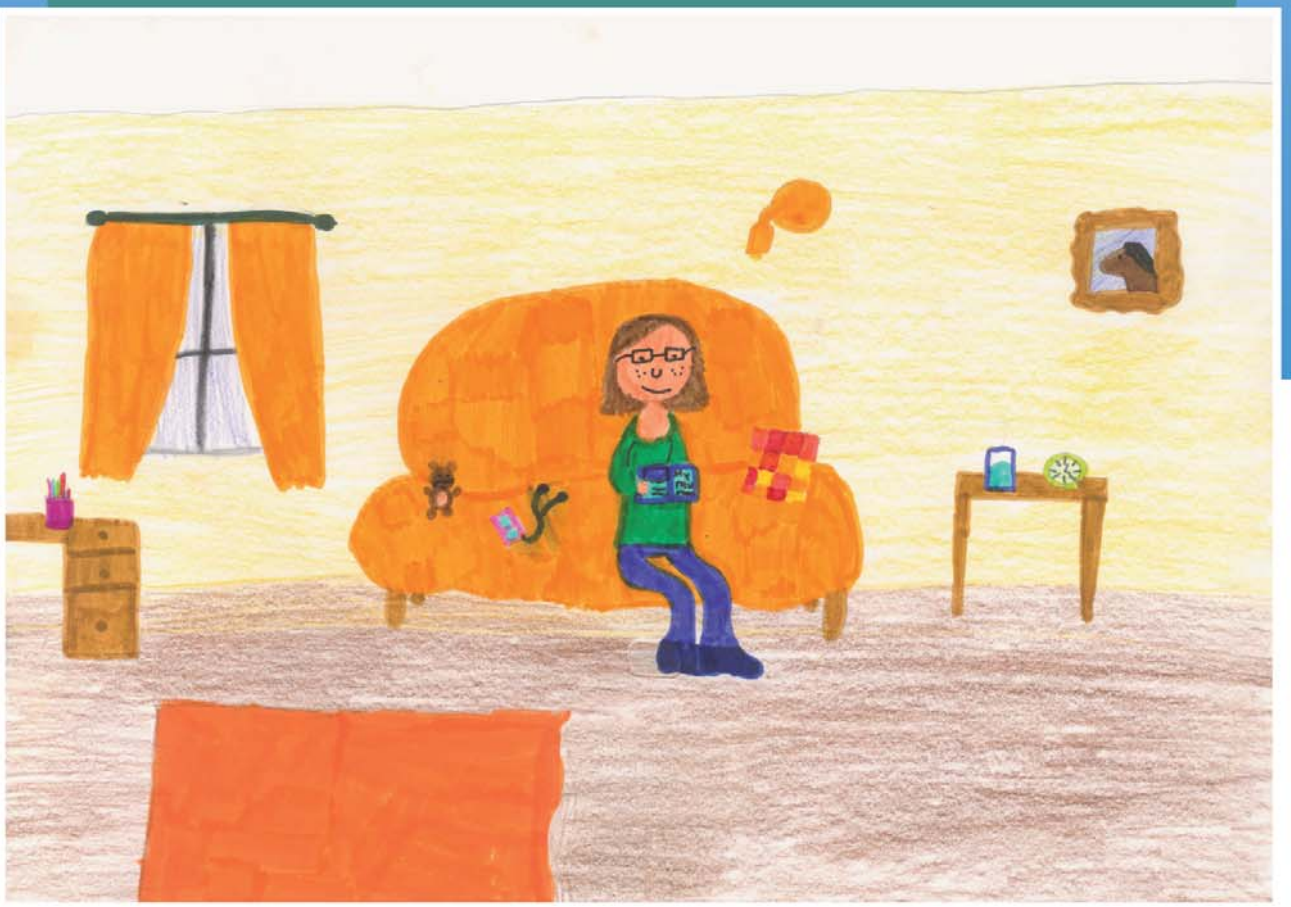
Sini Huemer

Training Reading Skills

Towards Fluency



JYVÄSKYLÄ STUDIES IN EDUCATION, PSYCHOLOGY AND SOCIAL RESEARCH 360

Sini Huemer

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Towards Fluency

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ABSTRACT

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This thesis evaluated the effects of training on the improvement of the reading skills, particularly on reading speed or fluency, of poor readers. In languages with a consistent orthography (like Finnish or German), children with reading deficits have considerable problems in reading speed. The aims of the present thesis were two-fold: first, they were related to the effectiveness of different types of training methods, and second, to the selection of the target units for training. In Study 1 the effects of computerized training (with the specific aim of improving grapheme-phoneme conversion) were investigated among Finnish-speaking children with poor pre-reading skills in Grade 1. The results showed that compared to the children in the control group, who received regular reading support, the children in the computer group improved their letter knowledge. However, in both groups the growth in the accurate reading skills was similar, and relatively rapid. The three further studies focused specifically on the improvement of reading speed among German- and Finnish-speaking children. In general, the short-term training methods utilising repeated readings led to larger improvements than regular school instruction. When general assisted reading practice was compared with computer-assisted repeated reading, the former showed larger improvements. General reading practice was associated with growth in global reading fluency; however, in the task which aimed at assessing the benefits of the computer program, both methods yielded improvements. These results raise methodological considerations, as the task which measured the effects of computer-trained skills, tapped into distal, rather than proximal, effects. In terms of the selection of the target units, training at the sublexical level had positive effects: first, the reading speed of sublexical multiletter units (such as consonant clusters or syllables) could be enhanced by repeated reading, and second, sublexical training was associated with improvements in the reading of words and pseudowords with the trained segments. Thus, training of sublexical multiletter units offers a way of achieving generalization effects. The finding highlights the need to reconsider the English-based theoretical notions of reading skills development in the context of a language with a consistent orthography.

Keywords: reading speed, reading fluency, reading disabilities, computer assisted instruction, repeated reading, sublexical units, transfer (learning)

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LIST OF PUBLICATIONS

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CONTENTS

1 INTRODUCTION

Knowledge of genetics and of the brain mechanisms involved in reading, and of the origin of reading deficits has increased enormously in recent years. Although the number of studies published on reading and reading disorders is large, knowledge concerning the remediation of reading disorders remains limited. This is especially the case where education specialists, teachers or parents would like poor readers to become fast and fluent readers, able to move through connected texts effortlessly and with high comprehension. Already more than two decades ago, Allington (1983) stated that fluency instruction was a neglected goal in reading research. Almost twenty years later in the influential "Report of the National Reading Panel" (National Institute of Child Health and Human Development, NICHD, 2000) it continued to be concluded that fluency is "a neglected aspect of reading". It is only in the last few years that increased attention has been paid to reading fluency. At least two research findings have influenced this growing interest: First, the training of phonological skills has shown limitations in relation to the gains in reading fluency. Most interventions aimed at improving reading skills have been targeted at training phonological skills, often with the aim to prevent severe reading deficits, since the majority of the reading researchers agree that reading deficits are due to impairments in representing, storing and retrieving phonological information (e.g., Ramus, 2003; Snowling, 2000). Instruction in phonological skills seems to be effective in enhancing phonological and reading skills, at least when reading accuracy has been used as an outcome measure (Bus & van IJzendoorn, 1999). However, in recent years a few studies have shown that training in phonological processing or decoding accuracy does not lead to large improvements in reading fluency among older pupils (e.g., Torgesen, Rashotte, & Alexander, 2001a; Torgesen, 2005). Furthermore, empirical evidence shows that reading fluency is one aspect of reading that is difficult to remediate (e.g., Lyon & Moats, 1997; Torgesen et al., 2001a; Thaler, Ebner, Landerl, & Wimmer, 2004). Second, there is evidence that in the languages with more transparent orthographies (e.g., German, Dutch, Italian or Finnish) children with reading deficits have considerable problems in reading speed or fluency; nevertheless, these children have less

severe problems in reading or decoding accuracy when compared to English-speaking children (de Jong & van der Leij, 2003; Holopainen, Ahonen, & Lyytinen, 2001; Landerl, Wimmer, & Frith, 1997; Wimmer, 1993; Zoccolotti et al., 1999). Instruction in phonological awareness and decoding accuracy may not be enough for these slow readers.

1.1 What is Reading Fluency, and How Does Reading Fluency Develop?

1.1.1 Definition of Fluency

European reading researchers seem to have adopted the concept of fluency as a synonym for word reading speed/rate, whereas in the USA a broad range of definitions of fluency has been presented. Chall (1996) describes the attainment of reading fluency as a phase in which "ungluing from print" occurs. This definition captures rather well the nature of the automatic, fast processing of print. But what factors are involved in "ungluing from print"?

In the "Report of the National Reading Panel" (NICHD, 2000) *fluency* is defined as the ability to read text quickly, accurately, and with proper expression. Kuhn and Stahl (2003) note in their review on reading fluency instruction that a consensus seems to have been reached on what constitutes the primary components of fluency: (1) accuracy in decoding, (2) automaticity in word recognition, and (3) the appropriate use of prosodic features, like pitch, intonation, and duration that contribute to expressive reading. Some researchers emphasize the contribution of automaticity to fluent reading (see e.g., Torgesen et al., 2001a), whereas others stress the role of prosody when reading connected texts (see e.g., Allington, 2006). *Automaticity* refers to a process during which conscious cognitive effort or attention is not required. LaBerge and Samuels (1974) suggested in their classic article that repetition is the key to automatic processes. During early stages of reading development, decoding and word recognition are slow and laborious; however, through practice these processes become automated. In the area of cognitive psychology fluent reading is often conceptualized on the basis of the dual-route model as reliance on visual-orthographic word recognition (Castles & Coltheart, 1993). Thus, especially in the research literature on English, the enhancement of reading fluency is closely related to the concepts of *orthographic learning* or to the development of *visual word recognition skills*.

Wolf and Katzir-Cohen (2001) provide a comprehensive working definition to fluency:

> In its beginnings, reading fluency is the product of the initial development of accuracy and the subsequent development of automaticity in underlying sublexical processes, lexical processes, and their integration in single-word reading and connected text. These include perceptual, phonological, orthographic, and

> morphological processes at the letter, letter-pattern, and word levels, as well as semantic and syntactic processes at the word level and connected-text level. After it is fully developed, reading fluency 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. (p. 219)

Wolf and Katzir-Cohen emphasize that in many earlier information-processing models of reading fluency a central focus was on the lower levels of processing (at micro level or at sublexical level). Another important dimension in their view is that reading fluency can be considered as a multi-componential skill. This kind of developmental and componential view on reading fluency may serve its purposes in highlighting this complex phenomenon and in planning assessment and interventions for dysfluent readers. However, the definition poses difficulties for empirical validation, as it seems to cover every process and subskill involved in reading.

The role of prosody in reading fluency is currently not precisely known. The most straightforward explanation is that prosody reflects the reader's understanding of the meaning of the text. However, Schwanenflugel, Hamilton, Kuhn, Wisenbaker and Stahl (2004) reported that although prosody was related to individual differences in word-reading efficiency, individual differences in prosody did not independently contribute to reading comprehension. In addition, prosody seems to be difficult to assess reliably (Torgesen & Hudson, 2006).

It is important to note that for the purposes of the present thesis the narrow definition of fluency is relevant: the focus of the present studies is on single word reading, with a specific emphasis on speed. Thus, the theoretical framework is close to the automaticity components of word recognition. In the light of the definition by Wolf and Katzir-Cohen (2001) the present studies seek to tap into micro level processing, in other words, the training programs used are targeted at the sublexical level. The objective is that by affecting processing at the sublexical level, processing at the upper level – the macro level - can also be improved. One reason for the selection of the focus on word reading accuracy and speed is that without the ability to read words fluently and with relative ease, reading lacks prosodic features and can hardly be expressive.

Theoretical models of reading skills automatization have suggested that when word processes become automated, more cognitive resources are available for higher level processes, like comprehension (La Berge & Samuels, 1974; Perfetti, 1985). There is empirical evidence to show that increasing reading fluency also improves comprehension (Kuhn & Stahl, 2003; O'Connor, White, & Swanson, 2007), and that the reading comprehension of slow decoders begins to develop rapidly only after their word recognition skills have reached the necessary level for text comprehension (Torppa et al., 2007). Some researchers have suggested that fluency is a prerequisite for understanding the meaning of text (Kuhn & Stahl, 2003); however, empirical evidence on the causal relation is scarce (O'Connor et al., 2007; Wolf & Katzir-Cohen, 2001). One view, which is

supported by empirical evidence, is that the relation between comprehension and fluency is bidirectional (Klauda & Guthrie, 2008; Pikulski & Chard, 2005).

1.1.2 Accuracy and Speed Problems among Children with Reading Deficits

In the research literature on English, the emphasis has typically been on word recognition accuracy. Acquiring accurate reading skills in the English language seems to constitute a hurdle for many children because of its irregular orthography, that is, the written script does not fully represent the phonemic structure of the spoken language. Comparisons between different orthographies have shown that whereas children learning to read a more transparent orthography (e.g., German, Dutch, Spanish, Finnish) are able to read words with considerable accuracy already at the end of the first grade (85 % - 93 %), English-speaking children reach the same level only in the fourth grade (Aro & Wimmer, 2003). In another study (Seymour, Aro, & Erskine, 2003) similar findings emerged: it could be estimated that readers of English required over 2,5 years to achieve the same level as that attained within the first year of reading instruction in the majority of the orthographies of the European languages investigated.

Wimmer and colleagues at the University of Salzburg were among the first to report that in transparent orthographies poor reading is reflected more as slow reading speed rather than inaccuracy (Landerl et al., 1997; Wimmer, 1993). These findings among German-speaking children have since been replicated in the orthographies of other languages; for example, in Finnish (Holopainen et al., 2001), in Dutch (Yap & van der Leij, 1993; de Jong & van der Leij, 2003), and in Italian (Zoccolotti et al., 1999). Wimmer and Mayringer (2002) reported an average word reading rate of 166 to 186 syllables per minute among typical 9- to 10-year-old readers. Children with different types of reading deficit showed a reading rate that was 1.5 to 2.5 times slower: depending on the sample studied their reading rate was between 68 and 95 syllables per minute. For Finnish-speaking children, speed of reading pseudowords of typical and poor readers has been reported in only one study (Holopainen, 2002). In this study poor readers in Grade 4 were approximately 1.5 times slower than the average readers. As a consequence of this laborious reading, poor readers do not receive the same amount of exposure to reading as average readers. Nagy and Anderson (1984) estimated that average/above average readers read 1 million words a year, whereas less skilled readers encounter ca. 100 000 words. Stanovich (1986) concluded that poor readers choose not to read because reading is unrewarding to them and, as a result, they increasingly fall behind in developing fluent reading skills.

As the majority of the research on reading has been conducted in the context of the English language, the number of studies dealing with reading acquisition and decoding accuracy is large. This focus on accuracy has also been reflected in the measures used and interventions conducted (see Share, 2008). However, in recent years in the research literature on English the relevance of

reading speed has also been noted (e.g., Kame'nui & Simmons, 2001; Ziegler, Perry, My-Wyatt, Ladner, & Schulte-Körne, 2003). There is evidence to show that besides difficulties in reading acquisition, English-speaking children with reading deficits have problems in reading speed (Landerl et al., 1997; Ziegler et al., 2003). Once the first hurdle (accuracy) has been overcome, a second (speed) presents itself. However, as problems in reading accuracy are often pervasive in the context of the English language, reading speed has remained a largely neglected topic.

1.1.3 German and Finnish

In the present thesis, the four studies were conducted among Finnish- and German-speaking children. These two languages and their writing systems are quite different; however, what these two languages share is that their orthographies are more transparent than that of English and that reading deficits are in them manifested more as reading speed problems as inaccurate reading. A consensus currently exists about the approximate classification of the orthographies of a number of languages in terms of their transparency (see Seymour et al., 2003); however little quantitative cross-linguistic research has been published on this issue (see Borgwaldt, Hellwig, & de Groot, 2005). The transparency of an orthography can be considered as a continuum. English is one of the most irregular orthographies, Finnish is one of the most regular, and German is somewhere inbetween. More specifically, in a study by Borgwaldt et al. (2005) ambiguities in word-initial letter-to-phoneme mappings in seven languages were calculated. Of these languages English had the most ambiguous orthography, followed by, in decreasing order, French, German, Portuguese, Dutch, Italian and Hungarian.

Finnish is an example of an almost purely phonemic alphabetic orthography (see also, Aro, 2006; Leinonen et al., 2001). The grapheme-phoneme correspondences are in Finnish regular and symmetrical. The number of standard Finnish phonemes is 21 and there are three additional consonant sounds, which are used in recent loan words only (Aro, 2006). Each phoneme is marked with the corresponding single letter (with one exception). Most Finnish words are polysyllabic. There are only approximately 50 monosyllabic words (Kyöstiö, 1980). The syllabic structure is rather simple and clearly defined, and the syllables are perceptually salient units of the spoken language. The Finnish orthography is transparent; however, Finnish morphology is complicated and opaque. Words are formatted by adding endings (i.e., bound morphemes, suffixes) to stems, and the functions of prepositions are expressed by 15 cases. Consequently, words tend to be relatively long. Any Finnish noun can have over 2000 orthographic forms, while for Finnish verbs the number is even higher (Niemi, Laine, & Tuominen, 1994). The inflections often also affect the stem (e.g. lammas-lampaan, *a sheep-of a sheep*), and thus, in many cases the ability to recognise the stem is not enough. Due to derivation and productive compounding, the number of lexical environments in which a typical Finnish

stem can exist is vast; thus, the morphological system is best described as agglutinative-fusional (Aro, 2006). From the perspective of literacy acquisition and recoding of novel words, the Finnish orthography is in many ways optimal. However, from the standpoint of fast word recognition skills long words owing to multiple inflections, present a challenge to a reader.

In German the grapheme-phoneme correspondences are more regular than in English, but they are less consistent than in Finnish. Consistency between graphemes and phonemes is especially high from the point of view of reading; however, in its spelling German is more irregular (Landerl & Thaler, 2006). It has been calculated from a lexical database that German has altogether 30 graphemes and 38 phonemes (Hofmann, Stenneken, Conrad, & Jacobs, 2007). However, the exact number probably depends how these are defined (Borgwaldt et al. (2005) found 29 letters and 43 phonemes in word-initial position). The only inconsistent consonant grapheme is v, which can be pronounced /f/ as in Vater and sometimes /v/ as in Vase, and a few other graphemes have context-dependent pronunciation (Landerl & Thaler, 2006). There are also a number of multiletter graphemes (e.g., sch, ch, ck, au, eu, ei, ie), which are presented as single graphemes in reading instruction. German adheres to the principle of morpheme consistency, that is, the spelling of morphemes is preserved in different word forms (e.g., fahren, Fahrer, gefahren, Gefährt). The syllabic structure is rather complex; however, syllable boundaries are used as an aid in early reading instruction. A typical feature of German is that it has complex consonant clusters in both onset and coda positions (e.g. *schlafen* 'to sleep'; *Arzt* 'a doctor').

1.1.4 Towards Fluency: Developmental Considerations

Share (2008) concludes in a recent review that despite the many disparities between English and the orthographies of other languages, there are also commonalities. One useful framework for conceptualizing the universal aspects of reading is to consider the transition from novice to expert in the case of readers. The end-state of skilful reading, reading fluency, looks extremely similar across diverse languages and orthographies. However, there are many different theoretical considerations pertaining to how children become fluent readers and what kinds of processes or developmental pathways are involved. In the following sections these developmental issues and theories are briefly presented. The emphasis is on the acquisition of fluent reading; however, as accurate reading skills are prerequisite for becoming a fluent reader, the general features of reading acquisition are also discussed.

Reading acquisition. As Wolf & Katzir-Cohen (2001) state in their definition of fluency, accurate reading skills are an important component of fluency: "*…fluency is the product of the initial development of accuracy and the subsequent development of automaticity...*" (p. 219). Concerning reading acquisition, there are a few English-based models (Ehri, 1995; 2005; Frith, 1985; Seymour, 2005), in which a different developmental sequence is suggested and

the development of skilful reading is portrayed as a succession of qualitatively distinct phases. Some models have described a preliminary process of word recognition that relies on global visual information, referred to as the logographic (Frith, 1985) or partial alphabetic phase (Ehri, 1995). However, as this phase has not been found in more consistent orthographies, it appears to be largely English-based (see Share, 2008). The most important phase in each model and across languages is the acquisition of letter-sound translation processes. A more detailed description of the relevance of letter-sound translation processes is provided by Share (1995). His self-teaching hypothesis postulates that phonological recoding, translating print to sound in novel words, is the key mechanism in reading development. Phonological recoding is based on the application of grapheme-phoneme rules and analogical skills, and provides a basis for the development of orthographic knowledge (Share, 1995).

The two most important prerequisites of reading acquisition are phonological or phonemic awareness and letter knowledge (see Share, 2008; Wagner, Torgesen, & Rashotte, 1994). Evidence has been found indicating that in orthographically more consistent languages, like Finnish, letter knowledge and phonemic awareness show a high degree of overlap (Aro et al., 1999; Lyytinen, Ronimus, Alanko, Poikkeus, & Taanila, 2007). Furthermore in orthographically consistent languages, phonological or phonemic awareness is acquired much more rapidly and easily than in irregular orthographies, such as English (de Jong & van der Leij, 1999; Mann & Wimmer, 2002), and phonological awareness is not a strong predictor of reading fluency (Holopainen et al., 2001; Landerl & Wimmer, 2008; Wimmer & Mayringer, 2002). A recent study by Puolakanaho et al. (2008) showed that in Finnish, letter knowledge was a predictor of reading fluency measured in Grade 2. The research evidence alluded to above has led some scholars to conclude that awareness of phonemic segments is best categorized as a reading subskill (e.g., Share, 1995; 2008). Share (2008) states that phonemic awareness and letter knowledge are best labelled as *corequisites* of alphabetic literacy. Also, Ehri and Soffer's (1999) term *graphophonemic awareness* describes the inseparability of the two. In terms of reading deficits, Vellutino, Fletcher, Snowling, and Scanlon (2004) suggest that word identification problems are related to both phonological awareness and letter-sound correspondences. More specifically, Vellutino et al. state in their review that reading problems in dyslexia may be the result of deficiencies in phonological awareness, alphabetic mapping, and phonological decoding, which in turn lead to difficulties in establishing the connections between the spoken and written counterparts of words.

Reading fluency development among typical readers. Children with good reading abilities seem to develop effective word recognition skills as a result of formal education and reading practice. However, relatively little is known how the normal course of development of orthographic representations in children's reading proceeds (e.g., Landi, Perfetti, Bolger, Dunlap, & Foorman, 2006). This knowledge would be important in order to understand the processes which are impaired in dysfluent reading and to devise intervention tools. Again, most of

the research has been conducted among English-speaking participants, that is, most of the empirical findings – as well as theoretical views – come from the research literature on English. In this section the most influential theoretical notions are presented first. It can be assumed that to some extent these ideas also apply to the German language: although German has a more regular orthography than English, these two languages belong to the same language group (Germanic languages) and many German words are cognate to English words. However, as the Finnish orthography differs so much from the English writing system, at the end of this section the applicability of the existing theories is discussed in the particular context of the Finnish language.

