Chapman, 1988; Lepola, Vauras, & Mäki, 2000). This lack of motivation can be seen within a year or so of school entry (Chapman, Tunmer, & Prochnow, 2000; Lepola, Poskiparta, Laakkonen, & Niemi, 2005; Kenna, Kear, & Ellsworth, 1995). A game-like computer-assisted reading environment, such as GraphoGame, might reduce that risk. In the computer-assisted environment provided by GraphoGame, a child presumably has a chance to learn to read in a more fun way, i.e., probably enhances willingness to practice reading and plausible bridges the practice to the world-level reading fluency outcomes. In contrast, children who receive less stimuli in their remedial reading practices in regular remedial reading instruction tend to find reading laborious and are thus likely to dislike reading and decoding practices (see e.g., Morgan, Fuchs, Compton, Cordray, & Fuchs, 2008).

6.1. Limitations

There are limitations, which should be taken into consideration in any attempt to generalize these results. First, our subjects were middle-class children apparently presenting with some decoding problems at school entry. Many interventions are for children from less advantaged backgrounds and our findings do not apply to them. Second, our sample size was quite small in the intervention groups and further replication is warranted before the program is adopted in practice. Third, although Finnish children begins formal schooling in the year a child reaches the age of seven, with adequate teaching the transparency of the Finnish language enables a child to read and spell accurately very rapidly (within a year) compared to children in other languages with more opaque orthographies. Therefore, if they are to be applied more widely, CARRI intervention needs testing among children learning to read in less regular orthography.

It was somewhat alarming that the regular type remedial reading intervention did not boost the word-level reading fluency outcomes of at-risk children any better than the mainstream approach. Regrettably, this confirmed the findings of Bentum and Aaron (2003) who reported that the existing remedial programs are not effective enough (see also Hatcher et al., 2004; Kennedy et al., 1986; Moody et al., 2000; Puma et al., 1997; Snow et al., 1998; Torgesen, 2005).This disquieting result requires further investigation as well as serious discussions in the field of the Finnish remedial reading training.

The ultimate goal of reading proficiency is to allow reader to focus on content. Differences in word-level reading fluency not only distinguish competent readers from poor, but inadequate word-level reading fluency is also a reliable predictor of reading comprehension problems (Stanovich, 1991). Given these findings the effect on reading comprehension of the computer-assisted remedial reading programs should also be investigated. However, that is for future studies to tackle.

The present findings are in line with those of McGuinness (2004), who suggested that school entrance examinations should be used as predictors of future word-level reading fluency outcomes. If risk for RDs is identified, it is possible to avoid compromised development of reading skills, including word-level reading fluency. Along with several other studies (e.g., Hudson et al., 2005; Torgesen et al., 2001, 2003) the present paper found that once struggling readers learn sound–symbol relationships through intervention and become accurate decoders they are well on their way to fluent reading that extends from word-level reading to more broader units.

In the present study, the lowest achieving 30% of 166 children were offered remedial reading instruction. Reason for this number was the figures presented by the Finnish Central Statistical Office (2009), which indicated that 26–30% of Finnish children receive remedial training in Grades 1 and 2. The results indicated that all school beginners, who are at risk for reading failure, should be entitled to a remedial reading intervention that is enriched with a computer-assisted reading training, such as GraphoGame. Computer-assisted remedial reading training in a group of 4–5 students can have both a preventive role and a permanent positive impact on word-level reading fluency. If the root levels of basic reading skills, such as letter–sound connection, phonology and accurate decoding, were tackled by a systematic early intervention that includes computerized training, at-risk children could also attain the adequate reading skills (e.g., Adams, 1990; Fuchs et al., 2001; Hasbrouck & Tindal, 1992; Samuels et al., 1992).

The results were especially promising for children, with deficits in letter knowledge or automatized naming or in their phonological abilities, measured prior to formal schooling. The present findings indicate that intensive letter–name and letter–sound training at least in the case of Finnish is required for the acquisition of adequate decoding and word-level reading fluency. Regular remedial reading instruction (i.e. RRI) was not enough. Instead, drilling in the computer controlled learning environment was needed to boost the acquisition of the word-level reading fluency skills.

6.2. Conclusions

In the present longitudinal study a quite large number of children were investigated, which is rather impressive in the field of remedial reading intervention. The other interesting point was that the study was conducted in a language other than English. More remedial reading intervention studies are required in both opaque and transparent orthographies. Furthermore, the paper had a special effort to understand individual differences by creating trajectories of reading development by different groups of pseudo individuals.

Based on the paper presented it seemed that children with different compromised pre-reading profiles will benefit from different kinds of interventions depending on their deficit profiles. There are at least two novelty aspects in the paper. First, early computerized intervention (15-min at the time) in such pre-reading skills as letter–sound connections, letter names and phonological abilities seemed to have a positive impact on future word-level reading fluency skills. Second, if a child has low pre-reading skills at school entry, her/his reading abilities can plausible be boosted by a computer application such as GraphoGame. When using GraphoGame each individual child will receive intervention that is individually adapted. Further, productive drill and practice in pre-reading and reading skills which makes the practice more effective and more motivated to the child to practice especially in the cases when the child has very low pre-reading skills at school entry. The present paper also has important educational applications to improve remedial reading interventions, especially for Finnish language. In sum, computer-assisted intervention programs such as GraphoGame[3] are important instruments in remedial teaching of children at risk for reading failure and, furthermore in contributing to cost-effective remedial practices.

Acknowledgements

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[3] GraphoGame is available free to all Finnish and Swedish speaking children for free via the support of the Ministry of Education of Finland.

Appendix A. Indices

Index A

$$\underset{\text{Grade 1 in May}}{\textit{Readings fluency}} = \begin{cases} .15 \times \textit{LK final level} - 0.59 \times \textit{LK slope} + 0.28 \\ \quad \times \textit{PA for the Mainstream Group} \\ .15 \times \textit{LK final level} - 0.59 \times \textit{LK slope} + 0.28 \\ \quad \times \textit{PA for the RRI Group} \\ .15 \times \textit{LK final level} - 0.59 \times \textit{LK slope} + 0.28 \\ \quad \times \textit{PA} + 0.33 \times \textit{RAN for the CARRI Group} \end{cases}$$

Index B

$$\underset{\text{Grade 2 in May}}{\textit{Readings fluency}} = \begin{cases} 0.85 \times \textit{reading fluency}(\text{May1stGrade}) \\ \quad \textit{for the Mainstream Group} \\ 0.85 \times \textit{reading fluency}(\text{May1stGrade}) \\ \quad \textit{for the RRI Group} \\ 0.70 + 0.85 \times \textit{reading fluency}(\text{May1stGrade}) \\ \quad + 0.29 \times \text{PA}\,\textit{for the CARRI Group} \end{cases}$$

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