Poor Readers' Decoding Skills

Effects of Training, Task, and Word Characteristics

Karel van den Bosch

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Karel van den Bosch

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Promotores: Prof. Dr. R. Schreuder
Prof. Dr. J.J. Dumont

Copromotor: Dr. W.H.J. van Bon

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Chapter 1. Introduction

Introduction and Survey of this Thesis

This thesis is about decoding skills of young children who are having reading difficulties. These children will be referred to as *poor readers*. There is ample evidence that poor readers' failure to identify printed words automatically and rapidly is caused by difficulties in phonological decoding. Decoding is defined as the ability to transform a string of letters into a phonological code (Perfetti, 1985, p.90). Although poor readers are often capable of identifying small words accurately, their decoding is very slow and requires much cognitive capacity. This interferes with comprehension of text and inhibits the acquisition of word-specific orthographic knowledge. The remediation of reading problems should therefore focus upon improving efficiency of word identification. Children should learn enough about decoding and word identification so that words can be identified without effort. Progress in phonological decoding is primarily established by practice in decoding itself. A training program that aims to improve poor readers' word recognition skills should therefore provide extensive practice in phonological decoding. Training should lead to more efficient decoding. Decoding ability can be expressed in terms of accuracy, automaticity, and speed. Decoding accuracy is essential for initial reading, but accuracy alone is not sufficient for word recognition skills to develop. Decoding processes should also be executed automatically and rapidly. For this reason, the element of time pressure is often introduced in training. The idea is that decoding speed can be increased by external pressure. In remedial practice, time pressure is already widely used. A well-known example of time pressure in reading remediation is the 'flash card' method. In this training method, a single word or pseudoword is printed on a card. The card is presented briefly. The task of the child is to read aloud the word or pseudoword. Sometimes a quick response is encouraged. The effects of such practice on poor readers' word recognition ability, however, is yet unknown.

The departure point of the present studies was the development of computerized versions of the flash card training method that provide extensive practice in decoding under time pressure. The efficiency of these programs on establishing progress in poor readers' word recognition skills was subsequently tested in two training studies. The effects of time pressure on training efficiency was of central importance. In the first study, two forms of time pressure, limited exposure duration and encouraging to respond quickly (response speeding), were imposed upon the reading process. The orthogonal combination of both factors produced four different training programs. Poor readers participated in a training that involved reading aloud single monosyllabic words and pseudowords. The results indicated that practice under conditions of limited exposure duration, without response speeding, was most successful in improving automaticity of word recognition and pseudoword decoding.

This type of training was examined in more detail in a second training study, using two control groups In order to verify whether limiting exposure duration during training had a positive effect on word recognition skill, one control group received training without any form of time pressure The second control group received no training at all, but participated in pre- and posttests only In this manner, the over all effect of training was assessed

An interesting result was obtained on both training studies Poor readers' reading speed was affected by word length Longer words required longer reading time Reading speed increased during training Surprisingly, equal progress in speed was found, irrespective of length This suggests that children decoded monosyllabic words and pseudowords in a fixed number of units that exceeded the level of individual graphemes and phonemes The assumption that training increased efficiency in decoding multi-letter units is consistent with a parallel progress in reading speed However, as yet, there is no evidence that children decode syllables of different length in a fixed number of multi letter units This possibility was investigated experimentally More specifically, the question whether onset and rime units are used in reading words and pseudowords was addressed

Finally, the question whether the progress in naming speed may have been the result of improved efficiency in length-independent processes of response production was addressed The contribution of three processes to naming latency, that is, generating a phonological representation, articulatory programming, and execution of a motor-speech code, was estimated The effects of stimulus length on each process was also determined If processes involved in response production would be unaffected by stimulus length, and if poor readers would prove to be deficient in processes of response production, then progress in response production might account for the parallel progress in naming speed

Chapter 1 presents a survey of the development of reading ability (§1 0), as well as an account of how differences in reading ability arise (§1 1) It is concluded that phonological decoding skills are fundamental for the development of reading ability, and that poor readers have difficulty with accurate and fast word recognition due to a decoding deficiency (§1 2) The remediation of reading problems should include training in word identification Earlier research to the effects of training poor readers' word recognition skills is discussed in §1 3 The first chapter ends with a discussion of the training programs that were subject of experimental research in this thesis (§1 4) Chapter 2 presents two experimental studies into the effects of practice in decoding under time pressure In chapter 3, the question whether onsets and rimes play a role in visual word processing is addressed Chapter 4 is concerned with processes of response production in a word and pseudoword naming task The question whether poor readers are slower than normal readers in preparing an articulatory response or executing this response is investigated in this chapter Finally, chapter 5 presents a general discussion of this thesis The implications of the present studies for the remediation of reading problems are discussed

1.0 The Development of Reading Ability

Normally, children learn to read in a few years. In the Netherlands, the initial phases of reading instruction generally focus upon the acquisition of knowledge and skills required for word identification. Children are taught that spoken words are composed of more or less distinct speech segments (phonemes), and that in printed words a phoneme is symbolized by a letter or by a letter combination (grapheme). A grapheme is a spelling unit consisting of one or more letters that corresponds to a single phoneme (Pring & Snowling, 1986). Knowledge of grapheme-phoneme correspondences (GPC knowledge) is essential for the development of reading ability (Perfetti, 1984, 1985, 1986). Children learn that, by systematically converting graphemes into their phonemic counterparts, a phonological representation of a regularly spelled word can be generated. Subsequently, this representation can be used to gain access to the lexicon and retrieve the word's meaning and other word-specific information (lexical access).

The ability to identify words through the application of grapheme-phoneme knowledge is referred to as 'phonological decoding skill', and is considered to be fundamental for the development of reading ability (Vellutino & Scanlon, 1987). Initially, phonological decoding is a slow and error prone process. With practice however, children improve their decoding skills and, as a consequence, accuracy and speed of access to meaning of words is increased. As a result of accurate decoding, the phonological representation of a word becomes associated with its orthographical form (Adams, 1990; Ehri, 1980, 1987; Jorm & Share, 1983). Ehri (1980) labels this bonding of orthographic and phonological information in memory as 'amalgamation'. Successful decoding leads to the amalgamation of orthographic and phonological information in memory, and the amalgamated word representation is what eventually enables rapid and efficient access to the lexicon (Ehri & Wilce, 1983; LaBerge & Samuels, 1974; Stanovich & West, 1989). Substantial evidence has been provided for this position (Backman, Hebert, Bruck, & Seidenberg, 1984; Reitsma, 1983a, 1983b). Clearly, decoding skills play a major role in the development of word identification ability.

After a period of decoding instruction and training, children are capable of practicing on their own. The development from beginning reading to skilled reading is primarily facilitated by reading itself (Stanovich, 1986). Knowledge that is important for reading is also enhanced by practice in reading. For example, a causal connection between vocabulary knowledge and reading ability has been demonstrated (Beck, Perfetti, & McKeown, 1982; Daneman, 1988; Dixon, LeFevre, & Twilley, 1988; McKeown, Beck, Omanson, & Perfetti, 1983). There is considerable agreement that vocabulary growth takes place through learning the meanings of unknown words encountered in oral and written language. "The very children who are reading well and have good vocabularies will read more, repeat familiar words, learn more word meanings, and hence read even better" (Stanovich, 1986, p.381). The same reciprocal relationship holds for decoding skill and reading ability.

Elementary knowledge of GPC rules is required for initial reading, but it is reading itself that brings about proficiency in decoding (Perfetti, 1986, Perfetti, Beck, Bell, & Hughes, 1987) Children's GPC knowledge is increasing at the very time they recognize a word (Backman et al , 1984, Perfetti, in press) Successful decoding provides a 'positive learning trial' (Jorm & Share, 1983), thereby increasing the quality of grapheme-phoneme knowledge This, in turn, raises the probability of successful identification of new words

Competent decoding allows the development of automaticity and speed at the word recognition level, which is essential for text comprehension (Ehri, 1987, Shankweiler & Liberman, 1972, Stanovich, 1982, 1986) Once again, the links between text comprehension and its cognitive components are reciprocal rather than unidirectional (Stanovich, 1986) Competent readers identify the words of a text accurately, automatically, and rapidly They are therefore likely to understand the meaning of the text Consequently, they learn many new words and hence read even more and better Readers who lack adequate word identification skills are likely to miss the gist of a text, thereby missing the opportunity to learn new words They are inclined to read less and get even further behind There is evidence that children who are reading well get more practice than their less-skilled peers Skilled readers' exposure to print is approximately three times higher than that of less-skilled readers (Allington, 1984, Biemiller, 1977-1978) Thus, once the initial principles have been mastered, progress in reading ability is primarily established by reading itself

1.1 Individual Differences in Reading Ability

Although acquiring competence in reading proves to be an easy matter for most children, some children have serious problems with it Reading is a complex skill, involving many cognitive components (Dumont, 1984, Dumont, 1990, chapter 2) In order to understand the underlying principles that cause reading problems, researchers have often compared good and poor readers on cognitive skills that are involved in reading If a clear difference could be found with respect to a particular component of reading ability, this could be interpreted as providing information about the causes of, and remedies for reading problems Differences between good and poor readers have been found on many cognitive skills involved in reading (see Stanovich, 1986, Vellutino, 1979) However, interpreting these differences is difficult because the various reading processes are interrelated instead of operating independently A low performance of poor readers on a particular skill may be the result of a deficit in a more basic skill Furthermore, as argued in the previous paragraph, reading is a self-reinforcing process Cognitive skills that are important for reading are also practiced by reading, thereby allowing further progress Thus, poor readers' deficit with respect to a particular skill may be the result rather than the cause of reading difficulties For these reasons, theories of individual differences in reading ability and reading problems should take into account the relations between the components of reading ability. The 'verbal efficiency' theory is such a model. It recognizes the interrelatedness of cognitive skills in reading. The theory is spelled out in detail elsewhere by Perfetti (Perfetti, 1985, 1988). A short outline of the model will be presented in the next paragraph.

Word Recognition and Comprehension

The verbal efficiency theory states that reading is composed of lower level linguistic skills serving lexical access, and higher level linguistic skills for text comprehension (Perfetti, 1985, p.5). The basic notion of the model is that individuals possess a limited amount of processing resources and that lexical access and comprehension are separate but interrelated processes, both requiring these resources. The more processing capacity consumed by lexical access, the less processing capacity available for comprehension. Thus, inefficient lexical access can impair comprehension. Word identification has the potential to be relatively nondemanding of resources. To the extent that word identification processes become attention free or 'automatic' (Ehri & Wilce, 1983), comprehension processes can operate smoothly. If, however, word identification requires a lot of processing resources, then comprehension of text is at risk. In this view, word identification skill plays a causal role in comprehension ability. This is supported by studies showing that children defined as skilled readers on the basis of comprehension measures are markedly superior to below-average comprehenders in their ability to name words rapidly and accurately (Shankweiler & Liberman, 1972; Stanovich, 1982, 1986). This relationship holds even for fluent adult readers (Mason, 1978; Stanovich, 1980). Lesgold and Resnick (1982) followed 127 beginning readers in their reading development. Word naming speed and comprehension measures were obtained on four occasions within a period of three years. Word naming speed contributed strongly to comprehension at later stages in reading development, but comprehension did not contribute to subsequent word naming speed. The authors concluded that word identification efficiency is causally related to text comprehension.

The relationship between word recognition efficiency and comprehension may be formulated in, at least, two ways. The *strong* version of the verbal efficiency model states that improving word identification is a sufficient condition for progress in comprehension. The *weak* version states that improving word identification is a necessary but not a sufficient condition for progress in comprehension. In either way, word identification is of central importance.

Mechanisms for the Recognition of Words

Having discussed the relation between word recognition skill and comprehension, it is necessary to examine the psychological mechanisms that mediate word recognition. According to the dual-route model (Coltheart, 1978), two representations may be used to recognize a printed word. One access representation is based upon visuo-orthographic features of the word. These features can be coded into a form that matches the orthographic representation of that word stored in the lexicon. A match between the coded orthographical features and the stored orthographical representation gives access to the word's meaning. This mechanism for word identification is generally referred to as the 'direct' route (Coltheart, 1978). The other mechanism for recognizing words involves phonological decoding. Access to the meaning of a word is mediated by a phonological representation. The string of letters is transformed into a phonological representation by the application of decoding rules (how this is accomplished is a subject of controversy, see chapter 3). A match between the generated phonological representation and the stored phonological representation in the lexicon gives access to the meaning of that word. This mechanism for word identification is generally referred to as the 'indirect' route (Coltheart, 1978).

There is substantial evidence that the indirect route characterizes beginning reading (Adams, 1990; Perfetti, Goldman, & Hogaboam, 1979). In normal reading, direct access to most words begins to develop very rapidly (Barron & Baron, 1977; Reitsma, 1983a, 1983b), and the reliance on decoding in word recognition slowly decreases as word recognition ability increases (Reitsma, 1984; Venezky, 1976, p.22). However, phonological decoding continues to play an important role in word recognition. Recent models of skilled word recognition generally include a phonological processing component (e.g. Brown & Besner, 1987; van Orden, Pennington, & Stone, 1990; Seidenberg & McClelland, 1989).

If two processes can be used to achieve lexical access, and both of them are necessary to develop efficient word identification ability, then a deficiency in either process could cause reading problems. There does not seem to be any evidence that good and poor readers differ in the quality of the visual information extracted from the stimulus (Bouma & Legein, 1980; Mitchell, 1982, p.161). Good and poor readers do seem to differ in their ability to make use of orthographic regularities in word recognition (Mason, 1975; Seymour & Porpodas, 1980; see also the introduction of paragraph 3.2). This however, is likely to be the result of differences in exposure to print. Thus, differences between reader groups in the ability to exploit orthographic regularities may be the result rather than the cause of reading difficulties.

There is substantial evidence that poor readers' problems with word recognition are primarily associated with difficulties in phonological processing in general (Bradley & Bryant, 1983; Bryant & Bradley, 1985; Wagner & Torgesen, 1987), and with phonological decoding in particular (Perfetti et al., 1987; Vellutino & Scanlon, 1987). Compared with good readers, poor readers have weaker knowledge of grapheme-phoneme correspondences (Backman et al., 1984; Bruck, 1988), are less inclined to employ a phonological decoding strategy (Barron, 1980; Mann, Liberman, & Shankweiler, 1980), and are less proficient in applying a decoding strategy if task demands force them to do so (Henderson, 1985; Hogaboam & Perfetti, 1978).

To summarize, the various components of reading skill are interrelated instead of operating independently. The verbal efficiency theory argues that word recognition and comprehension share the same processing resources. Automatic and rapid word recognition allows more processing capacity to be available for comprehension. Normal readers are superior to poor readers with respect to the ability to recognize words accurately, automatically, and rapidly. Two mechanisms for the recognition of words have been discussed. The direct route is based upon a match between a representation based upon the visuo-orthographic features of the word and an orthographic representation stored in the lexicon. The indirect route involves decoding rules to generate a phonological representation of the word. This phonological representation is subsequently used for entering the lexicon. There is evidence that poor readers' difficulties with word recognition originate in the indirect route. In fact, a decoding deficiency seems to be the primary cause of reading problems. As will be argued later, the acquisition of orthographical word representations that may be used for direct word recognition is largely dependent on decoding ability. Decoding skills are the basics for the development of reading ability. In the next paragraph the development of decoding skills and their importance for the acquisition of word recognition skills is more closely examined.

1.2 Decoding Skills

Decoding ability is often measured with a pseudoword naming task. A pseudoword is a letter string that, given its orthographical structure, might have been a real word but does not actually exist. In this task, subjects are required to read aloud a visually presented pseudoword. Naming a pseudoword can only be accomplished by some form of phonological decoding. Accuracy and naming latency are the dependent variables used to assess a subject's decoding skill. Researchers have often emphasized that in order to obtain a clear picture of a child's decoding ability, speed and automaticity criteria are certainly as important as accuracy (LaBerge & Samuels, 1974; Perfetti, 1985). Poor readers may be accurate decoders but execute this skill so slowly and capacity demanding that it strains the available cognitive resources (Stanovich, 1986). Further evidence for the importance of decoding *speed* is that pseudoword naming latency has proved to be the most consistently discriminating measure of reading skill (Perfetti, 1986). The development of decoding ability and its prerequisites will be discussed next.

Decoding involves the transformation of a visual representation into a phonological representation. Thus, children should be able to recognize the units of both visual and phonological codes, letters and phonemes. Visually segmenting and identifying letter units appears not to be a problem (Fischer, Liberman, & Shankweiler, 1978; Gibson & Levin, 1975). However, 'phonemic awareness', being aware that words consist of separate phonemes and being able to manipulate these phonemes, is another matter. There is substantial evidence that phonemic awareness is causally related to the development of decoding ability (Bradley & Bryant, 1983; Bryant & Bradley, 1985; Wagner & Torgesen, 1987). Perfetti (1985) distinguishes two phonemic awareness skills, phonemic *analysis* and phonemic *synthesis*. Phonemic analysis refers to the ability to name the phonemes of a syllable. Phonemic synthesis refers to the ability to combine isolated phonemes into a syllable. A longitudinal study to the relation between these skills and pseudoword reading revealed that skill in phoneme synthesis *preceded* progress in pseudoword reading, whereas phonemic analysis skill *followed* progress in pseudoword reading (Perfetti, 1985; Perfetti et al., 1987). Thus, according to this view, the causal chain in the acquisition of decoding ability is as follows. A child must be aware of the fact that a spoken word consists of a series of separate phonemes, a skill that is measured by phonemic analysis tasks. Furthermore, the child must be able to synthesize a series of phonemes into a phonological representation, a task that is measured by phonemic synthesis tasks. Finally, elementary knowledge of the correspondences between phonemes and graphemes is required to start reading. As the results by Perfetti et al. (1987) suggest, progress in phonemic synthesis initiates an improvement in decoding efficiency. A successfully decoded word enables the child to learn about the relation between orthography and phonology and to discover phonemic principles. In turn, the discovery of phonemic principles facilitates phonemic analysis skills and learning about the relation between orthography and phonology improves decoding skills.

Decoding ability plays an important role in the acquisition of word specific knowledge. Fast and accurate word decoding enables a reader to acquire orthographic knowledge of that word and to store it in the lexicon. This orthographical knowledge accumulates every time the word is successfully decoded. Eventually, the word representation becomes 'fully specified' (Perfetti, in press). All phonological and orthographical information of that word is represented in memory. In Ehri's terms, the bonding of phonological and orthographical information has produced an 'amalgamated' word representation (Ehri, 1980). Amalgamated word representations can be gained access to efficiently and rapidly (Stanovich & West, 1989). Thus, decoding skill provides the opportunity for orthographical representations to become established in memory as future access mechanisms for the recognition of words. However, decoding success is necessary but not sufficient. The acquisition of orthographic knowledge of a word is likely to fail unless decoding is accomplished accurately, completely and rapidly. Poor readers often rely on a few letters for decoding and may succeed, as often as not, in identifying such a partially recognized word. Yet, even if they succeed, the experience of having 'read' the word will contribute minimally to the growth of their orthographic lexicon. To the extent that they ignored the letters, bonding phonological and orthographical word information is impossible. As argued earlier, decoding speed is also important. Poor readers often fail to decode an orthographical unit automatically and rapidly. By the time the next decoding unit is identified, the first will have dissipated. Rapid decoding is required for the reader to become aware of the temporal contiguity of the word's comprising letter and sound units. Unless decoding is fast enough to keep all decoding units active in memory at the same time, the reader will fail to learn about the orthographic structure of words (Adams, 1990, pp.112-3).

To conclude, poor readers have problems with accurate and fast word recognition due to a decoding deficiency. This results in poor comprehension of text and a failure to acquire word specific orthographic knowledge. The implication is that the remediation of reading problems should focus upon the core of poor readers' difficulties, phonological decoding. Children should learn enough about decoding and word identification so that words can be identified without effort. This should enable them to acquire word specific orthographic knowledge and should allow them to allocate more cognitive capacity to comprehension processes (Perfetti, 1985).

Having concluded that the remediation of reading problems should include decoding, the next question is how decoding can be improved. There is evidence suggesting that decoding skills are principally acquired through practice (Reitsma, 1988a) and that in this respect, explicit teaching plays a minor role (Perfetti et al., 1987). Elementary knowledge of letter-sound relations is necessary for initial decoding, but it is reading itself that enables the child to become a proficient decoder. The question arises why practice in reading would be the primary factor of progress in decoding. Learning theories generally distinguish between declarative and procedural learning (e.g. Anderson, 1983; Newell & Simon, 1972). Declarative learning roughly amounts to the acquisition of *knowledge*, whereas procedural learning involves the acquisition of *skills*. This distinction is relevant for the interpretation of decoding progress. In order to decode a word, a reader needs sufficient declarative knowledge of the relations between graphemes and phonemes. In addition, decoding a word includes procedural components that operate upon this declarative knowledge, like retrieving phonemes from long-term memory and blend them into a phonological representation. Successful execution of a procedure increases the strength of the associated knowledge in declarative memory. Thus, decoding success has a positive effect on the quality of associated grapheme-phoneme knowledge. Through experience, procedures become more selective and are more likely to lead to rapid success. The learning underlying this selectivity is called *tuning* (Anderson, 1983, Rumelhart & Norman, 1978). Perfetti (in press) has described this as decoding rules becoming more *context-sensitive*. Pashler and Baylis (1991) conducted a series of experiments to the effects of practice on procedural skill. They trained subjects to respond rapidly to four elements of a larger set of stimuli (e.g. four letters or four digits). Practice produced an increase in response speed on trained items, but more importantly, it was demonstrated that progress is of an abstract nature and extends to the entire knowledge domain upon which the procedures operate. Thus, in terms of decoding, positive effects of practice in decoding letter strings should generalize to decoding performance on other letter strings that are not actually practiced.

In the next paragraph, some studies into the effects of practice in word reading on poor readers' word identification skills will be discussed.

1.3 Training Poor Readers' Word Identification Skills

There is ample evidence that the ability to identify words accurately, automatically, and rapidly plays a central role in the development of reading. Therefore, the remediation of reading problems often aims at improving the efficiency of word identification. As reading has a reciprocal positive influence on prerequisite processes for word identification (Perfetti et al., 1987; Stanovich, 1986), training should be carried out in the context of reading itself. The question is whether this training should involve reading isolated words or reading in a meaningful context. There are arguments for preferring isolated word reading. Stanovich (1980) has argued that the use of context information as an aid for word recognition is inversely related to reading ability. Efficient decoding skills enable good readers to identify words automatically and rapidly, without having to rely on additional context information. Poor readers however, are slow decoders. In order to compensate for their weak decoding skills, poor readers are likely to utilize the context as an aid for word recognition. There is substantial empirical evidence for this position (e.g. Briggs, Austin, & Underwood, 1984; Perfetti et al., 1979; Perfetti & Roth, 1981; West & Stanovich, 1982). Thus, during word recognition, poor readers tend to bypass phonological decoding by relying on other sources of information. For this reason, training should employ a reading task that provides a maximum of practice in phonological decoding. Other sources of information that might be used to facilitate word identification should be eliminated as much as possible.

The question whether training of word identification should be carried out in the context of meaning or should involve reading isolated words, was addressed empirically by Ehri & Roberts (1979). They taught beginning readers to read a set of 16 words. Half of the subjects learned to read the words in the context of sentences, the other half learned to read the words in isolation. The results indicated that, in a meaningful context, children learned more about the meaning of words, but less about their orthographic identity. Similar results have been obtained by Allington (1978) and Ceprano (1981). Ehri & Roberts (1979) argued that the advantage of learning to read words in isolation is "that readers have more time to study words as separate units, to analyze letter details, to note how letters map sounds, and to store more complete images in the lexicon" (p.684). Since we are concerned with the decoding aspects of word recognition rather than the acquisition of the meaning of words, the discussion of training studies in this section will be limited to those that employ an isolated word reading procedure.

Effects of Practice in Word Reading on Text Comprehension

The verbal efficiency theory states that text comprehension is limited by verbal coding inefficiency (Perfetti, 1985, p.233). Lesgold and Resnick (1982) concluded that efficiency in word identification is causally related to text comprehension (the study is discussed in §1.2). Their conclusion was based upon the pattern of correlations between word identification and text comprehension measures, obtained during the first three years of reading instruction However, the question remains whether improved word identification is a prerequisite or a sufficient condition for progress in comprehension (cf Ehri, 1987) Training studies are valuable to determine whether the relation is a causal one If training in word identification can be shown to improve text comprehension, then a causal relationship may be inferred However, there is little empirical evidence that training in word identification necessarily results in comprehension progress Fleisher, Jenkins, and Pany (1979) conducted a training study to investigate the strong version of the verbal efficiency model stating that improving word identification is a sufficient condition for progress in comprehension. Third-grade children were divided in a group of good and a group of poor readers on the basis of performance on a standard reading comprehension test After training, poor and good readers were compared with respect to their comprehension of a text During training, half the poor reader group practiced reading 70% of the words from that text Practice involved reading the words in isolation Practice continued until their speed of word recognition was comparable to that of good readers The other half of the poor readers as well as the good readers received no training Inferential and factual questions were administered to measure text comprehension The results indicated that comprehension was not facilitated by improved word identification Differences in text comprehension between the good and the poor readers were still large, and no differences were found between the trained and the untrained poor readers Although the trained poor readers were equally fast as the good readers in identifying the words in isolation, this was not expressed in comprehension This supports the idea that the increased recognition speed achieved by extensive practice in reading the words of a text in isolation is limited to a practice situation and does not transfer to more natural reading tasks The authors rejected the strong version of the verbal efficiency model and concluded that improved word identification is not sufficient to establish progress in comprehension

The study has been criticized by Blanchard and McNinh (1980) They argued that the differences in reading ability between good and poor readers were too large In addition, the experiment failed to control for the fact that poor readers lacked familiarity of experience with comprehension tasks Blanchard and McNinh suggest that the experiment did not provide a basis for a valid investigation of the decoding sufficiency hypothesis In this respect, Perfetti (1985) pointed out that progress in comprehension can be expected only when the improvement in word identification efficiency is based upon increased knowledge and procedures that serve rapid decoding Merely training children to identify a specific set of words more rapidly, as in the Fleisher, Jenkins, and Pany study, will not necessarily result in better comprehension (Perfetti, 1985, p 247) A similar point was made by van Bon (1986) He points out that boosting the reading speed to a limited set of words by repeatedly reading these words is likely to be the result of set-specific discrimination rather than improved word recognition This may account for the lack of transfer from practice to testing situation in the Fleisher, Jenkins, and Pany study It is likely that, as a result of practice, children became familiar with the comprising words of the set, and became more sophisticated in discriminating the individual members of that set. The successful identification of a word from the set required less and less orthographic cues and less and less decoding. Instead of reading, the training may have induced children to identify words by few and superficial features. This strategy may well work within a practice situation, but if the same words are encountered in a different situation, like in a text, the strategy is suddenly useless because the words are presented outside their training context.

The implication is that progress in comprehension can not be expected unless an improvement in word identification efficiency has been achieved that is not restricted to the context in which the words were practiced. This, however, is hard to achieve within the scope of a training study. It requires long-term practice in decoding tasks which are often seen as dull routines of drill. We know of only two studies supporting the decoding sufficiency hypothesis. Frederiksen et al. (discussed in Perfetti, 1986, p.19) trained low ability teenage readers in speeded word and letter processing and found a transfer effect on text comprehension. Roth and Beck (1987) investigated whether two microcomputer training programs for improving word recognition and decoding skills lead to improvement in reading comprehension. The programs produced substantial improvement in comprehension at the word and proposition-sentence level, but to no improvement at the passage level.

Experimental studies to the effects of long-term training in word decoding on text comprehension are very costly, both financially as in terms of human resources. This is presumably the reason why very few studies have examined the question whether training in word identification is sufficient for progress in comprehension. However, this question may seem more important than it is. If improvement in word decoding is not sufficient, it certainly is necessary for progress in text comprehension. Therefore, most researchers have concentrated on the question how word identification skills of poor readers can be trained most effectively.

Effects of Practice in Word Reading on Word Identification.

In normal reading situations, poor readers' word decoding requires much cognitive capacity and is executed very slowly. Therefore, poor readers have few opportunities to note how the letters of a word correspond to the sounds and store this information in the lexicon. However, decoding a word can be facilitated by repeated experience with that same word (Monsell, 1987; and see e.g. the study by Fleisher, Jenkins, and Pany, discussed in the previous section). Word identification time can be substantially reduced by prior presentation. Many training programs are based upon this observation. The burden that decoding places upon the cognitive processing system can be alleviated by repeated presentations of words. The idea is that if decoding requires less strain, children will be able to note how letters map sounds, and store orthographical images of these words in the lexicon. This should improve the recognition of these particular words permanently. In addition, the reader learns about the orthographic structure of words in general and extends his knowledge about the relation between letters and sounds. Thus, training poor readers to identify a set of words should improve their recognition of members of that set, and indirectly, improve their decoding performance on untrained words through increased knowledge of letter-sound correspondences.

Because of their decoding problems, poor readers may be expected to need more experience in reading a particular word than good readers to acquire the same amount of word specific information. In order to investigate how much practice is required to improve the recognition of words, Hogaboam and Perfetti (1978, experiment 3) compared skilled and less skilled third-grade readers with respect to the effects of practice in pronouncing pseudowords. Pseudowords were used to guarantee a zero value of prior whole-word experience for all subjects. The number of exposures to a pseudoword varied from 3 to 18. Two training conditions were included. In the *visual* condition, the subject was instructed to look at a pseudoword on a card and repeat the pronunciation given by the experimenter. In the *aural* condition, the subject did not see the pseudoword but simply repeated its pronunciation given by the experimenter. The posttest consisted of naming practiced and unpracticed pseudowords. Naming latency was the dependent variable. Both visual as well as aural experience was beneficial for reading speed, although readers appeared to benefit more from combined print and aural experience than from aural experience alone. Practice increased the performance of both reader groups. Skilled readers read the practiced pseudowords approximately 500 ms faster than unpracticed pseudowords. Three exposures were sufficient for a maximum improvement. A larger number of exposures during training did not increase naming speed on the posttest any further. Less skilled readers read practiced pseudowords approximately two seconds faster than unpracticed pseudowords. However, they required six exposures to attain their maximum naming speed. The difference in maximum reading speed acquired by skilled and less skilled readers was still quite substantial (i.e. 1 versus 2 second). The positive effect of training appears to be quite long-lasting. Effects of experience persisted at least 10 weeks after the actual experience. The observation that additional exposures beyond six presentations do not increase poor readers' word naming speed was also found by Reitsma and Vinke (1986). The results suggest that identification speed is rather easily affected by simple familiarizing experiences. Less-skilled readers need more word experience than good readers to attain their maximum reading speed. The observation that prior aural exposure to a pseudoword facilitated naming speed suggests that word phonology plays an important role in word decoding (a facilitating effect of aural experience has also been reported by van Daal, Bakker, Reitsma, and van der Leij (1986, experiment 2)). The training provided children with a rather passive form of reading experience. They did not have to decode the pseudowords themselves. It might be speculated that practice in actively decoding the pseudowords underlines the correspondences between letters and sounds more strongly, producing an even larger training effect, perhaps generalizing to untrained pseudowords and words.

Fiedorowicz (1986) conducted a training experiment in which poor readers (age 11 years), being diagnosed as having an 'oral reading deficit', were trained in reading aloud syllables and words. The training consisted of 43 sessions of 50 items each. If the 96% accuracy criterion was reached for a 50-trial run for three consecutive sessions, the emphasis shifted from accuracy to speed of response. Pre- and posttests consisted of reading trained and untrained syllables and words. A control group received no training but did participate in pre- and posttests. Children that received training were significantly faster and more accurate on trained syllables and words than the control group, but no between-group differences were found with respect to untrained syllables and words.

Van Daal, Bakker, Reitsma, and van der Leij (1986, experiment 1) obtained similar results. They conducted an experiment in which poor readers (approximately 10 years old) were trained in reading 96 high-frequency and 96 low-frequency words. The training consisted of 12 sessions and each word was presented three times. The words were presented in isolation on a monitor screen and the task of the subject was to read them aloud. Accuracy and naming latency were recorded. During training, children increased their accuracy and became significantly faster. Their naming latency was reduced from 4.5 seconds in the initial phases to 2.9 seconds in the final phases of training. Furthermore, the initial frequency effect on naming performance decreased during training and was completely eliminated after 11 practice sessions. After training, reading performance on untrained words was investigated. An untrained word was either totally different from trained words or was an orthographic neighbour of a trained word (one letter different). The idea was that if progress on trained words would be the result of a more efficient decoding of multi-letter units, then progress should transfer to untrained words with the same multi-letter units. However, reading performance on orthographic neighbours did not differ from orthographically unrelated words. The results do not support the idea that exposure to a word with a particular multi-letter unit facilitates reading other words also containing that multi-letter unit. This question was addressed in more detail by Reitsma (1988b). Beginning readers practiced reading a set of difficult, unfamiliar CVC or CVCC words either within a list of similar words or within a list of dissimilar word. A list consisted of nine words. The words of a similar word list differed from each other in either the initial consonant or the final consonant(s). The training consisted of 4 sessions. A list was repeated 4, 8, or 16 times. During training, reading time decreased for the similar word lists, but not for the dissimilar word lists. The posttest consisted of reading trained and untrained words. Reading performance on words that had been presented 16 times during training was better than on untrained words, but performance on words that had been practiced less than 16 times during training was not better than on untrained words. The untrained words were similar to the trained words. Reading speed on the untrained words was not affected by list type. Thus, practice in reading lists consisting of similar words is no more effective than practice in reading lists consisting of dissimilar words. Finally, reading speed with respect to the untrained words was not affected by frequency of presentation. Thus, no transfer of practice in reading words to similar other words was found, regardless how often the words were read. Similar results have been obtained with poor readers as subjects (Reitsma & Dongelmans, 1988). It was concluded that readers do not seem to acquire knowledge of letter-sound relations beyond the level of individual graphemes and phonemes (Reitsma, 1988b, p.355; Reitsma, 1990, p.62).

To summarize, the recognition of words can quite easily be improved by a few familiarizing experiences. Word phonology plays an important role in the beneficial effect of practice. The progress, however, is limited to words actually trained and does not transfer to untrained words.

Effects of Practice in Word Reading on Automaticity

So far, results of training in word recognition skills have been assessed in terms of accuracy and, in particular, in terms of naming speed with respect to reading trained and untrained words. In addition to speed and accuracy criteria, words should also be recognized automatically (Ehri, 1987; LaBerge & Samuels, 1974), that is, being attention free and requiring little cognitive capacity. In order to investigate whether readers recognize words, and decode pseudowords, automatically, researchers have often used a picture-word interference task (DeSoto & DeSoto, 1985; Guttentag & Haith, 1978; Pace & Golinkoff, 1976; Schadler & Thissen, 1981; Seegers, 1985; Stanovich, Cunningham, & West, 1981). In this task, subjects' speed in naming pictures printed with distracting words or pseudowords is compared with their speed in naming pictures with a consonant string. For example, a picture of a clock is presented with either the consonant string 'ngsl', the pseudoword 'nole', or the word 'nose' printed on top of it. The task of the subject is to ignore the distractor and to name the picture as quickly as possible. If the presence of printed words delays picture naming more than the presence of consonant strings, this is interpreted to indicate that the words are being recognized automatically. Similarly, if the presence of printed pseudowords delays picture naming more than the presence of consonant strings, this is interpreted to indicate that the pseudowords are decoded automatically.

Ehri and Wilce (1979, experiment 2) investigated whether repeated reading of words increased the interference created by these words in a picture-word interference task. First and second graders (6-7 years old) were trained in reading high-frequency words. Children that could already read these words correctly were trained to recognize them faster. Children that could not read these words were trained until they could identify them accurately. Before and after training, a picture-word interference task was administered. They used two naming conditions, pictures printed with the trained words and pictures without any distractor as baseline. Results indicated that interference increased for subjects who were initially unable to read the words. However, the opposite effect was observed among subjects who could initially read all the words and who learned to read them faster during training. The authors argued that automaticity in recognizing words is attained prior to maximum word recognition speed (Ehri & Wilce, 1979; Ehri & Wilce, 1983). The children who were trained in accuracy learned to recognize most of the words automatically. After training, they were unable to suppress recognizing these words. Accordingly, more of these words were involuntarily processed on the posttest than on the pretest, inducing more interference. The children who were trained in speeded recognition could already recognize the words automatically at the onset of training. Training merely speeded up the operations required for processing the word. As word processing required less time, its interference on picture naming was also reduced.

The conclusion is that automaticity of recognizing unfamiliar words can be achieved by extensive practice in reading these words. Furthermore, the picture-word interference task appears to be a useful instrument in order to determine whether a word is recognized automatically and whether the nature of the word recognition process is affected by training.

Conclusions on the Effects of Practice in Word Reading

The methods and results of the aforementioned training studies are summarized in Table 1.1.

Table 1.1 Method and results of the training studies discussed in §1.3

Fleisher et al., 1979	
Subjects:	normal readers; grade 4-5; N=36; sample split in 14 skilled and 22 less-skilled readers
Materials:	74 words, extracted from a text
Procedure:	half of the less-skilled readers received a single word flash card training; other half and skilled readers: no training; 1 session; training until criterion
Results:	tasks: reading aloud trained words and comprehension of a 104-word text containing the trained words; Although trained poor readers were equally good at reading trained words in isolation, they did no better than untrained poor readers with respect to comprehension
Hogaboam & Perfetti, 1978	
Subjects:	normal third-grade readers; N=12; sample split in skilled and less-skilled readers
Materials:	96 CVCVC pseudowords
Procedure:	3, 6, 12, or 18 presentations per pseudoword during training; 117 trials in total; two training conditions: printed and aural exposure,and aural exposure only; task: repeating the pseudoword's pronunciation provided by experimenter
Results:	posttest: reading aloud; both printed and aural practice is effective; effect reaches maximum after 3 (skilled readers) or 6 exposures (less-skilled readers); long-lasting effects

continued

(Table 1.1 continued)

Fiedorowicz, 1986

Subjects:	poor readers; age=11;8 years; *N*=16
Materials:	letter names, letter sounds, CV-CVCV syllables, CVCV words
Procedure:	single syllable (word) presentation, reading aloud, 43 sessions, 50 trials/session; 2150 trials in total; training until criterion
Results:	improvement on trained, but not on untrained words

van Daal et al., 1986

Subjects:	poor readers; age=9;8 years; *N*=14
Materials:	96 HF and 96 LF words
Procedure:	single-word presentation; reading aloud; 12 sessions; 3 trials per word; 576 trials in total
Results:	improvement on trained, but not on untrained words

Reitsma, 1988b

Subjects:	normal readers; age=6;8 years; *N*=32
Materials:	3 lists of 9 CVC words; words in list were orthographically and phonologically similar; all words were initially unfamiliar to the subjects
Procedure:	listwise presentation; list was practiced 4, 8, or 16 times; reading aloud task; 4 sessions, 252 trials in total
Results:	improvement on trained words after minimally 16 list presentations; no effect on untrained words

Ehri & Wilce, 1979

Subjects:	normal readers; age= 6;10 years; *N*=12; sample split in accuracy and speed readers (see text)
Materials:	40 HF noun-words
Procedure:	task: reading aloud and providing meaning; accuracy readers were trained on accuracy; speed readers were trained on speed; sessions 1-2; training until criterion
Results:	pre- and posttest: picture-word interference task; accuracy readers: increase in interference; speed readers: decrease in interference

The results seem to point to the conclusion that poor readers' recognition of words can be improved by repeated prior experience with these words. However, all studies failed to demonstrate a transfer effect from trained to untrained words. It seems that the beneficial effect of training on word recognition is limited to words that were actually practiced. The question is whether recognition of these particular words has improved permanently. There are arguments to doubt whether the positive effects of training extend to everyday reading situations. The design of the reviewed studies was such that after training on a set of specific words, children were required to read a list of trained words and a list of untrained words.

Presentation of lists was blockwise. The positive effects of practice in repeatedly reading words on their subsequent recognition are likely to be overestimated because the words were always member of a closed set. As mentioned earlier, it is likely that, as a result of practice, children became familiar with the comprising words of the set, and became more sophisticated in discriminating the individual members of that set. Instead of decoding, the training may have induced children to develop set-specific discrimination rules. This strategy may be effective for the identification of words within a training and testing environment, yet if the same words are encountered in a different situation, the positive effects of prior experience may be limited or even non-existent. The results of the earlier discussed Fleisher, Jenkins, and Pany study (1979), provides evidence for this assumption. Poor readers were trained to identify fluently a set of words extracted from a text. After training they were tested on their comprehension of that text. They did no better than a matched group of poor readers that had received no training.

It seems that mere practice in reading words might not be completely adequate to improve reading ability. If poor readers learn to identify words as a visual pattern and fail to recognize how letters function as symbols for sounds in pronunciations, no improvement in general word recognition skills as a result of practice may be expected (Adams, 1990; Ehri & Wilce, 1983). The problems of poor readers are not the result of insufficient exposures to printed words as such, but are the consequence of weak decoding skills. For this reason, poor readers have trouble with retaining and integrating spellings with their pronunciation in memory. As a result, when these words are read, it takes longer to locate the spellings and retrieve their pronunciations (Ehri & Wilce, 1983). Thus, rather than familiarize poor readers with a limited set of words, a more positive effect may be expected from a training procedure that provides ample opportunity to practice decoding skills and that emphasizes the relation between a word's spelling and its phonology. This would enrich the child's knowledge of letter-sound relations and enhances its decoding skills. Subsequently, a child would encounter more 'positive learning trials' (Jorm & Share, 1983), enabling him or her to associate the spellings and pronunciations of more words. A training procedure providing this form of practice might be successful in establishing a progress in *general* word recognition skills.