What is needed for rapid and accurate word recognition? The research literature suggests that lexical entries containing specific information about the orthographic structure of words are essential for accurate and rapid reading (Reitsma, 1983; Shaywitz & Shaywitz, 2005). These lexical entries involve direct connections between the written and spoken forms of words (Ehri, 1992b; Share, 1995). As already mentioned, a crucial prerequisite for growth in knowledge about the orthographic structure of words is the use of phonological recoding as a self-teaching device (Share, 1995). Self-teaching occurs during independent reading, that is, the constant presence of a tutor is not required. Typical readers acquire orthographic knowledge fast: a few repetitions of words are enough to establish connections between written and spoken forms of words (Ehri, 2002; Levy, 2001; Reitsma, 1983). The growth of orthographic knowledge is partly word-specific; in other words, this growth has an effect on the increase in the number and quality of individual word representations (Perfetti, 1992; Reitsma, 1983), and partly occurs through the generalization of letter-phoneme connections across large portions of the lexicon (Landi et al., 2006; Perfetti, 1992).

This notion of lexicalised connections and specific word representations is in line with the most influential computational models of reading processes in the context of the dual-route framework. These computational models (e.g., the dual-route cascaded model; Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; the CDP+ model, which belongs to dual-route framework but uses connectionist architecture; Perry, Ziegler, & Zorzi, 2007) postulate that there are two distinguishable sources of phonological information in reading. As formulated by Perry et al., the phonology of a written word is retrieved through a lexical-semantic pathway as well as assembled or activated through a spelling-sound mapping process. Fast visual word recognition relies on a direct route from orthography to word form in the mental lexicon. However, although these computational models have been often used as a theoretical framework for children's reading (see e.g., Ziegler et al., 2008), they do not provide plausible models for the development of reading skills (Perry et al., 2007). In addition, they apply only to monosyllabic words, which imposes limitations on the use this approach in explaining reading fluency growth in the context of German or Finnish. To simulate the reading of polysyllabic words Ans, Carbonnel, and Valdois (1998) developed a Multiple-Trace Memory (MTM) model. The model

proposes that all words and pseudowords are initially analysed by a global route. The global word recognition process usually fails when low-frequency words and pseudowords are encountered, after which analytic processes take over and items are decomposed into syllables. However, at present there is no evidence of the applicability of this model to orthographies other than French, and the model cannot explain certain effects in reading, such as the inhibitory effects of high-frequency syllables (Barber & Kutas, 2007). The connectionist (or "triangle") models developed by Seidenberg and colleagues (Plaut, McClelland, Seidenberg, & Patterson, 1996; Seidenberg & McClelland, 1989) have largely been seen as an alternative to the traditional dual-route framework. In these triangle models the basic idea is that the word recognition system involves three types of mental representations: orthographic, phonological and semantic. Lexical units as such do not exist; rather, the word recognition process is based on activating the appropriate set of distributed, sub-symbolic codes. In the model by Seidenberg and McClelland orthographic units do not represent psychologically real concepts, whereas the model by Plaut et al. includes letters or letter combinations as orthographic units.

One of the most influential theories related to reading fluency has been LaBerge and Samuels's (1974) theory of automatic information processing in reading. LaBerge and Samuels suggested that processing of the subskills at the micro level in reading (visual perception, sounding out, phrasing words together etc.) should ideally occur at an automatic level, imposing minimal requirements on attentional or cognitive capacity. Cognitive resources should be reserved for a more important task, for macro level processing, i.e., comprehension. This development towards automaticity emerges gradually. The first stage of the subskills involves visual coding and the unitization of visual stimuli, which may include letters, spelling patterns and words. By practice and exposure to the written language the visual stimuli become unitized and perceived as a single unit.

The Finnish orthography differs significantly from the English writing system. As mentioned above, words are formatted by adding endings to stems and the functions of prepositions are expressed by cases. Finnish words can have approximately 2000 (nouns) to 18 000 (verbs) orthographic forms. In addition, due to the agglutinative-fusional morphological system, the inflections in many cases also affect the stem, and consequently, the ability to recognise the stem is not enough. Thus, the use of orthographic strategies or word-specific representations in fluent word recognition is hampered by the presence of polysyllabic, long words and agglutinative morphology. The theoretical conceptions about the growth of fluency as well as the computational models based on English suggest that rapid and accurate reading relies on word-specific representations (Coltheart et al., 2001; Ehri, 2002; Perfetti, 1992; Perry et al., 2007; Share, 1995). However, owing to the specific features of the Finnish orthography it is not likely that the development of fluent word recognition relies on single word representations.

It is reasonable to assume that lexicality in Finnish involves direct connections between the written and spoken forms of words as well; however, the connections probably include sublexical multiletter units (e.g., syllables, frequent bigrams, morphemes) rather than single words. An important idea underlying the previously mentioned model developed for the reading of polysyllabic words by Ans et al. (1998) is that in word reading a process might exist inbetween the recognition of whole words and the serial mapping of single letters to phonemes. Similarly, Barber and Kutas (2007) state in a recent review that the word processing system could segment words into a variety of sublexical units associated with different kinds of information (phonological, syllabic, morphological). LaBerge and Samuels (1974) propose that in automatization of the reading processes visual code and the unitization of visual stimuli (letters, spelling patterns and words) as a single unit form the first stage. Share (2004) has also stated recently that decoding is not merely a process of retrieving phonemes onebyone and stringing these together. According to Share, multisyllabic words involve subgroupings of letters that must be unitized into syllabic and morphemic units. In Ehri's developmental theory (1992a) it is assumed that in the consolidated alphabetic phase associations between multiletter units and their corresponding phonological segments are acquired. In a recent paper, Marinus and de Jong (2008) found evidence that sublexical multiletter items (vowel digraphs) could function as perceptual units in Dutch-speaking children's and adults' reading.

To summarize, there is evidence for the existence of intermediate units inbetween the sequential parsing of single graphemes to phonemes and whole word recognition. However, the nature of these units is not precisely known (Barber & Kutas, 2007; Perry et al., 2007). This is even more so in the Finnish language, in which few studies have focused on the determinants of fluent reading. There is some evidence that fluent Finnish-speaking readers are able to use larger orthographic units in word identification (Leinonen et al., 2001). Examining the nature of orthographic units or the growth in orthographic knowledge among Finnish-speaking participants is not an easy task. In Finnish, since homophones or irregular words do not exist, the most important, and easiest to conduct, behavioural measure of fluent word recognition or growth in orthographic knowledge is reading speed. One way to investigate growth in orthographic knowledge (or to simulate the on-line processes of developing orthographic representations) is to conduct training studies assessing the learning of unfamiliar letter strings.

Longitudinal studies in which the development of children's reading skills has been investigated through years have shown that in reading fluency the status of an individual in the distribution of readers is highly stable (de Jong & van der Leij, 2002; Klicpera & Schabmann, 1993; Landerl & Wimmer, 2008). The correlations between word reading fluency in Grade 1 and later on, in Grade 3 or Grade 8, have been relatively high (de Jong & van der Leij, 2002; Landerl & Wimmer, 2008, respectively). Landerl and Wimmer reported that 70% of the children who showed slow and laborious reading at the end of Grade 1 were

still among the poorest readers almost 8 years later. To sum up, children who are fluent readers in their first school years remain fluent, whereas children who initially have poor fluency skills do not seem to be able to "close the gap".

Reading fluency development among poor readers. As noted above, children who at the beginning of school instruction have poor reading skills remain often slow readers throughout their school career. What is known about dysfluency and the specific problems of dysfluent readers? The available empirical evidence shows that children with reading deficits rely on an extremely slow and serial grapheme-phoneme decoding process and do not seem to be able to process larger orthographic units efficiently (Di Filippo, De Luca, Judica, Spinelli, & Zoccolotti, 2006; Spinelli et al., 2005; Ziegler et al., 2003). According to the majority of reading researchers the core deficit behind this slow and laborious decoding process is of a phonological nature (see e.g., Ramus, 2003; Snowling, 2000). Some researchers have argued that awareness of phonemes and/or good quality phoneme representations are necessary to learn grapheme-phoneme mappings (Hulme, Caravolas, Malkova, & Brigstocke, 2005; Hutzler, Ziegler, Perry, Wimmer, & Zorzi, 2004). Proponents of the phonological theory state that poor phonological skills or representations have an effect - through impairments in learning grapheme-phoneme mappings – on phonological decoding. Deficiencies in phonological decoding skills compromise children's application of the self-teaching mechanism which would lead to well-specified orthographic representations or to high-quality connections between spoken and written forms of words.

Whether phonological deficits are the only cause of impaired reading has been a topic of debate in recent years (see e.g., Vellutino et al., 2004; Wolf & Bowers, 1999). When discussing dysfluency and factors influencing the development of fluency/dysfluency, an important language skill is rapid serial naming. There is strong evidence that rapid naming of visual stimuli presented in a serial order is independently related to word identification, in particular to word and text reading speed (e.g., Bowers, 1993; Korhonen, 1995; van den Bos, 1998; Wimmer, 1993). Of specific importance is the naming of alphanumeric stimuli, e.g. letters and digits (Wolf & Bowers, 1999). In languages with more regular orthographies early naming speed appears to be a stronger predictor of reading fluency than phonological awareness (see Holopainen et al., 2001; Landerl & Wimmer, 2008; Moll, Fussenegger, Willburger, & Landerl, 2009; Wimmer, 1993; Wimmer, Mayringer, & Landerl, 2000). However, the underlying mechanism between rapid naming and reading speed is not precisely known. The two processes share a number of components, e.g., fast visual identification of serially presented stimuli, speeded access to and retrieval from the mental lexicon and efficient articulation of the phonological form. Wolf and Bowers suggest that slow naming could (1) arise from slowed processing of visual information and letter sequencies in words, leading through naming to the delayed induction of orthographic patterns. (2) Alternatively, slow naming could be an indicator of more general processing speed-deficit. In a recent large-scale study among German-speaking children Moll et al. (2009) found that the

association between rapid naming and reading fluency was not strongly mediated through orthographic processing. Moll et al. emphasize that this association has to do with the speed and efficiency of visual-verbal processing. Wimmer et al. (2000) argue that the main deficit could be located at the point where associations are formed between phonemes, triggered by graphemes, or between the graphemes of the written word and the segments of its phonological representation. Acknowledgement of the role of rapid naming is important in order to develop intervention methods. A better understanding of naming speed could hopefully lead to treatment tools that better correspond to the reader's needs (Wolf & Bowers, 1999).

Although a good deal is known about the processes involved in the development of reading skills, understanding of the underlying deficits or impaired domains in dysfluent reading remains limited and the complete picture is a rather complex one. In Table 1 the research findings related to the deficits of poor readers at different levels of reading processes are summarized. In part the different views on what constitute deficits in reading processes are due to attempts at characterising different subtypes of poor readers. A more detailed discussion on the possible subtypes of poor readers is beyond the scope of the present thesis. Aside from the debate on subtypes, many researchers have tried to find a unifying underlying deficit to explain dysfluent reading. Many studies have shown, in line with Vellutino et al. (2004), that poor readers struggle at the level of single letters or in the conversion - especially in its efficiency - of graphemes to phonemes; however, the specific nature of this deficit is conceptualized in various ways. The grain-size theory by Ziegler and Goswami (2005) states that children with reading deficits have problems in the automaticity of the smallest grain sizes, i.e. in grapheme-phoneme recoding. Other authors (Di Filippo et al., 2006; Ziegler et al., 2003) see the problem as manifested as an overreliance on serial grapheme-phoneme decoding. The empirical evidence also suggests that a deficit in the processing of multiletter features, or in parallel access to letter sequencies, underlies slow reading (Martens & de Jong, 2006; Ziegler et al., 2003); however, it is not explicitly defined whether these larger orthographic units are whole words or letter combinations.

More controversy surrounds the processing of the whole word. There is evidence that (at least some) poor readers have difficulties in using the lexical procedure or in automatic word recognition (Shaywitz et al., 2003; Valdois, Bosse, & Tainturier, 2004). Shaywitz et al. (2003) proposed that persistently poor readers rely more on rote memory for recognizing real words; however, this strategy is due to a deficit in analysing words through phonological processes or sound-symbol linkages. On the other hand, according to the grain-size theory the process of gaining access to whole words is relatively intact in poor reading; it might be delayed but it is not qualitatively different from that of typical readers (Ziegler & Goswami, 2005). To complicate the picture even more, children's reading in general, including typical readers, may not benefit from direct parallel orthographic access (Ziegler et al., 2003). One explanation

related to the underlying deficits in poor reading is that typical readers are able flexibly to employ different units and switch between sublexical and lexical processes, whereas poor readers are not able to perform this flexible switching between strategies; rather, they process all stimuli through sequential processes (Di Filippo et al., 2006; van der Leij & van Daal, 1999).

To summarize, at the moment there is no general consensus about the nature of what constitutes the (common) deficit in slow reading. The multiplicity of findings might be due to limited empirical evidence and/or due to heterogeneity across individuals indicating different subtypes of poor readers (see e.g., Ziegler et al., 2008).

Despite the different views as to the underlying deficits in slow reading, what seems to be clear is that the statement "reading a word a few times secures its connections in memory" by Ehri (2002, p.11) does not apply to slow readers. The key to the development of fluent reading skills is extensive practice; in other words, providing successive exposure to print (e.g., Kuhn and Stahl, 2003). According to the self-teaching hypothesis children with reading deficits need a large number of encounters with printed words to be able to achieve the transition from laborious decoding to efficient and fast visual word recognition. This view is in line with Wolf and Bowers's (1999) hypothesis on processing speed and orthographic pattern recognition. According to Wolf and Bowers, poor readers might need much more practice before representations of adequate quality are achieved. One may, however, ask whether accurate phonological decoding alone is a sufficient precursor for fluent word recognition skills? Landerl and Wimmer (2008) note that in their sample of slow readers, serious delays in the acquisition of phonological decoding were not evident by the end of Grade 1. The accuracy of grapheme-phoneme translation did not pose problems; however, some children did not seem to be able to make use of this self-teaching mechanism as efficiently as the rest of the sample (Landerl & Wimmer, 2008), or problems of automaticity in grapheme-phoneme translation (not measured in the study) may have disrupted the efficient use of the self-teaching mechanism.

Wolf and Katzir-Cohen (2001) take a broader view of reading fluency, as noted in the section on the definition of fluency. According to their developmental, component-based view dysfluent reading can have multiple sources relating to accuracy or timing problems within the system, but can also be caused by difficulties of coordination or integration across processes. Wolf and Katzir-Cohen have used the summary by Meyer and Felton (1999) as a basis for their explanation of the causes of dysfluency. Wolf and Katzir-Cohen state that dysfluency might be due to (1) a breakdown in the lower level processes, such as phonological and/or orthographic processing; (2) a failure to make higher order semantic and phonological connections between words, meanings and ideas (after lower-level perceptual identification has been completed) or (3) a breakdown in syntactic processing with deficits in prosody and rhythm in oral

TABLE 1 Possible Impairments Underlying Dysfluent Reading

Grapheme-phoneme		Multiletter/Parallel		Whole word
–	Ziegler & Goswami, 2005	–	Martens & de Jong, 2006; Ziegler et al., 2003	++ Shaywitz et al., 2003
++	Di Filippo et al., 2006; Ziegler et al., 2003			– Ziegler et al., 2003
				+ – Ziegler & Goswami, 2005
Poor readers do not flexibly adopt these strategies ⟷				Di Filippo et al., 2006; van der Leij & van Daal, 1999

Note.

– Specific impairments shown by poor readers

++ Over-reliance shown by poor readers

+ – Poor readers do not have specific impairments

reading. Although this broader view by Wolf and Katzir-Cohen is helpful in understanding that important processes take place beyond word recognition, the majority of reading researchers would agree with the first explanation: there is a rich body of literature suggesting that reading deficits are due to impairments in phonological skills and/or in rapid retrieval of the names of visual stimuli.

1.2 Selecting a Training Method: Previous Studies

Because of the general consensus concerning the relationship between phonological skills and reading development, most of the preventive/intervention research on poor reading has focused on the training of phonological skills. In recent years the importance of letter-sound correspondences has been noticed. Hatcher, Hulme, and Ellis (1994) conducted one of the first studies in which the effects of phonological training were compared with the outcomes of training using both phonology and reading (with an emphasis on letter-sound correspondences). They found that the combined training of phonology and reading produced the strongest gains in subsequent reading growth, thus substantiating their *phonological linkage hypothesis*. Meta-analyses of phonological training studies have shown that phonological training enhances both phonological and reading skills, and that the most long-lasting effects on reading skills can be achieved when the training of phonological skills is combined with the use of letters (Bus & IJzendoorn, 1999; Ehri et al., 2001). However, the majority of these studies have used reading accuracy as an outcome measure. The proponents of the phonological theory have argued that the route to fluency is through accurate and adequate phonological recoding skills, which enables independent reading practice, and through practice fluency ought to develop. Study I of the present thesis addressed the question whether it is possible to improve the growth of literacy in children with low pre-reading skills by a computer-assisted intervention.

Attainment of adequate phonological recoding skills is clearly a necessary pre-condition for the improvement of reading fluency; however, whether it is a sufficient pre-requisite remains unclear. In recent years it has been shown that training in phonological processing or decoding accuracy does not necessarily lead to large improvements in reading fluency among older pupils (e.g., Torgesen et al., 2001a; Torgesen, 2005), and that reading fluency is hard to remediate (e.g., Lyon & Moats, 1997; Torgesen et al., 2001a; Thaler et al., 2004). In addition, children with specific rapid naming-deficits do not necessarily benefit from phonological-based interventions (Wolf & Bowers, 1999). Studies II, III and IV are conducted in order to evaluate methods aiming at the improvement of reading speed.

When discussing interventions focused in particular on reading fluency two concepts are of importance: repetition and exposure to print (e.g., Kuhn and Stahl, 2003; LaBerge & Samuels, 1974). The common view is that through practice reading fluency improves. The training methods employed for improving reading fluency are summarized in Table 2. The most commonly used of these methods has been *repeated reading*. In addition to repeated reading practice there have been attempts simply to increase the amount of reading activities by general reading practice, typically with assisted practice (e.g., Baker, Gersten, & Keating, 2000; Kuhn & Stahl, 2003; O'Connor et al., 2007). In this approach the critical factor is the simple provision of exposure to print. In Table 2 these two major categories of reading fluency training are presented separately (for both categories assisted and independent training approaches are shown). In addition, a distinction is made between training programs utilizing "traditional" reading tasks presented on paper and those using computer-assisted methods. An additional axis in this table includes a division between speeded and unspeeded tasks. Speeded means that the program includes elements emphasizing rapid responding, whereas methods that do not set any speed limits or emphasize rapid responding are referred to as unspeeded. Through these divisions 12 sub-classes of reading fluency training methods can be proposed for consideration.

For the present thesis Table 2 provides a framework in which to discuss the studies and their findings. Therefore the methods relevant to the studies in the thesis are discussed in more detail below. Important among these are approaches that have used repeated reading. In addition, general assisted reading was used in Study II. Special interest is also attached to methods that are easy to implement in educational settings. When reading practice is the route to developing fluent and automatic reading skills, a relevant question is how to conduct this practice in a cost-effective way with minimal demands on schools, teachers, and parents, while at the same time creating a training environment that children perceive as motivating. As Torgesen and Hudson (2006) note

> "However, if one of our goals is to develop effective interventions for struggling readers, and our time to intervene is limited (as it always will be), then we should start with interventions that will have the biggest payoff." (p. 140)

It is important to mention that in this review the emphasis is on training methods that are conducted one-on-one or using computer-assisted methods. In reading fluency instruction, a wide range of approaches exists that are used with entire classes, more information on which can be found for example in articles by Kuhn & Stahl (2003) and Samuels (2006).

TABLE 2 The Most Typical Methods Used in Training Reading Fluency

	General reading practice			Repeated reading		
	Traditional		Computer-assisted	Traditional		Computer-assisted
	Independent	Assisted		Independent	Assisted	
Unspeeded	*Texts	*Texts	*Text/Sentence reading	*Texts *Word lists	*Texts *Word lists	*Texts *Words (*Sublexical items)
Speeded		*Texts	*Text/Sentence reading with acceleration procedures		*Texts *Word lists - Flashcards	*Texts *Words – Limited Exposure Duration (*Sublexical items)

1.2.1 General Practice

General reading practice refers to attempts simply to increase the amount of reading activities for poor readers. Training programs that have been conducted as general reading practice interventions have usually included assisted methods (e.g., Baker et al., 2000; Kuhn & Stahl, 2003; O'Connor et al., 2007; Shany & Biemiller, 1995). Assisted reading practice refers to a training strategy in which the emphasis is on providing extensive exposure to print with a model of fluent reading (Kuhn & Stahl, 2003). In this context exposure to print is provided without the aim of repeating the reading material. The training material for general practice mainly consists of texts (for computer-assisted methods sentences have also been introduced, see Tressoldi, Vio, & Iozzino, 2007 or Breznitz, 1997). Although a few studies have provided correlational evidence that the amount of independent reading practice (time spent on reading or exposure to print) contributes significantly to gains in reading achievement (e.g., Anderson, Wilson, & Fielding, 1988; Cunningham & Stanovich, 1991), there is evidence that assisted methods are more effective (NICHD, 2000). Since for the present thesis, assisted general practice is of relevance, this method is described next.

Assisted. In short, there is evidence showing that general assisted reading practice can be associated with gains in reading fluency and in reading comprehension scores (Baker et al., 2000; O'Connor et al., 2007; Shany & Biemiller, 1995). However, only a few studies have used experimental designs and positive outcomes have tended to emerge as a result of extensive practice (e.g. 32 to 98 hours). The disadvantage of general assisted reading practice is that when practice needs to be extensive and the continuous presence of an adult tutor (especially if the tutor should be a professional in education or literacy teaching) is required, this method is not a cost-effective way to administer training. Using volunteer tutors could offer an easy way to implement training in schools; however, little is known of its efficacy. Baker et al. (2000) found gains in reading fluency using volunteers as tutors and with brief volunteer training.

In the present thesis, general assisted practice was conducted without time limitations or emphasis on reading speed. Methods exist that can be described as speeded general reading practice (e.g., choral reading by Heckelman, 1969, in which special emphasis is put on a rapid rate, which the tutor models). However, little is known about its efficacy and computers have since provided a more useful way of creating speeded training environments. In Table 2 the cell for general speeded independent practice is empty, as it is hard to conduct a training program in which fast responding is emphasized but not monitored or assisted in any way.

1.2.2 Repeated Reading

Repeated reading was developed by Samuels (1979) in an attempt to apply LaBerge and Samuel's (1974) automaticity theory to practice. The original method of Samuels (see Samuels, 2006) included the following procedures: (1) an adult read a short passage extract from a story to the children during which the children looked at a printed copy of the passage; (2) the students practiced the passage alone; (3) when a student thought that he or she was ready, the student read the passage orally to the teacher, who recorded the word-per-minute rate as well as the number of errors; (4) the student continued reading the passage until the criterion rate of 85 words per minute was achieved; (5) after meeting the criterion the student was given the next passage of the story for practice. Progress in every passage was charted so that the student was able to follow his/her own progress. The original method contains many different elements: a model of fluent reading is provided, as are experiences of understanding what fluent reading feels like. The method involves elements of both independent and assisted practice. Additionally, speeded elements of practice are created by monitoring each student's progress in reading rate. In the studies conducted by Samuels (1979) and Dahl (1979) it was found that repeated reading improved reading speed and accuracy, also in struggling readers.

After the initial success of repeated reading it was recommended as remedial reading strategy (Kuhn & Stahl, 2003). It has since become the basis for many approaches in fluency instruction, and has taken many forms during the past two decades. Nowadays, repeated reading is simply a method based on the repetition of reading material (words or a passage). The original repeated reading method developed by Samuels (1979) included independent repeated reading practice of texts, as have many of the subsequent classroom interventions. However, many methods and training studies also include some type of assistance. Studies (II-IV) of the present thesis include computer-assisted repeated reading methods.

Usually, the number of re-readings has been predetermined or material has been reread until a specific reading rate criterion has been achieved. O'Shea, Sindelar and O'Shea (1985) found that fluency did not improve beyond four re-readings of a passage; thus, the need for the teacher to compute the word-per-minute rate was eliminated. However, it is important to note that in the study by O'Shea et al. (1985) the participants performed at an average reading level (some were even above grade level). From the point of improving the word recognition of poor readers four repetitions may not be enough. Although in experimental studies an increase in the reading speed of trained words has been observed after 5 – 15 exposures to the words (Levy, 2001; Reitsma, 1983), such rapid orthographic learning may not emerge in the reading development of children with reading deficits (Share, 1999). For example, Thaler et al. (2004) found that even after 66 to 150 exposures to a limited set of words poor readers did not attain the level of average readers. Similarly Lemoine, Levy, and

Hutchinson (1993) showed that 25 presentations of only ten words did not lead to age-adequate reading fluency among poor readers. A few encounters with words are not enough for poor readers to significantly improve their reading speed.

Training studies on the repeated reading of *single words* have typically been conducted within the experimental design tradition. These studies have revealed that repetitions of words or pseudowords can enhance the reading speed of poor readers (Berends & Reitsma, 2006a; 2006b; Judica, De Luca, Spinelli, & Zoccolotti, 2002; Lemoine et al., 1993; Levy, Bourassa, & Horn, 1999; Martin-Chang & Levy, 2005; Thaler et al., 2004; Wentink, van Bon, & Schreuder, 1997). However, when this kind of training has been targeted at the poorest readers, they have not attained the level of average readers (e.g., Thaler et al., 2004). In addition, the effects have been item-specific, that is, no generalization effects on the reading of other words, even on orthographic neighbour words, have been shown (e.g., Berends & Reitsma, 2006b; Lemoine et al., 1993; Lewandowski, Begeny, & Rogers, 2006; Lovett, Warren-Chaplin, Ransby, & Borden, 1990; Thaler et al., 2004).

Assisted. In traditional repeated reading methods assistance can be provided either by the teacher reading the text aloud to the children (e.g., Rose & Beattie, 1986), by peers (e.g. Mathes & Fuchs, 1993), or by audiotapes (e.g. Daly & Martens, 1994; Rose & Beattie, 1986). In programs or studies in which a teacher or a tutor has the possibility to work one-on-one with a child, they are also able to give individual modelling and/or feedback (e.g., Lemoine et al., 1993; Levy et al., 1999). Chard, Vaughn, and Tyler (2002) concluded in their review that although repeated reading without a model has been associated with gains in reading accuracy and fluency, repeated reading with a model seems to be more effective.

Computer-assisted. Repeated reading of words or texts has traditionally been administered through reading word lists or texts on sheets of paper (e.g., Dahl, 1979; Samuels, 1979; O'Shea et al., 1985). Flashcards, whose words are printed on index cards with the goal of recognizing the word within a specific time period, have also been used (e.g., Tan & Nicholson, 1997). Nowadays, with the development of the computer technology, many studies use computer-assisted or computer-mediated methods. The simplest way of administering repeated word reading on a computer is to present words onebyone on the screen for the child to read aloud (e.g., Lemoine et al., 1993; Thaler et al., 2004). Typically, during this type of task an adult tutor sits next to the child and notes the correctness of the child's response, and in many cases also gives feedback. Thus, this type of task is actually a combination of assisted and computer-assisted methods, but here such tasks are mainly referred to as computer-assisted. This method has been found to produce improvements in reading fluency, at least for the trained words (e.g., Lemoine et al., 1993; Thaler et al., 2004).

Speeded. Again, speeded independent repeated reading practice is difficult to imagine without some type of monitoring or assistance. However, a

number of speeded human-assisted and computer-assisted methods exist. Examples of human-assisted speeded text and word reading practice would be programs in which (1) a speed-criterion is set and the progress of the child is monitored or (2) the child names words displayed on flashcards within a certain time-limit. Computer-speeded tasks are also available. Computer-speeded word reading tasks have usually included a variation of the flashcard method: a word is presented on a computer monitor and if the child does not respond within a specified time, the word is automatically removed. Computer tasks using *limited exposure duration* (LED) have provided one approach to speeding up reading (e.g. van den Bosch, van Bon, & Schreuder, 1995; Wentink et al., 1997). Typically the presentation times of words or pseudowords have been adjusted on-line to the naming accuracy of the child: if naming is error-free, the presentation time is shortened. However, if the child makes many errors, the presentation time is again lengthened. Flashcards or tasks using limited exposure duration have been associated with gains in reading speed (e.g. van den Bosch et al., 1995; Wentink et al., 1997).

1.2.3 General Practice vs. Repeated Reading

Although a number of studies have addressed the enhancement of reading fluency, it is not yet clear whether growth in reading fluency appears through particular instructional activities (like repeated reading) or through the general mechanism of increasing the volume of children's reading (Kuhn & Stahl, 2003). Some studies have compared repeated and non-repeated approaches and found no differences between repeated reading of a small number of texts and non-repetitive reading of a larger set of texts (e.g., Mathes & Fuchs, 1993; O'Connor et al., 2007; Rashotte & Torgesen, 1985). Findings like these led Kuhn and Stahl to the conclusion that in training reading fluency what is of critical importance is the amount of time spent in reading texts, not repetition itself. On the other hand, the authors note that repeated reading may enable children to read more difficult material than they otherwise might be able to read. For words, Berends and Reitsma (2006b) found that to improve *word* recognition fluency, the critical element is the repetition of a set of words rather than exposure to many different words. This difference between repeated text and word reading practices might be due to the involvement of different mechanisms: repeated text reading, and possibly general reading of texts as well, might enhance the processing of connected texts, phrasing, syntactic skills, semantics, and prosody. Repeated reading of words aims at automaticity of word recognition, establishing good quality connections between the written and spoken parts of a word and it probably also produces item-specific effects, thereby improving the reading speed of the trained words. In order to achieve this skill, repetition is presumably essential.

In the present thesis in Study II general reading practice was compared with repeated reading practice. Repeated reading was conducted as computer-assisted training and it aimed at increasing the efficiency of access to sublexical

multiletter units (word-initial consonant clusters). General reading practice was conducted as paired reading instruction and it aimed at encouraging children to spend time on reading activities. The common goal in both programs was to improve word recognition skills, especially word recognition speed.

1.2.4 Independent, Assisted vs. Computer-assisted

Computer-assisted instruction is an appealing alternative when designing cost-effective training environments, as the continuous presence of an adult tutor is not required. At present no easily implemented speech recognition methods able to decipher the correctness of the reader's response exist in instructional environments. However, currently attempts are being made to develop automated tutors which could assess a student's oral reading through the student's interactions with the tutor, e.g. through word latencies, speech recognition and help-seeking behaviour (see Beck, Jia, & Mostow, 2004). Traditionally, independent computer practice has not included tasks in which a child reads aloud. One type of computer-assisted instruction is based on the text-to-speech technology, typically involving stories on computer with synthetic speech support (see e.g., Olson & Wise, 1992). In many cases computer-assisted independent practice has also included tasks in which the student can choose between different alternatives. In this case the task requirements must involve other elements: for example, semantics (e.g., if two written words belong to the same semantic category; picture-word matching, see Berends & Reitsma, 2006a or Irausquin, Drent, & Verhoeven, 2005); or orthographic processing (e.g. letter combinations are presented and the child has to decide if these combinations are included in a word or not, or decide whether two presented words are identical or not; see Berends & Reitsma, 2006a). In a couple of studies a program was used in which the requirement was to listen to a syllable and choose a corresponding written form from two options (Magnan, Ecalle, Veuillet, & Collet, 2004; this type of training was also one task in the study by Irausquin et al., 2005). All these types of independent computer practice require the selection of the right option from among alternatives and do not involve reading aloud. For all of the above-mentioned computer-assisted methods (text-to-speech, semantics, orthographic prosessing, listening-selecting) improvements in fluency have been found (Berends & Reitsma, 2006a; Magnan et al., 2004; Olson & Wise, 1992).

However, in the research literature on fluency only a few studies have directly compared independent, human-assisted and computer-assisted methods of treatment. In one study, Lewandowski et al. (2006) found that for third-grade students reading independently did not improve fluency, whereas groups receiving tutor-assisted and computer-assisted instruction significantly enhanced their fluency. However, this result was found only for reading accuracy and for the reading of one passage out of five passages; in reading speed, in a generalization task, and in 4 passage-reading tasks all the groups showed similar improvement. An important result was that both the tutor-

assisted and computer-assisted methods improved reading skills and did not differ from each other in reading outcomes. The authors concluded that the computer-based treatment provided support through error-free sight and sound word associations and involved some novelty elements which kept students engaged in the task, whereas the tutor-based assistance provided direct instruction, error-free modelling, attention focusing, and human attention. The benefit of the computer-based instruction was that it required little teacher time or supervision. It has to be noted that this study was conducted among typical and poor readers, and therefore there are some limitations in generalizing its findings only to poor readers. In addition, the intervention period was only 3 sessions, and thus the novelty of the computer-assisted instruction might be due to the short intervention period.

To summarize, there is evidence to show that computer-assisted instruction in reading can lead to improvements in reading fluency. In addition, there is evidence (although scarce) that human-assisted and computer-assisted instruction are equally effective. Moreover, instruction including modelling or assistance in some form or other is presumably more effective than independent reading practice alone (Chard et al., 2002; Lewandoski et al., 2006). Feedback and support seem to be essential. Computer-assisted methods save teacher time and resources; however, computer-administered tasks are (currently) limited to recognition-based exercises. Human assistance is suitable for oral reading and is flexible; humans are able to modify on-line instruction according to the needs of the struggling reader. More research comparing the effectiveness of computer-assisted and human-assisted methods, also with independent silent reading, is needed.

In the present thesis, independent reading practice was not included in the empirical studies. The training methods in the four studies included some form of assistance; however, as noted earlier, the interest was in methods that would be easy to implement in educational settings. Studies I – IV involved computer-assisted methods. Different types of computer-assisted tasks were used: the task used in Studies I – III enabled independent practice; however, the computer provided feedback, and also read the items aloud (the child's task was to select the correct written item for the pronounced item). In Study IV the child worked with an adult tutor, who gave assistance when needed (in case of an incorrect response). Additionally, in Study II a non computer-assisted method was evaluated. The method of instruction was a paired reading program, in which the children read books with an adult tutor.

1.2.5 Unspeeded vs. Speeded

In this section the focus is on studies that are relevant for the present thesis: repeated reading. According to the present author's knowledge no direct comparisons between methods emphasizing rapid responding and methods focusing only on repetitions have been done for classic repeated text reading interventions. For interventions focusing on word reading there are several

such studies. In the 1990s a few studies were published using a computerized flashcard method, or limited duration of exposure. In these studies flashcard practice or tasks using limited duration of exposure were associated with gains in reading speed (e.g. van den Bosch et al., 1995; Wentink et al., 1997). This type of task has also been found to be more effective than mere reading aloud (van den Bosch et al., 1995). However, in the study by van den Bosch et al. no data are provided on the improvement of the groups, and the participants' pre-test reading levels are not provided, which makes it difficult to draw conclusions as to the amount of improvement. Berends and Reitsma (2005; 2006a) did not find any beneficial effect of limited duration of exposure over unlimited presentation time in relation to reading speed gains in poor readers. In addition, Irausquin et al. (2005) recently published a study under a title stating that computer-presented speed-training was associated with benefits among poor readers. In the study speeded word decoding training was compared with context training, during which speed was not emphasized. It was found that speed-focused word training yielded higher gains in the reading of trained words and transfer words than did context training. However, because the methods used differed not only in the speed of presentation, but also in the training materials used, it is difficult to say whether the benefits of word training were attributable to the focus on words or to the speeded presentation.

In summary, the research done so far does not provide strong evidence as to whether reading fluency training programs should be speeded or not. In a couple of studies it has been shown that unspeeded methods do not show benefits over speeded methods. For the present thesis, no direct comparisons between unspeeded and speeded methods were conducted; however, the interventions differ whether an emphasis on speed has been included or not. Studies I – III included a method that could be called speeded, because the presentation time of the items was limited. However, this method did not involve very short presentation times, as often is the case in programs using a limited exposure time. In Study III a special emphasis was placed on rapid responding; the children were rewarded when they responded quickly. In Study IV the method used did not involve any explicit speeded presentation procedure. Similarly, in Study II the method used, which focused on general reading practice, did not include speeded tasks.

1.2.6 Background Factors in Responsiveness to Training

In evaluating training outcomes among poor readers and children at-risk for reading deficits, an important issue concerns the heterogeneity of the children and individual variation in responsiveness to training. Several phonological awareness training studies have raised the question as to whether all children profit from training (e.g., Lovett, Borden, Lacerenza, Benson, & Brackstone, 1994; Poskiparta, Niemi, & Vauras, 1999; Torgesen et al., 1999, 2001b). In many of these studies the initial level of phoneme awareness has been a predictor of subsequent reading growth. Furthermore, there are findings suggesting that the

characteristics of children at risk for reading delay extend beyond the domain of phonological weaknesses. For example, classroom teacher ratings of attention and behaviour, socioeconomic status, and home environment (Torgesen et al. 2001b), word span, alliteration, and rapid naming of German-speaking kindergarten children (Schneider, Ennermoser, Roth, & Küspert, 1999), and verbal intelligence, working memory, and the counting skills of Finnish first graders (Poskiparta et al., 1999) have also predicted reading development in children receiving training in phonological skills.

In training reading fluency among older students, similar background factors have been of interest in predicting response to training. Reading improvement during the training period has been associated with the participants' cognitive-linguistic skills, such as non-verbal reasoning skills, short-term memory, phoneme awareness, and rapid naming (e.g., Lovett & Steinbach, 1997; Torgesen & Davis, 1996; Torgesen et al., 1999). More specifically, at least in the early stages of reading development, one training study has shown that poor readers who are slow namers show slower growth in learning new words than do poor readers who are fast namers (Levy et al., 1999). Developmental data have shown that rapid naming skill associates strongly with reading fluency (e.g., Holopainen et al., 2001; Wolf & Bowers, 1999). Only a few studies have investigated whether the age of the participants is also related to responsiveness to training. The findings of these studies suggest that the amount of improvement shown by poor readers after reading training programs are comparable between different grades, e.g. English-speaking children attending Grades 2 to 6 (Lovett & Steinbach, 1997; O'Connor et al., 2007), or Italian-speaking children attending Grade 3 and 4 or older children attending Grade 6 to 8 (Tressoldi, Lorusso, Brenbati, & Donini, 2008).

In the present thesis, in Study I one aim was to evaluate whether the low initial levels of cognitive-linguistic abilities (letter knowledge, phoneme awareness, rapid serial naming, and short-term memory), nonverbal intelligence or attention problems reported by classroom teachers have an effect upon the efficacy of treatment. In Study II, in which two different types of reading fluency training programs (general, assisted reading vs. repeated, computer-assisted training) among poor readers were evaluated, one research question was related to background factors and their associations with the improvement in reading speed. The background factors selected were the age of the participants, non-verbal reasoning skills, short-term memory, phoneme awareness, and rapid naming.

1.3 Selecting Training Material: Previous Studies

The majority of the training studies aimed at improving fluency have included texts as reading material. The main reason for this might be that text reading is

a naturalistic reading task. If the reading of connected text does not mainly depend on fluent word recognition (as some researchers postulate), but rather on processes beyond single words, such as prosody and syntactic skills, then the use of texts can be justified. The proponents of the automaticity view would emphasize fast and fluent word recognition. According to Perfetti (1992) faster and more accurate word recognition is a pre-requisite for growth in reading fluency. Thus, a number of training studies have been directed at word recognition. However, presumably in fluent reading the processing of lower-level units, sublexical units, is also important, as noted by Wolf and Katzir-Cohen (2001). The phonological system is structured prior to reading acquisition (Ziegler & Goswami, 2005), and thus some phonological influences at the sublexical level could be reflected in visual word recognition (e.g., Cole, Magnan, & Grainger; 1999; Ferrand & Grainger, 1992; Perfetti & Bell, 1991). However, the critical unit used in visual word recognition may vary across languages along with differences in the forms of reading instruction used as well as in the phonological structure of the language, in the consistency of its orthography and in its phonological and orthographic neighborhood characteristics (Cole et al., 1999; Ziegler & Goswami, 2005). The possible sublexical items used in fluent reading are either single letter-sound correspondences or sublexical multiletter units (syllables, morphemes, consonant clusters, onsets, rimes etc.).

In addition to the fact that phonological processing at the sublexical level could be reflected in visual word recognition, the second, more practical, reason to target training at the sublexical level is related to the limitations of single word practice. Although the repeated reading of words has shown to be associated with improvements in word recognition (e.g., Berends & Reitsma, 2006a; 2006b; Judica et al., 2002; Lemoine et al., 1993; Levy et al., 1999; Thaler et al., 2004), the disadvantage of the method is that it does not lead to generalization effects. By the repeated reading of words the reading speed of the trained words improves, but no effects on other types of words, not even on orthographic neighbour words, have been shown (e.g., Berends & Reitsma, 2006b; Lemoine et al., 1993; Thaler et al., 2004). As a result, this type of training as a remedial one-to-one tutoring program is a time-consuming task that makes a heavy demand on resources. Harm, McCandliss, and Seidenberg (2003) suggested that interventions targeted at the whole-word level or at the sublexical level could be equally effective. Thus training directed at the sublexical level is a good alternative when designing training programs to improve fluency. An approach using sublexical units as training material is especially important in the context of the Finnish language, as Finnish words can have thousands of different orthographic forms and, because the inflections often affect the stem, the ability to recognise the stem is not in itself enough.

1.3.1 Grapheme-Phoneme Correspondences

Letter-sound (or grapheme-phoneme) correspondences have typically been trained in the early phases of reading acquisition. In recent years meta-analyses of phonological training studies have shown that the most long-lasting effects on reading skills can be achieved when the training of phonological skills is combined with the use of letters (Bus & IJzendoorn 1999; Ehri et al. 2001). Additional evidence for the importance of letter-related processing in reading development comes from longitudinal studies in which it has been found that letter knowledge measured before school age is a good predictor of reading acquisition in Grade 1 or 2 (e.g. Lyytinen et al., 2004a; Lyytinen et al., 2004b), or of reading fluency in Grade 2 (Puolakanaho et al., 2008). A few studies have been published in which letter-sound correspondences have been the major focus of a preventive intervention and which offer comparisons between letter-sound interventions and other training methods. Evidence from these studies suggests that training, with a major focus on letter-sound correspondences, can have positive effects on letter knowledge and phoneme awareness (Defior & Tudela, 1994; Hohn & Ehri, 1983; Rvachew, Nowak, & Cloutier, 2004). However, the impact on reading skills is inconclusive (e.g., Hohn & Ehri, 1983) or at least delayed. For example, in the studies by Defior and Tudela (1994) and Elbro and Petersen (2004) the effects on reading were not manifested until later during the follow-up tests. Thus, relatively little is known about the ways training programs focused on grapheme-phoneme correspondences affect reading skills, especially fluent reading. In the present thesis, Study I focused on training the correspondences between phonological and orthographic units, with the main emphasis on the connections between phonemes and graphemes. The goal was that by training grapheme-phoneme conversion, children would acquire accurate reading skills faster. This in turn would enable them to make an early start in the use of the self-teaching mechanism.

1.3.2 Sublexical Multiletter Units

As noted in the section on reading fluency development, there is evidence for the presence of the intermediate units inbetween the sequential parsing of single graphemes to phonemes and whole word recognition. These intermediate units are groupings of letters, that is, sublexical multiletter units. Given the item-specific effects of word naming intervention studies, and given that the acquisition of orthographic knowledge could derive from the ability to rely on multiletter features (Martens & de Jong, 2006), training of sublexical multiletter units could offer a way of achieving a bigger payoff in terms of transfer effects. If children learn to recognize these multiletter units more automatically, this is a step forward from the serial decoding strategy. Previous studies using multiletter sublexical units as training material have included training methods in which sublexical units have been presented *within words*. For example, Thaler et al. (2004) trained consonant clusters among German-

speaking poor readers. Besides direct training of consonant clusters, words embodying the trained clusters were included in the training method. A couple of studies have used visual methods to highlight the sublexical items trained: Tressoldi et al. (2007) focused their training on syllables among Italian-speaking poor readers and Levy et al. (1999) trained rimes or single phonemes among English-speaking children. In both studies the training units were visually highlighted (e.g., colored differently, underlined); moreover, the items were practiced within texts or words. All these methods have been associated with reading fluency gains.