A study into the effects of a training in word recognition skills employing a procedure that emphasizes the relation between a word's orthography and phonology has been carried out by Van Daal and Reitsma (1990). They investigated the effects of computerized speech feedback during training in reading difficult words on poor readers' word recognition skills. The idea was that poor readers have less opportunity than normal readers to learn about new words when reading them. If an unfamiliar word is encountered, the normal reader tests several alternative letter-sound mappings and arrives, in most cases, at the correct pronunciation and meaning. Poor readers have less opportunity to learn by this "self-teaching" method because their word decoding attempts are too often without success (p.136). Speech feedback on call might be of assistance in this respect. If, during training, a child had problems with reading a word, he or she could press a button upon which the computer provided digitized speech feedback. Two forms of speech feedback were compared, segmented word sound and whole-word sound. A third group received no speech feedback at all. Training involved reading single words comprising one, two, or three syllables. The training program consisted of 10-16 sessions with 50 words per session. After training, a posttest was administered including trained and untrained words (in random order). With respect to practiced words, children that received speech feedback did better than children in the no speech feedback condition. The type of sound feedback had no influence on this effect. With respect to the untrained words, children that received segmented word sound feedback during training tended to do better than the other two groups. This indicates that emphasizing the relation between a word's spelling and its component sounds is productive for the development of *generalized* word recognition skills. The study suggests that supporting poor readers' decoding of difficult words by supplying segmented word sound feedback may be beneficial to improving poor readers' word identification skills.

To conclude, familiarizing readers with words by repeated exposures tend to induce children to identify these words as visual patterns. The value of this type of training is limited because transfer to untrained words is lacking and the positive effects on trained words is generally restricted to training and testing situations. Obviously, training programs that accomplish progress in poor readers' *general* word recognition skills are necessary. Such a training program should provide children to learn how letters function as symbols for sounds in pronunciations. This may be achieved by extensive practice and success in decoding and, as demonstrated by van Daal and Reitsma (1990), by assistance in order to illuminate the relation between a word's orthography and phonology. Chapter 2 presents two experimental studies to the effects of training programs that aim to improve poor readers' word recognition skills by providing extensive practice in phonological decoding. These studies will be introduced in the next paragraph.

1.4 Introduction to the Present Training Studies

The studies described in chapter 2 investigate the questions whether and how progress in poor readers' word recognition skills can be established by practice in phonological decoding. For this purpose, a training program was developed. A simple training procedure was used. Single words and pseudowords were presented on a computer monitor. The task of the child was to read them aloud. Two forms of time pressure, *limiting the exposure duration of words* and *pressure upon the child to respond quickly* were introduced in training. Exposure duration was either limited or unlimited, and the subject was either instructed to respond quickly (response speeding) or not (no response speeding). The first experiment reported in chapter 2 compares the two forms of time pressure during reading with respect to the effects on poor readers' word identification skills. The second experiment reported in chapter 2 examines the most beneficial version of the training program more closely. In the present paragraph, the relevant aspects of the training programs and the subsequent training studies are discussed.

Subjects

The children selected to participate in the training programs were from schools for children with specific learning disabilities. On the average, a class consists of 16 children. Apart from instruction by the teacher, extra help is available by remedial teachers and speech therapists. The teachers usually receive additional schooling in order to address the specific needs of these children. To be admitted to these schools, children should be without emotional, sensory or neurological handicaps, and their IQ should be higher than 85 (for an English description of the Dutch school system, see Holmes (1983), and Nijhof and Streumer (1988)).

The teachers were asked to select children that were approximately 1-2 years behind in reading development. These children were asked to read aloud two lists of VC pseudowords. Children who were unable to read these pseudowords were not allowed to take part in the training programs. This was done to ensure that all subjects had acquired sufficient grapheme-phoneme knowledge and synthesis skills. Children should, in principle, be able to execute the skill that is the focus of training.

The children that participated in the training studies were not beginning readers, even though their skill levels were not much more advanced. These children had years of experience with reading; they knew what printed words are and understood their basic relation to spoken words.

Training Materials

It has been argued that the quality of a word's lexical representation determines whether the word is recognized automatically and rapidly (Ehri, 1980, 1987; Ehri & Wilce, 1983; Perfetti, 1985, 1986). A 'fully specified' word representation (Perfetti, in press), or, in Ehri's terms, an 'amalgamated' word representation allows automatic and fast access to its meaning. Poor readers have difficulty in acquiring fully specified or amalgamated word representations because of weak decoding skills. Therefore, poor readers' decoding skills should be improved. There is general agreement that these skills develop through practice (LaBerge & Samuels, 1974). It was decided to practice decoding skills through pseudoword reading. The reason for using pseudowords is that experience relevant for decoding can be stimulated more efficiently with pseudowords than with words. When reading words, poor readers tend to evade decoding, relying instead on contextual sources of information (Stanovich, 1980). Pseudoword reading however, compels decoding and minimizes the influence of context and lexical facilitation. Reading a pseudoword requires that the entire letter string is decoded, whereas a word's identity may be established by partial decoding, complemented by lexical facilitation. Thus, drill in phonological decoding is more likely to be realized by reading pseudowords than by reading words. Furthermore, poor readers are more aware of a pseudoword's constituent phonemes than of a word's constituent phonemes (Byrne & Shea, 1979). This is probably because the semantic structure of a real word is so salient to poor readers that it tends to detract them from becoming aware of the phonological structure.

The pseudowords used in training were monosyllabic, varying in orthographical structure from CVC to CCVCC. A C stands for a consonant grapheme, a V for a vowel grapheme. The training focused upon practice in decoding at the grapheme-phoneme level. For this reason, monosyllabic pseudowords were chosen. Reading polysyllabic words or pseudowords involves context-dependent grapheme-phoneme decoding rules (van Heuven, 1980).

The materials of the second training study consisted of pseudowords exclusively. In order to investigate the effects of training on lexical processing skills, a set of high-frequency words was also included in the first training study. These words were selected from Staphorsius, Krom, and de Geus (1989). This is a frequency count of printed Dutch words in books and textbooks for children from 7 to 13 years old.

Time Pressure

Having concluded that pseudoword reading is useful for practicing decoding skills, a next issue is what the pseudoword reading task should look like to obtain a maximum learning effect. Addressing this issue requires a reconsideration of the nature and importance of phonological decoding. Adequate decoding enables the reader to identify new and unfamiliar words, and provides opportunity to acquire orthographical knowledge of the word. In addition to complete and accurate decoding, speed is also essential. The poor readers of the present studies are able to decode simple pseudowords accurately. However, they are very slow at it. If children are already accurate at decoding, progress can still be achieved by increasing decoding speed. For these children, the training task should be designed in such a manner that it induces children to speed up the decoding process. This may be accomplished by imposing time pressure on pseudoword reading. Time pressure may be put on the output part by instructing children to respond as quickly as possible. It may also be put upon the input part of pseudoword reading by limiting the exposure duration.

Time pressure on reading is widely used in the remediation of reading problems. The flash card method is probably the best-known example. In this task, single high-frequency words are briefly presented on a card or computer monitor. The child has to read the words aloud. Normally, words are presented several times. The idea is that time pressure has a beneficial effect on recognition speed because it prevents children from dawdling and breaking words in too many parts. Often, the child is also encouraged to respond quickly. Thus, time pressure is primarily used to improve the recognition speed of familiar high-frequency words.

Advocates of the whole-language method also suggest that time-pressure on reading can be beneficial to improving reading speed, but practice should always be carried out in the context of meaning. Furthermore, the implementation of time pressure upon the reading process should be accomplished by regular methods rather than by mechanical devices. Their concern is that training in reading with machines places undesirable emphasis upon the mechanical aspects of reading (Bond, Tinker, & Wasson, 1979, pp.389-90; Tinker & McCullough, 1969, p.250). Instead, time pressure should be realized by motivation and incentives. For example, they suggest a training in which children have to read short texts (300-350 words) at each session. The teacher encourages the child to read as fast as possible with understanding. The teacher times the reading and computes the number of words per minute. The child is rewarded when he improves his reading speed compared with the previous session. After reading a text, the child should answer a number of questions.

Despite their dislike of mechanical instruments in reading remediation, Tinker and McCullough suggest an exercise in which children's reading rate is controlled by a device that paces the reader by moving a shutter, line by line, over the text he is reading. The reader is expected to keep ahead of the shutter (Tinker & McCullough, 1969, p.250). In this method, the reader is forced to improve his reading speed by means of a device that sets limits to the exposure time.

To conclude, time pressure is often used in the remediation of reading problems. Why should time pressure be efficient? LaBerge and Samuels (1974) argue that progress in reading ability requires the reorganization of perceptual chunks. Instead of reading letter-by-letter, word codes must be reorganized into larger units. Laberge and Samuels are not explicit with respect to the nature of these units, but a word training should reinforce children to adopt more efficient strategies of processing (p.316). The demand for accuracy should temporarily be relaxed in order to encourage chunking. In that view, training under time-pressure would be a good approach.

The two most-often used forms of time pressure in training are limiting the exposure duration of words and pressure upon the child to respond quickly. However, little is known about their effects on reading ability and which form of time pressure is most beneficial. Limiting the exposure duration may have a positive effect because it induces readers to scan the entire word before decoding the individual graphemes (Baddeley, 1986, p.222). Furthermore, it may reinforce the development of decoding rules operating upon larger units than at the level of individual graphemes and phonemes, so called 'chunking' (LaBerge & Samuels, 1974; Newell & Rosenbloom, 1979). Pressure upon the child to respond quickly may have positive effects on later phases in word recognition, like blending processes.

In this thesis, the effects of time pressure during training in decoding on poor readers' word recognition skills are investigated experimentally. The goal of the first training study is to compare the effects of response speeding and limited exposure duration. It will be investigated what form of time pressure is most beneficial. In the second study, the most beneficial form of time pressure during training will be examined more closely. It will be investigated whether time pressure during a training in decoding is more effective than a training without time pressure.

Type of Response

The simplest and most straightforward task to practice pseudoword decoding is a naming task, where the subject must simply name each pseudoword as it appears. The onset of his or her response is detected by a voice-operated relay, and the interval between pseudoword presentation and response initiation is measured as *naming latency*. The advantages of naming are: it compels to phonological decoding, it is a familiar response to subjects, and it requires little effort beyond decoding (Sternberg, Knoll, Monsell, & Wright, 1978, see also chapter 4).

However, there are indications that poor readers have difficulty with the conversion of a phonological code into a plan for articulation (Underwood & Briggs, 1984, but see chapter 4 of this book for contrary evidence). Allington (1984) has argued that oral reading imposes different demands from that of silent reading. Reading performance may be affected differently by these demands. Kusters (1987) has argued that poor readers are more likely to make reading errors when reading aloud because, in addition to word identification, reading aloud requires articulatory programming. This additional demand increases the load on the resources of the language system, thereby increasing the chance of errors. In itself, this might be taken as an argument to develop a training task that does not require overt articulation. However, in his work on the 'articulatory loop' hypothesis, Baddeley (1986) provides evidence that articulatory programming, as well as organizing and executing articulatory plans, are of central importance for the development of decoding ability. The skills that are required to produce an overt response after a phonological representation of a pseudoword has been generated by decoding rules, are also important for reading development.

In the present training programs, naming was considered to be the most appropriate task. Reading aloud a decoded pseudoword emphasizes the relationship between its written and spoken form. In that sense, reading aloud enhances knowledge between orthographical and phonological units (Adams, 1990, pp.220-1, Jorm & Share, 1983).

Feedback

The training focused upon extensive practice in decoding simple, monosyllabic pseudowords. No instructional component was included. Given unlimited processing time, all children that participated in the experiments should be able to read these pseudowords successfully. After each trial, subjects were informed whether their response was correct or incorrect. Because reading the pseudowords correctly should lie within the capabilities of all children, incorrect answers were considered to be the consequence of an overload in processing capacity rather than of insufficient grapheme-phoneme knowledge Hence, reexposure to the initially incorrectly pronounced pseudoword along with the correct pronunciation provided by the experimenter, should not be necessary. In order to provide maximum training intensity, corrective feedback was omitted.

Amount of Practice

Only a few exposures to a word are required to improve its recognition speed (see for example the study by Hogaboam & Perfetti (1978), described in §1.3). The goal of the present training programs, however, is to improve poor readers' general word recognition skills by providing practice in phonological decoding. Therefore, the words and pseudowords in the first training experiment were presented only once throughout the program. In the second study, it is investigated whether repeated exposures to pseudowords facilitates reading performance when these pseudowords are presented in mixed lists. A beneficial effect of repeated exposures in a mixed-list procedure can not be the result of improved set-specific discrimination.

Long-term training seems to be a prerequisite for generalized improvement (Perfetti, 1985). In the present training studies, children practiced 20 minutes per session, two days a week, for a period of approximately two months.

Measuring Progress

Practice in decoding should lead to more accurate, efficient, and automatic identification of words. In the long run, this should facilitate text comprehension (Perfetti, 1985). Reading performance may be measured at a number of levels, varying from letter identification to comprehension of text. In the present studies, the effects of practice will be investigated in terms of accuracy and speed of word and pseudoword naming (the second training study however, includes a sentence verification task in order to examine the effects of decoding practice on sentence comprehension).

The first training study used two standard reading tasks. The 'Eén-Minuut-Test' [One-Minute-Test] (Brus & Voeten, 1972) was administered to measure the ability to read isolated words. The 'Differentiële Zinnen Leestest' [Differential Sentence Reading Test] (Dommerholt, 1970) was administered to measure the ability to read words in the context of sentences. Standard tests were chosen in order to relate performance to that of normal readers. However, the results of the first study suggested that these tests were not sensitive enough to detect subtle changes in decoding ability. This lack of sensitivity may be related to the fact that these tests employ a continuous list procedure. Stanovich (1981) has argued that components that are irrelevant to reading may influence performance on such tasks considerably. Performance on tasks utilizing a discrete trial procedure are less likely to be affected by these irrelevant components. Therefore, in the second study, effects of training were measured by using word and pseudoword reading tasks employing a discrete trial procedure.

In both studies, a picture-word interference task was used to investigate whether practice in pseudoword reading had an effect on the automaticity of word and pseudoword decoding. Two hypotheses with respect to the locus of interference induced by words and pseudowords on picture naming have been raised. The interference might be due to simultaneously analyzing the stimuli, creating a semantic conflict (Seymour, 1979), or due to simultaneous activation of the incompatible verbal responses (Dyer, 1973; Klein, 1964). Empirical research clearly favors the latter position (LaHeij, 1988; see for review MacLeod, 1991). Thus, two verbal responses, one for naming the picture, the other for naming the word or pseudoword, become available simultaneously and automatically. The inappropriate response should be rejected, causing a delay. Thus, interference of pseudowords on picture naming is taken as evidence that the pseudowords, or at least some of the pseudowords, have been decoded automatically. Similarly, interference of words on picture naming is taken as evidence that the words, or at least some of the words, have been recognized automatically.

Chapter 2. Training Studies

2.0 Survey

This chapter presents two studies into the effects of practice in word and pseudoword reading under time pressure. The experiments were carried out at schools for special education with poor readers as subjects.

The goal of the first experiment was to investigate the effects of time pressure during training in word and pseudoword reading on poor readers' word recognition skills. All words and pseudowords were presented only once throughout the training program The effects of two forms of time pressure, *limiting the exposure duration of words* and *pressure upon the child to respond quickly*, were compared. Exposure duration was either limited or unlimited, and the child was either instructed to respond quickly (response speeding) or not (no response speeding). The orthogonal combination of both factors produced four different training programs. Poor readers were assigned to one of four training conditions The experiment employed a pretest-training-posttest design. The effects of training were assessed by two standard reading tests and a picture-word interference task as pre- and posttest, and by the development of speed and accuracy on reading words and pseudowords during training. The primary goal of the first study was to resolve the question which training procedure is most efficient. The results indicated that practice under conditions of limited exposure duration was more successful than the other training procedures

The effects of practice in reading briefly presented pseudowords on poor readers' word processing skills were examined more extensively in a second study. Again, a pretest-training-posttest design was utilized. Three groups of poor readers participated in this experiment. The first group received training in reading pseudowords under conditions of limited exposure duration (*Flash Card group*). The second group practiced reading the same pseudowords but without any constraints on the exposure duration (*Reading Aloud group*) Neither group was asked to respond quickly. The third group received no training (*No Training group*). A number of modifications were made to the training program that was used in the first experiment. The amount of practice in reading was increased and the training was limited to reading pseudowords only. Some pseudowords were presented several times during the program. Furthermore, a better technique for realizing limited exposure duration was developed. Four pre- and posttests were used to investigate the efficiency of the training programs. The effects of training were also assessed by examining the development of dependent measures obtained during training itself.

2.1 Limited Exposure Duration and Response Pressure during Word Training

The purpose of the first training experiment was to investigate the effects of limited exposure duration and response pressure during training in word and pseudoword reading on poor readers' word processing skills. Subjects were circa 9-12 year old children from schools for special education. Teachers were asked to select children that were approximately 1-2 years behind in reading development. Subsequently, a VC pseudoword naming task was administered in order to verify whether these children had acquired elementary knowledge of grapheme-phoneme correspondences and were able to apply this knowledge successfully in a simple decoding task. The task was administered without constraints on processing time. As the training involved reading isolated words and pseudowords, knowledge of grapheme-phoneme correspondences was essential. Children that were able to read most of the VC pseudowords correctly were selected to participate in training.

The training procedure was similar to a standard naming task: single words and pseudowords were presented on a computer monitor screen. The task of the child was to read them aloud. Both forms of time pressure had two levels (limited versus unlimited exposure duration, and speeded versus unspeeded responding). The orthogonal combination of both factors produced four different training programs. In one training program, children were required to read the presented words and pseudowords without any form of time pressure. In another program, the words and pseudowords were presented briefly, but no instruction to respond quickly was given. No limits were set on the exposure duration in a third program, but children were instructed to respond quickly. In the fourth program finally, both forms of time pressure were put into training simultaneously. Words and pseudowords were presented for a short period of time and children were required to respond quickly. Type of training was the between-subjects factor, thus a subject participated in one program only.

For each subject that participated in a training program in which exposure duration was limited, a standard exposure duration was determined. This duration was short enough to impose time pressure upon the child's word and pseudoword processing, but was long enough to identify a substantial percentage of words and pseudowords correctly. No adjustments were made with respect to the exposure duration at any time during the training program. Fast responding was accomplished by reinforcing fast responses and penalizing slow ones.

The training program consisted of 18 practice sessions of approximately 20 minutes each. Children participated individually twice a week, for nine weeks in total. In order to investigate the effects of training on phonological decoding as well as on lexical processing, both words and pseudowords were used as practice materials. Reading pseudowords compels to phonological decoding, whereas words may be recognized by their orthographical structure (Ellis, 1984). All words and pseudowords were monosyllabic. The question whether effects of training were related to orthographical complexity was addressed by using words and pseudowords of four different orthographical structures: CVC, CVCC, CCVC, and CCVCC. As stated earlier, the aim was to improve poor readers' decoding skills, and not to familiarize them with specific words through repetitive exposures. For this reason, words and pseudowords were presented only once during the training.

The training programs were compared with respect to their effects on reading performance measured by three pre- and posttests. The ability to read isolated words was measured by the Eén-Minuut-Test (Brus & Voeten, 1972). The ability to read words in the context of sentences was measured by the Differentiële Zinnen Leestest (Dommerholt, 1970). Finally, a picture-word interference task was used to assess whether automaticity of word and pseudoword processing was differentially affected by the training programs.

The effects of practice were also assessed by the development of speed and accuracy on reading words and pseudowords during training. If practice has a positive effect on phonological decoding, then progress in pseudoword reading should be observed during training because pseudoword reading compels to phonological decoding. Progress in word reading should be less because some high-frequency words may be recognized by their orthographical pattern. If however, practice should affect lexical processing but not phonological decoding, then performance on word reading might be expected to improve whereas pseudoword reading should not improve.

The interpretation of a possible improvement in speed of naming words and pseudowords requires that all processing components contributing to naming latency are taken into account. In addition to identification processes, naming requires the production of a response through articulation. Thus naming latency, the interval between stimulus presentation onset and the initiation of a vocal response, contains components of stimulus identification, as well as components of response production. It is possible that training under time pressure affects processes of response production in particular. In order to investigate whether a possible increase in naming speed on words and pseudowords is the product of improvement in response production, digits were included as practice material. At each training session, the children were required to name a series of digits. The subjects in this experiment can be expected to recognize digits automatically. Identification should require little cognitive capacity (Ehri & Wilce, 1983). Digit naming latency should therefore consist primarily of response production processes. If training affects efficiency of response production, then digit naming speed would also increase. If, however, response production is not affected by training, then digit naming speed would remain at the same level throughout training. Thus, the finding that digit naming latency does not change, and word and pseudoword naming latency decreases, would suggest that progress in word and pseudoword naming speed is the result of improved decoding processes.

Method

Subjects

Children qualified by their teachers as 'poor readers' were selected from three schools for special education. In order to test whether subjects had acquired elementary knowledge of grapheme-phoneme correspondences, a list of 34 VC pseudowords was administered. The list contained all vowels used in training, as well as all legitimate final consonants in Dutch. The list can be found in Appendix 2.1. Subjects were required to read the pseudowords aloud. Children that were able to read the VC pseudowords correctly were allowed to participate in the experiment. A total of 42 children (38 boys, 4 girls) met this criterion. Their age ranged from 8;9 to 12;9 years, with a mean of 10;4 years (*SD*=12 months). The scores on the standard reading test obtained on the pretest indicate that the children were at a reading level that is comparable to that of 'normal' readers at the start of second grade. The reading methods used by the schools are primarily based upon a phonics approach of reading instruction.

Design

This study employed a pretest-training-posttest design. Two forms of time pressure, limited exposure duration and response speeding, implemented in a training in word and pseudoword processing, were compared with respect to their effects on poor readers' reading ability. Both factors had two levels (limited versus unlimited exposure duration, and speeded versus unspeeded responding). The orthogonal combination of both factors produced four different training programs. The subject sample was divided in four groups, matched on two measures obtained in the pretest: (a) proficiency in word decoding, and (b) automaticity of word decoding. Two groups of 11 subjects, and two groups of 10 subjects emerged. Groups were randomly assigned to experimental conditions.
Effects of training on reading ability was assessed by three pre- and posttests. Furthermore, performance on the training task itself was also studied. The training programs will be presented first. Pre- and posttests will be described successively.

Training

Apparatus: In the training part of the study, an Apple IIGS computer was used. Children were seated approximately 60-80 centimeter from the monitor. The words and pseudowords were presented in white, lower case letters on a black background in the center of the screen. A four-letter string measured 9 by 2.1 centimeter. A letter font used in many text books for children was chosen. Naming latencies were measured accurately to the millisecond by a voice-activated relay attached to the computer.

Materials: The words and pseudowords were of four orthographical structures: CVC, CVCC, CCVC and CCVCC. Of each orthographical structure, 108 words and 108 pseudowords were required for the entire training program. High-frequency words (printed frequency count of more than 5 per million) were selected from Staphorsius et al. (1989). Verb inflections were not used. The corpus of Staphorsius contained too few CCVCC words that met the frequency criterion. Twenty-three additional CCVCC words were chosen from Weyters (1983). Of these, 16 had a printed frequency count of less than 2 per million, and 7 others were verb inflections. Pseudowords were created by changing the vowel of words. In cases where this procedure would inevitably result in a real word, the final consonant was changed in order to produce a pseudoword. The complete list of words and pseudowords can be found in Appendix 2.2. The set of pseudowords matched the set of words with respect to the distribution of vowels, and initial and final consonants (see Appendix 2.2 and 2.3, respectively). Furthermore, a set of six random digits was created for each session. A set consisted of six different digits. The nought was excluded.

Procedure.

General: The training programs consisted of 18 sessions of approximately 20 minutes each. Subjects practiced individually twice a week, for nine weeks in total. In each session 24 words, 24 pseudowords, and 6 digits were presented blockwise. The order of items within blocks was randomized. The order of presentation of blocks was balanced across subjects and across sessions.

Subjects were instructed to name the presented word, pseudoword, or digit. A maximum of 6.5 seconds was allowed for responding. Each trial started with a 50 ms beep, followed by an asterisk in the center of the screen. This served as fixation point and remained on the screen for 500 ms. The asterisk was immediately followed by the target stimulus that appeared on the screen in the same location. The exposure duration of the target stimulus was dependent on the training condition (see below). The response latency was determined for each trial. Latency was defined as the time between the onset of the target stimulus and the verbal response of the subject. By pushing buttons on the computer keyboard the experimenter indicated whether the stimulus was identified correctly and whether the clock was stopped by the verbal response of the subject. A correct response was followed by a picture of a smiling face. In case of a incorrect response, a sad looking face appeared on the screen. After an error, the item was not repeated.

After finishing a block, subjects received feedback about their performance by the computer. All subjects received feedback about accuracy. Feedback with respect to speed of responding was given only to children participating in a response-speeded training condition. The feedback provided by the computer was taken over by children in diagrams. This enabled children to perceive whether they improved during the program. At the start of each session, the experimenter tried to motivate the children to improve their performance.

Exposure Duration: The exposure duration was either limited or unlimited. A 'standard exposure duration' was determined for each subject that participated in a training condition in which exposure duration was limited. This standard exposure duration was to satisfy two criteria. On the one hand, the duration had to be short enough to impose time pressure upon word and pseudoword processing. On the other hand, the duration had to be long enough to enable children to identify a substantial percentage of words and pseudowords correctly. The standard exposure duration was obtained in the following manner: a block of 10 CVC pseudowords was presented with an exposure duration of 350 ms each. The task of the subject was to read the pseudowords aloud. In case of eight or more responses correct, the exposure duration was decreased in the subsequent block of 10 CVC pseudowords. When less than eight pseudowords were read correctly, the exposure duration was increased in the next block. This procedure was repeated three times. For a more detailed description, see Appendix 2.4. The mean standard exposure duration was 151 ms (*SD*=47), ranging from 90 to 400 ms. The obtained standard exposure duration was used throughout the training program for all words, pseudowords, and digits. No adjustments were made at any time during the training program. Stimuli were masked by non-letter symbols immediately after the exposure duration expired. A mask was used in order to erase the visual image of the target stimulus from the subject's sensory information store. The mask remained on the screen until the subject responded, or until the maximum time for a trial had expired.

Response Speeding: Response speeding was either present or absent during training. Fast responding was brought about by means of instruction and feedback. Subjects were instructed to read the words as fast as possible, without making mistakes. A fast response was followed by positive reinforcement, a slow response by negative reinforcement. A response was considered fast when its latency was shorter than the shortest of the two preceding items. A response was considered slow when its latency was longer than the slowest response of the three previous items. Subjects received feedback with regard to their reading speed on fast and slow responses only. Fast responses were followed by a picture of a hare on the screen. This symbolized fast reading. A picture of a turtle appeared on the screen in case of a slow response. The turtle symbolized slow reading.

Pre- and Posttests

Eén-Minuut-Test: A standard reading achievement test, the Eén-Minuut-Test (Brus & Voeten, 1972), was administered. This test consists of a list of isolated words of increasing difficulty. The task is to read the words as fast and accurately as possible. The number of words read correctly in one minute, is counted. The test has two parallel versions. Form A was administered in the pretest, form B in the posttest.

Differentiële Zinnen Leestest: The Differentiële Zinnen Leestest (Dommerholt, 1970) consists of four sets of 10 sentences each. Sets increase in difficulty. The task of the subject is to read the sentences aloud. The number of words read correctly within three minutes is counted. This test also has two parallel versions. Form A was administered in the pretest, form B in the posttest.

Picture-Word Interference Task: The picture-word interference task was developed in order to measure changes in poor readers' automaticity of word and pseudoword processing as a result of training. This task was tested before it was employed for that purpose. A report on the development and testing of the picture-word interference task can be found in Appendix 2.5.

Results

Pre- and posttests

The number of words read correctly on the Eén-Minuut-Test and the Differentiële Zinnen Leestest was counted. Furthermore, pseudoword interference and word interference was assessed in the manner as described in the method section. Each task was analyzed separately. Dependent variables were entered in analyses of variance with Exposure Duration (limited vs. unlimited) and Response Speeding (present vs. absent) as between-subjects factors.

Eén-Minuut-Test: Table 2.1 shows the mean number of words correct on pre- and posttest.

Table 2.1: Number correct on the Eén-Minuut-Test on pre- and posttests for all training groups (*SD* in parenthesis)

Response Speeding		Exposure Duration			
		Limited		Unlimited	
present	pretest	22.7	(10.1)	24.6	(10.7)
	posttest	31.9	(14.1)	32.2	(12.3)
not present	pretest	24.9	(9.9)	22.5	(9.9)
	posttest	29.4	(7.2)	26.2	(9.3)

The mean score of the subjects of the present study at the beginning of training was 23.7 words correct (*SD*=9.8). In a 'normal' reading development, this score is reached at the beginning of second grade. This confirms that the children of this study were approximately two years behind in reading development.

In order to test whether the four training groups were successfully matched on the Eén-Minuut-Test, an analysis of variance was performed with pretest scores as the dependent variable and Exposure Duration (2) and Response Speeding (2) as between-subjects factors. The main effects and the interaction between Exposure Duration and Response Speeding were not significant (all *F*'s<1). This demonstrates that, prior to training, groups did not differ with respect to this variable .

In order to test whether groups differed after training, an analogous analysis of variance was carried out with posttest scores as the dependent variable. No significant effects were obtained (all *F*'s<1, except for the main effect of Response Speeding ($F(1,38)=1.56$, $p=.219$)). The ability to read isolated words, as measured by the Eén-Minuut-Test, was not differentially affected by type of training.

Differentiële Zinnen Leestest: Table 2.2 shows the mean number of words correct on pre- and posttest.

Table 2.2: Number correct on the Differentiële Zinnen Leestest on pre- and posttests for all training groups (*SD* in parenthesis)

Response Speeding		Exposure Duration			
		Limited		Unlimited	
present	pretest	114.1	(47)	114.3	(41)
	posttest	128.1	(56)	131.5	(48)
not present	pretest	107.9	(35)	103.9	(41)
	posttest	135.8	(39)	112.9	(45)

The mean score of the subjects of the present study at the beginning of training was 110 words correct. According to the criteria of the Differentiële Zinnen Leestest, this score is attained by children with a 'normal' reading development at the beginning of second grade. These results confirm the earlier conclusion that the children of the present study were poor readers.

The four training groups were not explicitly matched on this variable. In order to test whether groups differed at the beginning of training with respect to this variable, an analysis of variance was carried out with the number of words read correctly on the pretest as the dependent variable. Exposure Duration (2) and Response Speeding (2) were the between-subjects factors. No significant effects were found (all *F*'s<1). Prior to training, groups did not differ in their ability to read words presented in sentences.

In order to test whether groups differed after training, an analogous analysis of variance was conducted with posttest scores as dependent variable. Again, no significant effects were obtained (all F's<1). The ability to read words in the context of sentences, as measured by the Differentiële Zinnen Leestest, was not differentially affected by type of training.

Picture-Word Interference Task: The four training groups were matched with respect to word interference. Word interference effect was defined as the delay in naming pictures printed with words relative to naming pictures printed with consonant strings. At the time of matching, we calculated the *mean* naming latency across pictures with a certain distractor. Word interference was then determined by calculating the difference between mean naming latency of pictures printed with words and pictures printed with consonant strings. However, after reexamining the issue of obtaining a measure of central tendency, the mean appeared to have its drawbacks. The *median* is a better characterization of central tendency than the mean for a series of response latencies (Noordman-Vonk, 1979, pp.10-14). The *median* picture naming latencies across pictures was assessed for each distractor condition retrospectively. Subsequently, word interference was assessed by subtracting the median latency of naming pictures with consonant strings from the median latency of naming pictures with words. Pseudoword interference was determined by subtracting the median latency of naming pictures with consonant strings from the median latency of naming pictures with pseudowords.

In order to test whether groups differed prior to training with respect to these variables, pseudoword interference and word interference on the pretest were entered in analyses of variance with Exposure Duration (2) and Response Speeding (2) as between-subjects factors. Table 2.3 shows mean values for pseudoword interference and word interference on pre- and posttest.

Significant main effects of Exposure Duration were found for both word interference and pseudoword interference ($F(1,38)=6.1$, $p<.05$, and ($F(1,38)=6.9$, $p<.05$, respectively). Inspection of Table 2.3 learns that, prior to training, interference from words and pseudowords on picture naming was larger for children that were about to participate in training with unlimited exposure duration, than for children about to participate in a training with limited exposure duration. No main effects of Response Speeding were found with respect to pseudoword interference and word interference ($F<1$, and $F(1,38)=1.3$, $p=.262$, respectively). The interaction between Exposure Duration and Response Speeding was also not significant with respect to pseudoword interference and word interference ($F<1$, and $F(1,38)=1.3$, $p=.260$, respectively). Collapsed across training groups, neither word interference, nor pseudoword interference differed from zero ($F(1,38)=2.34$, $p=.135$, and $F(1,38)=1.48$, $p=.232$, respectively), indicating that, prior to training, picture naming was not significantly delayed by the presence of words or pseudowords. However, after training, word interference and pseudoword interference differed significantly from zero

Table 2.3: Pseudoword Interference (PWI) and Word Interference (WI) (in ms) on pre- and posttests for all training groups (*SD* in parenthesis)

Response Speeding		Exposure Duration			
		Limited		Unlimited	
		Pseudoword Interference (PWI)			
present	pretest	- 17	(66)	24	(49)
	posttest	8	(44)	18	(52)
	difference	25		- 6	
not present	pretest	- 12	(61)	55	(84)
	posttest	94	(149)	20	(124)
	difference	106		- 35	
		Word Interference (WI)			
present	pretest	- 8	(79)	15	(58)
	posttest	43	(41)	29	(75)
	difference	51		- 14	
not present	pretest	- 8	(43)	55	(36)
	posttest	57	(42)	30	(58)
	difference	65		- 25	

($F(1,38)=20.85$, $p<.001$, and $F(1,38)=4.85$, $p<.05$, respectively). Thus, after training, subjects' picture naming was significantly delayed by both words and pseudowords.

In order to test whether exposure duration and response speeding had affected the increase in pseudoword interference and word interference, the differences between groups prior to training should be taken into account. Adjusting posttest scores through analysis of covariance is a possibility. However, correlations between pre- and posttest for pseudoword interference and word interference were low ($r=.01$, n.s., and $r=.33$, $p<.05$, respectively). Therefore, using covariates is not the most appropriate solution (Hand & Taylor, 1987, p.163). Difference scores between pre- and posttest latency were used instead. The difference in pseudoword interference between pre- and posttest, and the difference in word interference between pre- and posttest were entered in analyses of variance. Main effects of Exposure Duration were found for both pseudoword interference and word interference ($F(1,38)=5.56$, $p<.05$, and ($F(1,38)=12.3$, $p<.01$, respectively). Within-factor testing revealed that pseudoword interference and word interference increased for children that received a training in which exposure duration was limited ($F(1,38)=6.88$, $p<.05$, and ($F(1,38)=20.71$, $p<.001$, respectively). Pseudoword interference and word interference seemed to decrease a little for children of the unlimited exposure duration groups, but that was not significant (F's<1). Effects of Response Speeding were not significant for pseudoword interference and word interference ($F(1,38)=2.39$, $p=.130$, and $F<1$, respectively). Finally, the interaction between Exposure Duration and Response Speeding was not significant for pseudoword interference and word interference ($F<1$, and $F(1,38)=2.07$, $p=.159$, respectively).

Training Data

Naming latencies were determined for each subject for all experimental trials. Latencies of incorrect responses were not used. These accounted for 13% of the data. In addition, trials on which the response was correct but did not stop the timer, or on which the timer was stopped by a sound other than the name of the stimulus, were eliminated. These procedures resulted in a missing-value percentage of 11%. In addition, 4.5% of the data were lost due to a disk-crash.

For each session, the number of words and pseudowords read correctly was counted, and the median naming latency for words and pseudowords was calculated. This was done for each orthographical structure separately. Because there were six words and pseudowords per session for each orthographical structure, the median naming latency was calculated across six observations at most. For some sessions, calculating a median was impossible, because there were no valid observations. This problem was handled by substituting missing data by estimations through a 'running average' technique. This procedure estimates missing values as the average of adjacent sessions. In case there was a missing value on the first session, the average of the second and third session was substituted. Similarly, the mean of the 16^{th} and 17^{th} sessions replaced a missing value on the last session.

The median latency on digit naming was also calculated. Very few errors occurred in digit naming. Therefore, accuracy scores on this task were not used in analyses.

The first session was dropped from analyses, because too many data were missing. Session 6 was also excluded from analyses because the disk on which the data were collected, crashed. The 18 training sessions were divided into four blocks. The first block consisted of session 2-5, the second block of session 7-10, the third block of session 11-14, and, finally, the fourth block consisted of session 15-18. Means across medians were calculated for each block. These data were used for analyzing the course of development of dependent variables during training. Results with respect to accuracy and latency were analyzed separately.

Latency: In order to test whether speed of digit naming was affected by training, an analysis of variance was carried out with digit naming speed as dependent variable and Time (4 training blocks) as the within-subjects factor. Exposure Duration (2) and Response Speeding (2) were the between-subjects factors. The development of digit naming latency is shown in Figure 2.1.

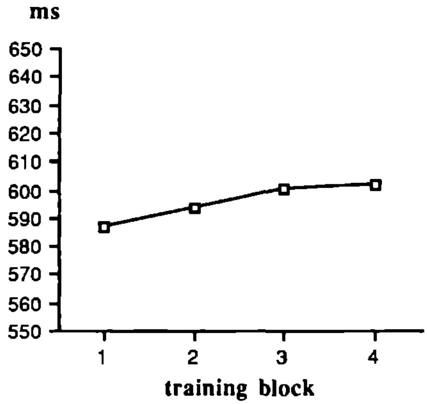


Figure 2.1: Digit naming latency, collapsed across training groups.

The main effect of Time was not significant ($F(3,36)=1.26$, $p=.304$). This demonstrates that digit naming speed remained at the same level throughout training. The interaction between Time and Response Speeding was significant ($F(3,36)=5.64$, $p<.01$). The instruction to respond quickly resulted in shorter digit naming latency ($F(1,38)=106$, $p<.001$). Within-group testing revealed that latency did not change for the speeded response group ($F<1$), but the unspeeded response group slowed down their speed of digit naming as training progressed ($F(3,36)=5.91$, $p<.01$).

In order to investigate the effects of training on alphabetic material, word and pseudoword latencies were submitted to an analysis of variance with Exposure Duration (2) and Response Speeding (2) as between-subjects factors. Time (4 training blocks) and Lexical Status (words and pseudowords) were tested within subjects. The development of over-all word and pseudoword naming latency is shown in Figure 2.2.

Pseudowords were harder to read than words, indicated by a main effect of Lexical Status ($F(1,38)=89.87$, $p<.001$). Children improved their naming speed during training, demonstrated by a main effect of Time ($F(3,36)=5.41$, $p<.01$). The improvement showed a linear trend ($F(1,38)=15.46$, $p<.001$) with the quadratic component approaching significance ($F(1,38)=3.41$, $p=.072$). Naming speed on both words and pseudowords improved during training, ($F(3,36)=4.45$, $p<.01$, and $F(3,38)=4.84$, $p<.01$, respectively), but the almost significant interaction between Lexical Status and Time ($F(3,36)=2.64$, $p=.064$) suggested that progress tended to be larger for pseudowords than for words.

Limiting exposure duration had no effect on naming latency ($F<1$). The instruction to respond quickly resulted in faster naming, indicated by a main effect of Response Speeding ($F(1,38)=5.70$, $p<.05$). However, the interaction between Time and Response Speeding

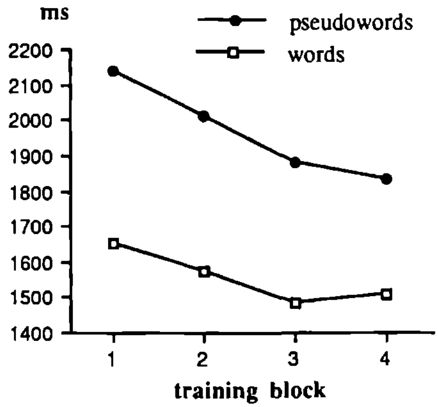


Figure 2.2: Word and pseudoword naming latency, collapsed across orthographical structure and training groups.

was not significant ($F<1$), indicating that the beneficial effect of training was similar for both levels of the factor. In fact, all interactions between Time and the between-subjects factors were not significant (all Fs<1), indicating that improvement was independent of type of training.

The relation between orthographical structure and lexical status (words and pseudowords), was also investigated. Latency data for all four orthographical structures of both words and pseudowords were entered in an analysis of variance with Orthographical Structure (4), Lexical Status (2), and Time (4 training blocks) as within-subjects effects. Figures 2.3 and 2.4 show the development of naming latency, split by orthographical structure and collapsed across training groups, for words and pseudowords, respectively.
Words and pseudowords with a more complex orthographical structure were harder to read than the more simple ones, demonstrated by a main effect of Orthographical Structure ($F(3,36)=70.46$, $p<.001$). The differences in latency between orthographical structures were larger for words than for pseudowords, indicated by an interaction between Orthographical Structure and Lexical Status ($F(3,36)=10.09$, $p<.001$). The interaction between Orthographical Structure and Time, as well as the three-way interaction between Lexical Status, Orthographical Structure, and Time were significant ($F(9,30)=7.23$, $p<.001$, and $F(9,30)=2.93$, $p<.05$, respectively). This suggests that the decrease in naming latency during training was not the same for all orthographical structures, and that the development of naming latency for the orthographical structures had different courses for words and pseudowords. Inspection of Figures 2.3 and 2.4 suggest that latencies on pseudowords were decreasing in parallel, while latencies on words were somewhat

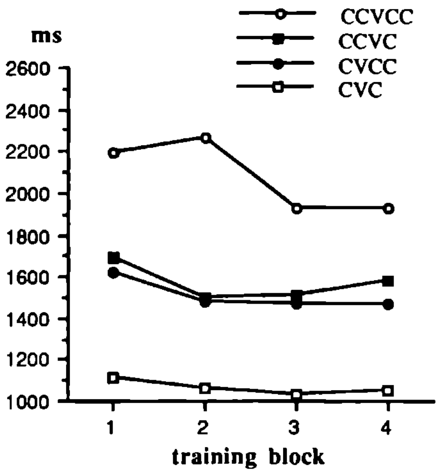


Figure 2.3: Word naming latency, split by orthographical structure and collapsed across training groups.