In this thesis, Studies II – IV were conducted with the aim of directly training sublexical multiletter units. Two types of units were of interest: word-initial consonant clusters among German-speaking children and syllables among Finnish-speaking children. Word-initial consonant clusters were chosen as training items for the two studies among German-speaking children, because they occur frequently in German and have been shown to be difficult for dyslexic children (Bruck & Treiman, 1990; Snowling, 1981; Treiman, 1991). The blending of the single phonemes making up consonant clusters in a letter-by-letter decoding manner is a time-consuming, laborious and linguistically demanding task (see Thaler et al., 2004). The aim of the direct training of consonant clusters was that children would be able to form memory representations of the consonant cluster spellings associated with the corresponding phonological segment. In the study conducted among Finnish-speaking children, syllables were chosen as training items. In Finnish, the syllable could be a critical unit in visual word recognition for several reasons. First, most Finnish words are polysyllabic. Second, the phonemic structure of syllables is relatively simple and syllables are clearly defined in Finnish. Third, syllables are perceptually salient units of the spoken language: the main stress is placed on the first syllable and the secondary stress on every second syllable thereafter (Aro, 2006). Fourth, syllabic information plays a central role in the initial reading instruction given in the first grade: syllables are explicitly marked in the reading instruction materials, and syllabic segmentation is used as an aid in early reading and spelling instruction.

The main aim of the present studies was to evaluate intervention programs targeted at the sublexical level. However, it is important to note that training in sublexical units is of little relevance if children are unable to apply this knowledge in word recognition. Therefore, in each study improvement in word reading or in larger items including the trained units (pseudowords) was the main interest.

1.4 Methodological Choices in Intervention Studies

When one conducts an intervention study and is reporting the study and its findings to teachers, parents or to the research community, people often ask: "Does it help? Is it effective?" However, as a researcher one is aware that effectiveness depends on many factors. Some of these are related to the design of the study: for example, to the selected participant group (typical, poor readers), to the control condition (no training, some other type of training), or to the measures used in investigating the outcomes (proximal and distal effects). There are a number of other factors that affect the assessment of interventions, especially in relation to remediation programs, which employ many different types of tasks and are often conducted by many tutors or teachers over a longer period of time (see Lyon and Moats, 1997). However, in the present thesis, the individual studies concern rather narrowly focused and small-scale interventions of short duration, and thus many of the factors related to teacher effects or how the interventions are defined are not relevant.

1.4.1 Interventions for Good vs. Poor Readers

One factor that has an effect on the outcomes of an intervention is the selection of the participant group. Affecting a specific skill is likely to be qualitatively different if the participant group consists of children who have already mastered the skill, but who are to be trained to perform better, compared to a group of children who are impaired in this skill. In the NRPreport (NICHD, 2000) it was found that guided oral reading was more beneficial to average readers than to poor readers. Nevertheless, it was emphasized in the report that of greater importance were the findings of some studies suggesting that readers at different levels of proficiency benefit from different aspects of the interventions studied. The NRP was unable to evaluate the effectiveness of these specific intervention features because of the small number of studies that addressed each specific feature. In the review by Kuhn and Stahl (2003) the results of fluency interventions are reported without differentiating studies conducted among poor readers from studies conducted among average-level or above-average readers. This makes evaluation of the specific features of effective interventions, particularly for poor readers, difficult. When designing interventions that should improve reading skills among children with reading deficits, the best way to do this is to select poor readers as participants.

1.4.2 Choice of Control Group

The choice of a control group in intervention studies targeted at poor readers is always a sensitive and hazardous enterprise. To control for the instructional methods and educational context, the investigators need to select from the same classroom as that of the trained group control children with similarly poor

reading skills but without providing any training for these children. However, such a method of selection involves ethical and practical dilemmas, as it is difficult to decide which children should receive training and which not. Additionally, the use of a control group without any training as a comparison to the intervention condition is problematic because of the "Hawthorne" effect: are the possible changes merely the result of devoting more attention to the intervention group or are they the direct result of the specific training? Ideally, to control for attention and re-test effects, an intervention study should include two control groups: one without training and one with another type of training. However, conducting such an intervention study for poor readers requires a lot of resources, and therefore relatively few reading fluency intervention studies have been done with experimental designs using appropriate control groups.

In the field of child psychology and psychotherapy the scientific evaluation of psychosocial interventions has been a topic of debate. Some of the outcomes of this debate may also have relevance for reading research, as many training programs seem to produce statistically significant improvements between pre- and post-test; however, these studies have employed many different types of designs, some without a control group, some with a no-treatment control group, and some with a control group receiving some other type of intervention. A general consensus on what is considered effective and discussion on whether interventions stated to be effective fulfil the criteria of a well-designed study seem to be lacking. In their review of psychosocial interventions Lonigan, Elbert, and Johnson (1998) summarize (on the basis of the report of the TaskForce on Promotion and Dissemination of Psychological Procedures, 1995) the criteria used to define well-established interventions and interventions that are probably efficacious. *Well-established interventions* are those for which two or more well-conducted group-design studies by different, independent investigative teams have shown the intervention to be superior to an alternative or established intervention (or a large series of single-case interventions with good experimental designs and comparisons with another treatment have been shown to be advantageous). Interventions with *probable efficacy* are those for which two or more group-design studies have shown use of the intervention to be more effective than no use of it (by different investigators or by one investigator when the design is well-conducted) or a small series of single-case experiments have shown the advantages of the intervention.

1.4.3 Outcome Measures

A third important issue in designing an intervention study is the selection of the outcome measures. Often a certain specific skill is trained, but with the aim of attaining improvements in another skill. For example, the training of phonological skills should lead to improvements in reading skills, or the training of sublexical units should transfer to word reading. In general, it is easier to obtain positive outcomes if only the trained skill is measured, possibly

even using the same procedure (similar task or computer program) as during training. It has been more difficult to achieve generalization or transfer to other types of tasks.

In the context of reading fluency studies Martin-Chang & Levy (2006) and Martin-Chang, Levy, and O'Neil (2007) have proposed what they term a *transfer-appropriate processing hypothesis.* The hypothesis is drawn from memory research (see Rajaram, Srinivas, & Roediger, 1998). According to this hypothesis transfer increases when the same cognitive processes are engaged during the training and transfer tasks. The same cognitive processes are engaged, when congruency between the training and transfer tasks is high. This notion has two implications: (1) to facilitate transfer, the outcome measures should have high congruency with the training task, and (2) training is of little relevance if one selects a test method that is congruent with the training task, but it does not resemble everyday reading tasks. Thus, when evaluating the effectiveness of a training program directed at improving reading, the transfer measures should also include tasks that are close to everyday reading situations or examine reading in an "authentic" situation. Another way to discuss transfer is to draw a distinction between proximal and distal effects. Proximal effects are attained in tasks that resemble the training program, whereas distal effects are shown in tasks that measure skills beyond the trained ones. It is important to note that in numerous training studies on reading skills these measurement issues are not discussed; however, the evaluation of the effectiveness of a training program is highly dependent on the tasks used.

In the present thesis, the following methodological issues were taken into account: each study was conducted among poor readers (or Study I among children with poor pre-reading skills). In each study, a control or comparison group was included. In Studies I, III, and IV the control groups did not receive any specific intervention beyond regular school instruction. In Studies II and III the different types of training methods used were compared with each other. Also in present studies the issue of transfer is taken up and discussed explicitly.

1.5 Aims of the Studies

The aim of this dissertation was to evaluate the effects of different types of training methods on the improvement of the reading skills of poor readers or children with low pre-reading skills. One important goal was to evaluate intervention methods in languages with a regular orthography (like Finnish or German). It was seen as important to the design of the studies that the training methods used should have theoretical and scientific foundation. Of special interest were methods that would be easy to implement in educational settings, in other words, to conduct training in a cost-effective way. Each study can be described as a small-scale intervention study with a short duration focusing on

specific research questions. One of the studies was conducted among first-graders, who were yet not able to read. Three of the studies were conducted in order to improve reading speed. Two studies were conducted among Finnish-speaking children, and two studies among German-speaking participants. Table 3 shows an overview of the studies and their methods.

Study I was directed at the improvement of reading acquisition among Finnish-speaking children with poor pre-reading skills. The goal was that by training grapheme-phoneme conversion, the children would acquire accurate reading skills, thereby enabling them to make an early start in the use of the self-teaching mechanism for developing fluent reading skills.

In Study II general reading practice was compared with repeated reading practice among German-speaking poor readers. Repeated reading was conducted as computer-assisted training with the aim of increasing the efficiency of access to sublexical multiletter units (word-initial consonant clusters). General reading practice was conducted as paired reading instruction. The common goal in both programs was to improve word recognition skills, especially word recognition speed.

Studies III and IV were experimental studies with short duration of training targeted especially at the issue of generalization: does training at the sublexical level show generalization effects on the reading of words and pseudowords containing the trained segments? Study II additionally addressed the question of the importance of reading aloud when compared to a training method in which oral reading was not required. This study was conducted among German-speaking poor readers. In Study IV the main interest was related to the role of the syllable as a functional unit in training reading speed among Finnish-speaking poor readers. Another goal was related to the transfer effects between different types of reading tasks.

TABLE 3 Overview of the Studies

	Aim	**Participants**	**Training Methods**	**Data Analyses**
Study I	Evaluation of the effects of computerized training on letter knowledge and reading skills	n = 44 Finnish-speaking children with poor pre-reading skills Grade 1	**Computer training:** Correspondences between phonological and orthographic units **Control**: Group receiving regular language and reading support	**Training effects:** Repeated measures ANOVA
Study II	Comparison of the effects of two different kinds of methods on reading speed	n = 39 German-speaking poor readers Grades 2 and 4	**Computer training:** Correspondences between phonological and orthographic units **Paired reading**: Assisted text reading	**Training effects:** Repeated measures ANOVA Post-hoc: Non-parametric tests **Relations between background factors and gains:** Correlations
Study III	Comparison of the effects of three different kinds of computerized repeated training methods on reading speed	n = 39 German-speaking poor readers Grades 2 and 3	**Association:** Correspondences between phonological and orthographic units **Reading aloud:** Reading items aloud **Combined:** Association + Reading aloud **Control:** Regular school instruction	**Training effects:** Repeated measures ANOVA t-tests Effect sizes (Cohen's d)
Study IV	Evaluation of the outcomes of repeated reading on reading speed	n = 36 Finnish-speaking poor readers Grades 4, 5 and 6	**Switching Replications Design** Group A received training first Group B received training second	**Training effects:** Repeated measures ANOVA **Associations between tasks:** Correlations

2 OVERVIEW OF THE ORIGINAL STUDIES

2.1 Study I: Computerized Training of the Correspondences between Phonological and Orthographic Units

In this study the outcomes of computerized training in the correspondences between phonological and orthographic units were reported. Forty-four Finnish-speaking first-graders with poor pre-reading skills were assigned to one of two groups, intervention or control. The children in the intervention group received computerized training over a 6-week period (mean 170 minutes in total) while the children in the control group received regular reading instruction only. In the computer-assisted program the connections between single phonemes and graphemes were the major focus of the training, but syllables and words were also introduced. The children were able to work with the program independently.

The results showed that the short intervention produced accelerated growth in letter naming during the training period. In the computer program the task of the child was to *select the orthographic item* that corresponded to the spoken item; in the outcome tasks children had to *name* letters. However, during the follow-up period, the control group children caught up with the intervention group children, and after 7 months of formal reading instruction the scores for both groups on the letter naming task approached the ceiling level. The results showed that both groups became *faster in the naming* of letters, and that there were no differences between the groups. The results of the reading acquisition analyses showed that in both groups rapid growth of reading skills was achieved. Accuracy levels during the follow-up tests in reading syllables and words were 88% for the intervention group and 84% for the control group. One of the important results was that no differential outcomes emerged between the groups in terms of reading acquisition.

In order to identify the risk factors which mediated/moderated responsiveness to the training program, groups of children whose performance

was below the median, separately for each of the six cognitive-linguistic abilities (non-verbal IQ, attention difficulties, letter naming, phoneme awareness, naming speed, and short-term memory) were selected. The intervention was more effective than ordinary instruction for children with *low letter knowledge* and who had a *poor short-term memory span,* in relation to improving their letter knowledge, and for children with *attention problems* and *low phoneme awareness,* in syllable and word reading.

To conclude, for children who were at the beginning of reading development, this type of training offered an intensive way in which to rehearse the memorizing of letter-sound correspondences. The combination of a highly regular orthography and systematic phonics instruction seemed to provide a good basis for the rapid acquisition of reading ability. Two possible reasons can be proposed for the finding concerning the lack of group differences in reading acquisition. First, the intervention was extremely short in duration. The second explanation for this lack of differential outcomes may relate to the activities of the control group, whose instruction might have been closer to that of the intervention group than we expected (regular reading and language support which consisted of synthetic phonics instruction supplemented by tasks of letter knowledge and phonological awareness). With this short training program we were unable to show differential outcomes in reading acquisition between the intervention and control group among children with low initial letter knowledge or slow serial naming. However, the results were promising for children with poor access to phonemic representations: their early reading acquisition was accelerated by the training given on the correspondences between phonological and orthographic units. One surprising finding was that children teacher-rated as having low attention abilities also profited from this game-like computerized training.

2.2 Study II: Training Reading Fluency: Many Ways to the Goal

The outcomes of two training programs, one computer-assisted and the other paired reading, aimed at improving reading speed for 39 German-speaking poor readers in Grades 2 and 4 were evaluated. During the 6-week training period (6 hours and 15 minutes in total) the specific target for the children in the *computer group* was to improve their reading of word-initial consonant clusters. A large number of stimulus presentations were offered. The child heard a phonological unit through headphones and clicked the corresponding orthographic stimulus, selecting from a number of options presented on the screen. This type of training enabled independent practice, as the continuous presence of an adult tutor was not required. The children in the *paired reading group* read books with an adult tutor. The paired reading intervention was aimed at keeping the child reading. Thus, the emphasis was on easy implementation, which was created by using adult volunteers as tutors.

The results showed that in reading words with the consonant cluster onsets, which aimed at assessing the benefits of the computer program, both groups exhibited a similar improvement in accuracy and speed. A post-hoc analysis was conducted to examine whether the children in the computer program improved at the sublexical level, which was the specific target of the computer program. It was found that computer training was associated with better reading of the trained sublexical items. However, these improvements did not show large generalization effects on reading of words embodying the consonant clusters. In terms of global reading fluency skills, the children in the paired reading group improved more than the children in the computer group. The positive effects in both groups were found after a relatively short training period; however, it is clear that in 6 weeks reading deficits can not be remediated. The post-test performances of the participants were still clearly below the average level. Neither of the groups improved their pseudoword reading skills.

One research question was whether the age of the participants or certain cognitive-linguistic skills (non-verbal IQ, short-term memory, phoneme awareness, and naming speed of digits) were associated with the gains in reading speed. Non-verbal reasoning abilities showed a statistically significant association with the gain in reading words with the consonant clusters. However, this relationship was strongly influenced by the results of just one student. Rapid naming speed was associated with the gains in global word reading fluency, that is, the children with slow naming skills showed a lower gain in word reading fluency than the children with faster naming skills. No other pre-treatment characteristic was related to the gains in word reading fluency. It is important to note that age did not show a significant correlation with the gain in reading speed.

The findings related to the effectiveness of the computer program can be discussed by drawing a distinction between proximal and distal effects. With respect to proximal outcomes, the effects of practicing the computer task itself, an improvement was found. However, with respect to the distal outcomes of the computer task, a word-list-reading task which did not resemble the training settings, the improvement was small. The results concerning the paired reading program suggest that exposure to print does not promote a rapid phonological recoding strategy, the reading of pseudowords, but helps pupils to recognize words more rapidly. From an instructional point of view, both types of training were designed to be easy to implement and non labour-intensive for schools and teachers. However, since the paired reading program showed advantages over computer training, it might be that social factors - regulated through active participation, attention and motivation - are critical in reading instruction.

2.3 Study III: Training Reading Fluency: Is It Important to Practice Reading Aloud and Is Generalization Possible?

This study evaluated the effects of three different types of computerized training in sublexical items (word-initial consonant clusters) on reading speed among 39 German-speaking poor readers in Grades 2 and 3. A *phonological-orthographic association group*, a *reading aloud group*, and a *combined group* were compared in performance with an untrained *control group*. In the association task the child heard a phonological unit through headphones and clicked the corresponding orthographic stimulus, selecting from a number of options presented on the screen. In the reading aloud condition the children read items aloud, and in the combined group both types of training tasks were introduced. During the training period (daily training for 10 to 15 minutes over 6 days) the total number of presentations of the trained onset cluster syllables was 36.

No differences were found between the intervention groups; thus, both oral articulation by the child and the phonological form provided by the computer were associated with similar gains in the development of reading speed. During the short-term training the intervention groups showed higher gains than the control group in their reading speed of the trained sublexical items. Thus, direct training of sublexical multiletter items can affect reading speed. One of the most important results of this study was that it showed that it was possible to achieve generalization from the sublexical level to words containing the sublexical segments, as the interventions were associated with better learning of the transfer words than the control condition. With respect to generalization effects the results were only partially successful, as in reading pseudowords no specific training-induced gains were found. The failure to achieve an interaction effect between test session and group in pseudoword reading might have a statistical explanation: the groups were small and there were large standard deviations within them. The generalization effect on pseudoword reading was similar, whether the pseudowords contained the trained segment as a syllable or as a non-syllabic letter string; thus, syllable boundaries did not play a significant role in generalization. The gains induced by the training were specific to the training materials and did not induce gains in general reading speed.

In summary, the present study suggests that for poor readers orthographic access to multiletter units without semantics can be enhanced by repeated reading practice. More importantly, training multiletter sublexical units facilitates training effects that are not limited to specific words, as sublexical training can lead to improvement at the word level, and the trained units occur in several words. Effective repeated reading exercises can be administered through different types of tasks (training associations between print and phonology, reading aloud); however, in training reading fluency the role of rapid mapping between phonology and orthography is presumably crucial.

2.4 Study IV: Repeated Reading of Syllables among Finnish-Speaking Children with Poor Reading Skills

In this study the outcomes of repeated reading of syllables in relation to reading speed among 36 Finnish-speaking poor readers in Grades 4 to 6 were investigated. A switching replications design was applied: Group A (n = 20) received training first during which Group B (n = 16) did not receive any specific intervention. After the mid-test the design was switched. The training material consisted of 30 syllables, which were practiced altogether 50 times over 10 training sessions (the duration of each session was 5 to 10 minutes). The training program was a computerized task in which the participants had to read syllables aloud.

The results showed that the reading speed of the trained syllables increased during training, whereas during the control period no significant improvements appeared. Thus, direct training of sublexical multiletter items had an effect on the reading speed of the trained items. An important finding of the study was that during the training period the reading speed of transfer pseudowords containing the trained syllables increased significantly. Thus, a transfer effect from the syllable-level to the pseudoword-level (to a larger context of written material) was obtained. This improvement was found both in the computer task, which resembled the training task, and in the list-reading task, which had lower congruency with the training method. Finally, repeated reading of a limited set of syllables did not lead to an increase in reading speed in the control task: reading a text in which the trained items were not included.

To summarize, the present study suggests that direct training in reading speed for multiletter units without semantics is possible. The results indicate that grapho-phonemic representations or processes at the sublexical level can be affected by training. In this study these sublexical multiletter items were syllables, as in the Finnish language syllables could be one critical unit in word reading. An important result was that training multiletter sublexical units facilitates new possibilities for transfer effects: one syllable (or another type of sublexical item) is contained in several words and thus training effects are not limited to specific words. The training effects were beyond the proximal, as a similar improvement in pseudoword reading was found both in the computer task and in the list-reading task. Finally, the findings confirm earlier conclusions: the effects of repeated reading of words or sub-lexical items are not due to changes in the general reading strategy, but rather to improvements in the orthographic processing or recognition of the trained items. Thus, the improvements induced by repeated reading training are *specific to the trained material.*

3 GENERAL DISCUSSION

3.1 Selecting a Training Method: Comparison of the Approaches Studied

In the four studies comprising the present thesis different types of methods of training reading were used. In Study I, a computer-assisted method was compared with a group that did not receive any specific treatment but attended regular school instruction, in Study II a computer-assisted repeated reading method was compared with general assisted reading practice (paired reading), in Studies III and IV different computer-assisted methods were used and the control group consisted of children attending regular school instruction. What can be said about the efficacy of these different types of programs?

3.1.1 Computerized Training Focusing on Grapheme-Phoneme Correspondences Enhanced Letter Knowledge

In Study I the participants were 44 Finnish-speaking first-graders with poor pre-reading skills. The children were assigned to one of two groups, computerized training group or control group. The results of Study I showed that computerized training focusing on the correspondences between phonological and orthographic units was associated with enhancement of the participants' letter knowledge. In the computer program, the child's task was to *select the orthographic item* that corresponded to the spoken item. After practicing with this program for less than 4 hours the intervention group showed benefits in letter *naming*. However, during the follow-up period, after 7 months of formal reading instruction, the control group children caught up with the intervention group children and the scores for both groups in the letter naming task approached the ceiling level. The results for speed of letter naming showed that both groups acquired speed in the naming of letters, with no differences between the groups. The results of the reading acquisition analyses showed that

in both groups rapid growth of reading skills was achieved. However, no significant differences in reading acquisition between the intervention and control groups emerged.

The main result was that the group receiving computerized training showed more rapid development in letter knowledge; however, this enhanced letter knowledge did not lead to more rapid reading acquisition. It is important to note that in Finnish, even among poor readers, adequate phonological recoding skills are acquired relatively quickly. Aro (2004) studied the acquisition of literacy of 63 first-graders and found that, within 4 months of beginning school, the children were able to read words with an 87% level of accuracy. The same materials were used in Study I, and this high level of accuracy was achieved during the follow-up tests after 7 months of reading instruction. Thus, on the group level the acquisition of reading by children with poor pre-reading skills was delayed by approximately 3 months compared to the group representing the normal population. At the follow-up tests children were able to read on average over 80% of the presented mono- and bi-syllabic items correctly, which should be a high enough level to enable independent reading practice. Thus, Finnish-speaking children, even with poor pre-reading skills, should be able to start independent reading practice already in Grade 1. We did not follow up the improvement in reading fluency after Grade 1, as we did not find any differences between the intervention and control group in reading acquisition. Thus, the hypothesis that faster acquisition of adequate recoding skills is the key to the development in reading fluency could not be tested.

The intervention was more effective than ordinary instruction for children with low letter knowledge and who had a poor short-term memory span, in *improving their letter knowledge,* and for children with attention problems as defined by teacher ratings and low phoneme awareness, in *syllable and word reading*. Thus, the present study suggests that it may be possible to improve the access to phonemes of children who have initial difficulties with this access. To facilitate this access, it is important to emphasize the connection between print and phonology in instruction and to provide a sufficient number of exposures to the phonemic representations. With this short training program we were unable to obtain differential outcomes between the intervention and control group either in terms of increasing the speed of retrieving phonemic representations or in terms of affecting the reading acquisition of children with low initial letter knowledge or rapid serial naming. Such an outcome can be interpreted in two ways. First, there is a difference between the speed of retrieving a phonological representation from the long-term memory and the quality of this representation, as suggested by de Jong and van der Leij (1999) or, second, that it is difficult to *quickly* improve speed-related processes in rapid naming (de Jong & Vrielink, 2004) or word recognition (Thaler et al., 2004).

Two conclusions can be drawn from the results of the present study. First, the results confirm earlier findings that children learning to read a more transparent orthography (e.g., German, Dutch, Spanish, Finnish) are able to

read words with quite a high level of accuracy already at the end of the first grade (Aro & Wimmer, 2003), and that inaccurate reading is not the main manifestation of poor reading (e.g., Holopainen et al., 2001; Landerl et al., 1997; Wimmer, 1993). Second, the main reading instruction method used in Finland – synthetic phonics –combined with a highly consistent orthography seems to provide a good basis for the rapid acquisition of reading ability. These two conclusions together with the result that the computerized training provided in the first grade did not affect speed-related processes imply that if the aim is to enhance reading speed, different types of approaches should be considered. One factor affecting the results of Study I might be that in Finland in the first grade the emphasis in reading instruction is heavily on the attainment of accurate reading skills, and the development of reading speed is not (yet) a specific aim (see also Aro, 2004). Finally, the conclusions presented above are consistent with the notion by Share (2008): training phonological skills and decoding accuracy may not be sufficient for attaining automatization in fluent skilled reading. The acquisition of well-specified representations through self-teaching may illuminate only one piece of what is a more complex phenomenon, that of becoming a fluent reader.

To summarize, in terms of training outcomes the computerized program did not lead to large differential effects compared to regular school instruction. However, from the instructional point of view the program had one benefit: it provided for the easy implementation of individually-targeted training. Children were able to work with the program independently - thus teacher time did not need to be allocated to tasks that required drilling, such as repetitive exercises for memorizing letter-sound associations. As Torgesen and Hudson (2006) note: as the time available to intervene is practically always limited, it is important to start with interventions that will have the biggest payoff.

3.1.2 General Assisted Practice Produced Global Gains, Repeated Computer-Assisted Practice Specific Gains Only

In Study II the main aim was to improve the word reading speed of German-speaking poor readers. The computer training was repeated practice: the sublexical multiletter units (word-initial consonant clusters) were repeatedly encountered. The paired reading could be described as general assisted reading practice. Both training programs consisted of 25 sessions and the duration of each session was 15 minutes. The results showed that in reading words with the consonant clusters, both groups exhibited a similar improvement in accuracy and speed. In a post-hoc analysis it was found that the computer training was associated with better reading of the trained sublexical items, which was the specific target of the computer program. In terms of global reading fluency skills, the children in the paired reading group improved more than the children in the computer group.

If the two methods are compared it can be concluded that the paired reading group showed benefits in a task in which this group was hypothesised

to improve; i.e., in global word reading fluency. However, the paired reading group also improved in a task which was the specific target of the computer training; i.e., words with the practiced consonant clusters. The computer group showed benefits only in reading words containing the trained clusters. Thus, it may be concluded that general, assisted practice was associated with broader improvements than repeated, computer-assisted training. However, despite the positive findings for the paired reading group, it has to be noted that the paired reading group performed at a lower level at the pre-test than the computer group; thus, there is a possibility that methodological factors affected the result. It might have been that in the paired reading group larger regression to the mean effect occurred during the training period enabling more positive results. To summarize, these findings have to be considered with a caution. However, the findings lend some support to the results of the earlier studies comparing repeated and non-repeated approaches, where no differences were found between repeated reading of a small number of texts and non-repetitive reading of a larger set of texts (e.g., Mathes & Fuchs, 1993; O'Connor et al., 2007; Rashotte & Torgesen, 1985), and to the conclusion drawn by Kuhn and Stahl (2003) that in training reading fluency the amount of time spent in reading texts is of critical importance. In the present study, reading connected texts with a tutor was associated with improvements in single word reading; thus, the effects of text reading are not limited to phrasing, syntactic skills, or prosody.

The two intervention groups differed from each other in several dimensions. Paired reading represented general, computer training repeated practice; paired reading was assisted, computer training computer-assisted. In addition, computer training included speeded elements, whereas in paired reading speed of reading was not emphasized. Thus, besides the differences in general vs. repeated practice, the different outcomes of the training programs might be related to the difference in the form of assistance. As stated in the introduction, computer-assisted methods save teacher time and resources. However, this form of assistance has some limitations: tasks administered through a computer are limited to recognition-based exercises. Human assistance can be given for oral reading and humans are able to adjust the instruction they give according to the need of the struggling reader. In addition, through human assistance active participation, attention and motivation might be enabled or supported. One additional benefit of the assisted type of text reading practice could be that it might also encourage children to read outside school contexts, thereby possibly increasing the amount of reading practice by more than the 15 minutes a day used for practice in school.

From an instructional point of view, both types of training were designed to be easy to implement and non labour-intensive for schools and teachers. Although the requirements in the paired reading program were kept to a minimum, the recruitment of volunteer tutors and management of timetables required some time and effort. Classwide Peer-Tutoring could be helpful as a means of efficient delivery (see Kuhn & Stahl, 2003). Computer training in turn is easy to administer and is cost-effective for schools. However, on the basis of

the findings of Study II more evidence about the effectiveness of the computer program is needed.

3.1.3 Repeated Practice Was More Effective Than Regular School Instruction

Studies III and IV were conducted with the aim of improving reading speed of the trained items among poor readers of German (Study III) and of Finnish (Study IV). In both studies repeated reading of sublexical items was applied, but different kinds of computer-assisted methods were employed. In these studies the comparison condition was a group receiving normal instruction; thus, the studies cannot be considered as comparison experiments between different dimensions of fluency training (such as general vs. repetitive, assisted vs. unassisted).

On the basis of the results of Studies III and IV it can be concluded that repeated reading/practice is effective in improving reading speed of sublexical items and transfer items containing the trained sublexical units. In both studies the intervention groups showed more rapid development than the control group. The total training duration in both studies was extremely short (1 hour to 1,5 hours) and the training items were a limited set of sublexical units; thus, it is obvious that these short-term studies have to be considered as experiments evaluating specific research questions, not as remedial reading programs for children with dyslexia. In both studies the training task was a combination of assisted and computer-assisted methods. Children practiced using the computer (reading items aloud or selecting the right written counterparts of spoken items); however, an adult tutor was present throughout monitoring that the children were attending to the training. In Study III the computer gave feedback on the correctness of the responses, in Study IV the human tutor provided feedback. Both forms of assistance worked well. Thus, repeated reading using either computer-assisted or assisted methods can be effective. The important common factor between these studies was assistance, which included providing feedback and monitoring that the children practiced undisturbed. Taken together these findings, they support the line of argument presented in the introduction: the repetition of reading material is one way to support struggling readers; however, the importance of assistance or support during practice should not be underestimated.

The results of Studies II (discussed above) and III showed some differences, although a similar type of training task was employed. In Study II the generalization effects of the computer training program were low, as in the task measuring generalization of the computer-trained skill (reading a list of *transfer words* containing the trained segments) both the computer and the paired reading group exhibited similar improvement. The results were to some degree different from those of Study III, in which generalization to the transfer words was found. There are three possible reasons for the differences in the results: (1) transfer issues, (2) the forms of assistance, or (3) speeded elements in training. First, the experimental task in Study III was more congruent with the

training program than that used in Study II, which might have facilitated higher gains. Transfer issues are discussed more thoroughly in a separate section below. Second, in both studies the computer gave feedback on the correctness of the responses. However, there were differences in the kind of assistance given: in Study III an adult tutor was in constant attendance monitoring that the children were attending to the training, and the children practiced one-on-one with an adult tutor. In Study II it was possible to have 4 children at a time for one session. Thus, although it was ensured that the children followed the instructions and could practice undisturbed, individual monitoring of the childrens' practicing was not possible. Third, in Study III the computer program was modified in order to encourage the participants to respond quickly; thus, the children may have been more aware of the importance of fast responding. This could have been one reason for the positive findings in generalization from the sublexical level to the word level. As, owing to the designs of the present studies, definitive explanations for the different results cannot be given, studies are needed in the future that more specifically investigate the effects of these factors on training gains.

3.1.4 What Can Be Said About Background Factors in Responsiveness to Training?

In the present thesis, the associations between background factors and training gains were evaluated in two studies. In Study I it was evaluated whether the low initial levels of cognitive-linguistic abilities (letter knowledge, phoneme awareness, rapid serial naming, and short-term memory), nonverbal intelligence or attention problems reported by classroom teachers have an effect upon the efficacy of treatment. In Study II, in which two different types of reading fluency training programs were evaluated, background factors included the age of the participants, non-verbal reasoning skills, short-term memory, phoneme awareness, and rapid naming.

In both studies it was found that nonverbal intelligence did not play a strong role in responsiveness to training. In Study I we wanted to identify the risk factors which mediated or moderated responsiveness to the training program. To examine this question, we selected groups of children whose performance was below the median in each examined skill, after which it was analysed whether the children in the intervention group differed in their development from the children in the control group. For the children with low non-verbal reasoning skills, both computerized training and exposure to regular reading and language support were equally effective. Although these children showed the poorest performance in non-verbal reasoning skills compared to the whole participant group of this study, it should to be noted that they were instructed in regular classroom settings and followed the normal curriculum, so they probably do not represent the lowest tail of the whole distribution. In Study II, non-verbal reasoning abilities had a statistically significant association with the gain in reading words with the consonant

clusters, which was a test specifically designed to evaluate the effectiveness of computerized training. The gains were higher, if the scores in the non-verbal reasoning test were relatively high. However, this relationship was strongly influenced by the results of just one student, so no definite conclusions can be drawn. Non-verbal reasoning skills were not associated with the gain in global reading fluency.

Rapid serial naming is one of most important skills in the context of the associations between background factors and training gains. In Study I, which was carried out at the beginning of school instruction in Grade 1, the development of children who were slow in colour and object naming was evaluated. Computerized training and regular reading support did not produce differential outcomes among children with slow naming. Thus, the group of children with slow naming speed did not specifically profit from the specific computerized intervention. However, these children, in general, showed the best gains in the reading measures. However, as in this study the participant group consisted of first-graders it is possible that the correlation between rapid naming and reading skills is not so important as yet. In reading instruction in Grade 1 there is a strong emphasis on accurate assembly, that is, rapid reading skills are not required. In Study II, naming speed was not associated with gains in the reading speed of words with the consonant clusters during the intervention period, which might be due to the specific nature of reading words with the consonant clusters and to the short intervention period. However, rapid naming speed was associated with gains in global word reading fluency, that is, the children with slow naming skills showed a lower gain in word reading fluency than the children with faster naming skills. This finding is consistent with the findings of Bowers (1993), Levy et al. (1999) and Holopainen et al. (2001). The correlation between rapid naming and gain in word reading fluency was statistically significant, but not very strong, $r_s(39) = .33$, $p < .05$. To conclude, Study I provides some evidence that in the early stages of reading acquisition, when reading accuracy is emphasized, rapid naming does not play such a strong role in responsiveness to training. In training reading speed among older students, the evidence of Study II and other studies suggests that children with slow naming do not show such large benefits as children with more rapid naming skills; however, in Study II the evidence for this was not very strong.

Were the other cognitive-linguistic skills associated with responsiveness to training? In Study I the computer-assisted intervention was more effective than ordinary instruction for children with *low letter knowledge* and who had a *poor short-term memory span* in improving their letter knowledge but not in improving their reading acquisition. Why was the computer-assisted training program more beneficial than regular school instruction only in letter knowledge? It may be the case that, especially for the group with low letter knowledge, many repetitions were required in order to learn the connections between the letter-sound correspondences, and that an intervention of such a short duration was insufficient to produce effects on reading. For children with

attention problems and low phoneme awareness the computer-assisted training led to higher gains in syllable and word reading than regular reading instruction. Thus, the results suggest that it may be possible to improve the access to phonemes of children who have initial difficulties with this access. To facilitate this access, it is important to emphasize the connection between print and phonology in instruction and to provide a sufficient number of exposures to the phonemic representations (see also, Hatcher, Hulme, & Snowling, 2004, and Magnan et al., 2004). Children with attention difficulties also benefited from the program. This stands in contrast to the findings by Torgesen et al. (1999) who concluded that the attention and behaviour control problems of children made it very difficult for them to profit from a one-on-one teaching situation. A game-like method of instruction, even during short training sessions (average 10 minutes), might offer a sufficient number of repetitions for learning a letter-sound conversion to help children with attention difficulties master the alphabetic decoding strategy. The characteristics of this program can be described as 'attention catching': concentration must be maintained in order not to miss points, the principles of the game are easy to master, and visual feedback is provided.

In Study II, in which reading speed was trained among dysfluent readers, of the cognitive-linguistic skills short-term memory and phoneme awareness had no associations with the gains in reading speed. Thus, neither phoneme awareness nor short-term memory mediated responsiveness to training. It is important to note that although the age of the participants was associated with reading speed at the post-test (older children being faster readers than younger participants), age did not show significant correlations with the *gain* in reading speed. This result is consistent with the findings of Lovett and Steinbach (1997); O'Connor et al. (2007) and Tressoldi et al. (2008). Tressoldi et al. concluded that it is 'never too late' to remediate reading fluency and accuracy. While the present study does not provide evidence for 'never too late', it suggests that training reading speed among older poor readers (in Grade 4) can yield gains similar to those of younger children (in Grade 2).

3.2 Selecting Training Material: Using Sublexical Units Increased Training Payoff

In each of the studies comprising the present thesis, sublexical units were chosen as training material. There were both theoretical and instructional reasons for this selection. First, from the theoretical point of view it has been stated that some phonological influences at the sublexical level could be reflected in visual word recognition (e.g., Cole et al., 1999; Ferrand & Grainger, 1992; Perfetti & Bell, 1991). Second, from the instructional point of view, in order to enhance fluent word recognition, the disadvantage of the most

commonly used method - repeated reading of words - is that it does not lead to generalization effects. As a result, a remedial program focusing on single words and using one-on-one tutoring methods would be a time-consuming task demanding a lot of resources.

3.2.1 Accuracy of Grapheme-Phoneme Conversion Improved

The results of Study I showed that although the computer-assisted training focusing on the correspondences between phonological and orthographic units was associated with growth in letter knowledge, no differential outcomes between the computer group and control group participating in regular school instruction in terms of reading skills appeared. The findings were consistent with the evidence obtained from earlier studies suggesting that training, with a major focus on letter-sound correspondences, can have positive effects on letter knowledge and phoneme awareness (Defior & Tudela, 1994; Hohn & Ehri, 1983; Rvachew et al., 2004). However, the impact of instruction in letter-sound correspondences on reading skills remains inconclusive (see also, Hohn & Ehri, 1983). As training did not lead to accelerated reading growth, the hypothesis that faster acquisition of adequate recoding skills is the key to the development in reading fluency could not be tested.

Recent evidence shows that even though children learn accuracy in relating letters to their corresponding sounds during the first year of school instruction in transparent orthographies, the automaticity of letter-sound integration continues to develop far beyond the early school years (Froyen, Bonte, van Atteveldt, & Blomert, 2009). Thus, there is probably a difference between mastering letter-sound associations and the automatic retrieval of sounds matching to their corresponding letters. In Study I speed of letter naming was also measured. The results showed no differential outcomes between the intervention and control group in increased speed of retrieving letter sounds or names. Thus, the computer-assisted intervention program was not particularly effective in improving the automaticity of the associations between letters and sounds. In order to obtain gains in automaticity, training should be continued for a longer period of time or more intensively. On the other hand, if differences between accurate and fast responses in associating letters with their corresponding sounds exist, there is a need to develop intervention methods that tap specifically into the automaticity of letter-sound associations.

3.2.2 Training of Sublexical Multiletter Units Led to Gains in Reading Speed

As noted in the introduction, there is evidence for the presence of intermediate units inbetween the sequential parsing of single graphemes to phonemes and whole word recognition. These intermediate units are groupings of letters; in the present thesis the term ‘sublexical multiletter units’ is used. Studies II – IV

of the present thesis were conducted with the aim of directly training sublexical multiletter units.

Consonant clusters among German-speaking children. Word-initial consonant clusters were chosen as training items for two studies among German-speaking children. These consonant clusters were added with a vowel or diphthong to ensure pronounceability. Although consonant clusters were the focus of training, some of these clusters that were added with a vowel can be considered as syllables. In Study III it was found that in total 36 presentations during 6 sessions were enough to produce an improvement in the reading speed of the trained sublexical items. More importantly, the children in the intervention groups showed more rapid development in their reading speed of the transfer words containing the trained segments than the children in the control condition. In sum, the results suggest that for poor readers orthographic access to multiletter units without semantics can be enhanced by repeated reading. The training of sublexical multiletter units induces effects that are not limited to specific words, as sublexical training can lead to improvement at the word level and as the trained sublexical units are encountered in many words.

The results of Study II are more difficult to interpret. In Study II the outcomes of computerized training aimed at increasing the efficiency of access to multiletter sublexical units were compared with the performance of children participating in a paired reading program. During computer training the average number of presentations of the consonant clusters varied between 40 and 139 (M = 96.2, SD = 7.5). The generalization effects of the computer training program were low, as in the task measuring generalization of the computer-trained skill (reading a list of *transfer words* containing the trained segments) both the computer and the paired reading group exhibited a similar improvement. Contrary to our expectations significant effects favouring the computer group in reading words with the clusters were not found; hence, we decided to conduct a post-hoc analysis to examine whether the children in the computer group improved at the trained sublexical level. Computerized training was indeed associated with gains during the training period in the accuracy of the correspondences perceived between the orthographic and phonological units, despite the increase in the number of orthographic alternatives and the acceleration in speed. In addition, accuracy in reading the consonant clusters aloud improved significantly from the pre-test to post-test.

To summarize, it is possible directly to train sublexical multiletter units by repeated practice. Training of these units leads to more accurate and faster reading. It seems also possible to achieve generalization from the sublexical level to the word level, that is, to transfer words containing the trained items. However, the evidence on generalization obtained from the two studies is not very strong. In Study III generalization effects were not shown in the reading speed of pseudowords with the trained segments. In addition, in Study II the transfer effects to the reading of a list of words containing the trained segments were low when compared to the outcomes of general reading practice. One explanation for the lack of generalization in Study II is that the contrast

condition - paired reading practice - was more effective than no treatment at all. During book reading the children probably also encountered quite a large number of consonant clusters (possibly also during independent reading practice outside the school context, which might have increased as a result of encouraging children to spend time on reading activities). However, there was a clear difference in the training methods used in the groups: the children in the computer group attended 25 sessions practicing only consonant clusters, whereas the children in the paired reading group spent a similar amount of time reading stories containing linguistic items of different types.

Syllables among Finnish-speaking children. In Study IV conducted among Finnish-speaking children, syllables were chosen as the items to be trained. The results showed that by repeated reading it was possible to improve the reading speed of sublexical multiletter units, that is, the reading speed of syllables. This improvement was obtained after 50 exposures over 10 sessions. An important finding of the present study was that during the training period the reading speed of transfer pseudowords containing the trained syllables increased significantly. Thus, a transfer effect from the syllable-level to the pseudoword-level (to a larger context of written material) was obtained. Pseudowords were chosen as a measure of transfer, as pseudoword reading compared to word reading is a less ambiguous measure of the efficiency of decoding (as it does not involve semantic factors, frequency or imageability effects). In Study III larger generalization effects were found for words than for pseudowords; indicating that it should be more difficult to find transfer effects on pseudowords than on words. It could be hypothesized that the findings of Study IV also apply to word reading.

Two limitations of the promising findings of selecting sublexical units as training material have to be noted. Firstly, Studies II and III did not include follow-up testing. In Study IV the design allowed us to examine the follow-up effects for one of the two training groups. The results showed that the positive training effects remained similar approximately two weeks after the training period had been finished. However, the lack of detailed investigation of the follow-up effects is one limitation of the present thesis. Secondly, in the studies that comprise the present thesis the reading level of typical readers was not examined. Therefore, it is unclear whether the reading speed of the trained items or transfer items will reach the normal range after training.

3.2.3 Effects Are Specific to the Trained Material

As noted in the introduction, the results of repeated word naming indicate that the effects of training are item-specific, that is, the repetition of words enhances word-specific orthographic representations (e.g., Berends & Reitsma, 2006b; Kuhn & Stahl, 2003; Thaler et al., 2004). However, generalization effects on the reading of other types of words are low (e.g., Berends & Reitsma, 2006b; Lemoine et al., 1993; Lewandowski et al., 2006; Lovett et al., 1990; Thaler et al., 2004). The findings of the present thesis suggest that training sublexical

multiletter units enables new possibilities for transfer effects: a single sublexical item is contained in several words, and thus training effects are not limited to specific words.

The findings of Studies III and IV also showed that repeated reading of sublexical items does not enhance general reading strategy, but rather the orthographic processing or recognition of the trained items. In neither studies did statistically significant improvements occur in reading tasks that did not include trained items, e.g., in a list of frequent words (Study III) or in text reading (Study IV). Thus, it can be concluded that the effectiveness of repeated practice does not rely on general factors, such as motivation or global reading strategy (e.g., which would facilitate more efficient processing or recognition of all the clusters/syllables of a written language). The improvements resulting from repeated reading training are best described as *specific to the trained material*. These findings mean that in order to conduct a remedial reading program for children with dyslexia with the aim of obtaining significant improvements in general reading speed, at least two conditions are required: the duration of the intervention should be much longer and the training materials should be more extensive.

3.2.4 Theoretical Conclusions on the Role of Sublexical Multiletter Units in Reading

To summarize, the studies that constitute the present thesis suggest that grapho-phonemic representations/processes at the sublexical level can be affected by training. This finding has important theoretical implications. The influential computational models of reading processes in the context of the dual-route framework (e.g., dual-route cascaded model; Coltheart et al., 2001; CDP+ model which belongs to the family of dual-route models but uses connectionist architecture; Perry et al., 2007) postulate that there are two distinguishable sources of phonological information in reading. As formulated by Perry et al., phonology of the written word is retrieved through a lexical-semantic pathway as well as assembled or activated through spelling-sound mapping process. The idea that larger sublexical multiletter units (including groupings of letters) operate as functional units in fluent word recognition can not unequivocally be categorized as either of these processes. The aim of the present studies was to facilitate fast and fluent access from orthographic units to their corresponding phonological segments. However, these representations/processes did not involve semantics or whole-word representations. In addition, it was expected that these units would not rely solely on serial processes or letter-by-letter mapping; instead, parallel processes would take place.

The idea of an intermediate level inbetween whole-word recognition and the serial mapping of single letters to phonemes is also important from the view point of the orthography of Finnish. As noted earlier, Finnish words are long, polysyllabic, and can have thousands of orthographic forms. The inflections

often also affect the stem; thus, in many cases the ability to recognise the stem is not enough. For these orthographic reasons it does not seem likely that the development of fluent word recognition relies on single word representations. However, it is reasonable to assume that lexicality in Finnish also involves direct connections between the written and spoken forms of words; however, these connections could include sublexical multiletter units rather than whole words.