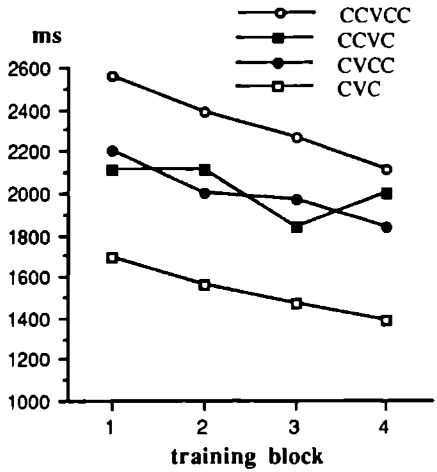
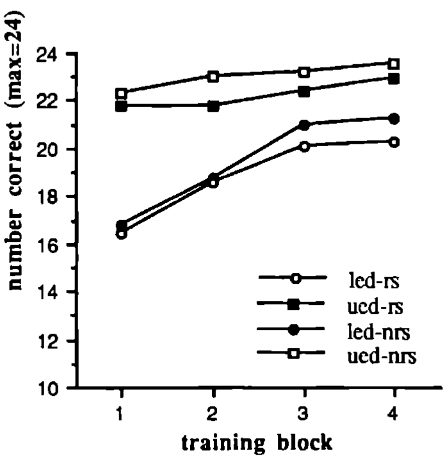


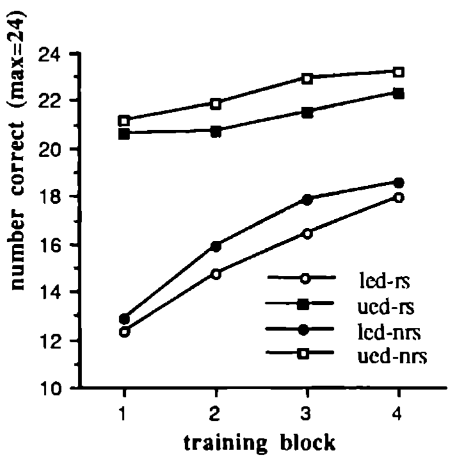
Figure 2.4: Pseudoword naming latency, split by orthographical structure and collapsed across training groups.

converging. This idea was tested by analyzing the most simple and most complex orthographical structure separately. For words of the CVC type, no decrease in latency over training was found ($F(1,38)=2.82$, $p=.101$). This suggest that subjects' naming speed for these words was at their maximum, allowing no further progress. In contrast, latency of CCVCC words decreased significantly ($F(1,38)=14.61$, $p<.001$). In sum, latency on the complex CCVCC words decreased, whereas latency on the more simple CVC words did not. This points to converging curves of developments. Subsequently, the difference in naming latency between CVC and CCVCC words was calculated for each training block and entered in an analysis of variance with Time (4) as within-subjects factor. A main effect of Time was found ($F(1,41)=10.96$, $p<.01$). The difference became smaller as training progressed, providing further evidence for converging development for words of different orthographical structures.

Figure 2.4 suggests that, in contrast to words, all pseudowords seemed to benefit equally from training, irrespective of orthographical complexity. This was tested by analyses within orthographical structures. Latencies on pseudowords of both the CVC and the CCVCC type were declining ($F(1,38)=18.93$, $p<.001$, and $F(1,38)=16.64$, $p<.001$, respectively). In order to test whether the observed improvement was parallel, difference in latency between CCVCC and CVC pseudowords was calculated for each block and entered in an analysis of variance with Time (4) as within-subjects factor. The effect of Time was not significant ($F(1,41)=2.47$, $p=.124$), thus providing evidence for a parallel decrease in response latency of both orthographical structures.

Accuracy: The number of words and pseudowords read correctly were submitted to an analysis of variance with Exposure Duration (2) and Response Speeding (2) as between-subjects factors. Time (4 training blocks) and Lexical Status (words and pseudowords) were tested within subjects. Number of words and pseudowords correct, collapsed across orthographical structure, are shown in Figures 2.5 and 2.6, respectively.





led-rs: Limited Exposure Duration and Response Speeding
ued-rs: Unlimited Exposure Duration and Response Speeding
led-nrs: Limited Exposure Duration and No Response Speeding
ued-nrs: Unlimited Exposure Duration and No Response Speeding

Figure 2.5: Number of words correct for both levels of the factors Exposure Duration and Response Speeding, collapsed across orthographical structure.

Figure 2.6: Number of pseudowords correct for both levels of the factors Exposure Duration and Response Speeding, collapsed across orthographical structure.

Pseudowords were harder to read than words, indicated by a main effect of Lexical Status ($F(1,38)=358.93$, $p<.001$). Children improved their accuracy during training, indicated by a main effect of Time ($F(3,36)=38.95$, $p<.001$). Performance on both words and pseudowords improved during training ($F(1,38)=102.5$, $p<.001$, and $F(1,38)=102.0$, $p<.001$), but the improvement was larger for pseudowords than for words, indicated by a significant Lexical Status by Time interaction ($F(3,36)=4.78$, $p<.01$).

A main effect of Exposure Duration was found ($F(1,38)=52.3$, $p<.001$). Children in training programs with limited exposure duration identified fewer words correctly than children receiving a training in which exposure duration was unlimited. Furthermore, the number of words correct for these two groups was related to lexical status, as indicated by an interaction between Exposure Duration and Lexical Status ($F(1,38)=125.97$, $p<.001$). The difference between pseudowords and words was much larger for the limited exposure duration group than for the unlimited exposure duration group. The interaction between Exposure Duration and Time was also significant ($F(3,36)=11.77$, $p<.001$), indicating that children in the limited exposure duration condition were able to improve their performance to a greater extent than children in the unlimited exposure duration condition. It must be noted that the latter group, having already identified many words and pseudowords correctly at the start of training, had less opportunity to improve their accuracy than children of the limited exposure duration group. The interaction between Response Speeding and Time was not significant ($F<1$), indicating that response speeding had no effect on the development of accuracy during training.

The effects of orthographical structure and lexical status (words and pseudowords) on accuracy were also investigated. The number of words correct for all four orthographical structures of both words and pseudowords were entered in an analysis of variance with Orthographical Structure (4), Lexical Status (2), and Time (4 training blocks), as within-subjects effects. Figures 2.7 and 2.8 show the development of number correct, collapsed across training groups, for each of the orthographical structures for words and pseudowords, respectively.

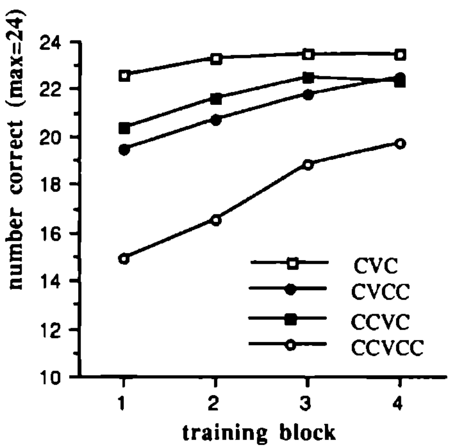


Figure 2.7: Number of words correct, split by orthographical structure and collapsed across training groups.

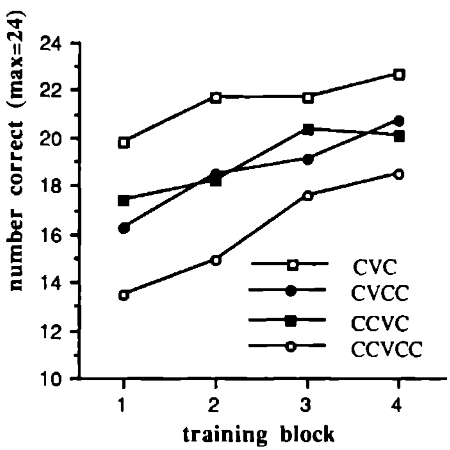


Figure 2.8: Number of pseudowords correct, split by orthographical structure and collapsed across training groups.

Words and pseudowords with a more complex orthographical structure were harder to read than the more simple ones, as demonstrated by a main effect of Orthographical Structure

($F(3,36)=104.37$, $p<.001$). The difference in accuracy between orthographical structures was larger for words than for pseudowords, indicated by an interaction between Orthographical Structure and Lexical Status ($F(3,36)=10.81$, $p<.001$). The interaction between Orthographical Structure and Time, as well as the three-way interaction between Lexical Status, Orthographical Structure, and Time were significant ($F(9,30)=20.76$, $p<.001$, and $F(9,30)=6.31$, $p<.05$, respectively). This suggests that the increase in number correct during training was not the same for all orthographical structures, and that the development of number correct for the orthographical structures had different courses for words and pseudowords. Words of the CVC type were identified correctly by most of the subjects at the onset of training. This was not found, however, for pseudowords of the CVC type. The significant three-way interaction is likely to be the result of near-ceiling performance on the more simple words at the beginning of training.

Discussion

This study investigated the effects of limited exposure duration and response pressure in training on poor readers' word processing skills. Effects were measured by three pre- and posttests as well as by the development of reading performance during training itself. The ability to read words in isolation was measured by the Eén-Minuut-Test. Subjects improved their number of words correct with 26% (six words) from pre- to posttest. This improvement is quite substantial. It equals the progress that 'normal' subjects of this reading level make in three months. However, the observed improvement was the same for all training groups. The two forms of time pressure had no differentiating effect with respect to this variable. A similar finding was observed with respect to the ability of reading words in the context of sentences, measured by the Differentiële Zinnen Leestest. Again, subjects improved their performance substantially from pre- to posttest (16%). However, once more, the different forms of training produced similar progress with respect to this variable. How should these results be interpreted? It seems obvious to conclude that word identification processes were not affected by type of training. This would be consistent with the obtained result that all groups performed similarly with respect to reading tests that measure word identification skill. However, it might also be argued that the question whether the training programs had a differentiating effect on word identification processes can not be resolved with the current data because the utilized tests may have been too insensitive to detect subtle between-group contrasts. An arguments for this latter position is put forward here. Both reading tests employ a continuous list procedure, whereby subjects read a series of sentences or isolated words. The number of words read correctly within a certain time span is counted. The measure obtained from such a procedure is likely to be partly determined by various sequential-response, scanning, and motor-production strategies that subjects may adopt (Perfetti, Finger & Hogaboam, 1978; Spring & Davis, 1988; Stanovich, 1981; Wolf, 1991). It may well be that the variance of the measures obtained from the reading tasks included too many reading-irrelevant processing components to detect subtle differences between training groups on word identification skill. Tasks employing a discrete trial procedure, in which the reaction time to each stimulus is determined separately, may be better suited for this purpose.

Prior to training, neither words nor pseudowords induced interference with subjects' picture naming. After training however, such interference was found. The training programs differed with respect to the increase in interference obtained with the picture-word interference task. Children trained in word and pseudoword reading under conditions of limited exposure duration showed an increase in interference from words and pseudowords on picture naming. This was not found for the unlimited exposure duration groups. Furthermore, the amount of interference induced by words and pseudowords was not differentially affected by training under speeded or unspeeded response conditions. The interference induced by words and pseudowords on subjects' picture naming is commonly interpreted as the result of automatic processing of words and pseudowords (e.g. Ehri & Wilce; 1983). A phonological code of the distractor becomes available automatically. The output channel is provided with two different responses, the name of the word and the name of the picture, of which the first has to be rejected. This causes a delay. The interfering phonological code may either be assembled through the application of GPC rules (decoding), or, in case of high-frequency words, retrieved directly from memory. The increase in interference found in this study is attributed to improved decoding efficiency, and not to improved speed of retrieving phonological codes from memory. There are two arguments for this position. First, forming a phonological code of a pseudoword necessarily involves decoding, and the increase in interference induced by pseudowords was significant. Second, words and pseudowords were shown only once during training. It may be considered very unlikely that children acquired complete representations after one exposure. The question why limiting the exposure duration during training has a positive effect on automaticity of decoding processes can not be settled with the present data. A possibility is that limited exposure duration induces the reader to scan the entire word or pseudoword in order to select the letters or letter combinations that form the most efficient input for decoding processes. Baddeley (1986) suggests that this would allow the reader to spot features such as double vowels that affects the way earlier items should be pronounced (p.222). It may also be that limited exposure duration encourages chunking of vowels and consonant(s). Children may group the vowel plus final consonant(s) together (Glushko, 1979; Goswami, 1986; Patterson & Morton, 1985; Treiman & Chafetz, 1987; Wise, Olson, & Treiman, 1990), or, instead, group the initial consonant(s) plus vowel (Fayne & Bryant, 1981; Kay, 1987). However, as mentioned earlier, the present data do not allow conclusions with respect to the mechanism(s) that underlie the increased automaticity of decoding processes. They merely show that a training procedure under conditions of limited exposure duration produces such an outcome.

Results with respect to performance in the training tasks itself will be discussed next. In order to investigate whether processes of response production were affected by training, subjects were required to name a series of digits at each session. Children of this age can be expected to recognize digits fast and automatically (Ehri & Wilce, 1983). This is supported by a short over-all digit naming latency of 596 ms. That is approximately 100 ms less than reported in studies by Perfetti, Finger and Hogaboam (1978) and Ehri and Wilce (1983). The high digit naming speed, together with the near-perfect accuracy, are in support of the assumption that children had no problems with digit identification. Therefore, digit naming latency is assumed to consist primarily of processing components that concern response production.
Of central interest is whether digit naming speed was improved by training. If not, this would indicate that a possible improvement in word and pseudoword naming speed may be attributed to processes preceding the phase of actual vocalization. The results showed no progress in digit naming speed. The conclusion that processes of response production were not affected by training may be premature however, as we will argue now. Although digit naming may be appropriate to measure processes of vocalization, there are arguments for questioning it as a control for articulatory programming. In discussions on naming tasks, authors generally make a distinction between an abstract phonological representation and an articulatory program (e.g. Gough, 1984; Henderson, 1982, p.179; Levelt, 1989, chapter 11). For the pronunciation of unfamiliar stimuli, it is indeed likely that articulatory programming takes place after word phonology is retrieved from the lexicon or assembled through decoding rules. However, for highly overlearned stimuli, such as high-frequency words and digits, the lexicon may very well include a more or less complete speech program. The contribution of articulatory programming to digit naming latency may have been small because complete speech programs were retrieved from memory. In that respect, digit naming differs from word naming, and from pseudoword naming especially. Thus, results on digit naming may not fully exclude the possibility that components involving articulatory programming were affected by training.

In order to compare the different forms of training, the development of performance on reading words and pseudowords during training was examined. Results of naming speed will be discussed first. Similar word and pseudoword naming latencies were obtained, irrespective whether the exposure duration was limited or not. Neither did this form of time pressure affect the development of naming latency during training. The instruction to respond as fast as possible produced much shorter response latencies than when no such instruction was given. However, the development of naming speed during training was not affected by response speeding. Apparently, naming speed can be influenced by emphasizing a fast response but the profit of training on reading speed was not differentially affected by either form of time pressure.

The observation that progress tended to be larger for pseudowords than for words suggests that decoding skill had improved. Improved decoding should affect performance on pseudowords more than on words, because pseudoword reading requires complete phonological decoding, whereas lexical factors may be involved in the recognition of familiar words. Furthermore, all words and pseudowords were presented only once. Consequently, progress can not be the result of increased familiarity with individual words and pseudowords.

Naming latency was related to number of phonemes. A response to a long word or pseudoword took more time than a response to a short word or pseudoword. At the same time, children became faster in naming words and pseudowords. For *pseudowords*, the improvement was not affected by the number of phonemes. The improvement in naming speed was equal for short and long pseudowords. This result is in agreement with a small scale study by van Bon, van Kessel, and Kortenhorst (1987). They also found equivalent progress for pseudowords of different length. These results seem to be in conflict with the idea of improved skill in grapheme-phoneme decoding. According to this notion, progress should be larger for long, than for short pseudowords, because reading long pseudowords requires more grapheme-phoneme decoding. In addition, for long pseudowords, the successive construction of a phonological code requires blending of more phonemes.
The progress in *word* naming speed, as opposed to progress in pseudoword naming speed, was related to the number of phonemes. Naming speed improved on the more complex CCVCC words, but not on the simple CVC words. The complex CCVCC words had a much lower printed frequency count than the CVC words. It is likely that subjects read the complex words through phonological decoding. In contrast, many of the short words were familiar to the subjects and may therefore have been recognized directly on their orthographical pattern, without phonological decoding. Thus, our position is that *all* pseudowords were phonologically decoded, whereas in word reading, the complex words were phonologically decoded and some of the more simple words were recognized directly. Because word identification through direct recognition is assumed to be faster than through phonological decoding, our position predicts that the differences in naming speed between orthographical structures should be larger for words than for pseudowords. This is exactly what we found. It is concluded that pseudowords are more appropriate than words for studying the nature of progress in decoding speed, because it is more likely that reading pseudowords involves decoding.

The observation that progress was length independent raises questions about the concept of decoding as a process of one-to-one mapping of graphemes and phonemes. It raises the issue whether larger units than individual graphemes and phonemes are involved in the decoding process. If children would process pseudowords of different length, counted in grapheme-phoneme units, in a fixed number of larger subword units, (e.g. by clustering consonants), then this might account for the parallel progress of naming speed. The issue whether decoding processes operate on larger subword units than individual graphemes and phonemes receives attention in chapter 3.

It is also conceivable that not decoding, but an other component of naming accounts for the length independent progress. Some researchers argue that poor readers have difficulty in organizing and executing articulatory plans (Baddeley, 1986; Spring & Capps, 1974; Underwood & Briggs, 1984). The results on digit naming speed make it unlikely that training affected the execution of articulatory plans. However, training may have improved the ability to organize articulatory plans (articulatory programming). As we argued earlier, this possibility is not ruled out by the results on digit naming speed. Under the assumption that training had a positive effect on articulatory programming, the length independent progress may be explained as follows. The over-all length effect would be explained by differences in decoding time, and the length independent improvement would be the result of progress in articulatory programming. This line of reasoning however requires evidence that articulatory programming of monosyllabic words is not affected by the number of phonemes involved. These issues receive further attention in chapter 4.

Results regarding accuracy in word and pseudoword reading will be discussed next. They have to be interpreted with caution due to near-ceiling performance on some word types. All groups improved on both words and pseudowords. The result that the limited exposure duration groups showed larger gains in accuracy is most likely to be the consequence of lower starting levels. The unlimited exposure duration groups had less opportunity to improve their accuracy because they already identified many words and pseudowords correctly at the start of training. The instruction to respond as fast as possible had no effect on the development of accuracy.

Once again, the difference in accuracy between orthographical structures was larger for words than for pseudowords, supporting the conclusion that some short words may have been recognized directly, whereas reading pseudowords always involved decoding.

Accuracy was related to number of phonemes. Short words and pseudowords were read correctly more often than longer words and pseudowords. This is in accordance with results on the latency variable. This time however, progress was related to length counted in graphemes. As Figures 2.7 and 2.8 show, the development in accuracy was more parallel for pseudowords than for words. The differential effect in accuracy for long and short words may simply be the result of a near-ceiling performance on short words. Substantial improvement on short words was hardly possible. This may have introduced the interaction effect.

The main purpose of this first experiment was to collect empirical evidence on the effects of two different forms of time pressure in word training. The most effective form of time pressure during training will be studied more extensively in a second training experiment. The combined results of all dependent variables do not unambiguously favor one of the investigated training procedures. Performance on the word and sentence reading tasks, administered in pre- and posttest, was similar for all groups. In addition, the development of performance on the training task itself did not single out one training procedure either. However, an important finding was that training in reading briefly presented words and pseudowords increased interference in a picture-word interference task. This result was interpreted to indicate that decoding processes were executed more automatically after training. It has been emphasized that processing printed words automatically is very important for the acquisition of reading skill (Ehri, 1987; LaBerge & Samuels, 1974). In that respect, this finding is significant. The other investigated factor of time pressure upon word processing, response speeding, yielded no significant differentiating effect on any of the measures of progress. Therefore, in the second training study, the effects of limiting exposure duration is examined more closely. Pressure upon response production is discarded as experimental manipulation in that study.

A number of methodological issues regarding the design of a word and pseudoword training experiment will be discussed. First, the observed progress from pre- to posttest on the reading tests was quite impressive. It suggests that a training in reading isolated words and pseudowords may lead to substantial improvement in word identification. However, the experimental design lacked a control group that received no training. The conclusion that word identification skills were improved as a result of training can therefore not be made. Adding a control group to the design is advised.

Second, a standard exposure duration was determined individually for each subject that participated in a training under conditions of limited exposure duration. This standard exposure duration was used throughout the entire program. Children improved their accuracy drastically in the first training sessions. Apparently, the effects of limiting exposure duration on accuracy diminished as training progressed. Whether there was still time pressure at later stages of training is questionable. A procedure that keeps the amount of time pressure upon word processing constant across training should be better for studying the effects of limited exposure duration.

Third, the amount of practice was limited to 24 words and 24 pseudowords per session. The entire program consisted of reading 432 words and 432 pseudowords within a nine-week period. In comparison with most other training studies this is a fair amount of practice. However, it may still be too little to expect a significant increase in word processing skill. More practice is recommended for future training studies.

Fourth, providing feedback seemed to have little impact on childrens' reading attitude, and it may be questioned whether children actually used the provided feedback on reading errors to enrich their grapheme-phoneme knowledge. It has been argued that improvement in word recognition is primarily established by decoding success. A successfully decoded word has the function of a 'self-teaching mechanism' (Jorm & Share, 1983) in the sense that this enables the reader to increase the quality of grapheme-phoneme knowledge. Thus, children learn primarily of learning trials with a positive outcome, not from failures. From a practical point of view, providing corrective feedback was extremely time consuming. This reduced the available time for practice in reading. A reduction in the amount of feedback in favor of practice in reading is recommended for a next experiment.

Fifth, performance on words and pseudowords of the CVC type were near ceiling level. Apparently, children of this reading level were able to identify most of these words successfully. These words may be less suited as practice material, because children were unable to improve their performance on these words.

Sixth, the observed progress in this study was attributed to improved decoding. If the goal of training is improving decoding skills, then pseudowords are of greater value in practicing these skills than words. The exclusive use of pseudowords in this type of training seems justified.

2.2 A Second Study on Limited Exposure Duration in Word Training

The first training study showed that a training in word and pseudoword reading under conditions of limited exposure duration had a beneficial effect on poor readers' phonological decoding skills. Such a training produced a significant increase in interference from words and pseudowords on picture naming. This was interpreted to indicate that decoding processes were executed more automatically after training. No positive effects of limited exposure duration on standard reading tests were obtained, however. It was speculated that these tests may haven been too insensitive for detecting subtle differences between training conditions. Furthermore, the results on pre- and posttests revealed that children improved their reading performance quite substantially. The conclusion that this progress was the result of training could not be drawn because the experimental design did not include a control group that did not receive training.

In this second training study, research on the effects of limited exposure duration on poor readers' word processing skills was continued. The purpose of this study was to investigate whether a training in pseudoword reading under conditions of limited exposure duration was more beneficial than a training with unlimited exposure duration. The procedure for realizing limited exposure duration during training was improved. Experimental tasks were developed that should be better at detecting training effects. Furthermore, a control group was included in the experimental setup in order to investigate the training's efficiency and assess its value for remedial practice.

Subjects were selected in the same fashion as in the first experiment. Children of circa 9-12 years old that attended schools for special education participated in this study. Teachers were asked to select children that were approximately 1-2 years behind in reading development. Subsequently, a VC pseudoword naming task (described in the first study) was administered. Children that were able to read most of the VC pseudowords correctly were selected to participate in training. Subjects were assigned to one of three conditions: a training program with limited exposure duration (labeled as Flash Card group), a training program with unlimited exposure duration (labeled as Reading Aloud group), and a control group that received no training (labeled as No Training group).

Again, the training procedure was similar to a standard naming task: single pseudowords were presented on a computer monitor screen. The task of the child was to read them aloud. In the first training study, a limited exposure duration was determined prior to training for each subject individually. This duration was not changed during the training program. A new procedure was developed in which exposure duration was continually adjusted in order to maintain a constant level of accuracy. After each trial, accuracy of the current pseudoword, together with the previous two pseudowords, was evaluated. Exposure duration was increased when two or more errors were made, and was decreased if no errors were made. If two out of three pseudowords had been read correctly, exposure duration remained unchanged. In this manner, the accuracy rate was maintained at a constant level of approximately 67%.

The goal of this training program was to improve poor readers' decoding skills through extensive practice in pseudoword reading. Pseudowords, rather than words, were chosen as practice materials because reading pseudowords compels to phonological decoding. However, lexical facilitation may play a role in pseudoword reading also. It has been shown that pseudowords that are one grapheme different from familiar words were read more easily than pseudowords that are two graphemes different (Pring & Snowling, 1986; Stanners & Forbach, 1973). This effect was particularly salient for poor readers. Pring and Snowling attribute this effect to autonomously consulting the orthographic lexicon to facilitate reading. In order to discourage a strategy based upon a similarity in orthographic features between pseudowords and familiar words, and to enforce complete phonological decoding, pseudowords that were orthographically dissimilar to high-frequency words were selected. This should reduce pseudoword reading through orthographic analogies with familiar words to a minimum. A pseudoword was considered similar to a word if it differed from it in only one letter position. In order to prevent the construction of a set of highly peculiar pseudowords, pseudowords were selected in such a fashion that their positional grapheme frequency matched the positional grapheme frequency of monosyllabic Dutch words (Bakker, 1972). Thus, pseudowords were dissimilar to individual high-frequency words, but were similar to words with respect to the distribution of graphemes. Pseudowords were of three orthographical structures, CVCC, CCVC and CCVCC. The first training study showed that children, with regard to accuracy and latency, performed similarly on naming CVCC and CCVC pseudowords (see Figures 2.3, 2.4, 2.7, and 2.8). Therefore, in this study, CVCC and CCVC pseudowords were classed as one.

The ability to utilize information of prior experience is of interest for the development of word recognition skills. Poor readers may fail to benefit from decoding individual words. By varying the experience with a pseudoword, it is possible to determine whether poor readers are making use of information acquired in earlier presentations. The assumption of repeated presentations is that word experience can be simulated with pseudowords. The intention was to provide systematic exposure to pseudowords and to observe the effects on reading performance on posttests and training task Pseudowords were presented one, four, or eight times during training

Groups were compared with respect to their effects on reading performance measured by four pre- and posttests A picture-word interference task was used to investigate whether automaticity of word and pseudoword processing was affected Due to organizational circumstances, a new picture-word interference task had to be developed A word reading task and a pseudoword reading task were administered In order to investigate the effects of a possible improvement in decoding skills on text comprehension, a sentence verification task was included as pre- and posttest In this task, a sentence would appear on the screen Subjects were to indicate, by pressing a button, whether the sentence was semantically correct or incorrect The strong version of the verbal efficiency model (see §1 1) predicts that progress in decoding should be sufficient for improvement in text comprehension All tasks employed a discrete trial procedure, in which the reaction time to each stimulus was determined separately Effects of training were also investigated by the development of the dependent measures during training Effects of repeated presentations were examined through the development of measures recorded during training, and by including a sample of repeatedly presented pseudowords in the picture-word interference task and the pseudoword reading task

Method

Subjects

Children qualified by their teachers as 'poor readers' were selected from two schools for special education In order to test whether subjects had acquired elementary knowledge of grapheme-phoneme correspondences, a list of 34 VC pseudowords was administered The list contained all vowels used in training, as well as all legitimate final consonants in Dutch The list can be found in Appendix 2 1 Subjects were required to read the pseudowords aloud. Children that were able to read the VC pseudowords correctly were allowed to participate in the experiment A total of 62 children (43 boys, 19 girls), met this criterion Their age ranged from 7,8 to 12,8 years, with a mean of 9,11 years (SD=13 months) The reading methods used by the schools are primarily based upon a phonics approach of reading instruction

Design

This study employed a pretest-training-posttest design Two experimental groups received a training in pseudoword processing a Flash Card group and a Reading Aloud group A third group served as control and received No Training The subjects of this latter group participated in pre- and posttests only. The subject sample was divided in three groups, matched on two pretest measures: (a) accuracy in pseudoword naming, and (b) automaticity of pseudoword decoding. Two groups consisted of 21 subjects, one group of 20 subjects. Assignment of groups to experimental condition was random. Effects of training on reading skill were assessed by four pre- and posttests. Performance during training itself was also studied.

Apparatus

An Apple IIGS computer was used. Pseudowords were presented in black, lower case letters on a white background in the center of the screen. A four-letter string measured approximately 3 by 0.7 cm. Children were seated approximately 60-80 centimeter from the screen. A letter font used in many educational text books was chosen. Naming latencies were measured by a voice-activated relay attached to the computer. Sentence verification latencies were recorded by means of a device with two buttons (a yes- and a no-button), which was also connected to the computer. Latencies were measured accurately to the millisecond.

Training

Materials: Monosyllabic pseudowords with one and two consonant clusters were used. The single-cluster pseudowords were of the CVCC and the CCVC type, and the double-cluster pseudowords were of the CCVCC type. The pseudowords used in training were orthographically dissimilar to high-frequency words. Orthographically dissimilar in this respect was defined as: 'no frequent word can be made by replacing one grapheme of the pseudoword by any other grapheme'. Frequent words were defined as words with a printed frequency count of more than five per million (Staphorsius et al., 1989). Furthermore, the positional grapheme frequency in the pseudowords matched the positional grapheme frequency of monosyllabic Dutch words (Bakker, 1972).
These criteria for selecting pseudowords ensured that they had the appearance of 'normal' words but were nevertheless orthographically dissimilar to high-frequency words. Three lists were constructed, consisting of 422 CVCC, 196 CCVC, and 386 CCVCC pseudowords, respectively. The lists can be found in Appendix 2.7.

Procedure.

General: The training programs consisted of 16 training sessions of approximately 25 minutes each. Subjects practiced individually twice a week, for eight weeks in total. In each session 96 pseudowords were presented, one at a time. Presentation order within sessions was randomized. The training program consisted of 176 CVCC, 176 CCVC and 352 CCVCC pseudowords. These pseudowords were, for each subject, randomly selected from the respective pseudoword files. This reduces the risk of obtaining results confounded by word-specific effects. A factor Frequency of Presentation was included in the design.

Pseudowords were presented 1, 4, or 8 times during the program. Successive presentations were spaced with equal intervals across the program. Thus, a pseudoword of the 'eight presentations' cell, reappeared every second session. Table 2.4 shows the number of pseudowords over the entire program, Table 2.5 shows the number of pseudowords per training session.

Table 2.4: Number of pseudowords of each Orthographical Structure and of each Frequency of Presentation across the training program

Frequency	Orthographical Structure					
	CVCC		CCVC		CCVCC	
	npw	npres	npw	npres	npw	npres
1	128	128	128	128	256	256
4	32	128	32	128	64	256
8	16	128	16	128	32	256
	176	384	176	384	352	768

Frequency: number of presentations per 16 sessions
npw: number of pseudowords
npres: number of presentations=frequency*npw

Table 2.5: Number of pseudowords of each Orthographical Structure and of each Frequency of Presentation within one training session

Frequency	Orthographical Structure		
	CVCC	CCVC	CCVCC
1	8	8	16
4	8	8	16
8	8	8	16
	24	24	48

Subjects were instructed to name the presented pseudoword. A maximum of 6.5 seconds was allowed for responding. Each trial started with a 50 ms beep, followed by an asterisk in the center of the screen. This served as fixation point and remained on the screen for 500 ms. Children were told to focus on the asterisk. The pseudoword appeared on the screen in the same location as the asterisk. Exposure duration of the pseudoword was dependent on the training condition (see below). The response latency was determined for each trial.

Latency was defined as the time between the onset of presentation and the verbal response of the subject. By pushing buttons on the keyboard the experimenter indicated whether the stimulus was identified correctly and whether the clock was stopped by the verbal response of the subject. In case of an incorrect response, the word FOUT [wrong], typed in blue colored capitals, was shown for one second. A correct response was followed by verbal approval of the experimenter, but no messages appeared on the monitor. At the end of each session, subjects received feedback about their performance (mean exposure duration for the Flash Card group, number correct for the Reading Aloud group) by the computer The feedback provided by the computer was taken over by children in diagrams. In this way, subjects were able to see whether they improved during the program. At the start of each session, the experimenter tried to motivate the children to improve their performance.

Flash Card Training: In the Flash Card program, reading was put under time-pressure. The task of the child was to name briefly presented pseudowords. As can be seen in Tables 2.4 and 2.5, the within-subjects design consisted of six cells (two levels of Orthographical Structure, and three levels of Frequency of Presentation). For each cell, the accuracy rate was maintained at a constant level by varying the exposure duration After each trial, accuracy of the current pseudoword, and the previous two pseudowords of the same cell (see Table 2.4), were evaluated. Exposure duration of pseudowords was increased with 17 ms when two or more errors were made, and was decreased with 17 ms if no errors were made. If two out of three pseudowords had been named correctly, exposure duration remained unchanged. In this way, the accuracy rate was maintained at a constant level of approximately 67%. In order to maintain the balance between accuracy rate and exposure duration across training sessions, each session started with the exposure durations with which the previous session had ended.
In order to determine an exposure duration that fitted a subject's capacity, a nil-session was held prior to training. Each subject started the nil-session with an exposure duration of 800 ms. The procedure was identical to the one used during training sessions, except for the fact that exposure duration was adjusted with intervals of 68, instead of 17 ms The first session of the training program started with the exposure duration with which the nil-session had ended. Pseudowords used in the nil-session were identical to the ones used in training with respect to orthographical structure and difficulty level. They did not return in training sessions, nor in pre- and posttests.
When exposure duration expired, the pseudoword was masked by non-letter symbols for 1.5 seconds. The mask remained on the screen until a response was given or until maximum trial-time had expired. The mean exposure duration (across all levels of frequency of presentation and orthographical structures) was calculated at the end of a session and presented as 'the time the subject needed to look at a word in order to identify it correctly'.

Reading Aloud Training: Exposure duration was unlimited in the Reading Aloud training (within the boundary of the maximum time available for each trial). Pseudowords were shown on the screen until the subject produced a verbal response that triggered the voice-key. At that moment the clock was stopped and the pseudoword was masked by non-letter symbols for 1.5 seconds. The number of pseudowords identified correctly was shown to the subject at the end of a session. Subjects participating in the Reading Aloud training also received a nil-session. The procedure was identical to the one used during training sessions.

Pre- and Posttests

Pseudoword Reading: A Pseudoword Reading task was used to assess whether accuracy and speed in pseudoword naming was affected by training in decoding. For the three levels of frequency of presentation (1, 4 and 8), 20 pseudowords were randomly selected from the training material. Twenty pseudowords that had not been presented during training, were added. Neither were these pseudowords used as distractor in the picture-word interference task. The 80 pseudowords in total (20 CVCC, 20 CCVC, and 40 CCVCC) were presented, one at a time, on a computer monitor screen. Subjects were instructed to read the pseudowords aloud, as accurately and quickly as possible. Each subject received a different randomization of the 80 trials. Exposure duration was unlimited. A maximum of 6.5 seconds was allowed for responding. Accuracy and response latencies were recorded.

Word Reading: A Word Reading task was used to assess whether a training in pseudoword decoding affected processing of words. Three word sets, of 54 CVCC, 54 CCVC and 76 CCVCC words respectively, were drawn from Staphorsius et al. (1989). All words had a printed frequency count of more than 50 occurrences per million. These word sets can be found in Appendix 2.8. For each subject, 16 CVCC, 16 CCVC, and 32 CCVCC words were randomly selected from these sets. The words were presented, one at a time, on a computer monitor screen. Subjects were instructed to read the words aloud, as accurately and quickly as possible. Each subject received a different randomization of the 64 trials. Exposure duration was unlimited. A maximum of 6.5 seconds was allowed for responding. Accuracy and response latencies were recorded.

Sentence Verification Task: A Sentence Verification task was used to assess the effects of training in decoding on text comprehension. Thirty semantically correct sentences (e.g. *kaas is geel* [cheese is yellow]) and ten semantically incorrect sentences (e.g. *een kat is een plant* [a cat is a plant]) were shown one-by-one, in random order, on the screen. Sentences consisted exclusively of frequent monosyllabic regular words. The sentences used for this task can be found in Appendix 2.9. The subjects' task was to indicate, by pressing a button, whether the sentence was correct or incorrect. Subjects were allowed to use their preferred hand at the *yes*-button. Furthermore, they were instructed to make their decision as fast as possible, without making mistakes. Each subject received a different randomization of the 40 trials. Exposure duration was unlimited. A maximum of 10 seconds was allowed for responding. Accuracy and response latencies were recorded.

Picture-Word Interference Task: A picture-word interference task was developed in order to measure changes in poor readers' automaticity of word and pseudoword processing as a result of training. This task was tested before it was employed for that purpose. Of central interest was whether the developed task was capable of demonstrating interference induced by words and pseudowords on normal readers' picture naming. A report of the development and subsequent testing of the picture-word interference task can be found in Appendix 2.10. The picture-word interference task used in pre- and posttest was similar to the tested task, but the tasks differed with respect to the selection of distractor triplets. In order to explore effects of repeated presentations during training on automaticity of pseudoword processing, pseudoword distractors were selected from the training material. The task required 48 pseudoword distractors. From all three levels of Frequency of Presentation (see Table 2.5), 16 pseudowords (4 CVCC, 4 CCVC, and 8 CCVCC) were randomly selected from the training material for each subject.
Word distractors were selected in the following manner: 54 CVCC, 54 CCVC and 76 CCVCC words were drawn from Staphorsius et al. (1989). All words had a printed frequency count of more than 50 occurrences per million. These words can be found in Appendix 2.8. Of these, 12 CVCC, 12 CCVC, and 24 CCVCC words were selected for each subject in such a fashion that the word distractor matched the pseudoword distractor in length, orthographical structure and initial consonant. None of the words were used as distractor in the picture-word interference task.
Finally, to each of the 48 word and pseudoword distractor couples, a consonant string was added, also matching in length and initial consonant.

Results

Pre- and Posttests

For all tasks, median latency and accuracy scores were calculated for each experimental within-subjects condition. Latencies of incorrect responses were not used. In addition, trials on which the response was correct but did not stop the timer, or on which the timer was stopped by a sound other than the response, were eliminated.
In order to eliminate between-groups differences prior to training, some analyses were carried out on adjusted posttest scores. The adjustment was being achieved through an

analysis of covariance with pretest performance serving as covariates. This procedure permits an evaluation of posttest differences, with differences in pretest performance levels statistically controlled. Using covariates in analyses of variance requires parallel slopes of regression of the covariate across all levels of the between-subject factor. Analyses revealed that this assumption was warranted for all dependent variables. Covariance adjustment may be expected to have a large impact on the size of the effect when the correlation between the dependent variable and covariate is high (Hand & Taylor, 1987, p.163). Correlations between pre- and posttest with respect to latency and accuracy are displayed in Table 2.6 and 2.7, respectively.

Table 2.6: Correlations between pre- and posttests on latency of dependent measures

Pretests	Posttests				
	PWI	WI	PWR	WR	SVT
PWI	.02	-.10	-.05	-.10	.05
WI	.00	.02	-.04	-.06	-.07
PWR	-.03	.07	.70 **	.60 **	.60 **
WR	-.04	-.00	.63 **	.76 **	.69 **
SVT	-.16	-.10	.47 **	.68 **	.80 **

PWI: Pseudoword interference
WI : Word interference
PWR: Pseudoword Reading
WR : Word Reading
SVT: Sentence Verification task (semantically correct sentences)
** p<.001

Table 2.7: Correlations between pre- and posttests on accuracy of dependent measures

Pretests	Posttests		
	PWR	WR	SVT
PWR	.48 **	.37 **	-.21
WR	.31 *	.38 **	.01
SVT	.03	.15	.16

PWR: Pseudoword Reading
WR : Word Reading
SVT: Sentence Verification task (semantically correct sentences)
** p<.001 * p<.05

Correlations were high for the word and pseudoword reading task The sentence verification task showed a high correlation for the latency variable, but not for the accuracy variable Finally, correlations with respect to word and pseudoword interference were low Each task was analyzed separately Pretest scores were included as covariates in all analyses of variance with exception of the analyses of word and pseudoword interference Analyses of variance were carried out with Treatment (3) as the between-subjects factor Planned comparisons were carried out between the Flash Card group and the Reading Aloud group, as well as between the Flash Card group and the No Training group

Pseudoword Reading: The percentage of pseudowords read correctly on the posttest was 81 The voice key was triggered by a sound other than the response of the subject in 8% of the observations The median naming latency was calculated across 76% of valid observations Median latency and number correct on the posttest were submitted to a multivariate analysis of variance with Treatment (3) as between-subjects factor, and Orthographical Structure (2) as within-subjects factors Pretest scores served as covariates Results with respect to pre- and posttest scores can be found in Appendix 2 12 Adjusted posttest means are displayed in Table 2 8

Table 2.8 Adjusted posttest means of number correct and naming latency (in ms) on Pseudoword Reading, split by Orthographical Structure

Group	CVCC/CCVC	CCVCC	*M*
	Number Correct (max=40)		
FC (n=20)	35 4	34 7	35 1
RA (n=21)	35 0	34 8	34 9
NT (n=21)	28 1	26 9	27 9
	Latency		
FC (n=20)	1826	2029	2018
RA (n=21)	2124	2428	2276
NT (n=21)	2021	2206	2114

FC Flash Card group RA Reading Aloud group NT No Training group

A main-effect of Treatment was found (F(4,112)=13 59, p< 001) Univariate results showed significant effects for latency as well as for accuracy (F(1,57)=4 7, p< 05 and F(1,57)=151, p< 001, respectively) The comparison between the Flash Card and the Reading Aloud group revealed that a training with limited exposure duration tended to result in shorter response latency (2018 versus 2276 ms, $F(1,57)=3.63$, $p<.07$), but no difference with respect to accuracy was found ($F<1$). The Flash Card group read more words correctly than the No Training group (35.1 versus 27.9, $F(1,57)=45.8$, $p<.001$). The difference in latency between these groups however, was not significant ($F(1,57)=1.6$, $p=.211$).