As this intermediate level is not represented in the most known computational models, are there other theoretical conceptions or models related to the role of sublexical multiletter units? The connectionist model proposed by Plaut et al. (1996) includes letters or letter combinations as orthographic units; in other words, this model predicts that sublexical multiletter units are used in reading. In simulating the reading of French polysyllabic words, Ans et al. (1998) propose a model according which words and pseudowords are initially analysed by a global route. However, when low-frequency words and pseudowords are encountered, the global word recognition process usually fails, after which items are decomposed in syllables. The intermediate level – the use of syllables - is included in this model; however, there is not much evidence of the applicability of this model to orthographies other than French, and the model has not found its way into mainstream reading science (see Share, 2008). There are also few other theoretical notions regarding the role of intermediate units between whole word recognition and serial grapheme-phoneme mapping. For example, Barber and Kutas (2007) state in a recent review that the word processing system could segment words into a variety of sublexical units associated with different types of information (phonological, syllabic, morphological). LaBerge and Samuels (1974) note in their automatization model that the first stage in automatization of reading process is characterized by visual code and the unitization of visual stimuli (e.g., spelling patterns) as a single unit. Similarly in Ehri's developmental theory (1992a) it is assumed that in the consolidated alphabetic phase associations between multiletter units and their corresponding phonological segments are acquired. Share (2004) concluded recently that multisyllabic words are not merely chains of letters; rather, they involve subgroupings of letters that must be unitized into syllabic and morphemic units.

To summarize, there are theoretical conceptions to support the role of sublexical multiletter units in reading. The present training studies suggest that these units can be directly trained; in addition, other researchers have found empirical evidence for the use of sublexical multiletter units in fluent reading (Marinus & de Jong, 2008). However, the precise nature and mechanisms of this intermediate level are not known, and to date no comprehensive models or theories exist that would explain the use of these units or that take into account developmental issues. The lack of models or theories might be partly related to the fact that the majority of reading research has been conducted in the context of the English language, and as in English the number of monosyllabic words is high, most of the reading materials used have been monosyllabic. As already

noted, some phonological influences at the sublexical level could be reflected in visual word recognition (e.g., Cole et al.; 1999; Ferrand & Grainger, 1992; Perfetti & Bell, 1991). However, as the phonological structure of languages differs, and there are differences in the consistency of languages' orthographies and in their phonological and orthographic neighborhood characteristics (Cole et al., 1999; Ziegler & Goswami, 2005), the critical units used in visual word recognition probably vary across languages. The present thesis provides evidence that for Finnish-speaking children the syllable could function as one such critical unit on the pathway towards fluent reading, while for German-speaking children consonant clusters may have a critical role in the development of skilled reading. Finally, in Studies II and III among German-speaking children the training units were consonant clusters added by a vowel. Some of these items can be considered as syllables. In Study III it was found that the generalization effect on pseudoword reading was similar for both the pseudowords containing the trained segment as a syllable and those in which it was a non-syllabic letter string; thus, syllable boundaries did not play a significant role in generalization. This finding stands in contrast with the findings of the Study IV among Finnish-speaking children, in which it was concluded that the syllables could function as critical unit in the development of fluent reading. The difference between Finnish and German is that in German the syllable structure is rather complex (e.g., Zieger & Goswami, 2005; Stenneken et al., 2007), which might reduce the possibility that the syllable is an important unit in visual word recognition. In addition, the findings of Study III were related to the role of syllables vs. non-syllables in enhancing generalization effects, whereas in Study IV only the role of syllables (and not the role of other types of linguistic items) in generalization was investigated.

3.3 Conducting an Intervention Study Involves Many Methodological Choices

3.3.1 Interventions Targeted at Good vs. Poor Readers

In the present thesis, each study was conducted among poor readers, except for Study I, whose participants were children with poor pre-reading skills. For Studies II, III and IV the central criterion for selection was poor performance (in Studies II and III below the 25th percentile, in Study IV below the 10th percentile) in individually administered standardized reading tests measuring reading speed or reading efficiency (correctly read words within a certain time-limit). In Study I the teachers selected and nominated the children in their classes who had poor pre-reading skills, such as letter knowledge. This was followed by individually administered testing of the children, whereby the children's inability to decode syllables or words was verified. In none of the studies, were

children diagnosed with dyslexia for the purposes of the study; instead we used the term 'poor readers' or 'children with poor pre-reading skills'.

As stated in the introduction, the effect of the training on a certain skill can be expected to be qualitatively different according to whether the participants are children who already master the skill, but who are being trained to perform better, or children who are impaired in this skill. Direct evidence on this issue is relatively scarce, as due to resource limitations in conducting studies an intervention often has to be targeted at those who really need it. However, there is some evidence that in the early stages of reading development the most severely impaired children are difficult to remediate (Vellutino & Fletcher, 2005); and that later on in reading fluency instruction certain types of reading methods are more beneficial to average readers than to poor readers (NICHD, 2000). Differences in the effectiveness of interventions between typical and poor readers have not been taken into account in some of the important reviews on reading fluency interventions (e.g., Kuhn & Stahl, 2003). In the present thesis, the inclusion of poor readers as participants probably decreases the possibility of finding large improvements; however, selecting these children makes it possible to draw conclusions about the improvement of deficient reading skills, and has importance for the planning of treatment or remediation tools.

3.3.2 Choice of Control Group Affects the Results

The choice of a control group in intervention studies targeted at poor readers is not an easy task. To control for re-test effects, an intervention study should include an untrained control group, and to control for attention effects, a group with another type of practice. However, conducting such an intervention study for poor readers requires a lot of resources, which are often not available. This was also the case with respect to the studies conducted for this dissertation.

A control condition was included in each of the present study, although the designs varied. In Study I the computer-assisted intervention was compared with regular reading and language support. Computerized training actually replaced a part of the reading and language support typically provided for struggling readers within the Finnish school curriculum. In Study II two different kinds of interventions were compared with each other. In this way we were able to provide an intervention for all the poor readers participating in the study. In Study III three different types of computer-assisted interventions were compared with a group that did not receive specific intervention. However, we had to select the children for the control group from different schools. Selecting poor readers for an untrained control group from the same classrooms as that of the training groups would have involved ethical and practical dilemmas. It would have been difficult to justify to teachers and parents for whom the intervention would be provided and for whom not. In Study IV the comparison condition was also an untrained control group, that is, these children participated only in regular school instruction. However, in Study IV a

switching replications design was applied; thus, both groups received training, but in a reverse order.

The conclusions drawn from the results of the studies would have been very different if had we not included a control condition in the designs. In almost each outcome measure targeted at reading skills the poor readers or children with poor pre-reading skills improved during the training period; thus, drawing conclusions about the effectiveness of training solely on the basis of the improvement during the training period is not enough. In studies in which we used control groups that did not receive any specific training, *re-test effects* were controlled for (Studies I, III and IV). In Study IV a group receiving another type of practice was not included; thus, the question remains whether the improvements were due to greater attention devoted to the intervention group. It has to be noted that if the improvements were only due to providing attention, equal gains should be expected in each reading task. However, the results showed that repeated reading of a limited set of syllables did not lead to an increase in reading speed in the control task: reading a text in which the trained items were not included. As the improvements were specific to the material including the trained segments, it can be concluded that the gains were training-induced, and not only a result of devoting increased attention to the children.

In Study I a group receiving regular reading and language support was included as a control condition for the computer-assisted training group. However, as the computerized training replaced part of the reading and language support, both groups received approximately same amount of attention. Reading support in Finland typically consists of synthetic phonics instruction, often supplemented with tasks on letter knowledge and phonological awareness. It may be that there was greater similarity in the instruction given to the two groups than we expected. In addition, in this study children from the same classroom were assigned to the intervention or the control group. When conducting specific training in one classroom for some children and not for others, teachers become aware of the main features of the training program and what researchers consider as effective instruction. Thus, it might be that through similarities in instruction the effectiveness of the computer-assisted training program was subjected to a stringent test.

In Study II the effects were *controlled for attention*, as two different kinds of training programs were introduced. A design of this kind has its limitations when the two methods lead to similar outcomes, as in such a case it is difficult to determine which element of training accounts for the gains and to exclude the possibility of a re-test effect. This result was found in the task of reading words with the word-initial consonant clusters, in which both intervention groups showed gains. Although research on reading speed improvement among German-speaking poor readers is scarce, estimates of growth in reading speed during just a few weeks (the duration of the training period) were obtained from two training studies and from cross-sectional data and a longitudinal study. On the basis of these comparisons the intervention groups

in Study II showed 1.5 to 10 times larger growth in reading than poor readers who did not receive any specific intervention. This design comparing two different types of training programs and without the inclusion of an untrained control group clearly has some limitations; however, it can provide useful information if specific hypotheses are created and/or information about the development in reading skills during a specific time period is available. The advantage is that ethical dilemmas related to the selection of a control group can be avoided.

An ideal intervention design should include a group of poor readers from the same classroom, and the random assignment of children to the intervention and control group. This was done in Study I and for the intervention groups in Study III. In the other studies it was not possible for practical reasons: given the distances between the schools it was not possible to randomize the children into the respective groups, as this would have required that the training was conducted at the same time in each school. Random assignment is especially critical if differences between schools and teachers in their instructional methods and educational context are expected to play a role in the development of reading skills during the intervention period. In the present studies reading development was evaluated over a short time-span (10 schooldays to 6 weeks); therefore, it was not expected that the methods of instruction used in schools would be the main cause for differences in reading development between the groups during this short period, particularly among children who had already passed the phase of initial reading instruction.

In the field of child psychology and psychotherapy there has been lively debate on the scientific evaluation of psychosocial interventions, whereas in reading research a general consensus as to what is considered effective, together with discussion as to whether interventions stated to be effective fulfil the criteria of a well-designed study seems to be lacking. For the purposes of the present thesis, the categorization of psychosocial interventions into *well-established interventions* and those with *probable efficacy* by Lonigan et al. (1998) was adopted. With respect to present four studies, none of the interventions meet the criteria for well-established interventions. However, two of the training approaches can be described as interventions with probable efficacy. First, in three studies (Studies II, III, IV) it was shown that direct training of multiletter sublexical units using repeated practice improves the accuracy and speed of reading of these units; and in two studies a transfer effect from the sublexical level to words or pseudowords containing the trained sublexical items was obtained. Second, from the standpoint of specific training methods; it was found that in two studies (III, IV) repeated reading aloud can lead to improvements in outcome tasks in which reading speed was measured (at the sublexical level and for transfer items). However, computerized training of the associations between phonological and orthographic units without the requirement of overt naming used in Studies I, II, and III requires further research. In Study III improvements that resembled the results of reading aloud were found. In Studies I and II the improvements gained by this type of

computer-assisted training were not large in the tasks that measured generalization of the trained skills.

3.3.3 Choice of Outcome Measures Affects the Results: Transfer Examined

An important issue in designing an intervention study is the selection of the outcome measures. In general, the findings of the present thesis lend support to the *transfer-appropriate processing hypothesis (TAP,* Martin-Chang & Levy; 2006; Martin-Chang et al., 2007), as in tasks in which congruency between the training and outcome tasks was higher, larger positive effects were obtained. In contrast, in outcome tasks in which larger transfer or generalization was required, the effects were smaller. Martin-Chang and colleagues relate the TAP-hypothesis to the debate on the differences in learning words in a context or in isolation. In the present thesis, it is possible to relate the TAP-hypothesis to the training methods as well as to the training materials.

One issue in the present studies relates to the use of computerized training without the requirement of overt naming. This type of training is appealing from an educational point of view: it enables independent practice, as the continuous presence of an adult tutor is not required. However, the method most commonly used to measure reading performance is reading aloud. Reading aloud enables assessment of both reading accuracy and speed. Using reading aloud as an outcome measure and intervention based on finding associations leads to a situation in which congruency between the training and outcome task is not very high. In this case children have to perform a transfer from *selecting* the relevant orthographic stimuli corresponding to the phonological item *to the pronunciation* of or sounding out those items. What kinds of results were found in the studies for tasks requiring transfer from the selection to the pronunciation of the items? On the basis of the results for *accuracy* of the trained items in Study I (letter naming) and in Study II (sublexical multiletter units) this transfer to sounding-out was not a particular problem, as an improvement was found in tasks requiring pronunciation. In addition, in Study III the association task led to improvements in the reading *speed* of the trained sublexical items and words with the trained items. Thus, association practice can produce positive effects on reading aloud, i.e., in a production task.

A second transfer issue is related to differences in reading isolated items presented one at a time on a computer screen compared to items presented on a paper in a list. In Study IV this transfer issue was taken into account by the inclusion of two kinds of outcome measure: a computer task, which resembled the training task, and a list-reading task, which did not have such high congruency with the training task. The results showed that a similar improvement in pseudoword reading was found in both a computer task and the list-reading task. In addition, with respect to the correlations, the computer task and list-reading task were quite strongly associated (correlations between these reading tasks measured at the same test session varied between .66 and

.81). Thus, the transfer step from reading single items on screen to reading items in a list was not so large. However, the two kinds of tasks did not totally overlap, but had some unique features of their own.

A third transfer issue is related to the training material used. In each study there was a requirement to generalize from *sublexical* items to *word* or pseudoword reading. Is transfer from sublexical items to larger items containing the trained segments possible? In Studies III and IV this generalization effect was found. However, in Studies I and II large generalization effects were not found. In these studies the development of the children in the control condition was similar to that of children in the intervention group, where the focus was on the training of sublexical items. In addition, in Studies I and II, in examining the outcomes of the computerized program, two major transfer steps occurred simultaneously: from practice based on selection to a task requiring pronunciation, and from the sublexical level to the word level. In addition, a third minor transfer step was required: practicing single items on a computer to reading items presented in a list on paper. Thus, due to this triple transfer the effects of the computer program were subjected to a stringent test. However, although the list-reading task did not have such a high degree of congruity with the computer task, we were interested in analysing the outcomes of training in an authentic reading task.

Although the TAP-hypothesis suggests that to facilitate transfer, the outcome measures should have high congruency with the training task, it is clear that training is of little relevance if a test method is selected that is congruent with the training task, but does not resemble an everyday reading task. An important question is: what type of task can be considered as an "authentic" reading task? In the present thesis, only list-reading tasks and computer tasks measuring the reading speed of items presented in isolation were used as outcome measures. List-reading tasks can be considered to be closer to "real world reading", as in everyday settings children read words on paper. However, the advantages of the computer task are a more detailed analysis of speed and accuracy at the level of single items, and being able to distinguish between the two. The most authentic task for children's everyday reading is a text reading task. The question regarding the differences or similarities between learning words in a context or in isolation has been debated in the research literature in recent years (see Landi et al., 2006; Martin-Chang & Levy, 2005; Martin-Chang et al., 2007). There is evidence to show that reading isolated words leads to improved reading fluency when these words are encountered later in a text, while, there are also findings that words trained in isolation do not show large transfer effects to text reading. This question concerning the possible differences or similarities between reading words in a context or in isolation was not a specific focus of the present thesis. In Study II both list-reading and text-reading tasks were administered; however, later on they were combined as one variable in the interests of economy of presentation of the results. The correlation between reading a list of frequent words and a text was, among second graders, r_s (18) = .78 and, among fourth graders, r_s(21) =

.87. Thus, in these data the reading of words in a list or in a text showed a close relationship. A suggestion for future studies would be that for deeper understanding of transfer effects it would be important to understand the relevant cognitive processes that underlie the training and outcome tasks. Some of these processes probably pertain to reading (e.g., reading aloud vs. silently) and some of them are tied to a particular task format (reading items in a list vs. single items presented on a computer screen). The question of reading isolated words in a list or in a context might be related both to general reading processes and to the task format.

Finally, in everyday situations when children are already in a stage of fluent reading and the main goal of reading is acquiring new knowledge, children typically read silently, whereas in situations in which reading performance is assessed, children often have to read aloud. This was also the case in the present thesis, as reading aloud is the most commonly used method of assessment, and it enables direct measurement of reading speed and reading accuracy. If one wants to assess *both* the accuracy *and* speed of silent reading, often elements that are not purely related to effectiveness of decoding (e.g., semantics, syntactic skills or orthographic processing) will be needed. Share (2008) suggests in a recent review that the dependence on oral reading in reading research may yield an incomplete picture of the nature of word reading. Unfortunately, little empirical data exist on this issue. Share concludes that indirect data indicate that oral and nonoral modes have both common and unique features.

The discussion of transfer issues developed as a by-product of the present thesis. Due to the different types of training methods used, different kinds of transfer steps emerged in the individual studies. In part the different results obtained from the studies are related to transfer issues and the congruency between the training and outcome tasks. It can be concluded that a well-conducted intervention study will include different types of outcome tasks: some tasks should be closely related to the trained task, in other words, proximal effects should be assessed to find out whether improvements are shown in the trained skill. On the other hand, the measurement of generalization is important in order to develop training programs of practical value, that is, by measuring distal effects conclusions can be drawn about the relevance of the program to reading instruction. Transfer effects probably consist of different steps, some smaller and some larger. The most difficult task is multiple transfer; that is, when the training program does not share many features with the outcome task. Another way of thinking about transfer leads to an interesting and highly relevant question: is the most efficient way to practice reading a method that is extremely close to an everyday reading situation, such as reading texts or paragraphs in books? At the moment, the research findings seem to suggest that ordinary reading is an effective way to improve reading. However, improvements do not occur very quickly. In addition, on the one hand there is a need among practitioners to employ theoretically and scientifically well-grounded intervention methods that are cost-effective and do

not place high demands on schools, teachers, and parents. On the other hand, in the research field the mechanisms of development in fluent reading among poor readers are not well understood. For these purposes it is important to conduct well-controlled experimental training studies. Further studies are needed to examine transfer issues, and in reporting the findings of training methods it would be extremely important for the readers to be informed whether the intervention was effective in terms of producing proximal or, in addition, distal outcomes. Nevertheless, it is important that discussion continues on what would be a valid, reliable reading assessment instrument for measuring the skills children in the stage of fluent reading need in everyday learning situations.

4 CONCLUSIONS

The studies that comprise the present thesis have been conducted in a research field in which relatively few studies exist: training the reading skills of poor readers, with the specific aim of developing reading fluency. More specifically, little is known about the effectiveness of different training methods in the context of languages with consistent orthographies, like Finnish or German. In addition, knowledge of reading fluency, its development or the impairments underlying fluency, remain very limited. Various views exist as to what are the critical elements of fluent reading, or how fluency can best be defined. In the present thesis the emphasis has been on the automatization of word reading. The ability to read words fast and with relative ease is a pre-requisite for reading to be expressive and have prosodic features, and in part, for reading comprehension.

One additional challenge in working on the training of fluent reading has been that the field is not very coherent, as the intervention studies published thus far have been conducted in the context of two different traditions: (1) educational science and special education, and (2) experimental psycholinguistics. In the field of education, many studies have their origins in clinical practice, and thus, experimental control has often been impossible, or has not played an important role. On the other hand, in the context of the experimental, psycholinguistic tradition, the duration of training has often been short and training materials specific, as otherwise controlling for different factors would be difficult. Due to the lack of a coherent overview and to methodological differences it has been difficult for researchers to draw general conclusions pertaining to the field as a whole on the basis of the results of different studies and the different training methods used in them. With these limitations in mind the present thesis provides a starting point for creating such an overview. One "product" of this thesis is a classification or summary of the different kinds of approaches used in training reading fluency (see Table 1). This classification developed in the course of the research and did not directly affect the designs of the present studies. However, the methods used in the

present studies can be assigned to the created categories. Study II compared two different approaches (repeated – general), Studies I, III, IV compared the effectiveness of a repeated intervention with regular school instruction. The studies of the present thesis can be best described as small-scale, tightly focused intervention studies of short duration. As little is known about training reading fluency, it is important to evaluate stepwise different kinds of approaches and components which could have an effect on the development of fluent and fast reading.

As at the outset of the present thesis no comprehensive or coherent view of the different methods used to train reading fluency existed, the selection of the methods finally employed was largely guided by the criterion of easy implementation in the school and educational contexts. As a result, in the four present studies different methods and designs were used. Drawing a general conclusion as to the effectiveness of individual methods is not an easy task, especially if the methodological factors affecting to the results are left outside the discussion. The most general conclusion that can be made on the basis of the results is: by training reading, reading skills improve. However, there are probably many ways to achieve this goal (computer-assisted, tutored reading), and large improvements do not appear quickly. Training of reading skills does not have to be an extraordinary or even special activity, or conducted only by educational specialists. Reading improvements are also achieved when volunteer tutors encourage children to spend time on reading activities during daily practice for few weeks, or when children practice relatively independently using computer software. However, it could be that the role of social factors and assistance in reading training programs is more important than has been acknowledged in the research field. The results of the present study imply that the importance of including human assistance in some form, even minimally, should not be underrated. Such an assistance might be related to attention: that the tutor is monitoring the child's progress, or trying to motivate the child to remain interested in training or spend time reading books. In the light of present knowledge, the challenge from the point of view of schools and the education system has more to do with finding a time, personnel and place to organize and conduct reading training systematically and persistently, and less with creating out-of-the-ordinary and exceptional (or expensive) training methods.

One question that is important in considering reading interventions is whether the key to the reading improvement is repetition of the reading material (repeated practice) or whether the critical factor is the amount of time spent on reading activities (general reading practice). Both methods were associated with improvements in reading skills; thus, the use of both methods can be recommended. The results of the present thesis imply that the *amount* of reading activities might be of critical importance; however, more evidence is needed before conclusions can be drawn as to whether one way is better than the other. Finally, improvements associated with reading training do not appear quickly: during just a few weeks or days remediation of reading deficits

can not be expected. In the present studies, the aim was to investigate whether word reading skills could be affected at all. From the point of remediation the results indicate that the road to fluent reading skills is long. If the amount of reading activities is critical and the road to automatization is long, it presents challenges for designing training environments that are easy to implement in everyday settings and which are perceived by children as motivating enough to keep them practicing. All the methods investigated in the present studies can be considered easy to implement, but more knowledge is needed about the motivational factors.

A profound discussion of the methodological factors affecting the results has not been a typical feature of articles dealing with reading training. It seems that this research field is lagging behind the field of child psychotherapy in which criteria for the classification of interventions according to the quality of their designs and for the use of the concept "effective interventions" are being debated. In the present thesis, discussion of the methodological choices that had to be made when designing intervention studies has an important role. When one is asked whether a specific intervention was effective, the most useful answers probably also refer to the methodological choices made: "it helped students who had *x* type of problems (or no problems at all), but not students who had *y* type of deficits", or "training method *i* was effective when compared to no training at all, but not more effective than training method *j*" or "it was effective in terms of *a*, but not in terms of *b*". For future reading intervention research, especially on reading fluency, it would be important not only to create a general overview of the methods used, but also to find agreement on the terms, according to which a given certain intervention can be called effective. Merely an improvement between the pre- and post-test, or using a test that does not resemble an everyday reading task, are clearly not enough to be able to claim that the method is effective.