A main effect of Orthographical Structure ($F(2,56)=17.1$, $p<.001$) indicates that CCVCC pseudowords were harder to read than CVCC/CCVC pseudowords. Univariate analyses revealed that children responded faster to CCVC/CCVC pseudowords than to CCVCC pseudowords (1990 versus 2221 ms, $F(1,57)=34.6$, $p<.001$). They were however, equally accurate with respect to both orthographical structures ($F<1$). The interaction between Orthographical Structure and Treatment was not significant ($F<1$).

Of interest is the question whether repeated presentations of pseudowords during training enabled children to respond faster and more accurately to these pseudowords. Median latency and number correct on the posttest were submitted to a multivariate analysis of variance with Treatment (2) as between-subjects factor. Frequency of Presentation (8, 4, and 1 presentation(s) during training) and Orthographical Structure (2) were tested within subjects. Pretest scores served as covariates. The No Training group was excluded from this analysis. Results with respect to pre- and posttest scores can be found in Appendix 2.13. Adjusted posttest means are displayed in Table 2.9.
The three-way interaction between Treatment, Orthographical Structure, and Frequency of Presentation approached significance ($F(4,27)=2.59$, $p=.059$). Univariate analysis revealed that the beneficial effect of repeated presentation on naming latency for the Reading Aloud group was equally large for the CCVCC pseudowords as for the CVCC/CCVC pseudowords, whereas for the Flash Card group, repeated presentation had a beneficial effect on naming latency for CVCC/CCVC pseudowords, but not for CCVCC pseudowords ($F(1,30)=9.22$, $p<.01$). The interaction between Orthographical Structure and Frequency of Presentation was not significant ($F<1$). Furthermore, the interaction between Treatment and Frequency of Presentation approached significance ($F(4,27)=2.17$, $p=.076$). Univariate analyses demonstrated that the interaction approached significance for the accuracy variable ($F(2,66)=2.72$, $p=.073$). The beneficial effect of repeated presentations on accuracy tended to be larger for the Flash Card group than for the Reading Aloud group. No effect for the latency variable was found ($F<1$). Finally, a main effect of Frequency of Presentation was found ($F(4,27)=3.31$, $p<.05$). Univariate analysis demonstrated that repeated presentations had no effect on latency ($F<1$), but had a significant positive effect on accuracy ($F(2,66)=9.42$, $p<.001$). The nature of this effect was linear, indicated by a significant linear component ($F(1,30)=8.94$, $p<.01$). This suggests that the beneficial effect of repeated presentations on accuracy was not yet at its maximum with eight occurrences during training.

Table 2.9: Adjusted posttest means of number correct and naming latency (in ms) on Pseudoword Reading, split by Frequency of Presentation and Orthographical Structure

Group	Orth.struct	Frequency of Presentation			
		8	4	1	*M*
		Number Correct (max=10)			
FC (n=20)					
	CVCC/CCVC	9.43	9.06	8.26	8.92
	CCVCC	9.17	9.18	8.28	8.88
	M	9.30	9.12	8.27	8.90
RA (n=21)					
	CVCC/CCVC	9.29	9.06	9.18	8.88
	CCVCC	9.06	8.32	8.83	8.74
	M	9.18	8.47	8.65	8.77
		Latency			
FC(n=20)					
	CVCC/CCVC	1776	1931	2074	1927
	CCVCC	2321	2296	2179	2265
	M	2049	2114	2127	2097
RA (n=21)					
	CVCC/CCVC	2203	2094	2059	2119
	CCVCC	2262	2415	2525	2401
	M	2233	2255	2292	2260

FC: Flash Card group. RA: Reading Aloud group.

Word Reading: The percentage of words read correctly on the posttest was 89. The voice key was triggered by a sound other than the response of the subject in 8% of the observations. The median naming latency was calculated across 84% of valid observations. Median latency and number correct on the posttest were submitted to a multivariate analysis of variance with Treatment (3) as between-subjects factor, and Orthographical Structure (2) as within-subjects factors. Pretest scores served as covariates. Results with respect to pre- and posttest scores can be found in Appendix 2.14. Adjusted posttest means are displayed in Table 2.10.

A main-effect of Treatment was found ($F(4,110)=2.81$, $p<.05$). Univariate results showed that the three training groups tended to differ with respect to naming latency ($F(2,56)=3.09$,

Table 2.10: Adjusted posttest means of number correct and naming latency (in ms) on Word Reading, split by Orthographical Structure

Group	CVCC/CCVC	CCVCC	*M*
	Number Correct (max=32)		
FC (n=20)	30.1	28.7	29.4
RA (n=21)	29.8	28.9	29.3
NT (n=21)	29.2	27.4	28.3
	Latency		
FC (n=20)	1094	1462	1278
RA (n=21)	1278	1776	1527
NT (n=21)	1166	1442	1304

FC: Flash Card group. RA: Reading Aloud group. NT: No Training group

$p<.06$), but not with respect to accuracy ($F(2,56)=1.96$, $p=.150$). Planned comparisons showed that the Flash Card group was faster than the Reading Aloud group (1278 versus 1527 ms, $F(1,56)=5.27$, $p<.05$). They were however equally accurate ($F<1$). The Flash Card group tended to read more words correctly than the No Training group (29.4 versus 28.3, $F(1,56)=3.64$, $p=.062$), but they did not differ with respect to naming speed ($F<1$).

A main effect of Orthographical Structure ($F(2,55)=8.44$, $p<.01$) indicates that CCVCC words were harder to read than CVCC/CCVC words. Univariate analyses revealed that children responded faster, and were more accurate to CCVC/CCVC words than to CCVCC words (1179 versus 1560 ms, $F(1,56)=12.26$, $p<.01$, and 29.7 versus 28.3 words correct $F(1,56)=4.34$, $p<.05$). The interaction between Orthographical Structure and Treatment was not significant ($F<1$).

Sentence Verification Task: The median sentence verification latency was calculated across 93% of valid observations. Accuracy scores on the pretest were near ceiling-level for all three groups. Evidently, the children's reading level was sufficient to verify whether a sentence made sense. For this reason accuracy measures were dropped from further analyses. Median posttest latency of responding to true and false sentences were submitted to an analysis of variance with Treatment (3) as between-subjects factor, and Type of Sentence (2) as within-subjects factor. Pretest latencies served as covariates. Results with respect to pre- and posttest scores can be found in Appendix 2.15. Adjusted posttest latencies are displayed in Table 2.11.

Table 2.11: Adjusted posttest latency (in ms) of correct responses of the Sentence Verification task, split by semantically true and false sentences

Group	True sentences	False sentences
FC (n=20)	3619	4696
RA (n=21)	3893	5104
NT (n=21)	3815	4785

FC Flash Card group RA Reading Aloud group NT No Training group

The effect of Treatment was not significant ($F(2,57)=1\ 21$, $p=\ 306$) The planned comparisons between the Flash Card group and the Reading Aloud group, and between the Flash Card group and the No Training group were both non-significant ($F(1,57)=2\ 38$, $p=\ 128$, and $F<1$, respectively)
Children needed substantially more time to reject a semantically incorrect sentence than to accept a semantically correct one, indicated by a significant main-effect of Type of Sentence (4862 versus 3776 ms, $F(1,57)=7\ 13$, $p<\ 01$) No interaction with the between-subjects factor was found ($F<1$)

Picture-Word Interference Task: The percentage of pictures named correctly on the posttest was 95 The voice key was triggered by a sound other than the response of the subject in 7% of the observations The median naming latencies were calculated across 91% of valid observations The correlations between pre- and posttest were low for word and pseudoword interference (both $r=\ 02$, n s) The covariance adjustment may therefore be expected to have a minor impact on the effect sizes (Hand & Taylor, 1987, p 163) For this reason, pre- and posttests were analyzed separately Word interference and pseudoword interference on the pre- and posttest can be found in Table 2 12
First, it was investigated whether groups differed prior to training Pseudoword interference and word interference on the pretest were entered in analyses of variance with Treatment as between-subjects factor No effect of Treatment was found ($F<1$) The constant component of the pseudoword interference variable was not significant ($F<1$), indicating that children named pictures with superimposed pseudowords equally fast as pictures with consonants strings However, naming latency tended to be *shorter* for pictures with words than for pictures with consonant strings ($F(1,58)=2\ 79$, $p=\ 1$)

In order to test whether groups differed after training, analyses of variance were carried out with pseudoword and word interference as dependent variables and with Treatment (3) as between-subjects factor No effect of Treatment was found ($F<1$) The constant component of the pseudoword interference variable was not significant ($F<1$), indicating that training did not affect interference form pseudowords on picture naming Children were

Table 2.12: Pseudoword Interference (PWI) and Word Interference (WI) (in ms) on pre- and posttest for each group (*SD* in parenthesis)

Group		PWI		WI	
FC (n=20)	pretest	-7	(93)	-21	(81)
	posttest	2	(41)	-31	(66)
	difference	9		-10	
RA (n=21)	pretest	2	(69)	-4	(58)
	posttest	-15	(66)	-22	(55)
	difference	-17		-18	
NT (n=21)	pretest	9	(68)	-18	(58)
	posttest	7	(77)	-9	(79)
	difference	-2		-9	

FC: Flash Card group. RA: Reading Aloud group. NT: No Training group

20 milliseconds *faster* in naming pictures with words than naming pictures with consonant strings. This difference was significant ($F(1,59)=5.63$, $p<.05$). This outcome is rather peculiar and in contrast with the results obtained in the testing part of this task. It is unclear how this reversed interference effect should be interpreted. Of central interest however, is whether interference induced by words on picture naming changed from pre- to posttest. This question was addressed by calculating the difference between pre- and posttest in word interference and entering this variable in a new analysis of variance. The constant component was not significant ($F<1$), indicating that training did not affect word interference. In addition, no effect of Treatment was found ($F<1$), demonstrating that groups did not differ in that respect.

The question whether the number of exposures to a pseudoword during training affected the interference of that pseudoword on picture naming, was investigated by including frequency of presentation of the pseudoword distractor as a factor. The No Training group was excluded from this analysis. Posttest pseudoword interferences of each cell of the within-subjects design were submitted to an analysis of variance with Treatment (2) as between-subjects factor. Frequency of Presentation (3) and Orthographical Structure (2) were tested within-subjects. No main or interaction effects were found (all F's<1). The interference from pseudowords on picture naming latency was not affected by the number of presentations during training. Furthermore, orthographical structure was not related to pseudoword interference.

Training Data

Naming latency was determined for each experimental trial The voice key was triggered by a sound other than the response of the subject in 6% of the observations for the Flash Card group, and in 7% of the observations for the Reading Aloud group The Reading Aloud group read 87% of the pseudowords correctly, and the Flash Card group read 70% correctly The Flash Card group should, by definition, read 67% of the pseudowords correctly, but as children improved during training, this percentage was a little higher

For each subject, the median naming latency of each session was calculated Similarly, for each subject of the Flash Card group, the median exposure duration of each session was calculated, and for each subject of the Reading Aloud group, the number of correctly named pseudowords of each session was counted This was done for each cell of the within subjects design separately

The 16 training sessions were divided into four training blocks Thus, each training block consisted of four sessions Means were calculated for each training block These data were entered in analyses of variance in order to test whether a dependent variable was affected by training

Latency: In order to test whether training affected naming speed, pseudoword naming latencies were submitted to an analysis of variance with Treatment (2) as between-subjects factor Time (4 training blocks), Frequency of Presentation (3) and Orthographical Structure (2) were tested within subjects Over-all pseudoword naming latency for both training groups, collapsed across orthographical structure and frequency of presentation, is displayed in Figure 2 9

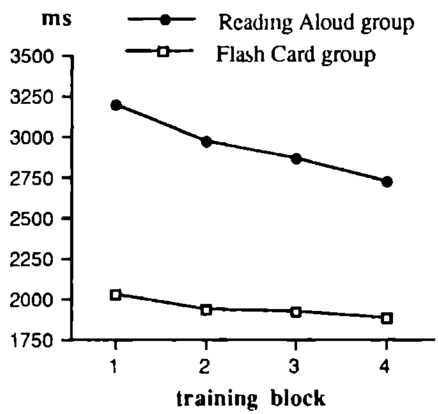


Figure 2.9 Pseudoword naming latency (in ms) for both training groups, collapsed across orthographical structure and frequency of presentation

Main effects of Treatment and Time were found ($F(1,39)=18.04$, $p<.001$, and $F(3,37)=6.44$, $p<.01$, respectively). The Flash Card group responded much faster than the Reading Aloud group. The main effect of Time indicates that naming speed increased over training. The improvement showed a linear trend, indicated by a significant linear component of the factor Time ($F(1,39)=18.39$, $p<.001$). The interaction between Treatment and that linear component of Time was also significant ($F(1,39)=5.15$, $p<.05$), indicating that the decline of response latency was steeper for the Reading Aloud group than for the Flash Card group.

The development of latency, split by *frequency of presentation*, and collapsed across orthographical structure and training groups, is shown in Figure 2.10.
Repeated presentations affected the speed with which pseudowords were named, indicated by a significant interaction between Time and Frequency of Presentation ($F(6,34)=2.89$, $p<.05$). The three-way interaction between Treatment, Frequency of Presentation, and Time was not significant ($F(6,34)=1.29$, $p=.288$) indicating that the beneficial effect of repeated presentations on naming latency was equal for both training groups.

The development of latency, split by *orthographical structure*, and collapsed across frequency of presentation and training groups, is shown in Figure 2.11.
A main effect of Orthographical Structure was found ($F(1,39)=84.86$, $p<.001$), indicating that subjects responded faster to CVCC/CCVC pseudowords than to CCVCC pseudowords. The interaction between Orthographical Structure and Treatment ($F(1,39)=12.64$, $p<.01$) reveals that the over-all difference between the orthographical structures was larger for the Reading Aloud group than for the Flash Card group (420 versus 187 msec, respectively). However, this difference remained stable throughout the

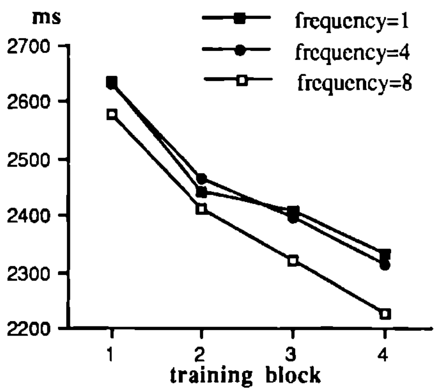


Figure 2.10: Pseudoword naming latency (in ms), split by frequency of presentation and collapsed across orthographical structure and training groups.

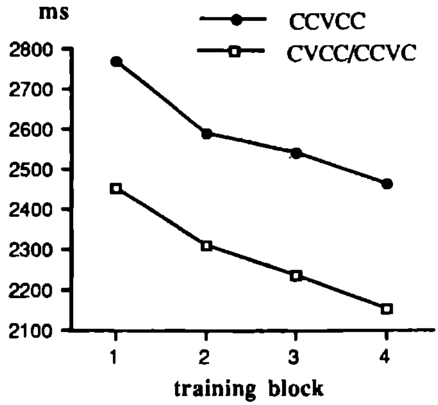


Figure 2.11: Pseudoword naming latency (in ms), split by orthographical structure and collapsed across frequency of presentation and training groups.

training program, indicated by a non-significant three-way interaction between Treatment, Orthographical Structure, and Time ($F(6,34)=1.80$, $p=.128$). The four-way interaction between Treatment, Frequency of Presentation, Orthographical Structure, and Time was not significant either ($F(6,34)=1.29$, $p=.288$). No interaction between Orthographical Structure and Time was obtained ($F<1$), indicating that the improvement in naming speed was equal for CVCC/CCVC and CCVCC pseudowords.

Exposure Duration (Flash Card group): In order to test whether training affected the required exposure duration, exposure durations were submitted to an analysis of variance with Time (4 training blocks), Frequency of Presentation (3), and Orthographical Structure (2) as within-subjects factors. The over-all exposure duration, required to identify 67% of the presented pseudowords correctly, decreased as the training program progressed, indicated by a significant effect of Time ($F(3,17)=54.31$, $p<.001$).

The development of exposure duration, split by *frequency of presentation* and collapsed across orthographical structure, is shown in Figure 2.12.

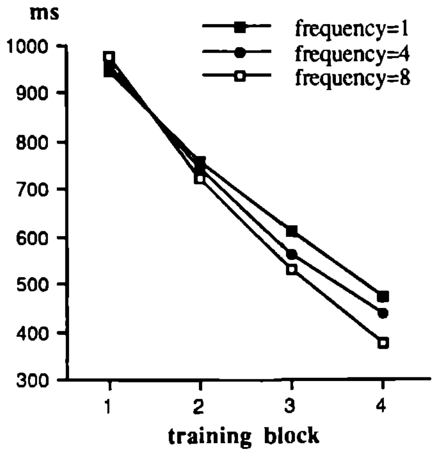


Figure 2.12: Exposure duration (in ms), split by frequency of presentation and collapsed across orthographical structure.

Repeated presentations of pseudowords reduced the required exposure duration on subsequent presentations, demonstrated by a significant interaction between Time and Frequency of Presentation ($F(6,14)=3.40$, $p<.05$). The beneficial effect of repeated presentations on the required exposure duration was not affected by orthographical structure, indicated by a non-significant three-way interaction between Time, Frequency of Presentation and Orthographical Structure ($F<1$).

The development of exposure duration, split by *orthographical structure*, and collapsed across frequency of presentation, is shown in Figure 2.13.

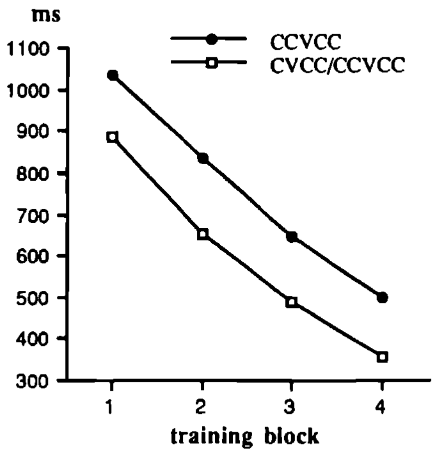


Figure 2.13: Exposure duration (in ms), split by orthographical structure and collapsed across frequency of presentation.

Naming a complex pseudowords required a longer over-all exposure duration than more simple pseudowords, demonstrated by a significant main effect of orthographical structure ($F(1,19)=10.93$, $p<.01$). However, no interaction between Orthographical Structure and Time was obtained ($F(3.17)=1.62$, $p=.222$), indicating that the decrease of exposure duration during training was not affected by orthographical structure.

Accuracy (Reading Aloud group): In order to test whether training affected accuracy, the number of pseudowords named correctly per training block were submitted to an analysis of variance. Time (4 training blocks), Frequency of Presentation (3), and Orthographical Structure (2) served as within-subjects factors. Children improved their accuracy during training, indicated by a main effect of Time ($F(3,18)=9.56$, $p<.001$).

The development of number correct, split by *frequency of presentation* and collapsed across orthographical structure, is shown in Figure 2.14.
Accuracy of pseudoword naming was not improved by presentations earlier in training, indicated by a non-significant interaction between Time and Frequency of Presentation ($F(6,15)=1.37$, $p=.287$). This is in contrast to latency and exposure duration data, which did show a positive effect of repeated presentations. The three-way interaction between Time, Frequency of Presentation, and Orthographical Structure was not significant either ($F<1$).

The development of accuracy, split by *orthographical structure*, and collapsed across frequency of presentation, is shown in Figure 2.15.

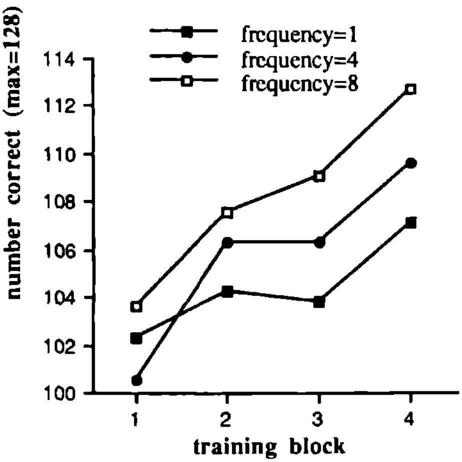


Figure 2.14: Number of pseudowords correct, split by frequency of presentation and collapsed across orthographical structure.

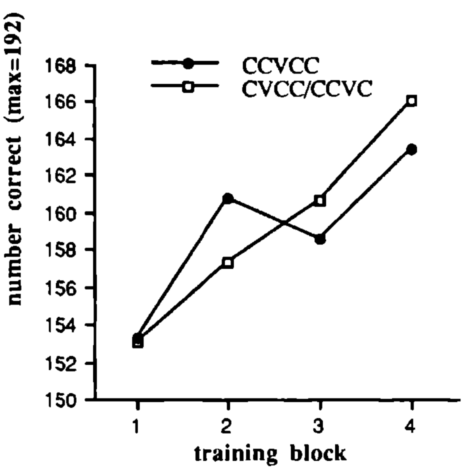


Figure 2.15: Number of pseudowords correct, split by orthographical structure and collapsed across frequency of presentation.

Subjects were, over-all, equally accurate on naming CVCC/CCVC as on naming CCVCC pseudowords, indicated by a non-significant main effect of Orthographical Structure ($F<1$). An interaction between Orthographical Structure and Time was found ($F(3,18)=3.70$,

$p<.05$). Inspection of Figure 2.15 suggests that the training effect was smaller for complex pseudowords than for orthographically more simple pseudowords.

Discussion

The over-all pattern of results suggests that a training in pseudoword decoding under conditions of limited exposure duration is more beneficial to word processing skills than a training without such time pressure. The efficiency of this type of training however, should not be overestimated. Comparisons between the Flash Card group and the No Training group produced significant results in favor of the Flash Card group on some of the dependent variables, but the size of the differences was generally small. Results with respect to pre- and posttests will be discussed first, followed by a discussion of results on the training task itself.

Results on the word reading task and the pseudoword reading task showed a similar pattern. The Flash Card group read more words and pseudowords correctly than the No Training group. They were however, equally fast. The higher accuracy of the Flash Card group is most likely the result of improved decoding skill as a result of training. The Flash Card group was faster than the Reading Aloud group at reading words, and tended to be faster at reading pseudowords. No difference between the training groups with respect to accuracy in word and pseudoword reading was found. The Reading Aloud group was remarkably slow. After eight weeks of training, they tended to be even slower than the No Training group with respect to reading words (223 ms) as well as pseudowords (162 ms). The fast processing of the Flash Card group, and the slow processing of the Reading Aloud group might be the consequence of the way they were trained. Reading pseudowords is an unconventional task. Pseudowords are also more difficult to read than words. Both groups were instructed to read as many pseudowords correctly as possible. However, at the end of each session, only the children of the Reading Aloud group received feedback with respect to accuracy (as a consequence of manipulating the exposure duration, the number correct of the Flash Card group was invariably 67%). The unlimited exposure duration of the Reading Aloud group provided sufficient processing time to achieve a maximum correct. This might have reinforced a strategy focusing upon accuracy at the expense of speed. However, the results on the pseudoword reading posttest demonstrate that they were not more accurate than the Flash Card group. Limiting the exposure duration during training may have produced other effects on reading strategy. At the end of each session, children of the Flash Card group were shown 'how much time they needed to look at a pseudoword in order to read it correctly'. Fast processing was required to cut this time down. Results on the pseudoword reading task of the posttest show that the Flash Card group produced faster responses than the Reading Aloud group, without loss in accuracy. Thus, limiting exposure duration might have induced children to allocate the available cognitive capacity more efficiently.

The verbal efficiency theory (Perfetti, 1985) states that comprehension is limited by verbal inefficiency. The strong version of the theory predicts that improvement in decoding should allow improvement in comprehension. Pseudoword reading is often used as a measure of phonological decoding ability (e.g. Perfetti, 1985, 1986). Over-all results on the pseudoword reading task suggest that the Flash Card group was better at decoding than the other two groups. With respect to the Sentence Verification task, the Flash Card group was 341 ms faster than the Reading Aloud group, and 142 ms faster than the No Training group. This is in support of the verbal efficiency theory. However, the observed differences were not statistically significant. Most likely, differences between groups in decoding ability were too small to obtain significant effects on sentence comprehension. Furthermore, results on this task showed high between-subjects and within-subjects variability. The time to decide whether a sentence made sense or not varied considerably from subject to subject and from sentence to sentence. Due to these factors, relatively large differences between means were not significant.

The first training study suggested that limiting exposure duration during training in word and pseudoword reading resulted in increased automaticity of word and pseudoword processing. In the second training study, we were unable to replicate this finding. No differential effects between groups were found with respect to word and pseudoword interference. No indication of interference induced by words or pseudowords on picture naming was found. In fact, the results on the pretest suggested that pictures with words tended to be named even *faster* than pictures with consonant strings (14 ms). At the posttest, a difference of 20 ms in the same direction was significant. It is unclear how this reversed interference effect should be interpreted. However, the effect did not change from pre- to posttest and was not differentially affected by training. Thus, limited exposure duration resulted in a significant increase in word and pseudoword interference in the first, but not in the second training study. What can be the cause of this inconsistency? The contradictory results may be the consequence of differences between the two employed picture-word interference tasks. The tasks differed in a number of aspects. Two of them will be discussed. Pictures were harder to recognize in the first than in the second picture-word interference task, suggested by shorter over-all naming latencies (898 vs. 868 ms, collapsed across distractor types and pre- and posttest). The line-drawings in the first task required longer visual processing than the more detailed pictures in the second task. Longer picture processing allows more time for decoding operations to commence. Interference of words and pseudowords may be less likely when pictures are easy to recognize. Subjects may be able to start picture naming before automatic decoding of the word or pseudoword has been initiated. The second difference between the two picture-word interference tasks concerns the presentation order of picture and distractor. In the first task, presentation of the distractor preceded the picture. In the second task, picture and distractor appeared simultaneously on the screen. For poor readers, an SOA between picture and distractor may increase the likelihood of finding interference effects, whereas this may have no effect for good readers Presumably, good readers initiate decoding faster than poor readers. Good readers may produce a phonological representation of the word or pseudoword before picture analysis is completed, whether the distractor is presented prior to the picture or not. This could explain why interference effects were found with third-grade normal readers when testing the second picture-word interference task. For poor readers on the other hand, asynchroneous presentation may be crucial for obtaining interference effects. A head start of the word or pseudoword in presentation onset may have initiated poor readers' decoding before picture analysis was completed. If however, picture and distractor are presented simultaneously, picture analysis may be completed before decoding of the word or pseudoword is initiated. In a sense, both differences between tasks refer to the argument that the second picture-word interference task provided insufficient opportunity for words and pseudowords to induce interference, at least with poor readers as subjects.

Results with respect to data collected during training will be discussed next Neither the Flash Card group nor the Reading Aloud group was instructed to respond quickly. Nevertheless, a large difference between training groups in naming latency was found. On the average, the Reading Aloud group was a full second slower than the Flash Card group Does limiting the exposure duration elicit fast responding? This question was addressed by comparing the reading speed under unspeeded response conditions (training) with the reading speed under speeded response conditions (pseudoword reading posttest). Recall that during the pseudoword reading posttest, subjects were instructed to read as quickly as possible. The difference in over-all reading speed between the last training block and the pseudoword reading posttest was relatively small for the Flash Card group (71 ms), and quite substantial for the Reading Aloud group (268 ms). Apparently, limited exposure duration elicits a fast response, whereas unlimited exposure duration does not

There is substantial agreement that phonological decoding skills are causally related to the development of reading ability (e.g. Bradley & Bryant, 1983; Dumont, 1984, 1990, Juel, 1988; Stanovich, 1982; Vellutino & Scanlon, 1987; Wagner & Torgesen, 1987). Poor readers have problems with identifying new and unfamiliar words because decoding requires much effort and often fails. Therefore, poor readers are supposed to have problems associating full and detailed descriptions of the phonological and orthographical attributes of words and store them as 'amalgamated' representations in long term memory (Ehri, 1980, Stanovich & West, 1989). It is often argued that the acquisition of amalgamated word representations is dependent on the competence in decoding (Jorm & Share, 1983, Perfetti, in press; Mitchell, 1982, p.184). In this respect, the effects of repetition are interesting It is important to note that subjects were not told that some pseudowords were presented more than once during training. They had the impression that each pseudoword was new. The interval between two successive presentations of a pseudoword was one week at minimum (every second session for eight presentations during training). The fact that some pseudowords were repeated should be hard to detect for naive subjects. Actually, no subject reported to notice the reoccurrence of pseudowords. Effects of repeated presentations on the posttest pseudoword reading task were investigated. Repeated reading of a pseudoword during training increased the probability that that pseudoword was read correctly on the posttest. This effect tended to be larger for the Flash Card group than for the Reading Aloud group. Repeated reading of pseudowords had no significant effect on the speed with which these words were read on the posttest. The effects of repeated presentations on performance during training was also investigated. The speed of naming pseudowords was affected by the number of presentations earlier in training. The beneficial effect of repeated presentations was equal for both training groups. Earlier presentations of pseudowords also affected the required exposure duration. Figure 2.12 shows that children needed less time for reading repeatedly presented pseudowords. With respect to accuracy however, no effect of repeated presentations was found. Earlier presentation of a pseudoword did not increase the probability that that pseudoword was read correctly at a later phase in training. Nevertheless, the combined results with respect to repeated presentations suggest that poor readers of this age were able to acquire pseudoword specific information and store it in long term memory. Questions with respect to the nature of this stored information remain unanswered. It is possible that subjects stored orthographical and phonological information of repeatedly presented pseudowords in the lexicon, which facilitated reading on successive presentations (see Ehri, 1980). It may also be that subjects stored articulatory programs of repeatedly presented pseudowords in long term memory. This should facilitate pronunciation when these pseudowords had to be read in a later phase (Balota & Chumbley, 1985). In other words, whether prior presentations facilitated recognition or response production is an issue that remains to be settled. The result that repeated presentations facilitated reading performance supports the view that a training in reading isolated words is a suitable task for the acquisition of word specific information (Ehri & Roberts, 1979; Juel, 1980; Hogaboam & Perfetti, 1978; Reitsma, 1983b).

The relation between orthographical structure and naming speed was also investigated. In the first study we found that over-all naming latency increased with length in terms of number of phonemes. The progress in naming speed, however, was not related to the number of phonemes. This finding was replicated in the present study. Once again, over-all naming latency was affected by length, but the observed improvement was not. In addition, the relation between progress in exposure duration and orthographical structure showed a similar pattern. Exposure duration was affected by number of phonemes. Children required a longer exposure duration to read a long pseudoword than to read a short pseudoword (approximately 300 ms longer). Once again, progress was independent of length. With respect to the development of accuracy however, progress was larger for long pseudowords than for short pseudowords. This is also in agreement with the results of the first training study.

The length independent progress in processing time, observed in training studies, seems to be a solid result. It is in conflict with the idea that training made children more proficient in grapheme-phoneme decoding, because this would predict progress to be larger for pseudowords consisting of more phonemes. Two possibilities have been proposed. First, decoding processes may operate on units exceeding the level of individual graphemes. This possibility will be investigated experimentally in chapter 3. Second, progress may not be the result of improved decoding, but of improved articulatory programming. This presupposes that speed of producing a speech program by articulatory programming is not affected by the number of phonemes. This second possibility will be investigated experimentally in chapter 4.

Finally, the issue of motivation can be raised. It might be argued that the Flash Card group performed better because they were more motivated. They received attention from the experimenter and were allowed to participate in a -presumably attractive- training. As a result, they may have been more eager to perform well on the posttest. However, the contribution of motivational aspects to performance may easily be exaggerated. A training in reading single pseudowords loses its attraction in a short time. The assumption that the No Training group in particular was motivated to perform well on the posttest because they were deprived of working with the computer for so long, and now finally had the chance to show what they were worth, makes more sense. However, the contribution of motivational aspects to performance can not be settled with the current data. It would require a fourth condition, in which pupils receive training in a skill that is irrelevant for reading performance. In the interpretation of results of the present study, motivational aspects had to be disregarded.

2.3 General Conclusions and Recommendations

The present studies warrant some conclusions regarding the effects of the investigated word training programs. Practice in word and pseudoword reading produces a substantial increase in naming speed. All of the words and pseudowords of the first experiment, and most of the pseudowords of the second experiment were shown only once. Thus, the progress in reading speed is not the result of increased familiarity with a limited set, but applies to all new words and pseudowords. The observation that digit naming speed did not change during training suggests that the progress in word and pseudoword naming speed is the result of improved decoding rather than of improved response production. Finally, progress in naming speed was obtained regardless whether the subjects were instructed to respond quickly or not. This may be taken as circumstantial evidence that the progress in reading speed was not the product of emphasis on this aspect of word identification.

The effects of two forms of time pressure during training were examined. The first study showed that pressure upon the child to respond quickly had no effect. In contrast, limiting exposure duration during training proved to be more effective than unlimited exposure duration. The first experiment showed that training in reading briefly presented words and pseudowords increased interference in a picture-word interference task, whereas a training with unlimited exposure duration did not. This could not be replicated in the second study. In the second study however, positive effects of limited exposure duration were obtained on other measures of word processing. It may be argued that the differences in favor of the group with limited exposure duration were fairly small and were observed in training-related tasks only. However, an important finding is that this type of training accomplished a progress in reading words and pseudowords not actually practiced. Many training programs succeed in improving reading performance on trained words, but generally fail to achieve a transfer to untrained words (see §1.3). The extensive practice in phonological decoding provided by the present studies resulted in improved identification of untrained words and pseudowords. As a result of practice, children decoded more accurately. This should enable them to *tune* their decoding procedures and increase their knowledge of letter-sound relations. Adequate decoding ability allows the reader to identify words without effort and acquire word specific knowledge. Successful decoding leads to the amalgamation of orthographic and phonological information in memory, and the amalgamated representation enables rapid and efficient access to the word in the lexicon. Accordingly, an improvement in decoding is important because it underlies an over-all progress in reading ability. In that respect, the results of the present training programs are significant, although the direct improvement in decoding ability is fairly small. These effects were obtained after eight weeks of training. Larger progress can be expected if children practice for longer periods of time.

The second study showed that training in pseudoword decoding is more effective under conditions of limited exposure duration than without time pressure. The procedure of varying the exposure duration as a function of accuracy proved to be an effective technique and should be easy to implement in remedial practice. In the present study, the accuracy criterion was set at 67%. As we argued earlier, children learn more from decoding success than from decoding failures. Therefore, positive effects of limiting exposure duration may be even larger if the accuracy criterion is set at a higher level, e.g. 90%.

If the goal of training is to improve decoding skills, then pseudowords may be better suited as practice materials than real words, because pseudoword reading compels decoding and minimizes the influence of context and lexical facilitation. Reading a pseudoword requires that the entire letter string is decoded whereas word reading may be facilitated by lexical factors. Thus, drill in phonological decoding is more likely to be realized by reading pseudowords than by reading words. However, a training that exclusively uses pseudowords might estrange children from the purpose of training. A proper remedial approach provides children with the opportunity to apply the knowledge and procedures acquired during training in more natural situations. Children ought to experience that an improvement in decoding ability through practice in pseudoword reading is beneficial to the recognition of words. For this reason, training in a remedial setting should not be limited to pseudowords only.

In the present studies, children were required to respond by reading aloud. The experimenter evaluated the verbal response of the child. It is not known whether the positive results of training are related to this reading aloud aspect. This is an important question because a precondition for drill in phonological decoding is that the child can practice on his own, without the need of a teacher. However, a reading aloud response can not be evaluated by a computer because spoken word recognition is not yet possible with the technology of today. Under the assumption that the positive effects of training are not dependent on the type of response, other response modalities may be used in remedial practice. Typing the briefly presented pseudowords on the computer keyboard is less suited because children might perform this task without actual decoding and blending. Children may produce a correct response by retrieving the series of letters from short-term memory. Furthermore, this technique is time devouring, allowing little time for practice in actual reading. A better method would be to remodel the naming task into a lexical decision procedure. The response in such a task would be very simple, just pressing one of two buttons. Besides pseudowords, the practice materials also includes words. A mixed presentation procedure is utilized. The task of the child is to press a *yes*-button if the letter string forms a word, and on the *no*-button if it does not. Alternative training procedures are discussed in the last section of chapter 5.

Chapter 3. Multi-Letter Units in Reading

3.0 Introduction

The present chapter addresses the problem of parallel progress in pseudoword naming speed during training in pseudoword reading. In both training studies described in chapter 2, naming latency was affected by the number of phonemes of words and pseudowords. However, the observed progress in naming speed was not. This result seems to be in conflict with the GPC view of phonological decoding. The dual-route theory (Coltheart, 1978) states that the translation of a pseudoword's orthography to its phonology is accomplished by the application of GPC rules. For each of the pseudoword's constituent graphemes, the associated phoneme is retrieved from long term memory. These phonemes are subsequently blended into a phonological representation. According to the GPC theory, improved decoding should have a larger impact on reading long-, than on short pseudowords, because reading long pseudowords requires more grapheme-phoneme decoding. However, three studies have demonstrated that naming speed to pseudowords of different length improved in parallel (see the training studies described in chapter 2; van Bon, van Kessel, & Kortenhorst, 1987). Therefore, we suggested that pseudoword reading might not be carried out in a grapheme-by-grapheme fashion, but might involve multi-grapheme units.

In contrast to the GPC view of decoding, recent models of word recognition propose that words are processed at a number of levels in parallel (e.g. Patterson & Morton, 1985; Perfetti, in press; Seidenberg & McClelland, 1989). Readers may access a variety of functional spelling units, ranging from individual letters to the entire word, depending on the subject's reading level, task demands, and word characteristics (Greenberg & Vellutino, 1988; Vellutino, 1982). Evidence that multi-letter units are sometimes involved in reading has been provided in experiments to the effects of number of letters on word naming latency. Naming long words takes longer than naming short words, but length effects tend to be larger for beginning readers (Samuels, LaBerge, & Bremer, 1978) and disabled readers (Manis, 1985; Seymour & Porpodas, 1980) compared with adult and skilled readers, respectively. This was interpreted to indicate that advanced readers process words in larger components (multi-letter units) than beginning and disabled readers and hence were less affected by increases in the number of letters.

It is likely that skilled readers process words and pseudowords in units exceeding the level of individual letters. However, there is no consent with respect to the nature of the multi-letter units. Several suggestions have been made. Gibson and Levin (1975) proposed the *spelling pattern*, Spoehr and Smith (1973) the *vocalic center group*, and Glushko (1979) the *orthographic neighbor*. Other authors believe that readers exploit the statistical regularities of orthography (such as frequently co-occurring letters). In that view, multi-letter units play a role, but there are no single perceptual units relevant to visual word identification (Adams, 1979, 1981; Seidenberg & McClelland, 1989).

Recently, Treiman (Treiman & Chafetz, 1987; Treiman & Zukowski, 1988; Wise, Olson, & Treiman, 1990) proposed that reading monosyllabic words involves processing of *onset* and *rime* units. The onset of a syllable is optional and contains, if present, its initial consonant(s). The rime is obligatory and consists of the vowel plus, if any, final consonant(s). For example, the onset of the word *start* is *st*, the rime is *art*. A similar model for processing monosyllabic words has been proposed by Patterson and Morton (1985). The experiments in the present chapter will be discussed in the light of Treiman's model. As we shall argue, the idea that words are processed at a number of levels, including onsets and rimes, might account for the parallel progress in naming speed. For the present purpose, we adopt the view that word reading includes perception of its constituent letters but that processing also involves higher levels of representation, that is, onsets and rimes. The words and pseudowords of the training studies were of the following orthographical structures: CVC, CVCC, CCVC, and CCVCC. Thus, they all contained an onset and a rime. It is likely to assume that the time required to identify an onset or rime increases with the number of constituent letters. This would account for the over-all difference in naming latency between words of different length. Naming long words took more time than naming short words. Suppose that the children that participated in training used onset and rime units in word and pseudoword reading, but that processing these subword structures was at a low level of efficiency. During training, the words and pseudowords were presented without a context and almost all groups had to read them under some form of time-pressure. As a result, this may have caused a more efficient processing of higher level structures, that is, onsets and rimes. As all words and pseudowords consisted of one onset and one rime, this would lead to a parallel progress. However, the above assumption is speculative, because there is yet no evidence that young readers use onsets and rimes as processing units in word and pseudoword reading.

Other multi-letter units than onsets and rimes might also account for the parallel progress. In fact, any conceptualization of reading in which words are processed in a fixed number of units may account for that result. For example, children may group adjacent consonants together and process them in one unit. Following this assumption, the words and pseudowords used in the training studies would involve three units in all cases. Similarly, supposing that training caused a more efficient processing of these units, this would also be in accordance with a parallel progress for monosyllabic pseudowords of different length.

The idea that multi-letter units, such as onset-rime or consonant bigrams, play a role in beginning reading may, in principle, account for the observed parallel progress. The children that participated in the training experiments may be characterized as beginning readers, despite their chronological age. Their reading level corresponded to that of first-grade pupils. Obtaining evidence that beginning readers employ these supposed units in reading is a first step to an explanation. If such evidence is obtained, it still needs to be demonstrated that training specifically improved skills that operate upon these units. In other words, obtaining evidence for the significance of onsets and rimes, or consonant bigrams, in young readers' visual word identification is a necessary, but not a sufficient condition for the explanation of parallel progress in naming speed for words and pseudowords of different length.

The central interest of this chapter is the question whether multi-letter units, particularly onset and rime units, play a role in the reading process of beginning readers. The purpose of the experiments presented in §3.1 and §3.2 is to investigate whether onsets and rimes play a role in visual word identification of beginning and skilled readers. In addition, the question whether young readers process consonant bigrams as one unit is also addressed in §3.2.