In relation to selecting the training material (target units) for reading intervention studies the present thesis provides relevant new information. To sum up, the results suggest that for poor readers the reading speed of sublexical multiletter units without semantics (like consonant clusters or syllables) can be enhanced by repeated reading. More importantly, sublexical training led to improvements in the reading of words and pseudowords with the trained segments. As sublexical training can lead to improvement at the word level and as the trained sublexical units will be encountered in several words, the effects of using sublexical multiletter units are not limited to specific words. Thus, the training of sublexical multiletter units can offer a way of achieving a bigger payoff in terms of generalization than the training of single words. This is especially important from the standpoint of the orthography of Finnish: due to the polysyllabic, lengthy and inflected words that characterize the language it is not likely that the development of fluent word recognition relies on single word representations, as seems to be the case in English. The finding that the sublexical multiletter units can be directly trained opens new possibilities for designing and thinking about interventions, and encourages continuation of

this line of research. However, more information is needed on the extent to which generalization to everyday reading skills occurs, while there is also a need to develop multiple ways to conduct training in order to keep the training motivating. Despite the promising results, two limitations of the present thesis have to be noted. Although the results of Study IV showed that the positive training effects remained similar approximately two weeks after the training period had been finished, the lack of detailed investigation of the follow-up effects is one limitation of the present thesis. Secondly, in the studies that comprise the present thesis the reading level of typical readers was not examined. Therefore, it is unclear whether the reading speed of the trained items or transfer items will reach the normal range after training. The finding related to the use of sublexical multiletter units also has theoretical implications: the parallel processing of these units may have a role in reading development, yet they are not taken into account in the most well-known theoretical or cognitive models of reading. Thus, the finding highlights the need to consider the applicability of the widely used English-based models of word recognition to more transparent orthographies.

With respect to the research field on training reading fluency, in which knowledge is limited, the present thesis provides a starting point, (1) for creating an overview or categorization of the methods used, (2) for the systematic evaluation of different types of training approaches or components, and (3) for the selection of training material or target units from the point of view of the payoff of training. To develop a remediation program for children with reading deficits that meets the criteria of being easy to implement, motivating and effective in producing improvements in everyday reading and generalization more work remains to be done.

YHTEENVETO

Lukemistaitojen harjoittaminen: tavoitteena sujuvuus

Tässä tutkimuksessa arvioitiin kokeellisten ja ajallisesti lyhytkestoisten harjoitteluohjelmien vaikutuksia lukemisvaikeuksia omaavien lasten lukemisen taitoihin. Väitöstyön tavoitteet liittyivät kahteen tutkimuskysymykseen: (1) ensinnäkin tutkimuksessa vertailtiin erilaisten harjoitustapojen vaikutuksellisuutta, (2) toiseksi mielenkiinto kohdistui siihen, millaisia kielen yksiköitä lukemisen harjoittelun kohteeksi kannattaisi valita. Erityisenä tavoitteena tutkimuksessa oli lasten lukunopeuden tai lukusujuvuuden kohentaminen.

Vaikka lukemisvaikeuksia koskeva tieto on viime vuosina lisääntynyt paljon, on tutkimuksen piirissä silti aihealueita, joista ei vielä kovin paljon tiedetä. Yksi tällainen ilmiö on lukemisen nopeus, erityisesti lukunopeuden kehittyminen lapsuus- sekä nuoruusiässä sekä syyt sille, miksi joillakin lapsilla lukeminen jää kovin työlääksi ja hitaaksi. Viime vuosina kiinnostus lukemisen nopeutta tai sujuvuutta kohtaan on kuitenkin lisääntynyt. Kaksi keskeistä tutkimushavaintoa ovat vaikuttaneet kiinnostuksen lisääntymiseen: (1) Useissa tutkimuksissa on havaittu eroja eri kieltä puhuvien lasten lukemaan oppimisen nopeudessa ja lukemisen vaikeuden ilmiasussa. Suurin osa lukemisen tutkimuksesta on tehty englanninkielisissä maissa. Englannin kieli poikkeaa kuitenkin kirjoitusjärjestelmältään selvästi suomen kielen kirjoitusjärjestelmästä: suomen kielen kirjoitusjärjestelmä on eräs säännönmukaisimmista, kun taas englannin kielen kirjoitusjärjestelmä on erittäin epäsäännönmukainen, sillä yhtä kielen äännettä voi vastata useampi kirjainmerkki. Englanninkielisillä lapsilla kestää useamman vuoden oppia kyky lukea sanoja oikein ja riittävällä tarkkuudella, kun taas esimerkiksi suomenkieliset lapset oppivat keskimäärin lukemaan sanoja tarkasti jo ensimmäisen luokan aikana. Koska lukemisen tarkkuus opitaan säännöllisen kirjoitusjärjestelmän kielessä melko nopeasti, liittyy lukemisvaikeuksien keskeinen pulma nimenomaan lukemisen hitauteen tai sujumattomuuteen. (2) Lukemisen harjoitukset, jotka ovat kohdistuneet lukemisen tarkkuuteen sekä sanan äännerakenteen analysointiin (fonologinen prosessointi) ovat osoittautuneet puutteellisiksi lukunopeuden kehittämisessä. Koska suurin osa tutkimuksesta tehdään englanninkielisissä maissa, niin suurin osa lukemisen harjoituksista tai lukemisen vaikeuksien kuntoutusohjelmista on keskittynyt lukemisen alkuvaiheiden eli kokoavan, sarjallisen lukemisen tukemiseen. Monet ohjelmat perustuvat fonologisten taitojen harjaannuttamiseen. Vaikka nämä harjoitteet ovat osoittautuneet tehokkaiksi alkavan lukemisen tukemisessa, on muutamissa tutkimuksissa havaittu, etteivät tämän tyyppiset harjoitukset auta kovinkaan hyvin lukunopeuden kehittymisessä. Lisäksi on olemassa havaintoja siitä, että lukunopeuden tai automaattisuuden kohentaminen on hyvin haasteellista. Tarvittaisiin siis lisätietoa siitä, miten erityisesti lukunopeuteen tai lukusujuvuuteen voisi harjoittelun kautta vaikuttaa. Tämän väitöstyön neljästä osatutkimuksesta ensimmäinen keskittyi suomenkielisten lasten alkavan lukemisen

vaiheisiin. Kolmessa muussa osatutkimuksessa tarkasteltiin erityisesti juuri lukunopeuden kehittymistä lapsilla, jotka olivat jo melko tarkkoja lukijoita, mutta joiden lukunopeus oli heikko. Näissä tutkimuksissa osallistujina oli sekä suomen- että saksankielisiä lapsia.

Ensimmäisessä osatutkimuksessa tutkittiin tietokoneharjoituksen vaikutuksia kirjaintuntemuksen ja lukemisen taitojen kehitykseen. Tässä tutkimuksessa käytetty tietokoneohjelma keskittyi ennen kaikkea kirjain-äänne-vastaavuuksien harjoittamiseen. Tietokoneohjelman keskeinen ominaisuus oli se, että lapset pystyivät harjoittelemaan ohjelman avulla melko itsenäisesti: lapset kuulivat kuulokkeiden kautta puhutun äänteen, tavun tai sanan ja heidän piti etsiä tietokoneruudulta vastaava kirjoitettu ärsyke. Harjoitusjakso oli melko lyhyt: lapset harjoittelivat kuuden viikon ajan kaksi tai kolme kertaa viikossa ja noin 10 - 15 minuuttia kerrallaan. Tutkimuksessa havaittiin, että lapset, joilla oli heikot lukemisen valmiudet ensimmäisen luokan alussa, hyötyivät ohjelmasta kirjain-äänne-vastaavuuksien oppimisessa. Lukemisen tarkkuuden oppimisen suhteen tulokset osoittivat, että tietokoneharjoitusta saanut ryhmä kehittyi yhtä nopeasti kuin kontrolliryhmä, joka osallistui koulun normaaliin erityisopetukseen.

Kolme muuta osatutkimusta, joissa erityisenä tavoitteena oli lukunopeuden kasvattaminen, pohjautuivat menetelmään, jota tutkimuskirjallisuudessa on eniten käytetty lukusujuvuuden parantamiseen: toistavaan lukemiseen. Toisen ja kolmannen osatutkimuksen osallistujat olivat itävaltalaisia, saksankielisiä lapsia. Molemmissa tutkimuksissa toistava lukuharjoitus kohdistettiin saksan kielen kannalta tärkeään rakenteeseen: useamman konsonantin yhdistelmiin eli konsonanttiklustereihin. Toisessa osatutkimuksessa vertailtiin tietokoneella toteuttavaa toistavaa lukemista aikuisen ohjaamaan yleiseen lukemisen harjoitteluun. Toistavan tietokoneharjoittelun pohjana oli sama menetelmä kuin ensimmäisessä tutkimuksessa eli puhutun ja kirjoitetun kielen vastineiden harjoittelu. Aikuisen ohjaama harjoittelu koostui aikuisen ja lapsen yhteisistä kirjan lukemisen tuokioista. Tämä harjoittelujakso kesti molemmissa ryhmissä yhteensä viisi viikkoa ja sitä toteutettiin joka koulupäivä 15 minuuttia kerrallaan. Tutkimustulokset osoittivat, että aikuisen ohjaama yleinen harjoittelu johti paitsi yleisen lukunopeuden lisääntymiseen myös parannuksiin tehtävässä, joka mittasi erityisesti tietokoneharjoittelun vaikutuksia eli konsonanttiyhdistelmiä sisältävien sanojen lukemisessa. Tietokonemenetelmä oli yhteydessä parannuksiin ainoastaan sellaisten sanojen lukemisessa, jotka sisälsivät harjoiteltuja konsonanttiyhdistelmiä. Näiden harjoittelujen vaikutukset eivät kuitenkaan olleet kovin laajoja ja tutkimustuloksiin vaikuttivat osaltaan menetelmälliset seikat. Yhtenä tärkeänä menetelmällisenä tekijänä oli se, että tietokoneharjoittelun vaikutuksia kartoittava tehtävä edellytti melko laajoja siirtovaikutuksia tietokoneharjoittelusta testitilanteeseen.

Kolmannessa osatutkimuksessa haluttiin selvittää, johtavatko erilaiset tietokoneharjoittelumenetelmät (ääneen lukeminen vs. tunnistava harjoittelu eli puhutun ja kirjoitetun kielen vastineiden etsintä) erilaisiin tuloksiin. Tässä tutkimuksessa jatkettiin konsonanttiyhdistelmien toistavaa lukemista saksankieli-

sillä lapsilla. Tulokset osoittivat, että lyhyen harjoitusjakson jälkeen sekä ääneen lukeminen että tunnistava harjoittelu johtivat lukemisen nopeutumiseen eikä harjoittelutapojen välillä ollut eroja. Lisäksi kolmannessa osatutkimuksessa havaittiin, että konsonanttiyhdistelmien harjoittelu johtaa paitsi näiden yhdistelmien nopeampaan lukemiseen myös siirtovaikutukseen sanatasolle. Ne sanat, jotka sisälsivät harjoiteltuja kirjainyhdistelmiä, luettiin harjoittelun jälkeen nopeammin. Neljännen osatutkimuksen osallistujat olivat suomenkielisiä lapsia ja tässä tutkimuksessa toistava harjoittelu kohdennettiin suomen kielen kannalta tärkeään rakenteeseen eli tavuihin. Tämän tutkimuksen tulokset osoittivat, että toistava tavujen ääneen lukemisen harjoittelu parantaa tavujen lukemisen nopeutta. Tärkeä tulos oli se, että myös harjoiteltuja tavuja sisältävien merkityksettömien sanojen lukeminen nopeutui eli harjoittelun vaikutukset näkyivät tavua suurempien yksiköiden lukemisessa.

Kahden viimeisen osatutkimusten keskeinen tulos on se, että sanan sisäisten osien eli subleksikaalisen osien (kuten konsonanttiyhdistelmien, tavujen) harjoittelu on tehokasta ja voi johtaa harjoiteltua osaa suurempien yksiköiden, sanojen, nopeampaan lukemiseen. Tämä tulos on merkittävä sekä käytännön valintojen kannalta että liittyen teoreettisiin kysymyksiin. Lasten kanssa lukemisen harjoitusta käytännössä tekevän on hyvä tietää, että toistavan lukemisen kohteeksi kannattaa poimia sellaisia sanojen osia, jotka esiintyvät useissa sanoissa. Tällä tavalla voidaan saavuttaa vaikutuksia, jotka yleistyvät yhtä harjoiteltua yksikköä laajemmalle. Teoreettiselta kannalta tulos on tärkeä siksi, että lukemisen mallit perustuvat lähes poikkeuksetta englannin kieleen. Englannin kieleen pohjautuvissa malleissa ajatellaan, että sujuva lukeminen pohjautuu lyhyiden, yksittäisten sanojen nopeaan tunnistamiseen. Suomen kielessä sanojen taivutusten runsaus ja pitkät, monitavuiset sanat asettavat rajoituksia kokonaisten sanojen nopealle tunnistamiselle. Yksi tärkeä askel tiellä sujuvaksi lukijaksi voikin olla tukeutuminen kirjainyhdistelmien (kuten tavujen) nopeaan lukemiseen.

Lukemisen sujuvuuden tai nopeuden parantaminen lapsilla, joiden lukemisen taidot ovat heikot, ei ole helppo tehtävä. Lyhyellä ja säännöllisellä harjoituksella voidaan saavuttaa parannuksia, mutta merkittävien muutosten aikaansaamiseksi tulee harjoituksen olla pitkäkestoista. Tämän tutkimuksen harjoitusmenetelmät pohjautuvat teoreettiseen näkemykseen siitä, että sujuva lukeminen kehittyy lukemisen taitoja harjoittamalla ja pitkälti toiston kautta. Tutkimuksessa käytettyjä menetelmiä on helppo soveltaa koulun ja kodin arkeen. Koulujen ja kotien käytännön kannalta tutkimustulokset kannustavat jatkamaan lukemisen harjoittelua, mutta toisaalta haastavat siihen, että koulu- tai tukijärjestelmien sisällä olisi mahdollista toteuttaa riittävän pitkäkestoista ja säännönmukaista harjoittelua sekä myös tarjota ohjausta ja tukea lapselle, joka on jo oppinut lukemisen alkeet, mutta kamppailee lukemisen hitauden kanssa.

REFERENCES

Allington, R. L. (1983). Fluency: The neglected reading goal. *The Reading Teacher, 37,* 556–561.

Allington, R. L. (2006). Fluency: Still waiting after all these years. In S. J. Samuels, & A. E. Farstrup (Eds.), *What research has to say about fluency instruction* (pp. 94-105). Newark: International Reading Association.

Anderson, R. C., Wilson, P. T., & Fielding, L. G. (1988). Growth in reading and how children spend their time outside of school. *Reading Research Quarterly, 23,* 285–303

Ans, B., Carbonnel, S., & Valdois, S. (1998). A connectionist multiple-trace memory model for polysyllabic word reading. *Psychological Review, 105,* 678–723.

Aro, M. (2004). Learning to read: The effect of orthography. University of Jyväskylä. Dissertation.

Aro, M. (2006). Learning to read: The effect of orthography. In R.M. Joshi & P.G. Aaron (Eds.), *Handbook of Orthography and Literacy* (pp. 531–550). USA, NJ: Erlbaum.

Aro, M., Aro, T., Ahonen, T., Räsänen, T., Hietala, A., & Lyytinen, H. (1999). The development of phonological abilities and their relation to reading acquisition: Case studies of six Finnish children. *Journal of Learning Disabilities, 32*, 457–464.

Aro, M., & Wimmer, H. (2003). Learning to read: English in comparison to six more regular orthographies. *Applied Psycholinguistics, 24,* 621-635.

Baker, S., Gersten, R., & Keating, T. (2000). When less may be more: A 2-year longitudinal evaluation of a volunteer tutoring program requiring minimal training. *Reading Research Quarterly, 35,* 494–519.

Barber, H., & Kutas, M. (2007). Interplay between computational models and cognitive electrophysiology in visual word recognition. *Brain Research Reviews, 53,* 98–123.

Beck, J.E., Jia, P., & Mostow, J. (2004). Automatically assessing oral reading fluency in a computer tutor that listens. *Technology, Instruction, Cognition, and Learning, 1,* 61–81.

Berends, I. E., & Reitsma, P. (2005). Lateral and central presentation of words with limited exposure duration as remedial training for reading disabled children. *Journal of Clinical and Experimental Neuropsychology, 27,* 886–896.

Berends, I. E., & Reitsma, P. (2006a). Addressing semantics promotes the development of reading fluency. *Applied Psycholinguistics*, *27*, 247–265.

Berends, I. E., & Reitsma, P. (2006b). Remediation of fluency: Word specific or generalised training effects? *Reading and Writing, 19,* 221–234.

Borgwaldt, S. R., Hellwig, F. M., & de Groot, A. M. (2005). Onset entropy matters – Letter-to-phoneme mapping in seven languages. *Reading and Writing, 18,* 211–229.

Bowers, P.G. (1993). Text reading and rereading: Determinants of fluency beyond word recognition. *Journal of Reading Behavior, 25,* 133–153.

Breznitz, Z. (1997). Enhancing the reading of dyslexic children by reading acceleration and auditory masking. *Journal of Educational Psychology, 89,* 103–113.

Bruck, M., & Treiman, R. (1990). Phonological awareness and spelling in normal children and dyslexics: The case of initial consonant clusters. *Journal of Experimental Psychology, 50,* 156–178.

Bus, A. G., & IJzendoorn, M. H. (1999). Phonological awareness and early reading: A meta-analysis of experimental training studies. *Journal of Educational Psychology, 91*, 403–414.

Castles, A., & Coltheart, M. (1993). Varieties of developmental dyslexia. *Cognition, 47,* 149–180.

Chall, J. S. (1996). *Stages of reading development* (2nd ed.). Fort Worth, TX: Harcourt-Brace.

Chard, D., Vaughn, S., & Tyler, B.-J. (2002). A synthesis of research on effective interventions for building reading fluency with elementary students with learning disabilities. *Journal of Learning Disabilities, 35,* 386–406.

Cole, P., Magnan, A., & Grainger, J. (1999). Syllable-sized units in visual word recognition: Evidence from skilled and beginning readers of French. *Applied Psycholinguistics, 20,* 507–532.

Coltheart, M., Rastle, K., Perry, C., Langdon, R., & Ziegler, J. C. (2001). DRC: A dual-route cascaded model of visual word recognition and reading aloud. *Psychological Review, 108,* 204–256.

Cunningham, A. E., & Stanovich, K. E. (1991). Tracking the unique effects of print exposure in children: Associations with vocabulary, general knowledge, and spelling. *Journal of Educational Psychology, 83,* 264–274.

Dahl, P. R. (1979). An experimental program for teaching high speed word recognition and comprehension skills. In J. E. Button, T. Lovitt, & T. Rowland (Eds.), *Communications research in learning disabilities and mental retardation* (pp. 33–65). Baltimore: University Park Press.

Daly, E.J., & Martens, B. K. (1994). A comparison of three interventions for increasing oral reading performance: Application of the instructional hierarchy. *Journal of Applied Behavior Analysis, 27,* 459–469.

Defior, S., & Tudela, P. (1994). Effect of phonological training on reading and writing acquisition. *Reading and Writing: An Interdisciplinary Journal, 6,* 299–320.

de Jong, P. F., & van der Leij, A. (1999). Specific contributions of phonological abilities to early reading acquisition: Results from a Dutch latent variable longitudinal study. *Journal of Educational Psychology, 91,* 450–476.

de Jong, P. F., & van der Leij, A. (2002). Effects of phonological abilities and linguistic comprehension on the development of reading. *Scientific Studies of Reading*, *6*, 51–77.

de Jong, P. F., & van der Leij, A. (2003). Developmental changes in the manifestation of a phonological dyslexic children learning to read a regular orthography. *Journal of Educational Psychology, 95*, 22–40.

de Jong. P. F., & Vrielink, L. O. (2004). Rapid automatic naming: Easy to measure, hard to improve (quickly). *Annals of Dyslexia, 54,* 65–88.

Di Filippo, G., De Luca, M., Judica, A., Spinelli, D., & Zoccolotti, P. (2006). Lexicality and stimulus length effects in Italian dyslexics: Role of the overadditivity effect. *Child Neuropsychology, 12,* 141–149.

Ehri, L. C. (1992a). Beginners need some decoding skill to read words by analogy. *Reading Research Quarterly, 27*, 12–26.

Ehri, L. C. (1992b). Reconceptualizing the development of sight word reading and its relationship to recoding. In P. B. Gough, L. C. Ehri, & R. Treiman (Eds.), *Reading acquisition* (pp. 107– 144). Hillsdale: Lawrence Erlbaum Associates.

Ehri, L. C. (1995). Phases of development in learning to read words by sight. *Journal of Research in Reading, 18,* 116–125.

Ehri, L. C. (2002). Phases of acquisition in learning to read words, and implications for teaching. *British Journal of Educational Psychology: Monograph Series, 2* (Serial No. 1), 7–28.

Ehri, L. C. (2005). Learning to read new words: Theory, findings, and issues. *Scientific Studies of Reading, 9,* 167–188.

Ehri, L. C., Nunes, S. R., Willows, D. M., Schuster, B. V., Yaghoub-Zadeh, Z., & Shanahan, T. (2001). Phonemic awareness instruction helps children learn to read: Evidence from the National Reading Panel's meta-analysis. *Reading Research Quarterly, 36,* 250–287.

Ehri, L. C., & Soffer, A.G. (1999). Graphophonemic awareness: Development in elementary students. *Scientific Studies of Reading, 3,* 1–30.

Elbro, C., & Petersen, D. K. (2004). Long-term effects of phoneme awareness and letter sound training: An intervention study with children at risk for dyslexia. *Journal of Educational Psychology, 96,* 660–670.

Ferrand, L., & Grainger, J. (1992). Phonology and orthography in visual word recognition: Evidence from masked nonword priming. *Quarterly Journal of Experimental Psychology, 42A,* 353–372.

Frith, U. (1985). Beneath the surface of developmental dyslexia. In K. E. Patterson, J. C. Marshall, & M. Coltheart (Eds.), *Surface dyslexia* (pp.301–322). London: Erlbaum.

Froyen, D. J. W., Bonte, M. L., van Atteveldt, N., & Blomert, L. (2009). The long road to automation: Neurocognitive development of letter-speech sound processing. *Journal of Cognitive Neuroscience, 21,* 567-580. Doi:10.1162/ jocn.2009.21061.