3.1 Onsets and Rimes in Visual Word Identification

According to some linguists, the English syllable has an hierarchical linguistic structure, being composed of an onset and a rime (Fudge, 1987). The optional onset contains the initial consonant(s), and the rime consist of the vowel plus final consonant(s). There is evidence that onsets and rimes function as 'psychologically real' units in speech perception (Cutler, Butterfield, & Williams (1987), short-term memory for spoken syllables (Treiman & Danis, 1988), and speech production (MacKay, 1972). For example, Mackay (1972) found that spoonerisms tend to involve the exchange of initial consonant clusters (e.g. *dreater swying* instead of *sweater drying*).

Since the written form of language represents its spoken form, Treiman (e.g. Treiman & Chafetz, 1987; Treiman & Zukowski, 1988) proposed that the natural units of phonological representation also play a role in visual word processing. A further reason for postulating onsets and rimes in reading, stems from the nature of English orthography. The pronunciation of a vowel is more often influenced by following consonant(s) than by preceding consonant(s) (compare *mind* and *find* vs. *mist* and *fist*). To summarize, Treiman presented two arguments for the onset-rime proposition in English: (a) onset and rime spelling units correspond to natural phonological units, and (b) the relation between English orthography and phonology. For these reasons, onset and rime units should be more functional in reading than other units.

Evidence for the use of onsets and rimes as functional spelling units in reading has been obtained in various tasks. In an anagram task, subjects recognized the word BLAST more easily when it was presented in the fragments BL and AST, than in the fragments BLA and ST (Treiman & Chafetz, 1987). In a lexical decision task, decisions were delayed by separating words in two parts by inserting a double slash. Latency was shorter for BL//AST, than for BLA//ST. The same results were found for pseudowords (FLUNT) (Treiman & Chafetz, 1987). In a pseudoword pronunciation task, manner of pronunciation was more determined by vowel plus consonant (rime), than by initial consonant plus vowel (Treiman & Zukowski, 1988; but see Patterson & Morton, 1985). Recently, Bowey (1990) provided further evidence for onsets and rimes as functional units in reading in an experiment using a priming paradigm. Finally, suggestive evidence has also been obtained with children as subjects. Wise et al. (1990) presented first-grade children a list of words. The words were familiar in meaning, but unfamiliar in print. Children were required to read these words. The percentage of words correct was calculated. Subsequently, children were trained in reading these words. Words were presented in two segments by means of a reverse-video presentation. Half of the words were segmented at the onset-rime boundary (onset-rime words), the other half were segmented after the vowel (postvowel words). Children were instructed to blend the word segments, and thus, to read the words. After training, the complete list of words was again administered (in normal presentation). Children improved more on onset-rime words than on postvowel words. This study involved the role of onsets and rimes in word learning. To our knowledge, no studies with respect to onset and rime units at the perceptual level have been carried out with children. To conclude, there is increasing support for the position that onsets and rimes are used by readers of the English language. There is evidence that the linguistic structure of the Dutch syllable also contains an onset and rime (van Trommelen, 1984). In a study on phonemic segmentation skills of Dutch first-grade children, Schreuder and van Bon (1989) found that phonemic segmentation of syllables consisting of an onset and rime was easier than of syllables lacking such a structure (e.g. VC words). This was taken as an indication that young children's phonological representation of words involve an onset and rime structure. With respect to the second argument, the relation between orthography and phonology, the effect of the final consonant(s) on vowel pronunciation of Dutch words is less salient than in English. The phonemes /r/ and, to a lesser extent, the /l/ slightly reduce the length of long vowels. However, in general, the influence of final consonants on vowel pronunciation is small. Hence, one may ask whether onsets and rimes play a functional role in reading Dutch. This question was taken up by Reitsma (1988b). He provided first-grade children with practice in reading words with recurring rimes. The purpose was to investigate whether this type of practice generalizes to untrained words also containing these rimes. However, after training, generalization words were read no faster than control words. This study is described more extensively in §1.3. Thus, no evidence was found that beginning Dutch readers utilize onsets and rimes as functional spelling units within the context of reading structure lists (Reitsma, 1990, p.60).

The purpose of the experiments presented in this paragraph was to investigate whether onset and rime units are functional in visual word identification of young and skilled readers. Experiment 1 investigated the role of onset and rime units on third-grade children's word naming. This study was repeated with skilled adult readers as subjects in experiment 2. Finally, the role of onset and rime units in skilled readers' visual word identification was examined with a lexical decision task in experiment 3.

Experiment 1

Treiman (Treiman & Chafetz, 1987; Treiman & Zukowski, 1988) proposes that the orthographical representation of a syllable has a similar hierarchical structure as its phonological representation, that is, an onset and a rime. The letter patterns corresponding to these units should play a role in accessing a word's orthographical representation in the lexicon. Furthermore, onset-rime-like units may also be involved in the translation of a printed letter string into a phonological representation. She proposes that nonlexical knowledge of letter-sound relations includes letter groups corresponding to onsets and rimes.

Evidence for the significance of onsets and rimes in reading has been demonstrated by Treiman and Chafetz (1987). They employed a lexical decision task. The words and pseudowords were presented in two parts, segmented by a double slash. The location of slashes within the words and pseudowords was varied. The slashes either preceded, or followed the vowel. They argued that if perception of the onset or rime was impaired by the double slash, this should delay decision latency. This was confirmed by their results. Lexical decisions were faster for BL//AST words than for BLA//ST words. In addition, similar results were found with respect to pseudowords. In the BL//AST condition, both onset and rime spelling units were unimpaired. In the BLA//ST condition however, the slashes interfered with the perception of AST as the rime, therefore delaying word recognition.

The purpose of the present experiment was to investigate whether young, third-grade 'normal' Dutch readers also use onset and rime units in word decoding. It is conceivable that the use of onsets and rimes units in visual word recognition is dependent on reading skill. It is unlikely that at the very early stages of reading development, children process words in units corresponding to onsets and rimes. When children start school, they learn that letters, or letter combinations, represent phonemes in print. Word decoding is, at that stage, a matter of grapheme-by-grapheme decoding. With reading experience, children start to process words in larger units. Sullivan, Okada, and Niedermayer (1971) found that high-ability first-graders were more efficient in decoding letter combinations than low-ability children when reading unknown words. As a result of practice in decoding, grapheme-phoneme connections become more context-sensitive and, feasibly, multi-letter and multi-phoneme representations are acquired (Perfetti, in press, p.13, p.25). The use of larger units, such as onsets and rimes, should therefore characterize more advanced stages of reading. If it turns out that young readers make use of onset and rime units in word processing, we expect this to be more conspicuous for relatively good readers. It may very well be that good readers are good readers *because* they process words in onsets and rimes.

Of primary interest was to examine whether onsets and rimes play a role in the translation of orthography to phonology. A naming task was preferred to a lexical decision task, because naming compels to the generation of a phonological representation, whereas a lexical decision might be based upon orthography, or upon a partly specified phonological representation (Gough, 1984; Henderson, 1985). Beginning readers were instructed to name printed regular high-frequency CVC words. A similar procedure for impairing the perception of spelling units of words as in the Treiman and Chafetz study was used. However, instead of the double slash, an asterisk (*) was chosen as a separation marker because, in a pilot-study, children tended to interpret the double slash as two letters -l-. Words were either segmented before the vowel (b*us), or following the vowel (bu*s). The onset-rime theory predicts that *b*us* should be easier to read than *bu*s*. However, an onset-rime segmentation distorts perception of the initial part of the word, whereas a postvowel segmentation distorts perception of the final part of the word. Studies on reading errors showed that cues from initial position of words are used more frequently than cues from medial or final positions in responding to words (Fagan & Eagan, 1986; Shankweiler & Liberman, 1972). Furthermore, early orthographical representations of words are likely to include initial letters (Eriksen & Eriksen, 1974; Perfetti & McCutchen, 1982; Perfetti, in press). Thus, alternatively, an onset-rime segmentation may have a more detrimental effect on word identification than a postvowel segmentation.

If onsets and rimes should play a role in word reading, and if in that respect good and poor readers should differ, then the direction of the interaction may go either way. The subjects still are beginning readers. The relatively good readers may have acquired orthographical representations of familiar words that include onset-rime units. Similarly, orthographic translation of unfamiliar words may involve onset-rime like spelling units. Poor readers on the other hand might have a less fully specified orthographical representation of familiar word, perhaps lacking an onset-rime structure. Likewise, decoding of unfamiliar words might be carried out in a grapheme-by-grapheme fashion. If this would be the case, then a violation of the onset-rime structure would affect performance of good readers only. However, it may also be that both the relatively poor and the relatively good readers have acquired onset-rime spelling representations. It is not unlikely that the quality of these representations would be more fully specified, stable, and redundant for the good readers than for the poor readers. If this would be so, then good readers should be *less* affected by a violation of the onset-rime structure than poor readers, because their high quality of representation allows them to resist visuo-orthographic distortions more effectively. In sum, it is difficult to tell whether impairing the orthographic pattern of a presumed functional spelling unit affects good readers more, or less than poor readers.

In the present experiment, perception of a supposed multi-letter unit was impaired by a within-unit segmentation. The assumption is that reading performance is differentially affected by a within-unit segmentation than by an outside-unit segmentation. In order to investigate whether this assumption is warranted, the effects of impairing the perception of vowel digraphs were also examined. Knowledge of digraph-phoneme correspondences is acquired in the very early stages of reading development. There is evidence that both good and poor beginning readers process letter combinations that represent vowel-sounds as one functional spelling unit (van Rijnsoever, 1988, p.52). This allows the investigation whether and how impairing the perception of multi-letter spelling units affects reading performance of beginning readers. A vowel digraph may be homogeneous, i.e. consist of two identical letters (e.g. d*oo*f [deaf]), or may be heterogeneous, i.e. consist of two different letters (e.g. d*ui*f [pigeon]). If varying the location of word segmentation should have a differentiating effect on reading performance, then we presume that a within-digraph segmentation should have a larger negative effect on reading performance than an outside-digraph segmentation. For example, *ka*as* [cheese], should be harder to read than *k*aas* or *kaa*s*. The pronunciation of a homogeneous digraph is associated with the pronunciation of its constituent letters. Doubling a vowel letter produces a lengthening of its pronunciation. The pronunciation of a heterogeneous digraph on the other hand, is totally different from the pronunciation of its constituent letters. The combination of the letters determine the phoneme in a unique fashion. Therefore, a within-digraph segmentation should have a larger detrimental effect on word reading for heterogeneous, than for homogeneous digraphs.

Method

Subjects

Seventy children (36 boys, 34 girls) of an elementary school participated in this experiment. Thirty-one children were from second grade, thirty-nine children from third grade. Their mean age was 7;9 years (SD=5.4 months) and 8;8 years (SD=5.8 months), respectively. Reading level was determined by the AVI test (van den Berg & te Lintelo, 1977). The AVI is a standard reading test to assess children's reading level. The task of the child is to read aloud a number of sentences on a card. If criteria regarding accuracy are met, the child goes on with the next, more difficult, card. The score is the number of cards on which the child passed. The mean score of the children was 5.83 (SD=1.91). The experiment was carried out in november, which means that second-grade and third-grade children had received 14 and 24 months of reading instruction, respectively. The reading method used at the school was primarily based upon the phonics approach, but contains also elements of whole word teaching.

Apparatus

Words were presented in lower case on a white background in the center of an Apple IIGS computer monitor. A four-letter string was approximately 3 by 0.7 cm. A letter font used in many text books for children was chosen. Children were seated approximately 60-80 centimeter from the screen. Naming latencies were measured accurately to the millisecond by a voice-activated relay attached to the computer.

Materials

A total number of 144 monosyllabic real words were selected from Staphorsius et al. (1989). All words were of the CVC type, hence, consisting of three phonemes.

In 48 words, the vowel was represented by a single letter (e.g. bek [beak]). The frequency of the letters a, e, i, o, and u, within the set of 48 words was 10, 10, 10, 9, and 9, respectively. The positional letter frequency of initial and final consonants matched the positional letter frequency of all Dutch CVC words (Bakker, 1972).

In 48 words, the vowel was represented by two identical letters (homogeneous digraph, e.g. beek [pond]). These words were derived from the single letter-vowel CVC words by changing the vowel only. Ideally, each homogeneous digraph CVC word should have a matching frequent single-letter-vowel CVC word with respect to initial and final consonant. However, this proved to be impossible. For eight homogeneous digraph CVC words, other initial and final consonants were selected. The frequency of the graphemes aa, ee, oo and uu, within the set of 48 words was 13, 13, 13, 9, respectively.

Finally, in 48 words, the vowel was represented by two different letters (heterogeneous digraph, e.g. beuk [beech]). These words were also derived from the single letter-vowel CVC words, by changing the vowel only. However, once again, it appeared to be impossible to derive frequent real words of every single-letter vowel CVC word. In seven homogeneous digraph CVC words other initial and final consonants were selected. The frequency of the graphemes eu, ie, oe, ui, au, ou, and ei, within the set of 48 words was 7, 7, 7, 7, 7, 7, 6, respectively.

The complete list of words is displayed in Appendix 3.1.

Procedure

The 48 single-letter-vowel CVC words were assigned to three segmentation conditions: (a) no asterisk (bek), (b) an asterisk preceding the vowel (b*ek), or (c) an asterisk following the vowel (be*k). The 48 homogeneous and 48 heterogeneous digraph CVC words were also assigned to three segmentation conditions: the asterisk preceding the digraph (e.g. *b*eek* and *b*euk*), the asterisk within the digraph (e.g. *be*ek* and *be*uk*), or the asterisk following the digraph (e.g. *bee*k* and *beu*k*).

Lists of 3*48=144 words were generated in such a fashion that each digraph type was used equally often in every segmentation condition and that members of a triplet of matching words did not appear in the same segmentation condition. This resulted in six lists. Table 3.1 shows examples of item triplets of each list. Note that order of presentation was random and that each member of a triplet was presented separately.

For each subject, only one list was used. Lists were balanced across subjects. Order of presentation of words was randomized for each subject. The experiment was run in two sessions of approximately 20 minutes each, with a two day lag between sessions. Subjects were told that they would see a word on the screen and that it often, but not always, would

Table 3.1. Examples of the distribution of words to segmentation condition for each list

List 1	List 2	List 3
bot - b*oot - bou*t	b*ot - boo*t - bo*ut	bo*t - bo*ot - b*out
b*ek - bee*k - bo*ek	be*k - be*ek - b*oek	bek - b*eek - boe*k
za*k - za*ak - z*iek	zak - z*aak - zie*k	z*ak - zaa*k zo*ek
List 4	**List 5**	**List 6**
bot - boo*t - b*out	b*ot - bo*ot - bou*t	bo*t - b*oot - bo*ut
b*ek - be*ek - boe*k	be*k - b*eek - bo*ek	bek - bee*k - b*oek
za*k - z*aak - zi*ek	zak - zaa*k - z*iek	z*ak - za*ak zie*k

contain an asterisk They were to ignore this and to read the word aloud as accurately and as fast as possible Each trial started with a short auditory attention signal (100 ms) and a fixation point (#) appeared simultaneously in the center of the screen (500 ms) Presentation of the word immediately followed A maximum of eight seconds was allowed for responding. By pushing buttons on the keyboard the experimenter indicated whether the word was identified correctly and whether the clock was stopped by the verbal response of the subject No feedback was provided Prior to the experiment proper, ten practice trials were presented

Results

Number correct and median naming latency were calculated for all experimental conditions Latencies of incorrect responses were not used Trials on which the response was correct but did not stop the timer, or on which the timer was stopped by a sound other than the response, were not used for the calculation of the median latency The number of missing values due to timing errors was 4 3% Many subjects identified nearly all words correctly The average score was 90 8% correct Accuracy was dropped from analyses Three children responded more slowly than two standard deviations from the mean with respect to naming single-letter-vowel CVC words presented without an asterisk They were removed from the subject sample

Reader Group Assignment

The median naming latency on CVC words with a single-letter-vowel, presented without an asterisk, was determined A median split produced a group of 35 relatively 'good', and 35 relatively 'poor' readers The spearman-rank correlation between the median naming latency and the score on the AVI-test was -.68 ($p<.001$). Children with a high score on the reading test were also fast single word readers.

The effects of segmenting words by inserting an asterisk was investigated. The mean of the two median naming latencies to segmented single-letter-vowel words (prevowel and postvowel) was compared with the median naming latency to the set of words without a segmentation. These latencies were entered in an analysis of variance with Reader Group (2) as a between-subjects factor, and Presence of Segmentation (present vs. not-present) as a within-subjects factor. Means are shown in Table 3.2.

Table 3.2: Mean naming latency (in ms) on single-letter vowel CVC words, segmented and not-segmented, split by Reader Group (*SD* in parenthesis)

Reader Group		segmented [a]		not segmented		difference
poor	(n=35)	1020	(228)	826	(151)	194
good	(n=35)	703	(101)	608	(39)	95

[a] mean of postvowel and onset-rime segmentation

Naming segmented words took more time than naming not-segmented words (862 vs. 717 ms, $F(1,68)=119.68$, $p<.001$). The interaction between Reader Group and Presence of Segmentation was significant ($F(1,68)=13.77$, $p<.001$). Although segmentation delayed both good and poor readers' naming speed ($F(1,68)=26.19$, $p<.001$, and $F(1,68)=107.45$, $p<.001$, respectively), the difference was larger for poor readers than for good readers.

Onset-Rime vs. Postvowel Segmentation

An onset-rime segmentation was compared with a postvowel segmentation with respect to effects on naming latency. Latencies were entered in an analysis of variance with Reader Group (2) as between-subjects effect. Point of Segmentation (onset-rime vs. postvowel) and Vowel Type (single-letter vs. digraph) were the within-subjects factors. Furthermore, homogeneous digraphs were compared with heterogenous digraphs by nesting the factor Digraph Type (homogeneous vs. heterogeneous) under the level 'digraph' of the factor Vowel Type. Means are shown in Table 3.3.

Naming words with a postvowel segmentation was *faster* than naming words with an onset-rime segmentation (815 vs. 839 ms, ($F(1,68)=5.30$, $p<.05$). The advantage of a postvowel segmentation over an onset-rime segmentation did not differentiate between single-letter and digraph vowels ($F<1$), but it tended to be larger for heterogeneous than for homogeneous digraphs (35 vs. 10 ms, $F(1,68)=3.08$, $p=.084$). No interaction between Reader Group and Point of Segmentation was found ($F<1$). The interaction between Reader Group, Point of Segmentation, and Vowel Type was not significant either ($F<1$).

Table 3.3: Mean word naming latency (in ms) in onset-rime and postvowel segmentation condition, split by Reader Group and Vowel Type (*SD* in parenthesis)

Reader Group		Point of Segmentation				
		OR [a]		PV [b]		PV-OR [c]
		Single-letter vowel CVC's				
poor	(n=35)	1039	(234)	1001	(251)	-38
good	(n=35)	711	(131)	695	(89)	-16
		Homogeneous digraph CVC s				
poor	(n=35)	931	(197)	926	(238)	-5
good	(n=35)	652	(61)	637	(58)	-15
		Heterogeneous digraph CVC's				
poor	(n=35)	1013	(259)	974	(295)	-39
good	(n=35)	686	(105)	655	(65)	-31

[a] onset-rime segmentation, as in b*os', b*oos', or 'b*oef'
[b] postvowel segmentation, as in 'bo*s', boo*s', or 'boe*f'
[c] difference between postvowel and onset rime segmentation

The factor Vowel Type compares naming latencies for single-letter-vowel-words with those for digraph-vowel-words The single-letter-vowel words consisted of three letters, the digraph-vowel words consisted of four letters In effect, this factor investigates the influence of number of letters (three vs four letters) while keeping the number of phonemes constant (three phonemes) Naming single-letter-vowel words took 53 ms *longer* than naming words containing a digraph (862 vs 809 ms, $F(1,68)=24\ 87$, $p<\ 001$) It took both good and poor readers longer to name a three-letter word than to name a four-letter word (703 vs 657 ms, $F(1,68)=9\ 56$, $p<\ 01$, and 1020 vs 961 ms, $F(1,68)=15\ 68$, $p<\ 001$, respectively) The interaction between Vowel Type and Reader Group was not significant ($F<1$), indicating that the difference between three- and four-letter words was similar for good and poor readers

Effects of Digraph Type will be presented next Naming words with a heterogeneous digraph was slower than naming words with a homogeneous digraph (832 vs 787 ms, ($F(1,68)=18\ 80$, $p<.001$) The interaction between Digraph Type and Reader Group approached significance ($F(1,68)=3.66$, $p=\ 06$), suggesting that the difference between homogeneous and heterogeneous digraph words was larger for poor than for good readers (65 vs. 26 ms, respectively)

Within-Digraph vs. Outside-Digraph Segmentation

A within-digraph segmentation was compared with a segmentation outside the digraph with respect to the effects on naming speed. Median latency on homogeneous and heterogeneous digraph CVC words were submitted to an analysis of variance with Reader Group (2) as between-subjects factor. Digraph Type (homo- and heterogeneous) and Point of Segmentation (within vs. outside digraph) were tested as within-subjects factors. Means are shown in Table 3.4.

Table 3.4: Mean word naming latency (in ms) in Within and Outside Digraph segmentation, split by Reader Group and Digraph Type (*SD* in parenthesis)

Reader Group		Point of Segmentation				
		WD [a]		OD [b]		WD-OD [c]
		Homogeneous digraphs				
poor	(n=35)	1091	(288)	928	(208)	163
good	(n=35)	716	(126)	645	(56)	72
		Heterogeneous digraphs				
poor	(n=35)	1328	(457)	994	(267)	335
good	(n=35)	725	(122)	670	(79)	55

[a] within-digraph segmentation, as in 'bo*os', or 'bo*ef'
[b] outside digraph segmentation: mean of onset-rime and postvowel segmentation
[c] difference between within-digraph and outside-digraph segmentation

Naming words segmented within the digraph was slower than naming words segmented outside the digraph (965 vs. 809 ms, $F(1,68)=86.31$, $p<.001$). Both good and poor readers were more delayed by a within-digraph segmentation than by an outside-digraph segmentation ($F(1,68)=7.03$, $p=.01$, and $F(1,68)=109.99$, $p<.001$, respectively). However, the difference was larger for poor readers than for good readers (249 vs. 63 ms, respectively), indicated by a significant interaction between Point of Segmentation and Reader Group ($F(1,68)=30.71$, $p<.001$). The three-way interaction between Point of Segmentation, Digraph Type, and Reader Group was significant ($F(1,68)=10.39$, $p<.01$). For poor readers, the difference between words with a within-digraph segmentation and words with an outside-digraph segmentation was larger for heterogeneous digraph words than for homogeneous digraph words (335 vs. 163 ms, $F(1,68)=17.32$, $p<.001$). For good readers, differences in means were in the opposite direction, but not significant (55 vs. 72 ms, $F<1$).

Discussion

The sensitivity of the experimental procedure was investigated by comparing reading performance on words with a within-digraph segmentation with those with an outside-digraph segmentation. If impairing the perception of a functional spelling unit should affect reading performance, then we predicted that a within-digraph segmentation should have a larger negative effect on reading performance than an outside-digraph segmentation. Results confirmed this prediction, indicating that the present technique of impairing the perception of a letter cluster that should necessarily be processed as a unit, delays word naming. Furthermore, the detrimental effect of a within-digraph segmentation was larger for poor, than for good readers. Since good readers' digraph representations are assumed to be higher in quality, it follows that a firmly established representational unit is less affected by visual distortions than a unit with a low level of representation.

The primary purpose of this study was to investigate whether young readers process words in onset and rime units. Speed of naming words with an onset-rime segmentation was compared with speed of naming words with a postvowel segmentation. Results with respect to digraph segmentations suggest that if onset and rime units are functional in word naming, then a postvowel segmentation should produce slower naming, because this segmentation impairs the perception of a functional unit, i.e. the rime. However, both good and poor readers were faster, rather than slower, at naming words with a postvowel segmentation. This is in conflict with the onset-rime idea. The results might indicate that children use other units in word processing than onsets and rimes (e.g. 'initial consonants(s) plus vowel' and 'final consonant(s)'). The postvowel advantage may also be an indirect consequence of the adopted procedure. As stated in the introduction, young readers' orthographical word representations are likely to include initial letters (Eriksen & Eriksen, 1974; Fagan & Eagan, 1986; Perfetti & McCutchen, 1982; Perfetti, in press; Shankweiler & Liberman, 1972). Thus, young readers' orthographical representations may not (yet) include higher levels of specification than individual graphemes. An onset-rime segmentation distorts perception of the initial part of the word, whereas a postvowel segmentation distorts perception of the final part of the word. Because orthographical representations tend to encompass initial, rather than final graphemes, word identification may therefore have been more impaired by an onset-rime segmentation than by a postvowel segmentation. According to this interpretation, onset and rime units do not (yet) play a role in visual word identification. The postvowel advantage is a rather trivial consequence of the segmentation procedure.

The results on the over-all impact of impairing word perception by using an asterisk as segmentation marker revealed that the detrimental effect was larger for poor, than for good readers. This suggests that, whatever units may be involved in word processing, good readers' units of word processing are less sensitive to orthographical distortions than those of poor readers.

A puzzling result was that naming three-letter words took longer than naming four-letter words. This is in conflict with other studies that report naming latency to increase with word length (Manis, 1985; Samuels, LaBerge, & Bremer, 1978). We will elaborate on this point in the discussion of the segmentation marker paradigm.

In summary, no support was found for the position that readers process words in onsets and rimes. This is in conflict with results reported by Treiman and Chafetz (1987). However, they used college student as subjects, whereas we studied word processing of young children. Perhaps beginning readers still process words at the level of graphemes and phonemes and are not yet skilled enough to process words in larger units. In order to test whether onsets and rimes do play a role in skilled reading, adults were used as subjects in experiment 2.

Experiment 2

In experiment 1 we found no evidence for the position that onsets and rimes are used by beginning readers in visual word identification. We raised the possibility that the subjects of that experiment may have been too young and that onsets and rimes may be used by more skilled readers. In order to test whether onsets and rimes do play a role in skilled reading, adults were used as subjects in this experiment.

In the previous experiment we found that word naming is delayed if perception of a letter cluster that necessarily should be processed as a unit is impaired. This detrimental effect on naming latency was larger for poor than for good beginning readers. The over-all impact of impairing word perception was also larger for poor than for good beginning readers. The question arises whether these effects are associated with poor reading ability or whether they are merely correlates of individual differences in reading speed. In order to investigate this question, the sample of skilled readers was divided in a group of relatively 'slow', and a group of relatively 'fast' readers.

Method

Subjects

Twenty-three students and PhD-students (10 male, 13 female) of the Department of Special Education participated in the experiment on a voluntary basis. They were not paid for participating in the experiment. Subjects were ignorant of the goal and nature of the experiment.

Apparatus, Materials and Procedure

Apparatus, Materials and Procedure were the same as in experiment 1, except that the experiment was run in one session.

Results

Number correct and median naming latency were calculated for all experimental conditions. Latencies of incorrect responses were not used. Trials on which the response was correct but did not stop the timer, or on which the timer was stopped by a sound other than the response, were not used for the calculation of the median latency. The number of missing values due to timing errors was 1.5%. The average score was 98.6% correct. Accuracy was therefore dropped from analyses. One subject responded more slowly than two standard deviations from the mean with respect to naming single-letter-vowel CVC words presented without an asterisk. This subject was removed from the subject sample.

Reader Group Assignment

The median naming latency on CVC words with a single-letter-vowel, presented without an asterisk, was determined. A median split produced a group of 11 relatively 'fast', and a group of 11 relatively 'slow' readers.

The effects of segmenting words by inserting an asterisk were investigated. The mean of median naming latencies to segmented single-letter-vowel words was compared with the median naming latency to such words without a segmentation. These latencies were entered in an analysis of variance with Reader Group (fast vs. slow) as the between-subjects factor, and Presence of Segmentation (present vs. not-present) as the within-subjects factor. Means are shown in Table 3.5.

Table 3.5: Mean naming latency (in ms) on single-letter vowel CVC words, segmented and not-segmented, split by Reader Group (*SD* in parenthesis)

Reader Group		segmented [a]		not segmented		difference
slow	(n=11)	569	(27)	526	(22)	43
fast	(n=11)	492	(34)	453	(22)	39

[a] mean of postvowel and onset-rime segmentation

Naming segmented words took more time than naming not-segmented words (531 vs. 490 ms, $F(1,20)=87.44$, $p<.001$). The interaction between Reader Group and Presence of Segmentation was not significant ($F<1$).

Onset-Rime vs. Postvowel Segmentation

An onset-rime segmentation was compared with a postvowel segmentation with respect to effects on naming latency. Latencies of words with an onset-rime segmentation and postvowel segmentation were entered in an analysis of variance with Reader Group (2) as between-subjects effect. Point of Segmentation (onset-rime vs. postvowel) and Vowel Type (single-letter-vowel vs. digraph) were the within-subjects factors. Furthermore, homogeneous digraphs were compared with heterogenous digraphs by nesting the factor Digraph Type (homogeneous vs. heterogeneous) under the level 'digraph' of the factor Vowel Type. Means are shown in Table 3.6.

Table 3.6: Mean word naming latency (in ms) in onset-rime and postvowel segmentation condition, split by Reader Group and Vowel Type (*SD* in parenthesis)

Reader Group		Point of Segmentation				
		OR [a]		PV [b]		PV-OR [c]
		Single-letter vowel CVC's				
slow	(n=11)	572	(29)	567	(31)	-5
fast	(n=11)	497	(36)	486	(34)	-11
		Homogeneous digraph CVC's				
slow	(n=11)	538	(32)	543	(29)	5
fast	(n=11)	474	(27)	467	(30)	-7
		Heterogeneous digraph CVC's				
slow	(n=11)	547	(26)	550	(24)	3
fast	(n=11)	470	(33)	474	(35)	4

[a] onset-rime segmentation, as in 'b*os', 'b*oos', or 'b*oef'
[b] postvowel segmentation, as in 'bo*s', 'boo*s', or 'boe*f'
[c] difference between postvowel and onset-rime segmentation

No effect of Point of Segmentation was found ($F(1,20)=1.21$, $p=.285$). Naming words segmented at the onset-rime boundary was equally fast as naming words segmented after the vowel. The interaction between Point of Segmentation and Vowel Type was not significant ($F<1$). The interaction between Point of Segmentation and Reader Group was not significant either ($F(1,20)=2.14$, $p=.159$). In sum, subjects produced similar naming latencies to words segmented at the onset-rime boundary and to words segmented after the vowel. This result was not affected by any of the other factors included in the design.

The factor Vowel Type compares naming latencies of single-letter vowel-words with those of digraph-vowel words. The single-letter-vowel words consisted of three letters, the digraph-vowel words consisted of four letters. In effect, this factor investigates the influence of number of letters (three vs. four letters) while keeping the number of phonemes constant (three phonemes). Naming single-letter-vowel words took 23 ms *longer* than naming words containing a digraph (531 vs. 508 ms, $F(1,20)=31.98$, $p<.001$). It took both fast and slow readers longer to name a three-letter word than to name a four-letter word (492 vs. 471 ms, $F(1,20)=12.90$, $p<.01$, and 569 vs. 544 ms, $F(1,20)=19.41$, $p<.001$, respectively). The interaction between Vowel Type and Reader Group was not significant ($F<1$), indicating that the difference between three-, and four-letter words was similar for fast and slow readers.

Naming words containing a homogeneous digraph was equally fast as naming words containing a heterogeneous digraph, indicated by a non-significant effect of Digraph Type ($F(1,20)=2.80$, $p=.110$). The interaction between Digraph Type and Reader Group was not significant either ($F(1,20)=1.10$, $p=.307$).

Within-Digraph vs. Outside-Digraph Segmentation

A within-digraph segmentation was compared with a segmentation outside the digraph with respect to the effects on naming speed. Median latency on homogeneous and heterogeneous digraph CVC words were submitted to an analysis of variance with Reader Group (2) as between-subjects factor. Digraph Type (homo- and heterogeneous) and Point of Segmentation (within vs. outside digraph) were tested as within-subjects factors. Means are shown in Table 3.7.

Table 3.7: Mean word naming latency (in ms) in Within and Outside Digraph segmentation, split by Reader Group and Digraph Type (*SD* in parenthesis)

Reader Group		Point of Segmentation				
		WD [a]		OD [b]		WD-OD [c]
		Homogeneous digraphs				
slow	(n=11)	570	(35)	540	(26)	30
fast	(n=11)	491	(29)	470	(27)	21
		Heterogeneous digraphs				
slow	(n=11)	606	(46)	549	(24)	57
fast	(n=11)	497	(43)	472	(33)	25

[a] within-digraph segmentation, as in 'bo*os', or 'bo*ef'
[b] outside digraph segmentation: mean of onset-rime and postvowel segmentation
[c] difference between within-digraph and outside-digraph segmentation

Naming words segmented within the digraph was slower than naming words segmented outside the digraph (541 vs. 508 ms, $F(1,20)=40.01$, $p<.001$). Both fast and slow readers were more delayed by a within-digraph segmentation than by an outside-digraph segmentation ($F(1,20)=9.24$, $p<.01$, and $F(1,20)=34.89$, $p<.001$, respectively). However, the difference tended to be larger for slow readers than for fast readers (43 vs. 24 ms, respectively), indicated by the interaction between Point of Segmentation and Reader Group ($F(1,20)=4.11$, $p=.056$). The interaction between Point of Segmentation and Digraph Type was not significant ($F<1$). The three-way interaction between Point of Segmentation, Digraph Type, and Reader Group was not significant either ($F(1,20)=3.14$, $p=.092$).

Discussion

This study addressed the question whether skilled adult readers process words in onset and rime units. The onset-rime idea predicts that words segmented before the vowel should be named faster than words segmented after the vowel, because a prevowel segmentation does not impair the perception of the onset and rime units. However, word latencies did not differ between these two segmentation conditions. In the previous experiment with beginning readers as subjects, an advantage of a postvowel segmentation over an onset rime segmentation was found. It was suggested that this may be related to the observation that poor readers' lexical word representations tend to include initial, rather than final graphemes (Eriksen & Eriksen, 1974, Fagan & Eagan, 1986, Perfetti, in press, Perfetti & McCutchen, 1982, Shankweiler & Liberman, 1972). A segmentation early in the word should therefore impair reading more than a segmentation later in the word. The advantage of a postvowel segmentation over an onset-rime segmentation disappeared with skilled readers. The orthographical representation of a particular word in the lexicon of a skilled reader is very likely to include all letters of that word. This is probably the reason why the location of segmentation had no differentiating effect on reading speed. In sum, the results do not provide support for the position that skilled readers utilize onset and rime units in word reading.

A within-digraph segmentation had a larger disruptive effect on word reading than an outside-digraph segmentation. These results indicate that impairing the perception of a letter cluster that necessarily should be processed as a unit, delays word naming. The detrimental effect was larger for relatively slow, than for relatively fast readers. This result was also found in the first experiment with respect to relatively good and poor beginning readers. In this study, all readers should be considered as expert readers. Apparently, the delay in word naming as a result of impaired perception of a functional spelling unit is associated with reading speed rather than reading ability.

The influence of a segmentation marker upon word naming speed was assessed on single-letter-vowel words. Because all phonemes of these words were represented by one letter, the segmentation marker did not interfere with processing at the phoneme level. Naming segmented words was slower than naming not-segmented words. The size of the delay was similar for fast and slow readers.

Once more, subjects needed more time to respond to three-letter words than to four-letter words. This is in conflict with other studies that report naming latency to increase with number of letters (Balota & Chumbley, 1985; Forster & Chambers, 1973; Frederiksen & Kroll, 1976). We will elaborate on this point in the discussion of the segmentation marker paradigm.

The results of the present and previous study disconfirm the position that beginning and skilled readers process words in onset and rime units. However, demonstrating the use of multi-letter units in word processing is, among other aspects, dependent on the task employed (Vellutino, 1982). Treiman & Chafetz (1987) used a lexical decision task and found that responses were faster to words and pseudowords segmented at the onset-rime boundary than for other segmentations. In the present studies we employed a naming task and found no such superiority for onset-rime segmentations. The incongruous results may be related to the nature of the task. A naming task and a lexical decision task differ with respect to the factors that influence the subjects response (see Seidenberg, Waters, Barnes, & Tanenhaus, 1984, p.397-8). The question whether onsets and rimes do play a role in lexical decision is addressed in experiment 3.

Experiment 3

The results of experiments 2 do not provide support for the position that skilled readers utilize onset and rime units in word naming. This finding is in contrast with a study by Treiman and Chafetz (1987). The possibility was raised that the incongruous results may have been the consequence of the nature of the reading tasks. Treiman and Chafetz (1987) used a lexical decision task, whereas we utilized a word naming task. The question whether onsets and rimes do play a role in skilled readers' lexical decisions is addressed in this experiment. In order to investigate how reading speed is related to possible effects, the sample of skilled readers was divided in a group of relatively 'slow', and a group of relatively 'fast' readers.

Method

Subjects

Thirty-six students and PhD-students of the Department of Special Education (16 male, 20 female) participated in the experiment on a voluntary basis. They were not paid for participating in the experiment. Subjects were ignorant of the goal and nature of the experiment.

Apparatus

The apparatus was identical to that of experiments 1 and 2 regarding the arrangement and organization of stimulus presentation A device with two buttons (a *yes* and a *no* button) was connected to the computer for the recording of data

Materials

The same words as in experiments 1 and 2 were used in this study In addition, a list of 40 pseudowords (16 with a single-letter-vowel, 12 with a homogeneous vowel digraph, and 12 with a heterogeneous vowel digraph) were generated The list of pseudowords is shown in Appendix 3 2

Procedure

Each of the six lists created for experiment 1 was split in two separate lists by selecting the even and odd words respectively Each list contained 3*24=72 words Again, all digraphs appeared equally often in every segmentation condition and members of a triplet of matching words did not appear in the same segmentation condition This resulted in 12 lists To each list, the 40 pseudowords were added So, each of the twelve lists contained the same 40 pseudowords, and all subjects received the pseudowords under the same segmentation condition For each subject, only one list was used Lists were balanced across subjects Order of presentation of words and pseudowords was randomized for each subject Subjects were told that they would see a word or pseudoword on the screen, and that often, but not always, it would contain an asterisk They were to ignore this symbol and to press the *yes* button if the letter string formed a word, and the *no* button if it did not Fast and accurate responding was emphasized

Results

Number correct and median decision latency were calculated for all experimental conditions Latencies of incorrect responses were not used Hardly any errors were made 4 1% of the words was erroneously evaluated as a pseudoword, and 4 9% of the pseudowords was judged as a word Accuracy was dropped from analyses For each subject, the mean of the median latencies of responding to single-letter-vowel CVC words and pseudowords presented without an asterisk was calculated Two subjects were slower than two standard deviations from the mean of this calculated variable These subjects were removed from the sample

Reader Group Assignment

The mean of median decision latencies on CVC words and pseudowords with a single-letter-vowel, presented without an asterisk, was determined A median split produced a group of 17 relatively 'fast', and a group of 17 relatively 'slow' readers.

The effects of segmenting words and pseudowords by inserting an asterisk were investigated. The mean of median decision latencies to segmented single-letter-vowel words and pseudowords was compared with the median naming latency to such words and pseudowords without a segmentation. These latencies were entered in an analysis of variance with Reader Group (fast vs. slow readers) as the between-subjects factor, and Lexical Status (words and pseudowords) and Presence of Segmentation (present versus not-present) as within-subjects factors. Means are shown in Table 3.8.

Table 3.8: Mean lexical decision latency (in ms) on single-letter vowel CVC words and pseudowords, segmented and not-segmented, split by Reader Group (*SD* in parenthesis)

Reader Group		segmented [a]		not segmented		difference
			words			
slow	(n=17)	772	(81)	616	(66)	156
fast	(n=17)	663	(90)	543	(32)	120
			pseudowords			
slow	(n=17)	919	(113)	810	(78)	109
fast	(n=17)	770	(121)	657	(41)	113

[a] mean of postvowel and onset-rime segmentation

A main effect of Presence of Segmentation was found $F(1,32)=90.78$, $p<.001$), indicating that lexical decision latency was longer for segmented words and pseudowords than for words and pseudowords without a segmentation (781 vs. 657 ms, respectively). The interaction between Presence of Segmentation and Reader Group was not significant ($F<1$), indicating that fast and slow readers' decision latencies were equally delayed by the asterisk. No interaction between Presence of Segmentation and Lexical Status was found ($F(1,32)=2.51$, $p=.123$), indicating that a *yes* decision was equally delayed by the asterisk as a *no* decision. Finally, the three-way interaction between Presence of Segmentation, Lexical Status, and Reader Group was not significant either ($F(1,32)=1.35$, $p=.253$).

Onset-Rime vs. Postvowel Segmentation

The onset-rime segmentation was compared with the postvowel segmentation. Latencies of words and pseudowords with an onset-rime segmentation and postvowel segmentation were entered in an analysis of variance with Reader Group (2) as between-subjects effect. Point of Segmentation (onset-rime vs. postvowel), Lexical Status (words vs. pseudowords) and Vowel Type (single-letter-vowel vs. digraph) were the within-subjects factors. Furthermore, homogeneous digraphs were compared with heterogenous digraphs by nesting the factor Digraph Type (homogeneous vs. heterogeneous) under the level 'digraph' of the factor Vowel Type. Means are shown in Table 3.9.

Table 3.9: Mean lexical decision latency (in ms) in onset-rime and postvowel segmentation condition, split by Vowel Type and Lexical Status (*SD* in parenthesis)

Reader Group		Point of Segmentation				
		OR [a]		PV [b]		PV-OR [c]
		Words				
		Single-letter vowel CVC's				
slow	(n=17)	759	(108)	784	(111)	25
fast	(n=17)	672	(101)	669	(111)	-3
		Homogeneous digraph CVC's				
slow	(n=17)	668	(89)	670	(68)	2
fast	(n=17)	552	(62)	609	(84)	57
		Heterogeneous digraph CVC's				
slow	(n=17)	657	(81)	633	(82)	-24
fast	(n=17)	563	(45)	577	(64)	14
		Pseudowords				
		Single-letter vowel CVC's				
slow	(n=17)	868	(138)	960	(149)	92
fast	(n=17)	775	(124)	786	(132)	11
		Homogeneous digraph CVC's				
slow	(n=17)	865	(133)	879	(125)	14
fast	(n=17)	708	(57)	761	(69)	53
		Heterogeneous digraph CVC's				
slow	(n=17)	825	(91)	852	(114)	27
fast	(n=17)	728	(86)	702	(49)	-26

[a] onset-rime segmentation, as in 'b*os', 'b*oos', or 'b*oef'
[b] postvowel segmentation, as in 'bo*s', 'boo*s', or 'boe*f'
[c] difference between postvowel and onset-rime segmentation

Responses to words and pseudowords with an onset-rime segmentation were *faster* than to words and pseudowords with a postvowel segmentation (720 vs. 740 ms, ($F(1,32)=8.70$, *p*<.01). The advantage of an onset-rime segmentation over a postvowel segmentation did not differentiate between words and pseudowords, nor between fast and slow readers (both *F*'s<1). These results indicate that both fast and slow readers performed better on words and pseudowords segmented at the onset-rime boundary. The advantage of an onset-rime segmentation over a postvowel segmentation did not differentiate between single-letter and digraph vowels either (*F*<1), but within vowel-digraph words and pseudowords, the onset-rime advantage was larger for homogeneous than for heterogeneous digraphs, as indicated by a significant interaction between Point of Segmentation and Digraph Type (32 vs -3 ms, *F*(1,32)=9.66, *p*<.01). The three-way interaction between Point of Segmentation, Digraph Type, and Lexical Status was not significant (*F*<1).

The factor Vowel Type compares decision latencies of words and pseudowords with single-letter-vowels to words and pseudowords with vowel digraphs. The single-letter-vowel words consisted of three letters, the digraph-vowel words consisted of four letters In effect, the factor Vowel Type tests the influence of number of letters (three vs. four letters) while keeping the number of phonemes constant (three phonemes). Means are shown in Table 3.10.

Table 3.10: Mean lexical decision latency (in ms), split by Number of Letters and by Reader Group (*SD* in parenthesis)

Reader Group		Number of Letters				
		three [a]		four [b]		difference
			Words			
slow	(n=17)	772	(81)	669	(67)	-103
fast	(n=17)	663	(90)	580	(57)	-83
			Pseudowords			
slow	(n=17)	919	(113)	872	(114)	-47
fast	(n=17)	770	(121)	735	(49)	-35

[a] mean calculated across onset-rime and postvowel segmentation of single-letter vowel CVC's
[b] mean calculated across onset-rime and postvowel segmentation of both homogeneous and heterogeneous digraph CVC's

A decision with respect to the lexicality of a letter string took *longer* for a three-letter word or pseudoword, than for a four-letter word or pseudoword (781 vs. 714 ms), indicated by a main effect of Vowel Type (*F*(1,32)=41.67, *p*<.001). Furthermore, the difference in decision latency between three-letter strings and four-letter strings was *larger* for words than for pseudowords, as indicated by the significant interaction between Vowel Type and Lexical Status (93 vs 41 ms, *F*(1,32)=6.31, *p*< 001) The two-way interaction between Vowel Type and Reader Group was not significant (*F*<1), indicating that the size of the length effect was equal for fast and slow readers. The three-way interaction between Vowel Type, Lexical Status, and Reader Group, was not significant either ($F<1$).

Within-Digraph vs. Outside-Digraph Segmentation

A within-digraph segmentation was compared with a segmentation outside the digraph with respect to the effects on decision latency. Median decision latency on homogeneous and heterogeneous digraph words and pseudowords were submitted to an analysis of variance with Reader Group (2) as between-subjects factor. Lexical Status (words vs. pseudowords), Digraph Type (homo- and heterogeneous) and Point of Segmentation (within vs. outside digraph) were tested as within-subjects factors. Means are shown in Table 3.11.

Table 3.11: Mean lexical decision latency (in ms) in Within and Outside Digraph Segmentation, split by Reader Group, Lexical Status, and Digraph Type (*SD* in parenthesis)

Reader Group		Point of Segmentation				
		WD [a]		OD [b]		WD-OD [c]
				Words		
				Homogeneous digraphs		
slow	(n=17)	775	(85)	669	(67)	106
fast	(n=17)	709	(118)	580	(57)	129
				Heterogeneous digraphs		
slow	(n=17)	907	(204)	645	(71)	262
fast	(n=17)	711	(99)	570	(50)	141
				Pseudowords		
				Homogeneous digraphs		
slow	(n=17)	972	(161)	872	(114)	100
fast	(n=17)	826	(78)	735	(49)	91
				Heterogeneous digraphs		
slow	(n=17)	1095	(240)	839	(91)	256
fast	(n=17)	856	(127)	715	(58)	141

[a] within-digraph segmentation, as in 'bo*os', or 'bo*ef'
[b] outside digraph segmentation: mean of onset-rime and postvowel segmentation
[c] difference between within-digraph and outside-digraph segmentation

A decision with respect to the lexicality of a letter string took more time when the word or pseudoword was segmented within the digraph than outside the digraph (857 vs. 703 ms, $F(1,32)=147.30$, $p<.001$). The difference was larger for slow readers than for fast readers (181 vs. 126 ms, $F(1,32)=4.84$, $p<.001$). The three-way interaction between Point of Segmentation, Digraph Type, and Reader Group was significant ($F(1,32)=5.04$, $p<.05$). Within reader group testing revealed that for slow readers, the detrimental effect of a within-digraph segmentation was much larger for heterogeneous digraphs than for homogeneous digraphs (259 vs. 103 ms, ($F(1,32)=15.70$, $p<.001$). This made no difference for fast readers (141 vs. 110 ms, $F<1$). The three-way interaction between Point of Segmentation, Lexical Status, and Reader Group was not significant ($F<1$). Finally, the four-way interaction between Point of Segmentation, Digraph Type, Lexical Status, and Reader Group was not significant either ($F<1$).

Discussion

This study addressed the question whether skilled adult readers process words and pseudowords in onset and rime spelling units. A standard lexical decision task was used. The onset-rime idea predicts that a lexical decision should be faster for words and pseudowords segmented before the vowel than for words and pseudowords segmented after the vowel, because a prevowel segmentation does not impair the perception of the onset and rime spelling units. The results confirmed this prediction. Lexical decisions for words and pseudowords with an onset-rime segmentation were faster than for words and pseudowords with a postvowel segmentation. The onset-rime advantage was similar for words and pseudowords. The onset-rime advantage did not differentiate between relatively fast and slow readers either.

A within-digraph segmentation had a larger disruptive effect on lexical decision time than an outside-digraph segmentation. This indicates that impairing the perception of a letter cluster that should necessarily be processed as a unit, delays visual word and pseudoword processing. The detrimental effect of a within-digraph segmentation was larger for relatively slow, than for relatively fast readers. This is in agreement with results of experiment 2, supporting the position that the delay in processing of words segmented within the digraph, compared with words segmented outside the digraph, is related to reading speed. Large differences are associated with slow processing. Furthermore, within-digraph segmentations of heterogenous digraph words and pseudowords delayed decision time of the slower readers more than within-digraph segmentations of homogenous digraph words and pseudowords. For fast readers, no such difference was found. The question whether, and how slow processing interferes with processing of digraphs, and heterogeneous digraphs in particular, remains to be settled.

Once again, a reverse length effect was found. Decision latency was longer for three-letter words and pseudowords than for four-letter words and pseudowords. This is in contrast with studies in the literature, which report no reliable effect of number of letters (Frederiksen & Kroll, 1976), or an increase of decision latency with the number of letters (Forster & Chambers, 1973). The reverse length effect was larger for words than for pseudowords. We will come back to this issue in the discussion of the segmentation marker paradigm.

General Discussion of Experiments 1 to 3

No evidence for the use of onset and rime spelling units in visual word identification was found in a naming task. Naming latencies of words segmented in an onset and rime were similar to naming latencies of words segmented after the vowel. This was found for both young and adult readers. In a lexical decision task with skilled readers however, responses to words and pseudowords with an onset-rime segmentation were faster than to words and pseudowords with a postvowel segmentation. This is in agreement with a study by Treiman and Chafetz (1987), who also demonstrated a reliable advantage for onset-rime segmentations with skilled readers in a lexical decision task. This suggests that onset-rime effects may be obtained with skilled readers in a lexical decision task, but not in a naming task.

Discussions on the differences between naming and lexical decision often focus on the contribution of phonological information to response latency (Gough, 1984; Henderson, 1985; van Orden, Pennington, & Stone, 1990; Seidenberg & McClelland, 1989; Seidenberg et al., 1984). Phonological information might be less important for lexical decision than for naming. Seidenberg et al. (1984, p.398) suggested that phonological information is gained access to in both tasks, but that a lexical decision can be made without reference to it. However, Treiman and Zukowski (1988) concluded that onsets and rimes are used in the translation from spelling to sound. If readers should indeed utilize onset and rime units in phonological processing, then it is puzzling why we failed to demonstrate onset-rime effects in a naming task because naming compels phonological processing.

The observation that skilled readers use onsets and rimes in lexical decision triggers the question whether beginning readers also use these units in a lexical decision task. Furthermore, it would be interesting to investigate what factors are responsible for the different results between naming and lexical decision. The current experiments however, were carried out in order to provide an explanation for the parallel progress in naming speed for words and pseudowords of different length, as observed in the training studies reported in chapter 2. Addressing the above questions experimentally is beyond the scope of this project. In the next experiment, we will again focus upon the role of onsets and rimes in beginning readers' word naming.

The absence of onset-rime effects in word naming might be related to a different relation between orthography and phonology in Dutch, in comparison with English. The pronunciation of the vowel in Dutch words is less influenced by its following consonant(s) than in English words. Dutch readers may therefore be less inclined than English readers to process words in onsets and rimes. However, the conclusion that onsets and rimes do not function as units of processing in Dutch word naming may be premature. The failure to find onset-rime effects may have been the consequence of an incorrect experimental manipulation. This issue will be discussed in the next paragraph, in which the validity of the employed experimental manipulation will be evaluated.

The Segmentation Marker Paradigm

The results of the previous experiments justify a reconsideration of the adopted manipulation. A naming task and a lexical decision task were employed in which the presented words were segmented in two parts by a segmentation marker (*). The location of the segmentation marker within the word was varied. Response latency was recorded. It was argued that if words were processed in onset and rime units, response latency should be related to the position of the asterisk within the word. There are arguments for distrusting the validity of results that have been acquired with this technique. Our doubts are based upon the finding of a reverse length effect. Subjects took longer to respond to three letter words than to four-letter words. This result was consistent across all three experiments, and is in conflict with other studies in the literature. Studies employing a word naming task report that naming latency *increases* with the number of letters, especially for unskilled readers (e.g. Mason, 1978, Seymour & Porpodas, 1980, see for review Henderson, 1982, chapter 7). The reverse length effect calls into question the validity of segmentation marker tasks as an instrument for measuring word identification processes. Naming words that contain interfering marker(s), like an asterisk (the present studies) or double slash (Treiman & Chafetz, 1987), may tap processes that are not in effect during normal word identification, thereby concealing effects of normal reading processes. This assumption is supported by the observation that some subjects reported the urge to substitute the asterisk by a letter in order to form an other existing word. They told the experimenter that the mere presence of the asterisk induced the substitution behavior, and that they were unable to suppress it. For example, the display *b*ot* [bone] induced some subjects to substitute the * by an -o-, thus forming the word *boot* [boat]. This false alternative had to be rejected, causing a delay in response latency. Such a mechanism may account for the reversed length effect. The number of possible words that can be constructed through replacing the asterisk by a letter is likely to differ between three- and four-letter words. In three-letter words, the letter replacing the asterisk can either be a consonant or a vowel. In four-letter words, the asterisk-replacing letter is likely to involve a consonant, because a vowel would produce three vowel letters in a row. This would result in a real word in only very few instances. It seems logical to assume that involuntary substitution produced a larger number of false alternatives for three-letter words than for four-letter words. Rejecting false alternatives causes delay. This would boost latency for three-letter words more than for four-letter words, thus producing a reversed length-effect. To conclude, the employed task may have elicited interfering processes that do not operate in normal word processing. This might have forced subjects to reorganize component processes for generating a phonological representation, possibly preventing onsets and rimes to play their role in word naming. In the lexical decision task however, an advantage of an onset-rime segmentation over a postvowel segmentation was found, despite a reversed length effect. This might be related to the quality of the phonological code. The interfering processes are believed to impair the production of a phonological representation. Naming requires the generation of a fully specified phonological representation in order to construct and execute an articulatory motor program, whereas a less fully specified phonological representation may be sufficient for a lexical decision. Therefore, interfering processes have more opportunity to impair performance in a naming task. In the next experiment we adopted a procedure that -most likely- does not elicit substitution strategies.

3.2 Further Research on Onsets and Rimes in Visual Word Identification

The results of the experiments of the preceding paragraph suggested that neither skilled, nor beginning readers use onsets and rimes as functional spelling units in word naming. The possibility was raised that the chosen experimental technique was inappropriate. Subjects may have adopted unnatural, task-specific processing strategies, conceivably concealing effects that otherwise might have been observed. A new technique was developed. This time, no segmentation marker was used. The words were segmented in two parts by a simultaneous shift in size and color of the letters. Two letter sizes (large, small) and two colors (red, black) were use. There is evidence that distortions in a word's visual pattern delays its processing (Adams, 1979). The disruptive effect of alternating letter size is larger than alternating the case of letters (Smith, Lott, & Cronell, 1969). Manipulating the perceptibility of functional spelling units by alternating color and size of its comprising letters should therefore affect reading performance.

The main purpose of the present study was to investigate whether beginning readers use onsets and rimes as units of processing in pseudoword naming. Pseudowords were used because orthographic consistency effects are more robust in low-frequency than in high-frequency words (Seidenberg et al., 1984). Thus, subsyllabic effects are more likely to be obtained in processing of unfamiliar words. Performance on reading pseudowords with a prevowel shift was compared with performance on reading pseudowords with a postvowel shift. For example, *g/oek* was compared with *goe/k* (the / indicates a shift in size and color of the letters. No / appeared in the pseudowords). If onset-rime units are used in pseudoword naming, *g/oek* should be easier to read than *goe/k* because the postvowel segmentation impairs the perception of the rime The onset-rime hypothesis was also tested on CCVC pseudowords Performance on reading pseudowords with a between-consonants shift was compared with performance on reading pseudowords with a prevowel shift For example, *st/es* was compared with *s/tes* If onset-rime units are used in pseudoword naming, *st/es* should be easier to read than *s/tes* because the between-consonants segmentation impairs perception of the onset As we argued earlier, it is likely that a possible use of onset and rime units in reading is related to reading skill If it turns out that onsets and rimes are utilized, we expect this to be more conspicuous for relatively good readers

The question whether good and poor readers differ with respect to the utilization of onsets and rimes in pseudoword reading was addressed In addition, all subjects participated in a word reading task Performance on this task was used to divide the sample in a group of relatively good and relatively poor readers

An important objection against studies claiming subword units of processing, such as onsets and rimes, has been put forward by Seidenberg (1987), and concerns the composition of stimulus words Many experiments failed to control for the fact that graphemes and grapheme combinations are disproportionally distributed within the words of a language For example, some graphemes frequently occur in particular positions within a word, while they seldom or never occur in other positions within words (positional frequency). Some graphemes occur frequently in combination, and sometimes on a particular position within words only ((positional) bigram frequency) The phenomenon that a grapheme is, to some extent, predicted by adjacent graphemes, is labeled as orthographic redundancy' (Adams, 1979, 1981) There is evidence that skilled readers use implicit knowledge of orthographic redundancy in word processing (Henderson & Chard, 1980, Massaro, Taylor, Venezky, & Jastrzembski, 1980, McClelland & Rumelhart, 1981) Word processing of normal and disabled young readers also tends to be facilitated by knowledge of orthographic redundancy (Horn & Manis, 1985) Although orthographic redundancy reflects a complex set of facts about the distribution of letter patterns that can not entirely be captured by a single measure (Seidenberg, 1987), there are indications that the positional bigram frequency of the constituent letter combinations of a word is the best candidate The mean positional bigram frequency of words correlates more with performance on reading those words than other statistically based measures of orthographic redundancy, like for instance, positional trigam frequency (Massaro et al , 1980)

Seidenberg's (1987) criticism on experiments that demonstrate subword units of processing, focuses upon the failure to take into account the aspect of orthographic redundancy He noticed that the boundary between two supposed subword units of processing often bisects the lowest-frequency bigram in the word For example, the bigram -re- in the word *reep* [candy bar] is less frequent than the bigram -ep- (their log bigram frequency is 9 6 and 10 4 respectively) If readers would exploit implicit knowledge of orthographic redundancy, it follows that *r/eep* should be easier to read than *ree/p*, because the postvowel segmentation impairs the perception of an orthographic redundant spelling pattern, whereas the onset-rime segmentation does not. Superficially, this would suggest that readers use onsets and rimes as functional units, whereas in reality, the emergence of onsets and rimes depends upon the orthographic properties of the word. Seidenberg (1987) proposes that the principle of orthographic redundancy might account for all observed subword effects. In the present experiment, we controlled for orthographic redundancy. All constituent bigrams of the four-letter pseudowords were high in frequency. In this manner, possible onset-rime effects can not be attributed to orthographic redundancy.

In the experiments of the preceding paragraph, in which word parts were physically separated by a segmentation marker, it was demonstrated that word naming was more delayed by a within-digraph segmentation than by a segmentation outside the digraph. In order to examine whether a color-size manipulation had the same effect, reading performance on pseudowords segmented within the digraph was compared with performance on pseudowords segmented outside the digraph. For example, *go/ek* was compared with the mean of *g/oek* and *goe/k*. The relation between digraphs and their corresponding phonemes are learned very early in reading instruction. Both good and poor readers process the letter combinations corresponding to those vowels as one functional spelling unit (van Rijnsoever, 1988, p.52). The question arises whether beginning readers also process letter combinations that do not correspond to a single phoneme, but to two phonemes, as in consonant bigrams. There is evidence that skilled readers process high-frequency consonant bigrams as a unit, whereas low-frequency bigrams are processed in a grapheme-by-grapheme fashion (Greenberg & Vellutino, 1988). Skilled readers are able to utilize their implicit knowledge of orthographic redundancy in order to facilitate word processing. For example, if the first letter of a Dutch word that begins with two consonants is an -s-, then it is more likely that the next letter will be a -t- than a -m-. Children may also have acquired implicit knowledge of such orthographic redundancies and utilize this knowledge during reading. The question whether beginning readers also process high-frequency consonant bigrams in units, and whether relatively good and poor readers differ in that respect, was addressed in this study. All consonant bigrams of the pseudowords were high in positional bigram frequency. Performance on reading CVCC and CCVC pseudowords with a between-consonants shift was compared with performance on reading pseudowords with an outside-consonants shift. Thus, C/CVC was compared with CC/VC, and CVC/C was compared with CV/CC. A between-consonants shift should interfere with utilizing the implicit knowledge of frequently co-occurring consonant combinations. There is opposing evidence whether this should affect good readers more or less than poor readers. Implicit knowledge of orthographical redundancy is acquired with reading experience. There is evidence that good readers are more proficient than poor readers in utilizing orthographic regularities (Mason, 1975; Mason & Katz, 1976). However, the interactive-compensatory hypothesis proposed by Stanovich (1980) states that, in actual reading, less skilled readers rely more heavily on orthographic regularities to compensate for weak decoding skills. Evidence for this position has been provided by Stanovich and West (1979). Van Rijnsoever (1988, p.76) demonstrated that the use of orthographic information in word recognition develops in a concave downward pattern. In the initial stages of reading development, knowledge of orthographical regularities is acquired. During that stage, good readers are more proficient than poor readers in using that information. Both reader groups show a maximum effect of orthographical redundancy in word processing at fourth grade. After that, the effect becomes less, but the decrease proceeds faster for good, than for poor readers. During that stage, poor readers rely more on orthographic redundancy than good readers. The subjects of the present study were children of the first grade. For this reason, a manipulation that interferes with exploiting orthographic redundancy should have a larger negative effect on good than on poor readers. Accordingly, a possible detrimental effect of a between-consonants shift should be larger for good than for poor readers.

Finally, in the experiments of the previous paragraph, we investigated the effects of number of letters with number of phonemes controlled for. In contrast, the present study allows analyses of length effects in terms of number of phonemes with number of letters controlled for. The words and pseudowords of the present study were of the CVC, CVCC, or CCVC structure. CVC words and pseudowords consisted of three phonemes, CVCC and CCVC words and pseudowords of four phonemes. All words and pseudowords consisted of four letters. There is evidence suggesting that the number of phonemes affects skilled readers' performance on a lexical decision task. Treiman and Chafetz (1987) presented five-letter words and pseudowords that consisted either of three, or of five phonemes ('thing' and 'wheck' vs. 'blast' and 'flunt'). Subjects took, on the average, 131 ms longer to respond to words and pseudowords with five phonemes than to those with three phonemes. However, the error-rate was *higher* in the three phoneme condition than in the five-phoneme condition (4.9% vs. 12.9%). It is important to add that the stimuli were presented with a double slash (e.g. 'bl//ast') in order to investigate whether onset and rime units were used in lexical decision. This manipulation may have affected length effects.

Method

Subjects

Thirty first-grade pupils of an elementary school participated in the experiment. Their mean age was 7;1 years and ranged from 6;5 to 8;6 years (*SD*=6 months). The experiment was carried out in april. The children had received eight months of reading instruction. The reading method used at the school is primarily based upon the phonics approach, but also contains elements of whole word teaching.

Apparatus

Words and pseudowords were presented in lower case on a white background in the center of an Apple IIGS computer monitor. A four-letter string was approximately 3 by 0.7 centimeter. A letter font used in many text books for children was chosen. Children were seated approximately 60-80 centimeter from the screen. Naming latencies were measured accurately to the millisecond by a voice-activated relay attached to the computer.

Materials

Pseudowords used in this experiment were monosyllabic, consisting of three phonemes (CVC) or four phonemes (CVCC and CCVC). The vowels in the CVCC and CCVC words were represented by a single letter. No consonant digraphs were used. Hence, all CVCC and CCVC words consisted of four letters. Pseudoword with a high positional bigram frequency in the positions 1-2, 2-3, and 3-4, were created (CELEX, 1988). Positional bigram frequency was defined in terms of 'tokens', that is, the frequency of occurrence of words containing the particular bigram, was taken into account. A list of 95 CVCC, and a list of 100 CCVC pseudowords were produced. The mean log bigram-frequency in position 1-2, 2-3 and 3-4 was 10.6, 10.7, and 10.3 for CVCC pseudowords, and 9.7, 9.6, and 9.8 for CCVC pseudowords.

All vowels in the CVC pseudowords were digraphs. In half of the words, the vowel was represented by two identical letters (homogeneous digraph, as in *kaaf*), in the other half the vowel was represented by two different letters (heterogeneous digraph, as in *kief*). Again, no consonant digraphs were used. Thus, all CVC pseudowords also consisted of four letters. A similar procedure as used on CVCC and CCVC pseudowords was adopted with regard to positional bigram frequency. A list of 66 CVC pseudowords with a homogeneous digraph, and 74 pseudowords with a heterogeneous digraph emerged. Their mean log bigram frequency was 11.5, 13.4, and 10.6 for homogeneous digraph CVC pseudowords and 11.4, 12.0, and 10.8 for heterogeneous digraph CVC pseudowords.

Pseudowords ending on a -d-, or a -t-, and therefore orthographically similar to Dutch verb conjunctions, were not used. The list of pseudowords and their log positional bigram frequencies can be found in Appendix 3.3. Note that the lists contains more pseudowords than were actually presented in the experiment. Each subject received a random selection of these pseudowords.

A word reading task was used to assess a subject's relative reading skill. For this task, 90 high-frequency words were selected from Staphorsius et al. (1989). The list consisted of 30 CVC's (15 homogeneous, 15 heterogeneous digraph), 30 CVCC's and 30 CCVC's. As in the pseudoword list, all words consisted of four letters. The median printed frequency was 1430, 160, and 90 occurrences per million words, for CVC, CVCC and CCVC words respectively. Mean log bigram frequency in position 1-2, 2-3 and 3-4 was 11.6, 13.6, and 12.8 for homogeneous CVC's, and 11.1, 11.8, and 12.0 for heterogenous CVC's. For CVCC and CCVC pseudowords, these figures were 11.1, 10.6, 9.6, and 9.7, 9.5, 9.8, respectively.

All words and pseudowords were regular with respect to grapheme-phoneme correspondences. The list of words with their corresponding frequency of occurrence, as well as their log positional bigram frequencies can be found in Appendix 3.4.

Procedure

For each subject, 60 CVCC, 60 CCVC and 120 CVC (60 homogeneous and 60 heterogeneous vowel digraphs) pseudowords were randomly selected from the pseudoword samples. Thus, each subject received a different set of pseudowords. The 90 words of the word reading task, used for the assessment of relative reading skill, were the same for each subject. Presentation of words and pseudowords was blockwise. Order of presentation within tasks was randomized for each subject. The experiment was conducted in two sessions of approximately 20 minutes each, with a three day lag between sessions. Subjects received the first half of the pseudoword trials in the first session, followed by the word reading task. In the second session, the rest of the pseudoword trials was administered. Each trial started with a short attention signal (100 ms) and a fixation point appeared simultaneously in the center of the screen (500 ms). Presentation of the word or pseudoword immediately followed. A maximum of eight seconds was allowed for responding. By pushing buttons on the keyboard, the experimenter indicated whether the stimulus was identified correctly and whether the clock was stopped by the verbal response of the subject. No feedback regarding the quality of response was provided.

Experimental Task.

Pseudowords were segmented in two parts by a simultaneous shift in color and size of the letters. Two sizes (large, small) and two colors (red, black) were used. It is important to emphasize that change in letter size does not imply a shift in case. All letters were presented in lower case. For CVCC and CCVC pseudowords, the shift in size and color was either within, or outside the consonant cluster. For CVC pseudowords, the shift was immediately after the first consonant, within the vowel digraph, or just before the last consonant. Assignment of pseudowords to condition was randomized. Size-color combinations were also randomly assigned to pseudoword segments. Subjects were told to ignore any distortions and just read the pseudowords quickly and accurately. Prior to the experiment proper, 10 practice trials were administered.

Reader Group Assignment.

A word reading task was used to divide the sample in group of relatively good and relatively poor readers. The words were presented in large black letters. Subjects were instructed to read the words quickly and accurately. Prior to the experiment proper, 10 practice trials were administered.

Results

Number correct and median naming latency were calculated for all experimental conditions. Latencies of incorrect responses were not used. Trials on which the response was correct but did not stop the timer, or on which the timer was stopped by a sound other than the response, were not used in the calculation of the median latency. The number of missing values due to timing errors was 5.5%. The over-all percentage of correctly identified pseudowords was 83.7. Although accuracy was high, it had not yet reached a ceiling level. Therefore, accuracy was included in analyses.

Reader Group Assignment

Z-scores of over-all accuracy and latency on the word reading task were determined. The correlation between accuracy and latency on reading words was -.43 ($p<.01$). The sign of the latency z-score was reversed to align direction of scales. The mean of both z-scores was calculated. Subjects with a positive mean were considered as relatively 'good' readers (n=16), subjects with a negative mean as relatively 'poor' readers (n=14).

Onset-Rime Effects

An onset-rime segmentation was compared with a postvowel segmentation with respect to accuracy and naming latency of CVC pseudowords. Number correct and median latency on homogeneous and heterogeneous digraph CVC pseudowords were submitted to a multivariate analysis of variance with Reader Group (2) as between-subjects factor. Effects of Location of Shift (onset-rime versus postvowel) and Digraph Type (homo- and heterogeneous) were tested within subjects. Means are shown in Table 3.12.

Table 3.12: Number correct and mean naming latency (in ms) on homogeneous and heterogeneous CVC pseudowords, split by Point of Segmentation (*SD* in parenthesis)

Reader Group		Point of Segmentation				
		OR [a]		PV [b]		PV-OR [c]
		Number Correct (max=20)				
		Homogeneous digraph CVC's				
poor	(n=14)	17.0	(2.3)	16.9	(2.8)	-.1
good	(n=16)	17.9	(2.5)	18.4	(1.7)	.5
		Heterogeneous digraph CVC's				
poor	(n=14)	17.1	(1.9)	16.3	(2.2)	-.3
good	(n=16)	18.6	(1.2)	18.6	(1.5)	0.0

continued

(Table 3.12 continued)

Reader Group		Point of Segmentation				
		OR [a]		PV [b]		PV-OR [c]
		Latency				
		Homogeneous digraph CVCs				
poor	(n=14)	2178	(612)	2160	(557)	-18
good	(n=16)	1207	(478)	1269	(565)	62
		Heterogeneous digraph CVC's				
poor	(n=14)	2203	(479)	2285	(508)	82
good	(n=16)	1283	(516)	1311	(485)	28

[a] onset-rime segmentation, as in k/aaf', or 'k/ief'
[b] postvowel segmentation, as in 'kaa/f', or 'kie/f'
[c] difference between postvowel and onset-rime segmentation

No effect of Location of Shift was found ($F(2,28)=1.05$, $p=.361$) Over-all performance on reading pseudowords segmented at the onset-rime boundary was equal to performance on reading pseudowords segmented after the vowel The interaction between Location of Shift and Reader Group was not significant ($F<1$) The interaction between Location of Shift and Digraph Type was not significant either ($F<1$) In sum, subjects performed similarly, irrespective whether the pseudoword was segmented at the onset-rime boundary or whether it was segmented after the vowel This result was not affected by any of the other factors included in the design

The onset-rime idea also predicts that C/CVC should be harder to read than CC/VC In a C/CVC segmentation, the shift in size and color should impair perception of the onset because the letters comprising that unit differ in size and color This was investigated by entering number correct and median naming latency on CCVC pseudowords in an analysis of variance with Reader Group (2) as between-subjects factor The effects of Location of Shift (within- or outside the onset) was tested within subjects Means are shown in the lower panel of Table 3 13

The main effect of Location of Shift was not significant ($F<1$), but the interaction between Reader Group and Location of Shift approached significance ($F(2,27)=2.95$, $p=.069$) Univariate analysis revealed that the interaction was significant for accuracy ($F(1,28)=5.12$, $p<.05$), but not for latency ($F<1$) Inspection of Table 3 13 suggests that good readers made more errors on C/CVC than on CC/VC, while the reverse was true for poor readers However, the differences between segmentation conditions were very small and subsequent within-group testing proved them to be non significant ($F(1,28)=2.24$, $p>.1$, and $F(1,28)=2.88$, $p>.1$, for good and poor readers, respectively)

Table 3.13: Number correct and mean naming latency (in ms) on CVCC and CCVC pseudowords, split by Point of Segmentation (*SD* in parenthesis)

Reader Group		Point of Segmentation			
		Within Cluster		Outside Cluster	
		CVCC pseudowords			
		Number correct (max=30)			
poor	(n=14)	21.6	(4.0)	23.1	(4.3)
good	(n=16)	26.4	(2.8)	25.6	(4.0)
		Latency			
poor	(n=14)	3194	(687)	3395	(683)
good	(n=16)	1683	(872)	1822	(885)
		CCVC pseudowords			
		Number correct (max=30)			
poor	(n=14)	23.5	(3.6)	22.3	(4.8)
good	(n=16)	25.4	(3.8)	26.4	(2.8)
		Latency			
poor	(n=14)	3324	(768)	3327	(774)
good	(n=16)	1764	(799)	1713	(714)

Within-Digraph vs. Outside-Digraph Segmentation

A within-digraph segmentation was compared with a segmentation outside the digraph with respect to the effects on reading performance. Number correct and median naming latency on homogeneous and heterogeneous digraph CVC pseudowords were submitted to an analysis of variance with Reader Group (2) as between-subjects factor. Effects of Location of Shift (within vs. outside digraph) and Digraph Type (homo- and heterogeneous) were tested within subjects. Means are shown in Table 3.14.

Reading performance was lower for pseudowords segmented within the digraph than for pseudowords segmented outside the digraph, indicated by a main effect of Location of Shift ($F(2,27)=36.17$, $p<.001$). This was found for both latency and accuracy (2210 vs. 1737 ms, $F(1,28)=18.38$, $p<.001$, and 16.4 vs. 17.6 correct $F(1,28)=69.01$, $p<.001$, respectively). The difference between within-, and outside-digraph segmentations was larger for poor than for good readers ($F(2,27)=5.79$, $p<.01$). Univariate analysis demonstrated that this effect approached significance for accuracy (a difference of 1.7 and 0.7 pseudowords correct for poor and good readers, respectively, $F(1,28)=3.93$, $p=.057$), and was statistically significant for latency (a difference of 655 and 290 ms for poor and

Table 3.14: Number correct and mean naming latency (in ms) for Within and Outside Digraph Segmentation, split by Reader Group and Digraph Type (*SD* in parenthesis)

Reader Group		Point of Segmentation				
		WD[a]		OD[b]		WD-OD[c]
		Number correct (max=20)				
		Homogeneous digraphs				
poor	(n=14)	16.9	(1.8)	16.9	(2.4)	0.0
good	(n=16)	18.1	(1.8)	18.1	(1.8)	0.0
		Heterogeneous digraphs				
poor	(n=14)	13.2	(3.5)	16.7	(1.8)	-3.5
good	(n=16)	17.3	(2.3)	18.6	(.9)	-1.3
		Latency				
		Homogeneous digraphs				
poor	(n=14)	2615	(555)	2169	(561)	446
good	(n=16)	1424	(519)	1238	(516)	186
		Heterogeneous digraphs				
poor	(n=14)	3109	(676)	2244	(467)	865
good	(n=16)	1690	(791)	1297	(498)	393

[a] within-digraph segmentation, as in 'ka/af', or ki/ef'
[b] outside digraph segmentation: mean of onset-rime and postvowel segmentation
[c] difference between within-digraph and outside-digraph segmentation

good readers, respectively, ($F(1,28)=10.38$, $p<.01$). Differences between within-, and outside digraph segmentations were larger for heterogeneous than for homogeneous digraphs, indicated by the significant interaction between Location of Shift and Digraph Type ($F(2,27)=6.79$, $p<.01$). This was found for both accuracy (a difference of 2.4 and 0.1 pseudowords correct for heterogeneous and homogeneous digraphs respectively, $F(1,28)=10.21$, $p<.01$), and for latency (a difference of 629 and 316 ms for heterogeneous and homogeneous digraphs respectively, $F(1,28)=13.16$, $p=.001$). The three-way interaction between Location of Shift, Digraph Type, and Reader Group was not significant ($F(2,27)=1.18$, $p=.321$).

Within- vs. Outside Consonant-Bigram Segmentation

In order to test whether consonant bigrams were processed as units, number correct and median naming latency on CVCC and CCVC pseudowords were entered in an analysis of variance with Reader Group as between-subjects factor, and Location of Shift (inside vs. outside consonant cluster) and Orthographical Structure (CVCC and CCVC) as within-subjects factors. Means are shown in Table 3.13.

No main effect of Location of Shift was found ($F(2,27)=2.23$, $p=.127$). The over-all reading performance was not affected by segmentation condition. The interaction between Reader Group and Location of Shift was not significant either ($F<1$). A significant interaction between Location of Shift and Orthographical Structure was found ($F(2,27)=6.03$, $p<.01$). Univariate analysis revealed that the effect was significant with respect to naming latency ($F(1,28)=11.1$, $p<.01$), but not with respect to accuracy ($F<1$). A shift in color and size within the consonant cluster resulted in faster naming of CVCC pseudowords (2439 vs. 2609 ms), but in slower naming of CCVC pseudowords (2544 vs. 2520). The three-way interaction between Reader Group, Location of Shift, and Orthographical Structure was significant ($F(2,27)=6.09$, $p<.01$). Univariate analysis revealed that the effect was significant with respect to accuracy ($F(1,28)=12.2$, $p<.01$), but not with respect to naming latency ($F<1$). Inspection of Table 3.13 learns that for poor readers, a shift in color and size within the consonant cluster resulted in a higher number correct for CCVC pseudowords, and in a lower number correct for CVCC pseudowords. Exactly the reverse was found for good readers. A shift in color and size within the consonant cluster resulted in a lower number correct for CCVC pseudowords, and in a higher number correct for CVCC pseudowords.

Length effects

The word reading task, used to assess subjects' reading level, consisted of reading CVC, CVCC, and CCVC words. All words consisted of four letters. However, words differed with respect to number of phonemes. CVC words consisted of three phonemes, CVCC and CCVC words of four phonemes. The mean percentage correct, and the mean of median naming latency on CVCC and CCVC words was calculated. These variables, together with mean percentage correct and median naming latency on CVC words, were entered in a multivariate analysis of variance with Reader Group (2) as between-subjects factor, and Length (three vs. four phonemes) as within-subjects factor. Means are shown in the upper panel of Table 3.15.

Main effects of Length and Reader Group were found ($F(2,27)=32.2$, $p<.001$, and $F(2,27)=37.5$, $p<.001$, respectively). The interaction between Reader Group and Length was significant ($F(2,27)=8.57$, $p<.001$). Univariate analysis revealed that the interaction was significant with respect to naming latency ($F(1,28)=17.2$, $p<.001$). Both good and poor readers needed more time to name a four-phoneme word than a three-phoneme word

Table 3.15: Percentage correct and mean naming latency (in ms), split by Number of Phonemes (*SD* in parenthesis)

Reader Group		Number of Phonemes				
		three[a]		four[b]		difference
		Words				
		Percentage correct				
poor	(n=14)	89.8	(5.5)	79.5	(10.6)	10.3
good	(n=16)	96.3	(3.6)	91.7	(4.3)	-4.6
		Latency				
poor	(n=14)	1468	(527)	2747	(723)	1279
good	(n=16)	840	(273)	1220	(678)	380
		Pseudowords				
		Percentage correct				
poor	(n=14)	84.1	(9.1)	75.5	(12.2)	-8.6
good	(n=16)	91.7	(6.2)	86.5	(10.0)	5.2
		Latency				
poor	(n=14)	2207	(503)	3310	(683)	1103
good	(n=16)	1268	(503)	1745	(806)	477

[a] mean calculated across hetero- and homogeneous digraph
[b] mean calculated across CVCC and CCVC

($F(1,28)=6.62$, $p<.05$, and $F(1,28)=65.51$, $p<.001$, respectively). However, the difference was substantially larger for poor readers. The interaction between Reader Group and Length approached significance with respect to percentage correct ($F(1,28)=3.37$, $p=.077$). Within reader group testing revealed that both good and poor readers read more three-phoneme words than four-phoneme words correctly ($F(1,28)=4.74$, $p<.05$, and $F(1,28)=20.7$, $p<.001$, respectively), but the difference tended to be larger for poor readers.

The exploration of the relation between number of phonemes and reading performance was extended to reading of pseudowords. It is important to realize that the pseudowords, in contrast to words, were presented with a shift in size and color of the letters. Results of analyses should therefore be interpreted with caution. The mean percentage correct, and the mean of median latencies across all experimental conditions of CVCC and CCVC pseudowords were calculated. In addition, the mean percentage correct, and the mean of median latencies CVC pseudowords with a pre- and postvowel segmentation were determined. Note that the within-digraph condition was excluded. These variables were entered in a multivariate analysis of variance with Reader Group (2) as between-subjects factor, and Length (2) as within-subjects factor. Means are shown in the lower panel of Table 3.15.

Again, main effects of Length and Reader Group were found ($F(2,27)=38.3$, $p<.001$, and $F(2,27)=17.7$, $p<.001$, respectively). The interaction between Reader Group and Length was also significant ($F(2,27)=5.93$, $p<.01$). Univariate analysis revealed that the interaction was significant with respect to naming latency ($F(1,28)=12.2$, $p<.001$). In comparison with words with three phonemes, both good and poor readers needed more time to prepare a response to a word with four phonemes ($F(1,28)=7.99$, $p<.01$, and $F(1,28)=34.4$, $p<.001$, respectively). The difference however, was substantially larger for poor readers. The interaction between Reader Group and Length with respect to percentage correct was not significant ($F(1,28)=1.43$, $p=.242$). Within reader group testing revealed that both good and poor readers read more three-phoneme words than four-phoneme words correctly ($F(1,28)=7.46$, $p<.05$, and $F(1,28)=17.6$, $p<.001$, respectively), but the difference in accuracy between three-, and four-phoneme words was similar for poor and good readers (8.6 and 5.3%, respectively).

Discussion

This study addressed the question whether beginning readers use onsets and rimes in pseudoword naming. In the previous experiments, we failed to obtain evidence for the use of onsets and rimes in word naming. The possibility was raised that the failure to find effects was due to an inappropriate experimental technique. For this reason, a new naming study, utilizing a different experimental manipulation was carried out. Again, no support was found for the idea that beginning readers process pseudowords in onset and rime units. Reading performance was similar, irrespective whether pseudowords were segmented at the onset-rime boundary or whether they were segmented after the vowel. This suggests that the rime is not a dominant spelling unit in the identification of pseudowords. Furthermore, the results with respect to CCVC pseudowords revealed that impairing the perception of the onset produced small and rather inconsistent effects on reading performance. This suggests that the onset is not a dominant spelling unit in the identification of pseudowords either. Over-all, the results indicate that Dutch beginning readers do not utilize onset and rime units in word and pseudoword naming. They do not support the suggestion made by Wise et al. (1990) that "onsets and rimes are easier units onto which to map print-to-sounds associations, compared with less salient or accessible units such as initial consonants plus vowel" (p.16). According to this view, onsets and rimes play a salient role in the production of a phonological representation. Onset and rime units would be involved in identification processes, that is, preceding lexical access. Wise et al. (1990) argue that onsets and rimes already play a role in beginning reading, and obtained evidence for this claim in a word-learning training experiment. First-grade children were trained in reading new words. Words were presented in two segments by means of a reverse-video presentation. Half of the words were segmented at the onset-rime boundary (onset-rime words), the other half were segmented after the vowel (postvowel words). Children were instructed to blend the word segments, and thus, to read the words. After training, the complete list of words was again administered (in normal presentation). Children read more onset-rime, than postvowel words correctly. During training, children were equally good at blending onset-rime words as blending postvowel words. Therefore, Wise et al. attributed the beneficial effect of onset-rime segmentation to factors influencing recognition beyond those that affect blending ease (p.12). Their study involved reading words, whereas our study involved reading pseudowords. At this reading level, both kinds of stimuli require phonological decoding. However, recognition is possible for words only. Perhaps the factor that words were recognized was responsible for the observed advantage of an onset-rime segmentation over a postvowel segmentation. The phonological representation of a word in the lexicon is supposed to be hierarchically represented at a number of levels, including an onset-rime structure (Treiman, 1988). During training, children were required to blend, and read aloud two word segments. It is possible that the phonological representations of onset-rime words were more activated than postvowel words, because a presented onset-rime segmentation would match the internal representation. Thus, onset-rime words might have been more activated than postvowel words. This difference in activation might be responsible for the result that children read more onset-rime words correctly on the posttest. Note that the posttest was administered immediately after training. If phonological priming should account for the better performance on onset-rime words, then this should support the position that phonological word representations include an onset-rime structure. However, it does not necessarily mean that onset and rime units are utilized in reading. Further research on these issues is required. In this respect, it is noteworthy that the researchers informed us that in subsequent experiments, they were unable to replicate their initial findings (R.K. Olson, personal communication, July 5, 1990).