Harm, M. W., McCandliss, B., & Seidenberg, M. S. (2003). Modeling the successes and failures of interventions for disabled readers. *Scientific Studies of Reading, 7,* 155–182.

Hatcher, P. J., Hulme, C., & Ellis, A. W. (1994). Ameliorating early reading failure by integrating the teaching of reading and phonological skills: The phonological linkage hypothesis. *Child Development, 65,* 41–57.

Hatcher, P. J., Hulme, C., & Snowling, M. J. (2004). Explicit phoneme training combined with phonic reading instruction helps young children at risk of reading failure. *Journal of Child Psychology and Psychiatry, 45,* 338–358.

Heckelman, R. G. (1969). A neurological-impress method of remedial reading instruction. *Academic Therapy Quarterly, 4,* 277–282.

Hofmann, M. J., Stenneken, P., Conrad, M., & Jacobs, A. M. (2007). Sublexical frequency measures for orthographic and phonological units in German. *Behavior Research Methods, 39,* 620–629.

Hohn, W. E., & Ehri, L. C. (1983). Do alphabet letters help prereaders acquire phonemic segmentation skill? *Journal of Educational Psychology, 75,* 752–762.

Holopainen, L. (2002). Development in reading and reading related skills: a follow-up study from pre-school to the fourth grade. University of Jyväskylä. Dissertation.

Holopainen, L., Ahonen, T., & Lyytinen, H. (2001). Predicting delay in reading achievement in a highly transparent language. *Journal of Learning Disabilities, 34,* 401–413.

Hulme, C., Caravolas, M., Málková, G., & Brigstocke, S. (2005). Phoneme isolation ability is not simply a consequence of letter-sound knowledge. *Cognition, 97*, B1–B11.

Hutzler, F., Ziegler, J. C., Perry, C., Wimmer, H., & Zorzi, M. (2004). Do current connectionist learning models account for reading development in different languages? *Cognition, 91,* 273–296.

Irausquin, R. S., Drent, J., & Verhoeven, L. (2005). Benefits of computer-presented speed training for poor readers. *Annals of Dyslexia, 55,* 246–265.

Judica, A., De Luca, M., Spinelli, D., & Zoccolotti P. (2002). Training of developmental surface dyslexia improves reading performance and shortens eye fixation duration in reading. *Neuropsychological Rehabilitation, 12*, 177–198.

Kame'nui, E. J., & Simmons, D. C. (Eds.). (2001). The role of fluency in reading competence, assessment, and instruction: Fluency at the intersection of accuracy and speed [special issue]. *Scientific Studies of Reading, 5*, 203–210.

Klauda, S. L., & Guthrie, J. T. (2008). Relationships of three components of reading fluency to reading comprehension. *Journal of Educational Psychology, 100,* 310–321.

Klicpera, C., & Schabmann, A. (1993). Do German-speaking children have a chance to overcome reading and spelling difficulties? A longitudinal survey from the second until the eighth grade. *European Journal of Psychology of Education, 8,* 307–334.

Korhonen, T. (1995). The persistence of rapid naming problems in children with learning difficulties. *Journal of Learning Disabilities, 28,* 232–239.

Kuhn, M. R., & Stahl, S. A. (2003). Fluency: A review of developmental and remedial practices. *Journal of Educational Psychology, 95,* 3–21.

Kyöstiö, O.K. (1980). Is learning to read easy in a language in which the grapheme-phoneme correspondences are regular? In J.F. Kavanagh & R.I. Venezky (Eds.), *Orthography, reading, and dyslexia* (pp. 35-49). Baltimore, ML: University Park Press.

LaBerge, D., & Samuels, S. J. (1974). Toward a theory of automatic information processing in reading. *Cognitive Psychology, 6*, 293–323.

Landerl, K., & Thaler, V. (2006). Reading and spelling acquisition and dyslexia in German. In R.M. Joshi & P.G. Aaron (Eds.), *Handbook of Orthography and Literacy* (pp. 121 – 134). USA, NJ: Erlbaum.

Landerl, K., & Wimmer, H. (2008). Development of word reading fluency and spelling in a consistent orthography: An eight-year follow-up. *Journal of Educational Psychology*, *100*, 150–161.

Landerl, K., Wimmer, H., & Frith, U. (1997). The impact of orthographic consistency on dyslexia: A German-English comparison. *Cognition, 63,* 315–334.

Landi, N., Perfetti, C. A., Bolger, D. J., Dunlap, S., & Foorman, B. R. (2006). The role of discourse context in developing word form representations: A paradoxical relation between reading and learning. *Journal of Experimental Child Psychology, 94,* 114–133.

Leinonen, S., Müller, K., Leppänen, P. H. T., Aro, M., Ahonen, T. & Lyytinen, H. (2001). Heterogeneity in adult dyslexic readers: Relating processing skills to the speed and accuracy of oral text reading. *Reading and Writing, 14,* 265–296.

Lemoine, H. E., Levy, B. A., & Hutchinson, A. (1993). Increasing the naming speed of poor readers: Representations formed across repetitions. *Journal of Experimental Child Psychology, 55*, 297–328.

Levy, B. A. (2001). Moving the bottom: Improving reading fluency. In M. Wolf (Ed.), *Dyslexia, fluency, and the brain* (pp. 357–379). Timonium, MD: York Press.

Levy, B. A., Bourassa, D. C., & Horn, C. (1999). Fast and slow namers: Benefits of segmentation and whole word training. *Journal of Experimental Child Psychology, 73,* 115–138.

Lewandowski, L., Begeny, J., & Rogers, C. (2006). Word-recognition training: Computer versus tutor. *Reading and Writing Quarterly, 22,* 395–410.

Lonigan, C., Elbert, J., & Johnson S. (1998). Empirically supported interventions for children: An overview. *Journal of Clinical Child Psychology, 27*, 138–145.

Lovett, M. W., Borden, S. L., Lacerenza, L., Benson, N. J., & Brackstone, D. (1994). Treating the core deficits of developmental dyslexia: Evidence of transfer of learning after phonologically- and strategy- based reading training programs. *Journal of Educational Psychology, 30,* 805–822.

Lovett, M. W., & Steinbach, K. A. (1997). The effectiveness of remedial programs for reading disabled children of different ages: Does the benefit decrease for older children? *Learning Disability Quarterly, 20,* 189–210.

Lovett, M. W., Warren-Chaplin, P. M., Ransby, M. J., & Borden, S. L. (1990). Training word recognition skills of reading disabled children: Treatment and transfer effects. *Journal of Educational Psychology, 82,* 769–780.

Lyon, G. R., & Moats, L. C. (1997). Critical conceptual and methodological considerations in reading intervention research. *Journal of Learning Disabilities, 30,* 578–588.

Lyytinen, H., Ahonen, T., Eklund, K., Guttorm, T. K., Kulju, P., Laakso, M.-L., et al. (2004a). Early development of children at familial risk for dyslexia – Follow-up from birth to school age. *Dyslexia, 10,* 146–178.

Lyytinen, H., Aro, M., Eklund, K., Erskine, J., Guttorm, T. K., Laakso, M.-L., et al. (2004b). The development of children at familial risk for dyslexia: Birth to school age. *Annals of Dyslexia, 54,* 184–220.

Lyytinen, H., Ronimus, M., Alanko, A, Poikkeus, A.-M., & Taanila, M. (2007). Early identification of dyslexia and the use of computer game-based practice to support reading acquisition. *Nordic Psychology, 59,* 109–126.

Magnan, A., Ecalle, J., Veuillet, E., & Collet, L. (2004). The effects of an audio-visual training program in dyslexic children. *Dyslexia, 10,* 131–140.

Mann, V. A., & Wimmer, H. (2002). Phoneme awareness and pathways into literacy: A comparison of German and American children. *Reading and Writing, 15,* 653–682.

Marinus, E., & de Jong, P. F. (2008). The use of sublexical clusters in normal and dyslexic readers. *Scientific Studies of Reading, 12,* 253–280.

Martens, V. E. G., & de Jong, P. F. (2006). The effect of visual word features on the acquisition of orthographic knowledge. *Journal of Experimental Child Psychology, 93,* 337–356.

Martin-Chang, S. L., & Levy, B.A. (2005). Fluency transfer: Differential gains in reading speed and accuracy following isolated word and context training. *Reading and Writing, 18,* 343–376.

Martin-Chang, S. L., & Levy, B.A. (2006). Word reading fluency: A transfer appropriate processing account of fluency transfer. *Reading and Writing, 19,* 517–542.

Martin-Chang, S.L., Levy, B.A., & O'Neil, S. (2007). Word acquisition, retention, and transfer: Findings from contextual and isolated word training. *Journal of Experimental Child Psychology, 96,* 37–56.

Mathes, P. G., & Fuchs, L. S. (1993). Peer-mediated reading instruction in special education resource rooms. *Learning Disabilities Research and Practice, 8,* 233–243.

Meyer, M. S., & Felton, R. H. (1999). Repeated reading to enhance fluency: Old approaches and new directions. *Annals of Dyslexia, 49,* 283–306.

Moll, K., Fussenegger, B., Willburger, E., & Landerl, K. (2009). RAN is not a measure of orthographic processing. Evidence from the asymmetric German orthography. *Scientific Studies of Reading*, *13*, 1-25

Nagy, W., & Anderson, R. C. (1984). How many words are there in printed school English? *Reading Research Quarterly, 19,* 304-330.

National Institute of Child Health and Human Development. (2000). Report of the National Reading Panel. Teaching children to read: An evidence-based assessment of the scientific research literature on reading and its implications for reading instruction. Washington, D.C.: U.S. Government Printing Office.

Niemi, J., Laine, M., & Tuominen, J. (1994). Cognitive morphology in Finnish: Foundations of a new model. *Language and Cognitive Processes, 9,* 423–446.

Olson, R. K., & Wise, B. W. (1992). Reading on computer with orthographic and speech feedback. *Reading and Writing, 4,* 107–144.

O'Connor, R. E., White, A., & Swanson, H. L. (2007). Repeated reading versus continuous reading: Influences on reading fluency and comprehension. *Exceptional Children, 74,* 31–46.

O'Shea, L. J., Sindelar, P. T., & O'Shea, D. (1985). The effects of repeated readings and attentional cues on reading fluency and comprehension. *Journal of Reading Behavior, 17,* 129–142.

Perfetti, C.A. (1985). *Reading ability.* New York: Oxford University Press.

Perfetti, C. A. (1992). The representation problem in reading acquisition. In P. B. Gough, L. C. Ehri, & R. Treiman (Eds.), *Reading Acquisition* (pp. 145 – 173). Hillsdale: Lawrence Erlbaum Associates.

Perfetti, C. A., & Bell, L. (1991). Phonemic activation during the first 40 ms of word identification: Evidence from backward masking and priming. *Journal of Memory and Language, 30*, 473– 485.

Perry, C., Ziegler, J.C., & Zorzi, M. (2007). Nested Incremental Modeling in the Development of Computational Theories: The CDP+ Model of Reading Aloud. *Psychological Review, 114,* 273–315.

Pikulski, J. J., & Chard, D. J. (2005). Fluency: Bridge between decoding and reading comprehension. *The Reading Teacher, 58,* 510–519.

Plaut, D. C., McClelland, J. L., Seidenberg, M. S., & Patterson, K. (1996). Understanding normal and impaired word reading: Computational principles in quasi-regular domains. *Psychological Review, 103,* 56–115.

Poskiparta, E., Niemi, P., & Vauras, M. (1999). Who benefits from training in linguistics awareness in the first grade, and what components show training effects? *Journal of Learning Disabilities, 32,* 437-446.

Puolakanaho, A., Ahonen, T., Aro, M., Eklund, K., Leppänen, P., Poikkeus, A.-M. et al. (2008). Developmental links of very early phonological and language skills to second grade reading outcomes. *Journal of Learning Disabilities, 41,* 353–370.

Rajaram, S., Srinivas, K., & Roediger III, H. L. (1998). A transfer-appropriate processing account of context effects in word-fragment completion. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 24,* 993–1004.

Ramus, F. (2003). Developmental dyslexia: specific phonological deficit or general sensorimotor dysfunction*? Current Opinion in Neurobiology, 13,* 212–218.

Rashotte, C., & Torgesen, J. (1985). Repeated reading and reading fluency in learning disabled children*. Reading Research Quarterly, 20,* 180–188.

Reitsma, P. (1983). Printed word learning in beginning readers. *Journal of Experimental Child Psychology, 36,* 321–339.

Rose, T. L., & Beattie, J. R. (1986). Relative effects of teacher-directed and taped previewing on oral reading. *Learning Disabilities Quarterly, 9,* 193–199.

Rvachew, S., Nowak, M., & Cloutier, G. (2004). Effect of phonemic perception training on the speech production and phonological awareness skills of children with expressive phonological delay. *American Journal of Speech-Language Pathology, 13*, 250–263.

Samuels, S. J. (1979). The method of repeated readings. *The Reading Teacher, 32,* 403–408.

Samuels, S. J. (2006). Toward a model of reading fluency. In S. J. Samuels, & A. E. Farstrup (Eds.), *What research has to say about fluency instruction* (pp. 24–46). Newark: International Reading Association.

Schneider, W., Ennermoser, M., Roth, E., & Küspert, P. (1999). Kindergarten prevention of dyslexia: Does training in phonological awareness work for everybody? *Journal of Learning Disabilities, 32,* 429–436.

Schwanenflugel, P J., Hamilton, A. M., Kuhn, M. R., Wisenbaker, J. M., & Stahl, S. A. (2004). Becoming a fluent reader: reading skill and prosodic features in the oral reading of young readers. *Journal of Educational Psychology, 96,* 119–129.

Seidenberg, M., & McClelland, J. (1989). A distributed developmental model of word recognition and naming. *Psychological Review, 96,* 523–568.

Seymour, P. H. K. (2005). Early reading development in European orthographies. In M. J. Snowling & C. Hulme (Eds.), *The science of reading: A handbook* (pp. 296–315). Oxford, UK: Blackwell.

Seymour, P. H., Aro, M., & Erskine, J. M. (2003). Foundation literacy acquisition in European orthographies. *British Journal of Psychology, 94,* 143–174.

Shany, M.T., & Biemiller, A. (1995). Assisted reading practice: Effects on performance for poor readers in Grades 3 and 4. *Reading Research Quarterly, 30,* 382–395.

Share, D. L. (1995). Phonological recoding and self-teaching: sine qua non of reading acquisition. *Cognition, 55*, 151–218.

Share, D. L. (1999). Phonological recoding and orthographic learning: A direct test of the self-teaching hypothesis. *Journal of Experimental Child Psychology, 72,* 95–129.

Share, D. L. (2004). Orthographic learning at a glance: On the time course and developmental onset of self-teaching. *Journal of Experimental Child Psychology, 87,* 267–298.

Share, D. L. (2008). On the Anglocentricities of current reading research and practice: the perils of overreliance on an "outlier" orthography. *Psychological Bulletin, 134*, 584–615.

Shaywitz, S. E., & Shaywitz B. A. (2005). Dyslexia (Specific reading disability). *Biological Psychiatry,* 1301–1309.

Shaywitz, S. E., Shaywitz, B. A., Fulbright, R. K., Skudlarski, P. Mencl, W. E., Constable, R T., et al. (2003). Neural systems for compensation and

persistence: young adult outcome of childhood reading disability. *Biological Psychiatry, 54,* 25–33.

Snowling, M. J. (1981). Phonemic deficits in developmental dyslexia. *Psychological Research, 43,* 219–234.

Snowling, M. J. (2000). *Dyslexia* (2nd ed.). Oxford, UK: Blackwell.

Spinelli, D., De Luca, M., Di Filippo, G., Mancini, M., Martelli, M., & Zoccolotti, P. (2005). Length effect in word naming latencies: Role of reading experience and reading deficit. *Developmental Neuropsychology, 27,* 217–235.

Stanovich, K. E. (1986). Matthew effects in reading: Some consequences of individual differences in the acquisition of literacy. *Reading Research Quarterly, 21,* 360–406.

Stenneken, P., Conrad, M., & Jacobs, A. M. (2007). Processing of syllables in production and recognition tasks. *Journal of Psycholinguistic Research, 36,* 65–78.

Tan, A., & Nicholson, T. (1997). Flashcards revisited: Training poor readers to read words faster improves their comprehension of text. *Journal of Educational Psychology, 89,* 276–288.

TaskForce on Promotion and Dissemination of Psychological Procedures, Division of Clinical Psychology (1995). Training in and dissemination of empirically-validated psychological treatments: Report and recommendations. *The Clinical Psychologist*, 48, 3-23.

Thaler, V., Ebner, E. M., Wimmer, H., & Landerl, K. (2004). Training reading fluency in dysfluent readers with high reading accuracy: Word specific effects but low transfer to untrained words. *Annals of Dyslexia, 54,* 89–113.

Torgesen, J.K. (2005). Recent discoveries from research on remedial interventions for children with dyslexia. In M. Snowling and C. Hulme (Eds.), *The science of reading* (pp.521–537). Oxford: Blackwell Publishers.

Torgesen, J. K., Alexander, A. W., Wagner, R. K., Rashotte, C. A., Voeller, K. K., & Conway, T. (2001b). Intensive remedial instruction for children with severe reading disabilities: Immediate and long-term outcomes from two instructional approaches. *Journal of Learning Disabilities, 34,* 33–58, 78.

Torgesen, J. K., & Davis, C. (1996). Individual difference variables that predict response to training in phonological awareness. *Journal of Experimental Child Psychology, 63*, 1–21.

Torgesen, J.K., & Hudson, R. F. (2006). Reading fluency: Critical issues for struggling readers. In S. J. Samuels, & A. E. Farstrup (Eds.), *What research has to say about fluency instruction* (pp. 130–158). Newark: International Reading Association.

Torgesen, J. K., Rashotte, C., & Alexander, A.W. (2001a). Principles of fluency instruction in reading: Relationships with established empirical outcomes. In M. Wolf (Ed.), *Dyslexia, fluency, and the brain* (pp. 333–355). Timonium, MD: York Press.

Torgesen, J. K., Wagner, R. K., Rashotte, C. A., Rose, E., Lindamood, P., Conway, T., & Garvan, C. (1999). Preventing reading failure in young

children with phonological processing disabilities: Group and individual responses to instruction. *Journal of Educational Psychology, 91,* 579–593.

Torppa, M., Tolvanen, A., Poikkeus, A.-M., Eklund, K., Lerkkanen, M.-K., Leskinen, E., & Lyytinen, H. (2007). Reading development subtypes and their early characteristics. *Annals of Dyslexia, 57,* 3–32.

Treiman, R. (1991). Children's spelling errors on syllable-initial consonant clusters. *Journal of Educational Psychology, 83,* 346–360.

Tressoldi, P. E., Lorusso, M. L., Brenbati F., & Donini, R. (2008). Fluency remediation in dyslexic children: does age make a difference? *Dyslexia, 14,* 142–152.

Tressoldi, P. E., Vio, C., & Iozzino, R. (2007). Efficacy of an intervention to improve fluency in children with developmental dyslexia in a regular orthography. *Journal of Learning Disabilities, 40,* 203–209.

Valdois, S., Bosse, M. L., & Tainturier, M. J. (2004). The cognitive deficits responsible for developmental dyslexia: Review of evidence for a selective visual attentional disorder. *Dyslexia, 10,* 339–363.

van den Bos, K. P. (1998). IQ, phonological awareness and continuous-naming speed related to Dutch poor decoding children's performance on two word identification tests. *Dyslexia, 4*, 73–89.

van den Bosch, K., van Bon, W.H.J., & Schreuder, R. (1995). Poor readers' decoding skills: Effects of training with limited exposure duration. *Reading Research Quarterly*, 30, 110–125.

van der Leij, A., & van Daal, V. H. P. (1999). Automatization aspects of dyslexia: Speed limitations in word identification, sensitivity to increasing task demands, and orthographic compensation. *Journal of Learning Disabilities, 32,* 417–428.

Vellutino, F.M., & Fletcher, J.M. (2005). Developmental dyslexia. In M. J. Snowling & C. Hulme (Eds.), *The science of reading: A handbook* (pp. 362–378). Oxford, UK: Blackwell

Vellutino, F. M., Fletcher, J. M., Snowling, M. J., & Scanlon, D. M. (2004). Specific reading disability (dyslexia): what have we learned in the past four decades? *Journal of Child Psychology and Psychiatry, 45,* 2–40.

Wagner, R. K., Torgesen, J. K., & Rashotte, C. A. (1994). Development of reading-related phonological processing abilities: New evidence of bidirectional causality from a latent variable longitudinal study. *Developmental Psychology, 30,* 73–87.

Wentink, W. M. H., van Bon, W. H. J., & Schreuder, R. (1997). Training poor readers' phonological decoding skills: Evidence for syllable bound processing. *Reading and Writing: An Interdisciplinary Journal, 9,* 163–192.

Wimmer, H. (1993). Characteristics of developmental dyslexia in a regular writing system. *Applied Psycholinguistics, 14,* 1–33.

Wimmer, H., & Mayringer, H. (2002). Dysfluent reading in the absence of spelling difficulties: A specific disability in regular orthographies. *Journal of Educational Psychology, 94,* 272–277.

Wimmer, H., Mayringer, H., & Landerl, K. (2000). The double-deficit hypothesis and difficulties in learning to read a regular orthography. *Journal of Educational Psychology, 92,* 668–680.

Wolf, M., & Bowers, P. G. (1999). The double-deficit hypothesis for the developmental dyslexia. *Journal of Educational Psychology, 91*, 415–438.

Wolf, M., & Katzir-Cohen, T. (2001). Reading fluency and its intervention. *Scientific Studies of Reading, 5,* 211–239.

Yap, R., & van der Leij, A. (1993). Word processing in dyslexics: An automatic decoding deficit? *Reading and Writing: An Interdisciplinary Journal, 5,* 261–279.

Ziegler, J., Castel, C., Pech-Georgel, C., George, F., Alario, F.X., & Perry, C. (2008). Developmental dyslexia and the dual route model of reading: Simulating individual differences and subtypes. *Cognition, 107,* 151–178.

Ziegler, J. C., & Goswami, U. (2005). Reading acquistion, developmental dyslexia, and skilled reading across languages: A psycholinguistic grain size theory. *Psychological Bulletin, 131*, 3–29.

Ziegler, J. C., Perry, C., My-Wyatt, A., Ladner, D., & Schulte-Körne, G. (2003). Developmental dyslexia in different languages: Language-specific or universal? *Journal of Experimental Child Psychology, 86,* 169–193.

Zoccolotti, P., De Luca, M., Di Pace, E., Judica, A., Orlandi, M., & Spinelli, D. (1999). Markers of developmental surface dyslexia in a language (Italian) with high grapheme-phoneme correspondence. *Applied Psycholinguistics, 20,* 191–216.