The results with respect to the comparison between within versus outside digraph segmentations were in agreement with the results of experiment 1 of the previous paragraph. Within-digraph segmentations had a larger disruptive effect on pseudoword reading than outside-digraph segmentations. Furthermore, the detrimental effect of a within-digraph segmentation was larger for poor, than for good readers. Differences between within-, and outside digraph segmentations were larger for heterogeneous than for homogenous digraph pseudowords. This result may be explained by the assumption that the frequency of occurrence of a spelling unit determines its quality of representation. The mean log bigram frequency of heterogeneous digraphs and homogeneous digraphs in medial position of printed four-letter words is 12.0 and 13.4, respectively (CELEX, 1988). For this reason, a high quality of representation should be attained earlier for homogeneous, than for heterogeneous digraphs. Good readers may have acquired a high level of representation of both digraph types, whereas poor readers may have a qualitatively lower representation of heterogeneous digraphs. These results on the comparison between within-digraph and outside digraph segmentations indicate that impairing the perception of a functional spelling unit by alternating size and color of the letters is a manipulation that is sensitive enough to affect reading performance

The question whether beginning readers process consonant bigrams as functional spelling units in reading was addressed Performance on reading pseudowords with a between-consonants segmentation was compared with performance on pseudowords with an outside-consonants segmentation A segmentation in between the two consonants resulted in faster naming of CVCC pseudowords, but in slower naming of CCVC pseudowords In addition, poor readers read more C/CVC than CC/VC pseudowords correctly, but less CVC/C than CV/CC pseudowords Exactly the reverse was found for good readers The results are inconsistent and do not seem to indicate that these readers processed consonant bigrams as a unit.

Finally, the relation between number of phonemes and reading performance was addressed in this study Both good and poor readers were faster and more accurate at naming three-phoneme words and pseudowords than at four-phoneme words and pseudowords Besides, the difference was much larger for poor than for good readers This suggests that poor readers' difficulty in phonological decoding increases with the number of phonemes involved However, in addition to phonological decoding, other processes are also involved in pseudoword naming In discussions on naming tasks, authors generally make a distinction between an abstract phonological representation and an articulatory program (e g Gough, 1984, Henderson, 1982, chapter 7, Levelt, 1989, chapter 11) The question arises if poor readers' problems with longer words are related to phonological decoding only Other processes in naming, like articulatory programming, may also be deficient. This question will be addressed in chapter 4

The Color-Size Technique

A shift in color and size of letters of a pseudoword did not seem to raise confusion with respect to the phonology of the pseudoword At least, no subject reported to be confused with respect to the pronunciation of the pseudoword No reverse length effects were found with respect to number of phonemes On the contrary, response latencies to four-phoneme words and pseudowords were longer than to three-phoneme words and pseudowords, with the number of letters controlled for In contrast to the technique of separating word parts by a segmentation marker, the color-size manipulation did not seem to elicit 'unnatural' reading strategies In conclusion, the experimental technique of manipulating color and size of the letters of a word seems to be a useful procedure for investigating processing of subword units

3.3 Summary and Conclusions

The reason for conducting the experiments of the present chapter arose from the observation that training in pseudoword reading resulted in a parallel progress in naming speed for all pseudowords, irrespective of length (see chapter 2). This result is in conflict with the GPC theory (Coltheart, 1978), predicting that progress should be larger for long, than for short pseudowords, because reading long pseudowords requires more grapheme-phoneme conversions. The possibility was raised that the units involved in reading may be larger than individual graphemes. Treiman and her colleagues (e.g. Treiman & Chafetz, 1987; Treiman & Zukowski, 1988; Wise et al., 1990) proposed that skilled and beginning readers process words and pseudowords in onset and rime spelling units. This idea would harmonize with the observed training studies. Suppose that children do utilize onset and rime spelling units in reading, but were still at a low level of processing. Training may have caused a more efficient processing of these units. As all words and pseudowords consisted of two subword units, this would lead to a parallel progress. The primary purpose of this chapter was to investigate whether onset-rime units play a role in the reading process of beginning Dutch readers. A similar technique as used by Treiman and Chafetz (1987) was employed. The perception of words was impaired by segmenting them in two parts by a marker (*). Word parts either corresponded, or did not correspond to the onset-rime structure. If onset-rime spelling units would be used, reading should be easier if the segmentation did not interfere with the perception of these units. The results of the first experiment opposed the onset-rime idea. Naming words with unimpaired onset-rime spelling units was slower than words segmented after the vowel. However, the results suggested that the employed technique produced unreliable results. The same question was addressed in experiment 4. This time however, pseudowords were segmented in two parts by a shift in color and size of the letters. No effects with respect to point of segmentation were found. The conclusion is that onsets and rimes do not seem to be functional spelling units for beginning readers.

The question whether skilled readers utilize onsets and rimes was addressed in experiments 2 and 3. Skilled readers do not seem to utilize onsets and rimes in word naming. However, an effect in favor of an onset-rime segmentation over a postvowel segmentation was found with respect to lexical decision speed. The question why onset and rime spelling units do seem to play a role in lexical decision, but not in naming, is very interesting. We feel that it must have something to do with a different role of phonological information in both tasks. However, this is only speculative. Whether, and how phonological processing affects performance on both tasks can not be decided with the current data. Addressing this question was beyond the scope of the present project.

A second possibility for multi-grapheme processing, also capable of accommodating the parallel progress, was raised. Children might process high-frequency consonant bigrams in units. Following this assumption, the words and pseudowords used in the training studies always involved three units. Training may have caused a more efficient processing of these units. This would account for the parallel progress of pseudowords of different length. This suggestion was investigated in experiment 4. No evidence that beginning readers process adjacent consonants in units was found.

The present chapter dealt with the question whether beginning readers utilize spelling units that exceed the level of individual graphemes. Two proposals for multi-grapheme units, onsets and rimes, and consonant bigrams, were investigated experimentally. However, no evidence that beginning readers utilize these units was found. The possibility that the subjects of the training experiments decoded words in either of the proposed units, and that training affected the efficiency of processing these multi-grapheme units, should as yet be discarded.

A different hypothesis was raised to account for the parallel progress in naming speed for pseudowords of different length. The progress may not have been the result of improved decoding, but of improved articulatory programming. If it should be discovered that the speed of producing a pseudoword's articulatory program is unaffected by its number of phonemes, and that training in pseudoword reading has a positive effect on this skill, then this might account for the parallel progress. The question whether beginning readers' speed of producing a pseudoword's articulatory program is affected by its number of phonemes, and whether reading skill is a factor of importance in this respect, will be investigated experimentally in chapter 4.

Chapter 4. Naming Latency and Reading Skill

Introduction

In the present chapter three components of pseudoword naming latency are investigated: (a) generating a phonological code, (b) articulatory programming, and (c) execution of the speech program (actual vocalization). The purpose of the present chapter is to investigate whether the execution time of each component is affected by the number of phonemes, and whether this time is influenced by the reading skill of the subject. The interaction between number of phonemes and reading skill with respect to the execution time of each component is also investigated.

The reason for addressing these questions is a puzzling result obtained in the training studies (see chapter 2). Poor readers received a training in pseudoword reading. A quite substantial improvement in naming speed of approximately 10-14% during training was observed. The positive effects were not word-specific because each pseudoword was shown only once during the entire training program. In both training experiments, naming latency was affected by the number of phonemes of pseudowords. However, the observed progress in naming speed was not. The progress can not be the result of improved grapheme-phoneme decoding because this would predict that the positive effects of training should be larger for long than for short pseudowords because long pseudowords require more decoding. The possibility was raised that training did not affect the ability to generate a phonological code, but instead, had a positive effect on components that follow this phase. According to this view, training has a positive effect on processes involving response production rather than on decoding skill. In the first training study, we endeavored to control for this possibility. In addition to naming words and pseudowords, children were required to name a series of digits at each session. Children of this age and reading skill can be expected to recognize digits automatically (Ehri & Wilce, 1983). Digit naming latency should therefore pertain primarily to processes involving response production. The digit naming speed did not improve during training, pointing to the conclusion that skills involving response production were not affected by training. However, after re-examining the issue, digit naming speed seemed to have its drawbacks as a control measure. The representation of highly familiar stimuli in the lexicon might include a level of phonological representation that comes close to a speech code. Digit naming may have been realized by retrieving a ready-for-use speech program from long term memory. In contrast to pseudoword naming, digit naming may have required little articulatory programming. The possibility that progress in pseudoword naming speed during training was the result of improved articulatory programming was therefore not ruled out.

If practice in pseudoword reading has a positive effect on articulatory programming, the results of the training studies may be explained as follows. The over-all difference in naming latency between long and short pseudowords would be the result of differences in decoding time, and the parallel progress in naming speed would be the result of improved articulatory programming. This position presupposes that poor readers have problems with articulatory programming, otherwise it would be difficult to understand why training produced such impressive progress in naming speed. Moreover, in order for the articulatory programming hypothesis to be consistent with the result of parallel progress in naming speed for pseudowords of different length, the time to construct an articulatory program of monosyllabic pseudowords should not be affected by the number of phonemes involved. These assumptions will be investigated experimentally in the present chapter by comparing relatively good and poor beginning readers with respect to the speed with which they construct an articulatory program and by examining the effects of number of phonemes on this variable.

The investigation of subcomponents of naming latency makes it necessary to disentangle the task into distinguishable phases. Naming a visually presented pseudoword may be roughly divided into three phases (a) producing an abstract phonological representation through phonological decoding, (b) articulatory programming, and (c) execution of a speech motor program (Henderson, 1982, p.188). The contribution of each component to naming latency was isolated by comparing subjects' response latencies on three different experimental tasks.

An Immediate Pseudoword Naming task, a Delayed Pseudoword Naming task, and a Lexical Decision task were administered. In the Immediate Pseudoword Naming task, subjects were to name a visually presented pseudoword as quickly as possible. In the Delayed Pseudoword Naming task, a pseudoword was presented on the screen. The subjects were instructed to read the pseudoword but to hold back their response An asterisk appeared on the screen after approximately four seconds, prompting the subject to name the pseudoword as quickly as possible. In the Lexical Decision task, either a word or a pseudoword was presented. The task of the subject was to indicate whether the letter string was a real word or not, by pushing one of two buttons. They were to make their decision as soon as possible immediately after stimulus presentation onset. Beginning readers (end of first grade) participated in this experiment. In addition to the three experimental tasks, a Word Reading task was administered. A median split on reading performance on this task produced a group of relatively 'good', and a group of relatively 'poor' readers

The following assumptions concerning the components contributing to response latency were made. In the Immediate Pseudoword Naming task, all three distinguished components contribute to response latency. In the Delayed Pseudoword Naming task, pseudoword presentation preceeds the prompt for response production. This enables children to prepare a phonological representation and to construct a speech program through articulatory programming (Henderson, 1982). Phonological decoding and articulatory programming should be completed before the prompt. Therefore, they will not contribute to response latency. A lexical decision, finally, is influenced by phonological information (Coltheart, 1978; Seidenberg et al., 1984), but this decision latency does not necessarily require the translation of the abstract phonological representation into a speech program (Bentin & Frost, 1987; Seidenberg & McClelland, 1989). Lexical decision latency should therefore not contain components of articulatory programming or actual vocalization.

All words and pseudowords of the present study had four letters but consisted of either three or four phonemes. In this way, the effect of number of phonemes could be investigated with the number of letters controlled for.

The assumptions concerning the various components affecting a naming response lead to the following predictions.

If poor readers' problems with word naming are limited to decoding difficulties, then poor readers should be slower than good readers in the immediate pseudoword naming task and the lexical decision task, but not in the delayed pseudoword naming task. In addition, a Reader Group by Number of Phonemes interaction should be found in the immediate pseudoword naming task and the lexical decision task. Longer pseudowords require more decoding and should therefore delay poor readers more than good readers. The view that poor readers' difficulties are restricted to phonological decoding implies that no effect of Reader Group, nor an interaction between Reader Group and Number of Phonemes on the delayed pseudoword naming should be obtained.

If the problems of poor readers originate solely in the preparation of an articulatory program, then poor readers should be slower on the immediate pseudoword naming task, but not on the other two tasks. It may also be that poor readers have difficulty with both phonological decoding as well as with articulatory programming. If this should be so, then the difference between good and poor readers should be larger on the immediate pseudoword naming task than on the lexical decision task, because naming requires decoding as well as articulatory programming, whereas a lexical decision requires decoding only.

Finally, if actual vocalization is the sole source of poor reader's problems, then poor readers should be slower on both the immediate and the delayed naming task, but not on the lexical decision task.

Method

Subjects

Thirty-one first-graders from elementary school participated in the experiment. Their mean age was 7;2 years and ranged from 6;1 to 7;8 years (*SD*=4 months). The experiment was carried out in June. At the moment of testing, children had received ten months of reading instruction. The Eén-Minuut-Test (Brus & Voeten, 1972), was administered by the teachers just a week before the experiment started. The mean score was 27.5 (*SD*=12.1), with a range from 11 to 59 words read correctly within one minute. According to the criteria of the Eén-Minuut-Test, a score of 27 on this test corresponds to a reading level achieved by children at the beginning of second grade. The reading method used by the school is primarily based upon the phonics approach, but also contains elements of whole word teaching.

Apparatus

The same apparatus as utilized in experiment 3.2 was employed. In addition, a device with two buttons (*yes* and *no* button) was connected to the computer in order to record lexical decision latencies.

Materials

The pseudowords used in this experiment were monosyllabic, consisting of three graphemes (CVC) or four graphemes (CVCC and CCVC). The same pseudowords as used for the experiment described in §3.2 were used. The complete lists can be found in Appendix 3.3. The lists contained more pseudowords than were actually used in the experimental tasks. Each subject received a random selection of these pseudowords.
The same 90 words (30 CVC, 30 CVCC, and 30 CCVC) as used in experiment 4, described in §3.2, were used in the word reading task. The list can be found in Appendix 3.4. Each subject received the same set of words.

Procedure

The Word Reading task was used to assess the child's reading skill. Performance on this task was used to divide the sample in a group of relatively good and relatively poor readers. Furthermore, three experimental tasks were administered: an Immediate Pseudoword naming task, a Delayed Pseudoword naming task, and a Lexical Decision task. Tasks were administered in two sessions of approximately 25 minutes each, three days apart. The Lexical Decision task and the Word Reading task were administered in one session, the other two tasks in the other session. Order of sessions, as well as order of tasks within a session, was balanced across subjects. Order of presentation within tasks was randomized for each subject.

Word Reading Task.

The 90 words used in the Word Reading task were the same for each subject. Children were instructed to read the words quickly and accurately. The number correct and median naming latency were determined. Prior to the experiment proper, 10 practice trials were administered.

Immediate Pseudoword Naming Task.

For each subject, 28 three-phoneme CVC pseudowords (14 with a homogeneous digraph, 14 with a heterogeneous digraph) were randomly selected from the CVC pseudoword sample. Analogously, for each subject, 28 four-phoneme pseudowords (14 CVCC, and 14 CCVC) were randomly selected from their respective pseudoword samples. Each trial started with a short auditory attention signal (100 ms) and a fixation symbol appeared simultaneously in the center of the screen (500 ms). Presentation of the pseudoword followed immediately. At that moment the clock was started. Children were instructed to read the pseudoword aloud, as quickly and accurately as possible. A maximum of 8 seconds was allowed for responding. By pushing buttons on the keyboard the experimenter indicated whether the answer was correct, and whether the clock was stopped by the verbal response of the subject. No feedback regarding the quality of response was provided. Prior to the experiment proper, 10 practice trials were administered.

Delayed Pseudoword Naming Task.

For each subject, 28 three-phoneme CVC pseudowords (14 with a homogeneous digraph, 14 with a heterogeneous digraph) were randomly selected from the CVC pseudoword sample. Analogously, for each subject, 28 four-phoneme pseudowords (14 CVCC, and 14 CCVC) were randomly selected from their respective pseudoword samples. None of these pseudowords were used in any of the other tasks.

The procedure until presentation of the pseudoword was identical to the immediate pseudoword naming task. The pseudoword remained on the screen for 3 seconds. Children were instructed to read the pseudoword, but to hold back their response. After 3 seconds elapsed, the pseudoword disappeared and a blank screen was shown for a variable interval of 1 - 1.5 second. Children were told that a blank screen meant that they were 'to get ready' because the signal to respond was about to appear. Next, a matrix of 3 by 3 #'s appeared in the center of the screen. This served as trigger for the response. At that moment, the clock was started. Children were instructed to read the pseudoword aloud, as quickly and accurately as possible. Evaluation of the response by the experimenter was identical to the procedure as described for the Immediate Pseudoword naming task. Prior to the experiment proper, 10 practice trials were administered.

Lexical Decision Task.

For each subject, 28 three-phoneme CVC pseudowords (14 with a homogeneous digraph, 14 with a heterogeneous digraph) were randomly selected from the CVC pseudoword sample. Analogously, for each subject, 28 four-phoneme pseudowords (14 CVCC, and 14 CCVC) were randomly selected from their respective pseudoword samples. None of these pseudowords were used in any of the other tasks. A number of 28 three-phoneme (14 homogeneous digraph CVC words, and 14 heterogeneous digraph CVC words), and 28 four-phoneme (14 CVCC, 14 CCVC) words were selected from

Staphorsius et al. (1989), and assigned to the *three-phoneme* and *four-phoneme* condition of the word part of the lexical decision task. All the words represented objects or animals that should be familiar to the subjects. The words had a printed frequency count of more than 10 per million occurrences. None of these words were used in the Word Reading task. The procedure until presentation of the (pseudo)word was identical to the Immediate Pseudoword naming task. Children were instructed to press the yes-button in case a word was presented and the no-button in case a pseudoword was presented. They were instructed to respond as quickly as possible without making mistakes. In order to reduce error-variance, children were allowed to use their hand of preference for the yes-button. A maximum of 8 seconds was allowed for responding. No feedback regarding the quality of response was provided. Prior to the experiment proper, 10 practice trials were administered.

Design

Table 4.1 displays the distribution of words and pseudowords for the immediate pseudoword naming task, the delayed pseudoword naming task, and the lexical decision task.

Table 4.1: Number of words and pseudowords per task, split by Number of Phonemes

Lexical status	Number of Phonemes					
	three	four	three	four	three	four
	int [a]		ldt [b]		dnt [c]	
words			28	28		
pseudowords	28	28	28	28	28	28

a Immediate Naming task
b Lexical Decision task
c Delayed Naming task

Results

For each subject, the number correct and median response latency were calculated for all experimental conditions. Latencies of incorrect responses were not used. Trials on which the response was correct but did not stop the timer, or on which the timer was stopped by a sound other than the response, were not used in the calculation of the median latency. The number of missing values due to incorrect responses and timing errors was 14.1%, and 6.8%, respectively. Table 4.2 displays the correlation matrix of median latencies on all dependent variables.

Table 4.2: Correlation matrix of latency variables

	ldtneg	pseudonaming	delayed	words
ldtpos	.88 **	.87 **	.31	.92 **
ldtneg		.84 **	.20	.85 **
pseudonaming			.20	.91 **
delayed				.29

ldtneg	correct no-decisions
ldtpos	correct yes-decisions
pseudonaming	Immediate Pseudoword naming
delayed	Delayed Pseudoword naming
words	Immediate Word naming

** $p<.001$

As Table 4.2 shows, correlations between dependent variables were high, except for the delayed naming task. Data were submitted to analyses of variance with Reader Group (good versus poor readers) as between-subjects factor, and Number of Phonemes (three versus four phonemes) as within-subjects factor.

Word Reading Task

Over-all accuracy on the word naming task was high (M=94%). The correlation between accuracy and latency on reading words was -.77 ($p<.001$), indicating that accurate readers were also fast readers. Word naming latency was also strongly correlated with the score on the Eén-Minuut-Test ($r=-.86$, $p<.001$). For each subject, the median word naming latency was determined. A median split produced a group of 16 relatively 'good' and 15 relatively 'poor' readers.

Immediate Pseudoword Naming Task

Means are shown in the lower panel of Table 4.3.

Poor readers were slower than good readers ($F(1,28)=124.3$, $p<.001$), and naming four-phoneme words was slower than naming three-phoneme words ($F(1,28)=35.63$, $p<.001$). Within-group testing revealed that both good and poor readers responded more slowly to four-phoneme pseudowords than to three-phoneme pseudowords (466 ms, $F(1,28)=3.07$, $p=.091$, and 116 ms, $F(1,28)=42.69$, $p<.001$, respectively). However, the length effect was larger for poor than for good readers, as indicated by a significant interaction between Reader Group and Number of Phonemes ($F(1,28)=12.78$, $p<.001$).

Table 4.3: Mean latency (in ms) of Immediate Word and Pseudoword Naming, split by Number of Phonemes (*SD* in parenthesis)

Reader Group		Number of Phonemes				
		three		four		difference
		words				
poor	(n=15)	1606	(552)	2572	(667)	966
good	(n=16)	758	(133)	877	(248)	119
		pseudowords				
poor	(n=15)	2070	(443)	2536	(444)	466
good	(n=16)	931	(174)	1047	(288)	116

Delayed Pseudoword Naming Task

Means are shown in Table 4 4

Table 4.4: Mean naming latency (in ms) of Delayed Pseudoword Naming, split by Number of Phonemes (*SD* in parenthesis)

Reader Group		Number of Phonemes				
		three		four		difference
poor	(n=15)	669	(128)	669	(130)	0
good	(n=16)	613	(165)	650	(165)	37

No main effects of Reader Group and Number of Phonemes were found (F<1, and (F(1,28)=1.38, p=.250, respectively). The interaction between Reader Group and Number of Phonemes was not significant (F(1,28)=1.35, p= 255) Good and poor readers did not differ in the speed of generating a prepared response. Furthermore, latency of a prepared response was unaffected by a difference in word length of one phoneme.

Lexical Decision Task

Means are shown in Table 4 5.

Lexical Status (words versus pseudowords) was included as within-subjects factor in the analysis of variance. The main effect of Lexical Status (F(1,29)=107 10, p< 001) demonstrates that yes-decisions were faster than no-decisions The interaction between

Table 4.5: Mean Lexical Decision latency (in ms), split by Number of Phonemes (*SD* in parenthesis)

Reader Group		Number of Phonemes				
		three		four		difference
		words				
poor	(n=15)	2209	(539)	3009	(612)	800
good	(n=16)	1271	(295)	1507	(352)	236
		pseudowords				
poor	(n=15)	3222	(438)	3694	(408)	472
good	(n=16)	1881	(520)	2160	(557)	279

Reader Group and Lexical Status was not significant ($F(1,29)=2.31$, $p=.139$), indicating that a no-decision was equally more difficult than a yes-decision to poor readers as it was to good readers.

A main effect of Number of Phonemes was found ($F(1,29)=152.99$, $p<.001$). Within-group testing revealed that both good and poor readers took longer to respond to four-phoneme strings than to three-phoneme strings (1834 vs. 1576 ms, $F(1,29)=26.27$, $p<.001$, and 3352 vs. 2716 ms, $F(1,29)=150.15$, $p<.001$, respectively). However, the interaction between Reader Group and Number of Phonemes ($F(1,29)=27.43$, $p<.001$) revealed that this difference was larger for poor than for good readers.

The three-way interaction between Reader Group, Lexical Status, and Number of Phonemes was also significant ($F(1,29)=8.47$, $p<.01$). For poor readers, a larger length effect was observed for words than for pseudowords (800 versus 472 milliseconds, $F(1,29)=12.90$, $p<.001$), whereas for good readers, the length effect was equally large for words as for pseudowords (236 versus 279 milliseconds, $F<1$).

Word and Pseudoword Naming

Results on the lexical decision task revealed that poor readers showed larger length effects on pseudowords than on words, whereas length effects on both words and pseudowords were equally large for good readers. In order to test whether these results can be generalized to naming tasks, a posthoc analysis was carried out. Median naming latencies of words and pseudowords were submitted to an analysis of variance with Reader Group as between-subjects factor, and Lexical Status (words versus pseudowords) as within-subjects factor. Means are shown in Table 4.3.

Exactly the same pattern of results emerged. Naming latency was longer for pseudowords than for words ($F(1,28)=7.68$, $p<.01$). The interaction between Reader Group and Lexical Status was not significant ($F<1$). Pseudoword reading was more difficult than word reading, the difference being similar for both good and poor readers.

A main effect of Number of Phonemes was found ($F(1,28)=158.35$, $p<.001$). Within-group testing revealed that both good and poor readers took longer to name a four-phoneme string than a three-phoneme string (962 vs. 845 ms, $F(1,28)= 6.69$, $p<.05$, and 2554 vs. 1838 ms, $F(1,28)=219.37$, $p<.001$, respectively). However, the significant interaction between Reader Group and Number of Phonemes ($F(1,28)=81.89$, $p<.001$) revealed that this difference was larger for poor than for good readers.

The three-way interaction between Reader Group, Lexical Status, and Number of Phonemes was also significant ($F(1,28)=14.73$, $p<.001$). However, for poor readers, a larger length effect was observed for words than for pseudowords (966 versus 466 milliseconds, $F(1,28)=27.77$, $p<.001$), whereas this made no difference for good readers (119 versus 116 milliseconds, $F<1$).

Discussion

In this study, naming latency was disentangled into three components: (a) producing an abstract phonological representation through phonological decoding, (b) articulatory programming, and (c) execution of the speech program. It was investigated whether relatively good and poor first-grade readers differ with respect to the execution time of each component. The effects of length on execution time were also examined.

Results on the Delayed Naming task demonstrate that poor readers are equally fast as good readers when it comes down to actual vocalization of an already identified pseudoword. First-grade poor readers do not appear to be characterized by a general deficit in their ability to rapidly vocalize words. The speed of initiating a prepared response was not affected by the number of constituent phonemes of the pseudoword to be vocalized. This is in agreement with studies by Forster and Chambers (1973), Mason (1978), and Manis (1985) who also found that speed of initiating a prepared word naming response was not affected by number of letters.

Poor readers were significantly slower than good readers on the Immediate Pseudoword naming and the Lexical Decision task. The response latency of both tasks include a component of phonological decoding. The tasks differ with respect to articulatory programming. Immediate pseudoword naming necessarily requires articulatory programming, whereas a lexical decision does not. Still, the difference in latency between the two reader groups was similar for both tasks. This suggests that poor readers' problems are not the result of deficient articulatory programming skills, but lie in the component that both tasks have in common: phonological decoding. It is concluded that differences in decoding ability account for the differences in response latency between the relatively good and poor readers. In that respect, it is interesting to investigate how the number of phonemes affect decoding performance.

The number of phonemes had a significant effect on naming latency as well as on lexical decision latency. This was found with respect to both words and pseudowords. The pattern of length effects on the Lexical Decision task was similar to that on the Immediate Pseudoword Naming task. Both good and poor readers took longer to process a four-phoneme string than a three-phoneme string, but poor readers were more delayed by an extra phoneme than good readers. The similarity in pattern of over-all length effects between the two tasks suggests that poor readers' difficulty with processing long words and pseudowords are limited to decoding. Articulatory programming does not seem to be a factor in this respect.

A posthoc analysis revealed a Reader Group by Lexical Status by Number of Phonemes interaction on both the naming and the lexical decision task. The results showed that for good readers, a similar length effect was obtained for words and pseudowords. For poor readers on the other hand, the length effect was twice as large for words as for pseudowords. This finding may be explained as follows: The subjects were at an early stage of reading acquisition. It is likely that poor readers had acquired word specific orthographical knowledge of simple, high-frequency words only. The three-phoneme words had a higher printed frequency count than the four-phoneme words (1430 vs. 250 occurrences per million, respectively). Therefore, lexical facilitation due to orthographic familiarity was likely to play a significant role for three-phoneme words, but not for four-phoneme words, thus increasing the length effect. Good readers, on the other hand, are likely to have acquired word specific orthographical knowledge of more difficult words also. Therefore, for good readers, orthographic familiarity facilitated processing of three- and four-phoneme words equally.

The finding that poor readers showed larger length effects on words than on pseudowords is in contrast with a study by Hogaboam & Perfetti (1978). Third- and fourth-grade children were required to name (high-frequency) words and pseudowords that either consisted of one, or two syllables. One-syllable words and pseudowords consisted of three letters, two-syllable words and pseudowords consisted of five letters. Although the authors do not report test results of the interaction between Reader Group, Lexical Status, and Number of Syllables, the means of their Table 1 (p.719) indicate that for less-skilled readers, the Number of Syllables effect was approximately 400 ms larger for pseudowords than for words. The inconsistent outcome of both studies may be related to the subject samples. Hogaboam & Perfetti used third- and fourth-grade children, whereas we studied reading performance of first-grade children. In another study, Perfetti and Hogaboam (1975) observed that less skilled third-grade readers could identify high-frequency words almost as rapidly as skilled readers. Perhaps that the words, even the longer words, were orthographically familiar to the less-skilled readers, thus reducing the length effect for words.

Conclusions

It is concluded that differences in decoding ability between good and poor readers account for the observed difference in naming latency between the two reader groups. Articulatory programming and vocalization do not seem to be factors of importance in this respect. These findings have relevance for the interpretation of progress in pseudoword naming speed, as observed in our training studies (see chapter 2).

The time to execute a speech program is not affected by the number of phonemes. In that respect, vocalization skill would be an appropriate candidate to account for the parallelism of progress in naming speed. However, poor readers perform normally with respect to this skill. It would be hard to understand why a training in pseudoword reading would produce such impressive gains in a normal functioning skill. Considering that the over-all increase in naming speed during training is even larger than the time to execute a speech program, the possibility that the increase in naming speed is the result of improved efficiency in executing speech programs, should be ruled out.

The time to transform an abstract phonological code into a speech program by articulatory programming processes does not seem to be affected by number of phonemes. Effects of length are equally large in a task that necessarily requires articulatory programming (naming) as in a task that does not necessitate the construction of speech program (lexical decision). This suggests that articulatory programming does not contribute significantly to the length effect. In that respect, articulatory programming would also be an appropriate candidate to account for the parallelism of progress in naming speed. However, once again, poor readers do not seem to perform below standard with respect to this skill. If poor readers would be characterized by a deficiency in articulatory programming, the differences between reader groups should have been larger on the naming tasks than on the lexical decision task. However, the pattern of performance was similar, suggesting that poor readers have no problems with articulatory programming. The differences between good and poor readers in naming latency seems to be solely determined by decoding ability.

The subjects of the present study were all within the range of 'normal' reading ability. The sample was divided in a group of relatively good and relatively poor readers. No severely disabled readers were included. The suggestion that the poor readers in our training studies had no difficulty with articulatory programming, because the present study demonstrates that this skill does not discriminate between good and poor readers of a sample of 'normal' readers, may not be correct. The problems of the poor readers in our training studies may have been more severe. There are skills that differentiate between reading disabled children and their normal peers, but do not discriminate between relatively good and poor readers within the normal range of reading ability. For example, there are indications that problems with rapidly generating the names of words characterizes severely disabled readers (Denckla & Rudel, 1976; Underwood & Briggs, 1984; Wolf, Bally, & Morris, 1986), but does not differentiate between relatively good and poor readers within the normal range of reading ability (Perfetti, Finger, & Hogaboam, 1978; Stanovich, 1981;

van der Weijden & Willems, 1990; Wolf, 1991). The present study shows that good and poor readers of the same reading level as the poor readers in our training studies do not differ with respect to articulatory programming skills. In order to be sure whether this holds for reading disabled children also, the experiment should be rerun with a group that meets the selection criteria used in the training studies.

To conclude, the parallel progress in naming speed for words and pseudowords of different length, as observed in chapter 2, has not been clarified yet. It was argued that the progress could not have been the result of improved grapheme-phoneme decoding. No evidence for the use of onset -rime units in decoding was found (see chapter 3), and the present chapter shows that it is unlikely that processes that follow the generation of a phonological code are responsible for the progress in naming speed. Although there is ample evidence that phonological processing abilities are of vital importance for reading development (e.g. Bruck, 1988; Ehri, 1987; Vellutino & Scanlon, 1987), and progress in decoding ability goes hand-in-hand with improvement in reading performance (Lesgold & Resnick, 1982), we do not yet have a precise picture of what cognitive processes are involved when decoding speed is improved through training.

Chapter 5. General Discussion and Conclusions

This final chapter starts with a discussion of the theoretical framework of this thesis. The training studies will be summarized successively. The results of these training studies have implications for models of decoding and reading problems. These will be discussed in the next section. Finally, suggestions for the remediation of reading difficulty are presented.

5.1 Theoretical Framework

There is ample evidence that phonological decoding skills play a key role in the development of reading ability. Decoding is defined as the ability to transform a string of letters into a phonological code (Perfetti, 1985, p.90). The construction of a phonological code may be decomposed in three components, (a) assessing the orthographic units of translation and retrieving the corresponding phonological units from memory (orthographic translation), (b) storing these phonological units in a temporary memory buffer, and (c) blending the contents of this memory buffer into a phonological representation. This abstract phonological representation can be used to gain access to the lexicon and retrieve the word's meaning. This phonological representation may also be used to produce the word's pronunciation. In order to read the word aloud, articulatory programming is required to transform the abstract phonological representation into a ready-for-use speech program, which in turn has to be executed by the speech muscles. The component processes of decoding and naming are displayed in Figure 5.1.
We will return to processes of articulatory programming and execution of speech programs shortly. First, we will focus our attention on decoding ability.

Good decoding skills enable the reader to identify words accurately, automatically, and rapidly. This facilitates comprehension of text and the acquisition of word-specific orthographic knowledge. There is general agreement that poor readers have problems with phonological decoding. For these children, word identification is a slow and error prone process. This results in poor text comprehension and a failure to acquire word specific orthographic knowledge. The implication is that the remediation of reading problems should focus upon the core of poor readers' difficulties, phonological decoding. Children should learn enough about decoding and word identification so that words can be identified without effort. There is evidence that progress in phonological decoding is primarily established by practice in decoding itself. Consequently, the treatment of reading difficulties should therefore provide extensive practice in phonological decoding.

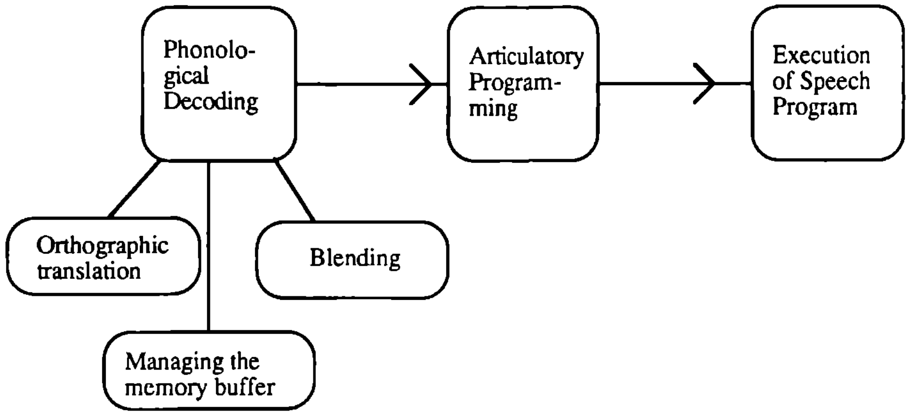


Figure 5.1 The components involved in the production of a naming response are displayed at the upper level, the three components involved in the construction of a phonological code are displayed at the lower levels.

Decoding ability can be expressed in terms of accuracy, automaticity, and speed. In order to obtain a clear picture of a child's decoding ability, speed and automaticity criteria are certainly as important as accuracy (LaBerge & Samuels, 1974; Perfetti, 1985). Although poor readers are often capable of reading short, regular words accurately, decoding proceeds very slowly and requires much cognitive capacity (Stanovich, 1986). The observation that decoding speed has proved to be the most consistently discriminating measure of reading skill (Perfetti, 1986) provides further evidence for the significance of decoding speed in reading development. Thus, poor readers should be trained to decode words accurately, automatically, *and* rapidly. For this reason, the element of time pressure is often introduced in training. The idea is that decoding speed can be increased by external pressure. Two forms of time pressure were distinguished, *limited exposure duration* and encouraging the child to respond quickly (*response speeding*). Limiting the exposure duration may have a positive effect because it induces readers to scan the entire word before decoding the individual graphemes (Baddeley, 1986, p.222), and may reinforce the development of decoding rules operating upon larger units than individual graphemes and phonemes, so called 'chunking' (LaBerge & Samuels, 1974; Newell & Rosenbloom, 1979). According to this view, limited exposure duration affects an early phase of decoding in which phonological values are assigned to orthographic units, so-called *orthographic translation*. In contrast, response speeding presumably affects later phases of decoding. It may have a positive effect because it reduces the time the child has to hold already decoded items in the temporary memory buffer. Furthermore, response speeding may induce children to develop more efficient blending procedures. The principle of time pressure in reading remediation is already widely applied. A well-known example of time pressure in reading remediation is the 'flash card' method, in which words and pseudowords are presented briefly, and the task of the child is to read the word or pseudoword aloud. Sometimes a quick response is encouraged.

5.2 Training Studies

In the first training study, the effects of limited exposure duration and response pressure on poor readers' word processing skills were investigated. Poor readers participated in a training that involved reading aloud single monosyllabic words and pseudowords. Thus, a naming task was utilized to measure decoding processes. In view of the fact that the training programs emphasized practice in phonological decoding, each word and pseudoword was shown only once throughout the program. Effects of training were evaluated by pre- and posttests and by examining the development of accuracy and naming speed on reading words and pseudowords during training. However, in order to interpret the naming speed data obtained during training in terms of decoding, the extra components of naming should be taken into consideration. For example, a possible increase in naming speed on words and pseudowords may be the result of improved articulatory processing or faster execution of a speech code rather than improved decoding. Digits were included as practice material in order to control for response production processes. A digit naming task does not involve decoding, but does require the production of vocal response. The results showed that digit naming speed did not improve during training, pointing to the conclusion that skills involving response production were not affected by training. With respect to word and pseudoword reading, children increased their naming speed quite substantially. The training groups did not differ in this respect. As digit naming speed remained constant during training, the increase in word and pseudoword naming speed was attributed to improved decoding. However, after re-examining the appropriateness of digit naming as control task, this measure was considered to be a good control for processes involving the execution of a speech code, but may not be suitable to control for articulatory programming processes. The possibility that the progress in word and pseudoword naming speed was the result of improved articulatory programming could therefore not be ruled out. We argued that this suggestion assumes that poor readers have problems with articulatory programming, otherwise it would be difficult to understand why training produced such impressive progress in word and pseudoword naming speed. In chapter 4 we investigated this assumption experimentally. The results demonstrated that neither speed of articulatory programming nor speed of actual vocalization differentiates between good and poor readers. Accordingly, it was considered as unlikely that the considerable progress in word and pseudoword naming speed during training was the result of improved articulatory programming skills. We therefore concluded that improved decoding skills account for the observed progress.

The results with respect to pre- and posttests demonstrated that the effects of training were not affected by response speeding. Response speeding is assumed to affect primarily the final phases in decoding, like blending. The absence of an effect of response speeding suggests that blending processes did not improve during training. The results showed that training effects were larger under conditions of limited exposure duration. Training in reading briefly presented words and pseudowords increased interference in a picture-word interference task, whereas a training with unlimited exposure duration did not. This was interpreted to indicate that decoding processes were executed more automatically after a training under conditions of limited exposure duration. Limited exposure duration is assumed to affect the early phases of decoding. The positive effects of this form of time pressure suggest that the progress in decoding speed is likely to be obtained in an early phase in decoding, presumably the phase of orthographic translation. We will return to this issue shortly.

In the second training study, research on the effects of limited exposure duration on poor readers' word processing skills was continued. Two groups received practice in reading monosyllabic pseudowords. One group received training under conditions of limited exposure duration (Flash Card group), the other group under conditions of unlimited exposure duration (Reading Aloud group). A third group received no training (No Training group) and was included in order to investigate the training's efficiency and assess its value for remedial practice. In this experiment, a different procedure for realizing limited exposure duration during training was utilized. The exposure duration was continually adjusted in order to maintain a constant level of accuracy. Again, effects of training were evaluated by pre- and posttests and by examining the measures obtained during training. As in the first study, children increased their pseudoword naming speed during training quite substantially. The two training groups did not differ in this respect. Furthermore, the average exposure duration that the children of the Flash Card group needed in order to identify 67% of the pseudowords correctly, decreased from 1000 ms at the start of training to 400 ms at the end of training.

In order to investigate whether poor readers acquire word specific information through repeated decoding, the presentation frequency of pseudowords was varied. Pseudowords were presented one, four, or eight times during training. The combined results with respect to repeated presentation suggest that poor readers of this age were able to acquire word specific information about pseudowords and use this information to their benefit on future decoding trials. Repeated decoding may have lead to storing orthographic and phonological information of pseudowords in the lexicon. It may also be that subjects stored articulatory programs of the repeatedly presented pseudowords in long term memory (Balota & Chumbley, 1985). In other words, whether repeated presentation facilitates recognition or response production is an issue that remains to be settled.

The results of the pre- and posttests will be discussed next. In the first training study, interference in a picture-word interference task increased after training under conditions of limited exposure duration. This result could not be replicated in the second study. It was suggested that the contradictory results were the consequence of differences between the two employed picture-word interference tasks. Further research on this subject is needed to answer the question whether a Flash Card training produces an increase in interference in a picture-word interference task. With respect to speed and accuracy measures obtained on word and pseudoword naming tasks, the over-all results showed that training under conditions of limited exposure duration had a larger positive effect than a training with unrestricted exposure duration, or no training at all.

To summarize, the effects of training were not affected by response speeding. Whether children were encouraged to respond quickly or not did not affect the beneficial effect of training. In contrast, the positive effects of training were larger if children practiced under conditions of limited exposure duration. The observation that limited exposure duration has a positive effect and response speeding has not, suggests that progress is obtained by improved efficiency in orthographic translation rather than in blending processes. This immediately raises the question why limiting the exposure duration would increase efficiency of orthographic translation. Does limiting the exposure duration produce a quantitative or qualitative improvement? In other words, does limiting the exposure duration merely speed up the process, or does it induce a qualitatively different, more efficient approach? The positive effects of this type of training may stem from the fact that limited exposure duration promotes a decoding approach in which children assign phonological values to orthographic units more rapidly. The content of the temporary memory buffer is more quickly filled with phonological elements. This would reduce the memory load. If that view would be correct, then the positive effects of limited exposure duration would be quantitative. However, the alternative position is also possible. Limited exposure duration makes word decoding more difficult. Under these circumstances, children may implicitly become aware that a grapheme-by-grapheme manner of decoding is relatively inefficient and time consuming. Time pressure may reinforce the development of decoding rules operating upon larger units than individual graphemes and phonemes, so called 'chunking' (LaBerge & Samuels, 1974; Newell & Rosenbloom, 1979). In that view, the positive effects of limited exposure duration would be qualitative. Finally, a combination of both speculations is also possible. The results of the present studies do not provide answers with respect to the mechanisms that might explain the positive effects of limited exposure duration. Investigating this question requires information about the size of the processing units in each of the decoding components. There are as yet no tasks that provide reliable information about this aspect.

Interesting results were obtained on both training studies regarding the development of naming speed during training. Poor readers were trained in reading monosyllabic words and pseudowords of different length. Children increased their reading speed as training proceeded. As we concluded earlier, decoding skills rather than processes of response production account for the obtained progress in naming speed. In chapter 1 we argued that pseudowords are more appropriate than words for studying the nature of decoding processes. For this reason we restrict the present discussion to results obtained on pseudoword naming.

An over-all length effect was found, demonstrating that it took children longer to name a short pseudoword than a long pseudoword. This is in agreement with the traditional GPC theory (Coltheart, 1978), stating that decoding is a grapheme-by-grapheme process. A puzzling result was that the progress in naming speed was equally large for simple, short pseudowords as for orthographically more complex, long pseudowords. This result is in conflict with the GPC theory. If decoding should take place at the level of individual graphemes and phonemes only, then progress should be larger for pseudowords consisting of more phonemes. Instead, the present results suggest that units larger than individual graphemes and phonemes must also play a role.

5.3 Implications for Models of Decoding and Reading Difficulties

The results of the present training studies have implications for models of decoding or reading difficulties. The explanation of parallel progress in naming speed requires a model of decoding that specifies units of processing that exceed the level of individual graphemes and phonemes.

Treiman recently presented a model of multi letter units in visual word recognition, stating that readers utilize onsets and rimes as perceptual units (Treiman & Chafetz, 1987, Treiman & Zukowski, 1988). Research on speech production has provided evidence that, in English, onset and rime units are involved in the construction of a phonological code (Cutler, 1987, Levelt, 1989, chapter 8, MacKay, 1972). In reading however, the construction of a phonological code is preceded by a phase of 'orthographic translation'. Orthographical units below the word level are translated into corresponding phonological units. These phonological units are subsequently used to construct an abstract phonological code, that, in turn, may be used as input for articulatory processes. Following the argument that printed words represent their spoken form, Treiman argued that the units involved in spoken language should also be functional in processing written language. Treiman and her colleagues tested this hypothesis and found evidence that, in English, onsets and rimes play an important role in visual word processing (Treiman & Chafetz, 1987, Treiman & Zukowski, 1988). They argue that readers assemble the pronunciation of words and pseudowords by assigning phonological values to orthographic onset and rime units. According to this view, onsets and rimes are functional in the early phases of decoding. The onset-rime model, in which words and pseudowords are decoded in a fixed number of units, would be able to account for the finding of parallel progress in naming speed. In chapter 3 of this book we investigated whether onset and rime units play a role in beginning and adult readers' word decoding. This question was addressed by either impairing or accentuating the onset-rime structure of visually presented words in a naming task. The results of the experiments demonstrated that this manipulation had no effect on reading performance. Thus, there are no indications that, in Dutch, onset and rime units play a role in mapping orthographic units onto phonological units. Therefore, the hypothesis that training affected the efficiency of translating orthographic onset-rime units into phonological onset-rime units should as yet be discarded. However, onsets and rimes may be used in other phases of decoding, such as the temporary storage of decoded elements and blending the units into a phonological representation.

Another possible multi-letter unit that might be involved in decoding is the syllable. This unit would also be able to account for the parallel progress because all words and pseudowords that were used in the training studies were monosyllabic. There are indications that decoding processes at the level of syllables play a role in visual word naming. Klapp, Anderson, and Berrian (1973) investigated the effect of number of syllables on naming latency with number of letters controlled for (e.g. *clock* versus *camel*). One-syllable words were named significantly faster than two-syllable words. It could be demonstrated that the main part of this syllable effect emerged in the construction of a phonological code rather than in articulatory processes (see for a detailed discussion of this experiment: Henderson, 1982, pp.181-4; Levelt, 1989, pp.414-6). Mason (1978) found that the syllable effect was larger for poor than for good readers, and larger with pseudowords than with words. This can be taken as support for the position that the syllable effect emerges in the construction of a phonological code. If practice in pseudoword reading would increase the efficiency of syllable processing, this would produce a similar improvement for all monosyllabic pseudowords.

To conclude, we propose that the successive components of decoding differ with respect to the units of processing. The results with respect to digraph segmentations obtained in chapter 3 show that both good and poor readers utilize multi-letter units in the phase of orthographic translation. A within digraph segmentation had a larger disruptive effect on pseudoword naming than an outside digraph segmentation, suggesting that beginning readers group letters together in orthographic translation if these letter combinations form a single grapheme and should therefore necessarily be processed as one unit. There is, however, no evidence that beginning readers use larger units than single graphemes in orthographic translation. Rather, the over-all difference in naming speed on pseudowords differing in one grapheme only, and the absence of onset-rime effects in chapter 3, are in support of the position that beginning readers employ single graphemes and phonemes in the phase of orthographic translation. This conclusion has implications for interpreting the parallel progress in naming speed for pseudowords of different length, obtained in the training studies. It suggests that multi-letter units must be involved in some other component of decoding. Multi-letter units may be used in the temporary storage of decoded units, but, more likely, play a role in blending multi-phoneme units into a phonological representation. Further research is needed to determine whether multi-phoneme units are actually used in decoding. A next issue would be to assess the features of these blending units. Do they correspond to the onset-rime structure, or are syllable units involved in the construction of a phonological code? It may also be that blending is a process in which multiple units play a role. For example, decoding may be viewed as a 'slots-and-fillers' process in which phonemes fill the onset-rime slots, and these, in turn, fill a syllable slot.

In our discussion of the mechanisms that underlie phonological decoding, we distinguished three component processes: orthographic translation, managing the memory buffer, and blending. It may very well be that these components carry different weights in the explanation of reading difficulties. Poor readers may have problems with one of these component processes in particular. An approach to answer this question would be to investigate whether poor readers differ from good readers with respect to the unit of processing in each of the decoding components.

Differences between good and poor readers with respect to the unit of processing are often inferred from the effects of *number of letters* on naming latency. Naming long words takes longer than naming short words, but the size of length effects decreases with reading ability (Manis, 1985; Samuels et al., 1978; Seymour & Porpodas, 1980). The question whether the processing unit exceeds the level of individual graphemes and phonemes is more appropriately addressed by manipulating the *number of graphemes and phonemes* rather than the number of letters, because phonemes are the smallest possible units that might be used in orthographic translation. The effects of number of phonemes on poor and good readers' word identification speed were investigated in chapter 4. The results showed a similar pattern as the length effect in terms of number of letters. Naming speed was inversely related to number of phonemes, but length effects were larger for poor than for good readers. Poor readers' greater sensitivity to word length may be attributed to smaller units of *orthographic translation* (McCormick & Samuels, 1979). Good readers may be less affected by an increase in the number of letters because they use larger units for orthographic translation than poor readers. We will now discuss this interpretation. If it is true that poor readers decode words in a grapheme-by-grapheme fashion, and good readers use larger units, then this may account for poor readers' larger sensitivity to word length. However, a Length by Reader Group interaction with respect to decoding time is, by itself, not sufficient to conclude that this effect arises in the phase of orthographic translation. It may also be that good and poor readers use the same units for orthographic translation, but that poor readers have more difficulty with storing and retrieving decoded elements in, and from, the *temporary phonological memory buffer*. Finally, poor readers' greater sensitivity to word length may also be the consequence of having problems with *blending*. If poor readers have special difficulty in blending the phonological elements into a proper phonological representation when more elements are involved, this would also account for their greater sensitivity to word length.

Knowledge about the relation between component decoding processes and reading proficiency is not only important from a theoretical point of view, but may also have consequences for the treatment of reading difficulties. It may lead to the development of treatment procedures that specifically address the decoding component(s) that lie at the basis of reading difficulties. We will now discuss the issue how such knowledge can be obtained experimentally.

In chapter 4 we distinguished between three components of *naming time*: the construction of a phonological code, articulatory programming, and executing a speech motor program. By administering a series of experimental tasks to each subject, we attempted to estimate the contribution of each component to total naming time (see the introduction of chapter 4). The construction of a phonological code, or the process of phonological decoding, has also been decomposed in three components: orthographic translation, managing the memory buffer, and blending. An analogous approach as used in chapter 4 may be used to examine the contribution of each component process to *decoding time*. For example, Torgesen, Rashotte, and Greenstein (discussed in Baddeley, 1986, p.217) tested the suggestion that reading difficulty stems from problems in maintaining phonological units in the temporary memory buffer. They showed that disabled readers had severe problems when they were asked to name a word of which the constituent phonological segments were presented aurally, with a two-seconds lag between successive presentations. The rationale of this task is that the component of orthographic translation is excluded. If reader group differences still exist, then it can be inferred that poor and good readers differ (also) with respect to the other component processes involved in decoding. The task used in the Torgesen et al. study excluded the component of orthographic translation, but required managing the temporary memory buffer and blending the units into a phonological representation. The burden on memory processes was artificially increased by presenting the constituent elements in intervals. Torgesen et al. argued that if poor readers have difficulty in keeping already decoded items active, they should perform poorly on this task. The results confirmed their prediction. This suggests that reading problems do not arise solely from a deficiency in declarative knowledge of the relations between graphemes and phonemes, or in a deficiency in procedural skills that are involved in orthographic translation. It seems that subsequent processing of the phonological units in order to obtain a proper phonological representation are also impaired.

The task used in the Torgesen et al. study still contained two decoding components: managing the memory buffer and blending. It may be possible to reduce the significance of this latter component in the following way. After the series of phonemes have been presented in intervals, a target phoneme is presented. The task of the subject is to decide whether the target phoneme occurred in the series of stimulus phonemes. Although it can not be ruled out that blending takes place, the significance of this component is reduced. Another modification would be to present a target grapheme instead of a phoneme and ask the subject to decide whether the target grapheme corresponds to one of the phonemes of the presented series. This may shed light on the question whether additional problems arise for poor readers when they have to make a phoneme-grapheme conversion.

However, the issue which decoding component is most strongly associated with reading difficulty can not be settled by investigating each component separately. The construction of tasks that systematically eliminate or reduce the share of one or two constituent decoding components is needed. Administering these tasks to subjects that differ with respect to reading proficiency may provide an answer to the question which decoding component is most important for explaining decoding difficulty.

Research on the components of decoding, and on the question whether there are qualitative differences between good and poor readers on each of these components is important. It may lead to a better understanding of the causes of reading difficulty. In addition to comparative research, training studies are also important. Training studies are necessary to establish if there is a causal connection between a certain skill and reading proficiency. If training in some skill can be shown to improve reading performance, it can be inferred that this skill plays a causal role in the acquisition of reading ability (Wagner & Torgesen, 1987). In the context of the results of the present training studies, it is important to resolve the question whether the mechanism that underlies improvement as a result of training, is identical to the mechanism that underlies 'normal' reading progress. If so, the practical value of this type of training is high, because it addresses the components of decoding that are also involved in normal reading improvement.

5.4 Suggestions for the Remediation of Reading Difficulties

The central question of the training studies was whether time pressure during training in reading aloud words and pseudowords had a beneficial effect on poor readers' word identification skills. The results allow some recommendations for the remediation of reading problems.

The treatment of reading difficulties should focus on decoding ability. If children are able to decode a word accurately, automatically, and rapidly, then they should become aware of the temporal contiguity of the word's comprising letter and sound units (Adams, 1990). This will enable children to acquire word-specific orthographic information that should facilitate identification of that word in the future. Thus, improving decoding skills should be a central goal of training. Training should speed up decoding processes and should increase knowledge of the relationship between orthography and phonology. Practicing decoding skills in the context of word reading has the advantage that word-specific orthographic knowledge that may be acquired during training can be used to the reader's benefit in 'normal' reading situations. However, in §1.4 we argued that drill in phonological decoding is more likely to be realized by reading pseudowords than by reading words, because pseudoword reading compels to complete decoding and poor readers are more aware of the relationship between the constituent graphemes and phonemes of a pseudoword than of a word (Byrne & Shea, 1979). A training that consists of reading pseudowords exclusively has its drawbacks. It does not provide the opportunity for children to perceive that the skills they practice during pseudoword decoding have relevance for the identification of normal words. In other words, such a training may estrange children from the training's objective, the acquisition of skills to identify words accurately and rapidly. Fortunately, children can be persuaded to adopt a phonological decoding strategy in word reading by utilizing mixed lists of words and pseudowords. There is evidence that if words are embedded in a list of pseudowords, readers are more likely to adopt a phonological decoding strategy than when these words are presented separately (Bryant & Bradley, 1980). For these reasons, it is advised to include both words and pseudowords as training materials.

A remedial program that aims to increase poor readers' word identification skills by practice in decoding should present the words and pseudowords briefly. Limiting the exposure duration increases the beneficial effect of training. As the results demonstrated, even poor readers need very little time to look at a word or pseudoword in order to read it correctly. This demonstrates once again that poor readers do not have difficulty in extracting visual information from the stimulus (Bouma & Legein, 1980; Vellutino, 1979), and supports the view that reading problems are decoding problems.

In order to impose time pressure upon the reading process, a training program should be able to present words and pseudowords with an exposure duration of less than 100 ms. It goes without saying that this is impossible to achieve by hand. Adequate control over the exposure duration requires the use of a computer. Fortunately, computers are becoming more and more popular in educational and remedial settings, and several computerized word reading programs are already available.

In the second training study, we developed a procedure for the application of limited exposure duration that keeps the amount of time pressure during training constant. This procedure proved to be effective, and is easy to realize. The exposure duration was varied as a function of accuracy. After each trial, accuracy of the current trial, together with the previous two trials, was evaluated. Exposure duration was increased when two or more errors were made, and was decreased if no errors were made. If two out of three trials were correct, exposure duration remained unchanged. In this manner, the accuracy rate was maintained at a constant level of approximately 67%. In §2.3 we argued that children learn primarily from positive learning trials, and that for this reason the accuracy criterion should be set at a higher percentage. We recommend an accuracy criterion of 80% or higher.

In the present training studies, we administered the posttests approximately one week after the last training session was held. Thus, we have not established the long-range impact of training. The reason for not addressing this question is that we assume that positive effects of training can only be durable if practice in decoding is sustained for a long period of time. Preferably, children should practice every day for approximately 20 minutes. Furthermore, the remediation of reading difficulties should not be limited to training in single-word and pseudoword reading, but this type of training should be used in combination with other elements of reading instruction.

The simplest and most straightforward task to practice pseudoword decoding is a naming task, where the subject must simply read aloud each word or pseudoword as it appears. Some researchers have expressed their doubts as to whether naming is a good response to evaluate reading performance. They argue that it places additional demands on the processing system that do not play a role in silent reading (Allington, 1984, Kusters, 1987). The product of decoding is an abstract phonological code. This abstract phonological code may be sufficient in silent reading tasks, but naming requires that this abstract code is transformed into a ready-for-use speech program by articulatory programming processes. There are some indications that poor readers have difficulty with articulatory programming (Underwood & Briggs, 1984). However, the experiment presented in chapter 4 of this book provides no support for this claim. In contrast to these criticisms, naming has the advantage that it compels phonological decoding. It has often been argued that phonological processing is more important in naming, than in other tasks (Gough, 1984; Henderson, 1985; van Orden et al., 1990; Seidenberg et al., 1984). Furthermore, reading aloud words and pseudowords makes the relationship between the written and spoken form explicit. Naming is therefore considered to enhance knowledge of the relations between orthography and phonology.

Unfortunately, speech-recognition technology is not yet sufficiently advanced to assess whether a spoken response to a visually presented word or pseudoword is correct. Consequently, a reading aloud task necessarily requires someone (e.g. the teacher) to evaluate the child's responses. A training in which the child can practice on his own, without the help of teacher, would be more practical. This requires a type of response that can be evaluated by the computer. A few possibilities will be discussed.

A simple solution is to let the child spell a briefly presented word or pseudoword by typing it on the keyboard. The computer can check whether the typed response matches the presented letter string. However, this solution should be regarded as less appropriate for three reasons. First, verifying that the child has typed the correct letter sequence does not necessarily mean that he or she has decoded the word or pseudoword. Second, typing places high demands on working memory capacity. Third, a typing response requires much time. This would interfere with the primary goal of providing extensive practice in decoding.

An other possibility is to utilize a lexical decision paradigm as a training procedure. In this task, a letter string appears (briefly) on the screen. The subject is to decide whether the string forms a word or not. The response is very simple, just pressing one of two buttons. Thus, in this task, the subject has to determine whether there is a match between an orthographical stimulus and a stored semantic representation. The assumption underlying this procedure for training in decoding is that phonological decoding processes play an intermediary role between orthography and semantics. There is indeed evidence that phonological decoding processes are used when making word/nonword decisions (Coltheart, 1978). Thus, a procedure employing a lexical decision paradigm should also be fit for practice in phonological decoding. It might be argued however, that verifying whether a string of letters forms a word or not, is an activity that does not play a role in normal reading.

Another possibility for a computerized version of a training in phonological decoding is the semantic decision task. The procedure resembles the lexical decision task. In this task, a word appears (briefly) on the screen. The subject is to decide whether the word belongs to a certain semantic category (e.g. vegetables). Once again, the response is very simple, just pressing one of two buttons. It is, like the lexical decision task, based on the assumption that phonological decoding processes play an intermediary role between orthography and semantics. The semantic decision task has the advantage that it is more closely associated with processes that are important in normal reading.

Finally, a training procedure that requires more advanced technology will be discussed. A computer equipped with a speech-synthesizer module unlocks sophisticated training techniques. Consider e.g. a procedure in which a word or pseudoword is presented aurally by the speech-synthesizer of the computer. Two (or more) letter strings appear (briefly) on the screen. The subject indicates, by pressing a button, which letter string corresponds to the spoken word. The advantage of this technique is that this task, in contrast to lexical decision, pertains directly to the relation between orthography and phonology. The task does not require semantic processing.

Only a few examples have been discussed. Other training techniques are possible too. What is important is that children get ample practice in decoding, through which they should be able to increase their knowledge of the relationship between orthography and phonology, to identify words more rapidly, and eventually, to acquire word-specific orthographic information.

To conclude, effective remediation of reading difficulties requires further research on the question which components of decoding are causally related to problems with word identification. This may provide us with a better understanding of the causes of reading difficulty, and enables the development of treatment procedures that specifically address the component(s) of decoding that lie at the basis of word identification problems.

Summary

This thesis is concerned with the decoding skills of young poor readers. Training studies were carried out in order to investigate the effects of practice in decoding on word identification skills. The unit of processing when decoding words and pseudowords was the subject of experimental investigation in a subsequent series of experiments. Finally, the question was addressed whether the difference between good and poor readers in word and pseudoword reading time is limited to decoding, or whether they differ with respect to other components of naming as well.
The chapters of this book will be summarized successively below.

Chapter 1 presents a theoretical framework of reading development, as well as an account of individual differences in reading ability. The ability to identify words accurately, automatically, and rapidly plays a central role in the development of reading. The remediation of reading problems should therefore focus upon improving the efficiency of word identification. From a discussion of studies into the psychological mechanisms that mediate word recognition, it is concluded that phonological decoding skills are fundamental to the development of reading ability, and that poor readers have problems with accurate and fast word recognition due to a decoding deficiency. Decoding is defined as the ability to transform a string of letters into a phonological code (Perfetti, 1985, p.90). In order to become better readers, poor readers should learn enough about decoding so that words can be identified without effort. Decoding ability can be expressed in terms of accuracy, automaticity, and speed. Decoding accuracy is essential for initial reading, but accuracy alone is not sufficient for word recognition skills to develop. Decoding processes should also be executed automatically and rapidly. For this reason, the element of time pressure is often introduced in training. The idea is that decoding speed can be increased by external pressure. The question whether practice in decoding under time pressure has a positive effect on poor readers' word recognition ability is addressed experimentally in chapter 2. For this purpose, computerized training programs were developed. These programs are discussed in detail in the final paragraph of chapter 1.

Chapter 2 presents two pretest-training-posttest studies into the effects of practice in decoding under time pressure. A simple training procedure was used. Single monosyllabic words and pseudowords were presented on a computer monitor. The task of the child was to read them aloud. Poor readers (9-11 years) participated in the studies.
The main purpose of the first experiment was to collect empirical evidence on the effects of different forms of time pressure in word training. Two forms of time pressure, *limiting the exposure duration of words* and *pressure upon the child to respond quickly*, were compared. Exposure duration was either limited or unlimited, and the child was either instructed to respond quickly (response speeding) or not (no response speeding). The

orthogonal combination of both factors produced four different training programs Children were assigned to one of four training conditions The effects of training were assessed by two standard reading tests and a picture-word interference task as pre- and posttest, and by the development of speed and accuracy on reading words and pseudowords during training

The combined results of all dependent variables did not unambiguously favor one of the investigated training programs However, an important finding was that practice in reading words and pseudowords under conditions of limited exposure duration increased interference in a picture-word interference task This result was interpreted to indicate that decoding processes were executed more automatically after training

The effects of limited exposure duration were examined more closely in a second training study In addition to a picture-word interference task, word and pseudoword naming tasks were developed in order to measure effects of training on word identification skills

Three groups of poor readers participated in this experiment One group received training in reading pseudowords under conditions of limited exposure duration Another group practiced reading similar pseudowords but without any constraints on the exposure duration Neither group was asked to respond quickly A third group received no training Again, the effects of training were assessed by pre- and posttests as well as by the development of speed and accuracy on reading pseudowords during training

On the posttest, the group that practiced under conditions of limited exposure duration was faster in reading words, and tended to be faster in reading pseudowords, than the other training group Furthermore, the group that practiced under conditions of limited exposure duration was more accurate in reading pseudowords and tended to be more accurate in reading words than the group that received no training The over-all pattern of results suggests that a training in pseudoword decoding under conditions of limited exposure duration is more beneficial to word processing skills than a training without such time pressure Unfortunately, the finding that training in reading briefly presented pseudowords increased interference in a picture-word interference task, as obtained in the first study, could not be replicated The absence of an interference effect in the second study is likely to be the consequence of differences between the two employed picture-word interference tasks

The results with respect to the development of reading performance during training demonstrated that children became much faster in reading words and pseudowords This improvement was found for all groups All the words and pseudowords of the first experiment, and most of the pseudowords of the second experiment were shown only once Thus, the progress in reading speed was not the result of increased familiarity with a limited set, but of improved decoding skill

An interesting result was obtained in both training studies The *over-all* reading time was affected by length in terms of number of graphemes and phonemes Children took more time to read longer words and pseudowords The *progress* in naming speed during training, however, was not affected by number of phonemes Thus, over-all naming latency was affected by length, but the observed improvement was not. The parallel progress is in conflict with the idea that training made children more proficient in grapheme-phoneme decoding, because this would predict progress to be larger for pseudowords consisting of more phonemes. Two possibilities were proposed. First, decoding processes may operate on units exceeding the level of individual graphemes. This possibility is investigated in chapter 3. Second, progress may not be the result of improved decoding, but of improved articulatory programming. This possibility is investigated in chapter 4.

Chapter 3 addresses the problem of parallel progress in naming speed during training in pseudoword reading. The possibility that beginning readers' decode words in larger units than individual graphemes and phonemes was investigated.

Recently, Treiman proposed that reading monosyllabic words involves processing of *onset* and *rime* units. The onset of a syllable is optional and contains, if present, its initial consonant(s). The rime is obligatory and consists of the vowel plus, if any, final consonant(s). For example, the onset of the word *start* is *st*, the rime is *art*. As all monosyllabic words and pseudowords used in training had one onset and one rime, this theory might account for the obtained parallel progress in reading time. The primary purpose of the experiments presented in this chapter was to investigate whether Dutch readers utilize onset-rime subword structures when reading monosyllabic words and pseudowords. A similar manipulation as used by Treiman and Chafetz (1987) was employed. The perception of words was impaired by segmenting them in two parts by a marker (*). Word parts either corresponded, or did not correspond to the onset-rime structure. The assumption of this experimental technique is that, if a spelling unit is important for word processing, reading should be easier if the segmentation does not interfere with the perception of this unit. In order to test this assumption, the effects of impairing the perception of vowel digraphs were also examined. These digraphs are made of two letters, representing a single (vowel) phoneme, and should therefore necessarily be processed as one unit.

Third-grade Dutch readers participated in the first experiment. Words were of the CVC type. The speed of naming words with an onset-rime segmentation was compared with the speed of naming words with a postvowel segmentation, and the speed of naming words with a within-digraph segmentation was compared with the speed of naming words with an outside-digraph segmentation. A within-digraph segmentation had a larger negative effect on reading performance than an outside-digraph segmentation, indicating that the employed technique is sensitive enough to demonstrate the use of multi-letter spelling units in word processing. However, the results provided no support for the position that readers process words in onsets and rimes.

In order to test whether onsets and rimes do play a role in *skilled* reading, the same naming task was administered to adult readers in experiment 2. Again, the results provided no support for the position that readers process words in onsets and rimes.

Evidence for the functionality of onsets and rimes in English word processing, as presented by Treiman and Chafetz (1987), was obtained with a lexical decision task, and with skilled readers as subjects The question whether onsets and rimes do play a role in skilled Dutch readers' lexical decisions was addressed in experiment 3 In agreement with the results obtained by Treiman and Chafetz (1987), decisions with respect to the lexicality of a letter string segmented at the onset-rime boundary were made faster than for letter strings with a postvowel segmentation The onset-rime advantage was similar for words and pseudowords The question why onset and rime spelling units do seem to play a role in lexical decision, but not in naming, is very puzzling

The vowel in the CVC words used in experiment 1, 2, and 3 was either represented by one letter or by two letters Thus, the effect of number of letters could be investigated (three or four letters) while keeping the number of phonemes constant (three phonemes) A *reversed* length effect was found in all three experiments Subjects took longer to respond to three-letter words than to four-letter words This result was consistent across all three experiments, and is in conflict with other studies in the literature This suggests that the procedure in which words are physically segmented produces unwanted side-effects

In experiment 4, a new technique for investigating subword effects was developed The task of the child was to name presented pseudowords The pseudowords were of the CVC, CVCC, or CCVC type This time, no segmentation marker was used The pseudowords were divided into two parts by a simultaneous shift in size and color of the letters First-grade readers participated in this study In addition to the onset-rime hypothesis, the question was addressed whether beginning readers process high-frequency consonant bigrams in units Again, the results provided no support for the idea that beginning readers decode pseudowords in onset-rime units, nor did they indicate that beginning readers process consonant bigrams as one unit

To conclude, the possibility that the subjects of the training experiments decoded words in either of the proposed units, and that training affected the efficiency of processing these multi-grapheme units, should be considered unlikely

Chapter 4 addresses the question whether the progress in pseudoword naming speed during training was the result of improved articulatory programming ability rather than of improved decoding skills In this view, the results of the training studies may be explained as follows The over-all difference in naming latency between long and short pseudowords would be the result of differences in decoding time, and the parallel progress in naming speed would be the result of improved articulatory programming This presupposes that poor readers should have difficulty with articulatory programming, otherwise it would be difficult to understand why training produced such impressive progress in naming speed Moreover, in order for the articulatory programming hypothesis to be consistent with the result of parallel progress in naming speed for pseudowords of different length, the time to construct an articulatory program of monosyllabic pseudowords should not be affected by the number of phonemes involved These assumptions were investigated experimentally by comparing relatively good and poor beginning readers with respect to the speed with which they construct an articulatory program and by examining the effects of number of phonemes on this variable.

Firstly, the results provided no support for the idea that poor and good readers differ with respect to articulatory programming. Secondly, it was demonstrated that relatively poor readers are equally fast as good readers when it comes down to actual vocalization of an already identified word. Finally, length effects, in terms of number of phonemes, were larger for poor, than for good readers. The results indicated that this larger length effect was limited to the decoding phase of pseudoword naming.

To conclude, the possibility that the progress in naming speed during training is the result of improved articulatory programming should be considered very unlikely. Instead, the results point to the conclusion that gains in reading speed are the result of increased decoding efficiency. Thus, the result of parallel progress in naming speed for words and pseudowords of different length has not been clarified. Although there is ample evidence that phonological processing abilities are of vital importance for reading development, and progress in decoding ability goes hand-in-hand with improvement in reading performance, we do not yet have a precise picture of the cognitive processes that are involved when decoding speed is improved through training.

In **Chapter 5,** the theoretical framework of the research presented in this thesis is reviewed. The main findings are summarized and the implications for models of decoding and reading problems are discussed.

Phonological decoding is conceptualized as consisting of three constituent components: (a) assessing the orthographic units of translation and retrieving the corresponding phonological units from memory (orthographic translation), (b) storing these phonological units in a temporary memory buffer, and (c) blending the contents of this memory buffer into a phonological representation. The finding of parallel progress in naming speed suggests that the unit of processing exceeds the level of individual graphemes and phonemes in at least one of these components. The studies presented in chapter 3 do not support the position that beginning readers use multi-grapheme units in the phase of orthographic translation. Instead, the over-all difference in naming speed on pseudowords differing in one grapheme only suggests that single graphemes and phonemes are the principal units in the phase of orthographic translation. Multi-grapheme units are more likely to be involved in the other components of decoding. It is suggested that onsets and rimes, and/or syllables, are likely to play a role in the temporary storage of decoded units or in blending the units into a phonological representation.

It is argued that knowledge of the relation between component decoding processes and reading proficiency is important, not only from a theoretical point of view, but also because it may have consequences for the treatment of reading difficulties. Suggestions how such knowledge can be obtained experimentally are presented.

Finally, the results of the studies in this thesis suggest that a training program in which decoding skills are practiced by reading briefly presented words and pseudowords may be a valuable aid in the remediation of reading problems of young poor readers. Recommendations with respect to the organization of such a program are presented in the final section of this chapter.

Samenvatting

Dit proefschrift gaat over fonologische decodeervaardigheden van jonge, zwakke lezers. In trainingsexperimenten werd het effect nagegaan van oefening in fonologisch decoderen op woordidentificatie. Vervolgens werd in een serie experimenten onderzocht of lezers bij de verwerking van woorden en pseudowoorden grotere eenheden dan grafemen en fonemen gebruiken. Tenslotte werd onderzocht of verschillen tussen goede en zwakke lezers in reactietijd op het benoemen van woorden en pseudowoorden uitsluitend het gevolg zijn van verschillen in decodeervaardigheid.
De hoofdstukken worden hieronder samengevat.

In **hoofdstuk 1** wordt een uiteenzetting gegeven van de ontwikkeling van leesvaardigheid. Het accuraat, automatisch, en snel identificeren van woorden van essentieel belang is voor het leren lezen. Het verbeteren van woordidentificatie zou daarom een belangrijke plaats moeten innemen bij de behandeling van leesproblemen.
Het 'dual-route' model onderscheidt twee mechanismen om tot de identificatie van woorden te komen: de 'indirecte' route via fonologisch decoderen, en de 'directe' route waarbij het woord wordt herkend op basis van bekendheid met de orthografische structuur. Uit de literatuur blijkt dat het onvermogen van zwakke lezers om woorden snel en accuraat te identificeren het gevolg is van problemen met fonologisch decoderen. Decoderen wordt gedefinieerd als de vaardigheid om een reeks letters te coderen tot een fonologische representatie (naar Perfetti, 1985, p.90). Vooruitgang in leesvaardigheid vereist een niveau van fonologisch decoderen dat de lezer in staat stelt woorden snel, en zonder moeite te identificeren. Decodeervaardigheid kan worden uitgedrukt in termen van accuratesse, automaticiteit en snelheid. Accuraat decoderen is een *noodzakelijke*, maar geen *voldoende* voorwaarde voor de ontwikkeling van leesvaardigheid. Het decodeerproces moet tevens automatisch en snel worden uitgevoerd. Om de efficiëntie in het fonologisch decoderen op te voeren wordt bij training vaak gebruik gemaakt van tijdsdruk. De gedachte is dat kinderen sneller leren decoderen wanneer zij dit oefenen in een taak waarbij efficiënte verwerking noodzakelijk is. Deze veronderstelling is experimenteel getoetst in hoofdstuk 2. Voor dit doel werden trainingsprogramma's ontwikkeld. De ontwikkeling van deze programma's en de selectie van de proefpersonen is toegelicht in §1.4.

In **hoofdstuk 2** wordt verslag gedaan van twee experimenten naar de effecten van oefening in decoderen onder tijdsdruk. De gebruikte oefenprocedure was simpel: eenlettergrepige woorden en pseudowoorden werden gepresenteerd op een computerbeeldscherm. De taak van het kind was deze woorden en pseudowoorden hardop te lezen. Zwakke lezers van 9-11 jaar oud namen deel aan dit onderzoek.
Het doel van het eerste experiment was om de effecten na te gaan van twee vormen van

tijdsdruk tijdens training in decodeervaardigheid. Deze vormen van tijdsdruk waren: *beperking van presentatieduur* en *nadruk op snelle benoeming*. Beide vormen van tijdsdruk hadden twee niveaus. De presentatieduur van woorden en pseudowoorden was beperkt òf onbeperkt, en de leerling kreeg wel of niet de opdracht snel te reageren. De orthogonale combinatie van deze twee vormen van tijdsdruk leverde vier verschillende trainingsprogramma's op. Zwakke lezers namen deel aan één van de vier programma's. Voor en na de training werden twee leestests en een plaatje-woord-interferentietaak afgenomen. Tijdens de training werd de accuratesse en benoemsnelheid op het lezen van woorden en pseudowoorden geregistreerd. De resultaten gaven geen aanleiding om ondubbelzinnig voor één van de vier oefenprocedures te kiezen. Echter, een belangrijke uitkomst was dat training in het hardop lezen van kort aangeboden woorden en pseudowoorden leidde tot een toename van interferentie in de plaatje-woord-interferentie taak. Dit resultaat wijst erop dat, na training, het decodeerproces vaker automatisch werd uitgevoerd.
De effecten van beperkte presentatieduur werden nauwkeuriger bestudeerd in een tweede trainingsexperiment. Naast een (nieuwe) plaatje-woord-interferentie taak werden woord- en pseudowoordbenoemtaken gebruikt als pre- and posttest. Zwakke lezers werd verdeeld over drie condities. Eén groep kreeg oefening in het hardop lezen van kort aangeboden pseudowoorden. Een tweede groep werd geoefend in het lezen van gelijksoortige pseudowoorden, maar zonder beperkingen van de presentatieduur. Een derde groep kreeg geen training. De groep die oefende onder beperkte presentatieduur was na training sneller in het lezen van woorden, en neigde tot grotere snelheid in het lezen van pseudowoorden, dan de groep die oefende zonder presentatieduurbeperking. Verder las de groep die oefende onder beperkte presentatieduur meer pseudowoorden correct dan de groep zonder training, en neigde ertoe meer woorden foutloos te lezen dan de geen-training-groep. De resultaten wijzen erop dat oefening in het decoderen van kort aangeboden pseudowoorden effectiever is dan een dergelijke training zonder beperking van de presentatieduur. De eerdere bevinding dat beperking van de presentatieduur tijdens training leidt tot een toename van interferentie in een plaatje-woord-interferentietaak kon niet worden bevestigd in dit tweede experiment. Het uitblijven van een toename in de interferentie is vermoedelijk het gevolg van verschillen tussen de gebruikte plaatje-woord-interferentietaken.
Tijdens de training gingen de kinderen de woorden (experiment 1) en pseudowoorden (experiment 1 en 2) steeds sneller lezen. Deze vooruitgang hing niet samen met de trainingsprogramma's. Alle woorden en pseudowoorden uit experiment 1, en de meeste pseudowoorden uit experiment 2, werden slechts éénmaal gepresenteerd. Dus, de vooruitgang in leessnelheid was het resultaat van verbetering in decodeervaardigheid, niet het gevolg van verhoogde bekendheid met een beperkte set woorden en pseudowoorden.
In beide studies werd een opmerkelijk resultaat gevonden. De benoemtijd nam toe met het aantal te coderen grafemen. Kinderen hadden meer tijd nodig voor het benoemen van lange, dan van korte pseudowoorden. De *vooruitgang* in leessnelheid hing echter niet samen met het aantal te coderen grafemen. De snelheidswinst tijdens training was even groot voor

lange, als voor korte pseudowoorden. Dus de totale benoemtijd hing samen met lengte, maar de vooruitgang niet. Dit resultaat is niet in overeenstemming met de veronderstelling dat oefening leidt tot een efficiëntere grafeem-foneem codering. Twee alternatieve verklaringen werden aangevoerd. Ten eerste: beginnende lezers decoderen woorden in een vast aantal subwoord-eenheden die groter zijn dan individuele grafemen en fonemen. Training heeft geleid tot een efficiëntere uitvoering van deze processen. Deze mogelijkheid wordt onderzocht in hoofdstuk 3. Ten tweede: de vooruitgang is niet het resultaat van verbeterde decodeervaardigheid, maar van vooruitgang in articulatorische programmering. Deze mogelijkheid wordt onderzocht in hoofdstuk 4.

In **hoofdstuk 3** wordt nader ingegaan op de mogelijkheid dat beginnende lezers bij het decoderen multi-grafeem eenheden gebruiken. Recentelijk werd door Treiman gesteld dat de *onset* en de *rime* een belangrijke rol spelen bij de verwerking van eenlettergrepige woorden en pseudowoorden. De onset van een lettergreep is optioneel en bestaat uit de begin-medeklinker(s); de rime bestaat uit de klinker plus de rest. Dus, de onset van het woord *start* is *st*, de rime is *art*. De woorden en pseudowoorden die gebruikt werden in de trainings-experimenten hadden alle één onset, en één rime. Dus, het onset-rime idee zou de parallelle vooruitgang kunnen verklaren.

Een aantal experimenten werd uitgevoerd om na te gaan of lezers van het Nederlands onset-rime eenheden gebruiken bij de visuele verwerking van woorden en pseudowoorden. De experimentele techniek was analoog aan die van Treiman en Chafetz (1987). De verwerking van woorden werd bemoeilijkt door ze op te delen in twee segmenten met behulp van een scheidingsteken (*). Deze techniek veronderstelt dat het lezen van een woord minder nadelig wordt beïnvloed door het scheidingsteken wanneer de woorddelen overeenkomen met de veronderstelde eenheden van verwerking dan wanneer de woorddelen daarmee niet overeen-stemmen. Om deze veronderstelling te toetsen werd het effect van verstoring van klinker-digrafen nagegaan. Klinkerdigrafen bestaan uit twee letters die één foneem representeren. Accuraat decoderen vereist daarom dat de twee letters als één eenheid van verwerking worden gebruikt. Aan het eerste experiment namen leerlingen deel uit de vijfde groep van het basisonderwijs. De woorden waren van het CVC-type. De snelheid in het benoemen van woorden was de afhankelijke variabele. Een opdeling binnen de digraaf had een groter nadelig effect op de leessnelheid dan een opdeling buiten de digraaf. Dit wijst erop dat de gekozen experimentele techniek gevoelig genoeg is om het gebruik van multi-letter eenheden aan te tonen. Woorden met een onset-rime opdeling werden even snel gelezen als woorden die nà de klinker, dus binnen de rime, waren opgedeeld. De resultaten gaven dus geen steun aan de onset-rime hypothese.

Het experiment werd herhaald met volwassen proefpersonen. Opnieuw werden geen aanwijzingen voor het gebruik van onset-rime-eenheden geconstateerd.

In experiment 3 werd nagegaan of volwassen Nederlandse lezers onsets en rimes gebruiken bij de visuele verwerking van woorden en pseudowoorden in een lexicale decisie taak. De resultaten waren in overeenstemming met die van Treiman en Chafetz (1987). De beslissing

of een reeks letters al dan niet een bestaand woord vormden werd sneller gemaakt als die reeks letters gesegmenteerd was in overeenstemming met de onset-rime structuur, dan wanneer deze nà de klinker was gesegmenteerd Het is nog onduidelijk waarom onsets en rimes wel een rol lijken te spelen in een lexicale decisietaak, maar niet in een benoemtaak
De klinker van de CVC-woorden die gebruikt werden in experiment 1, 2 en 3 bestond uit één of twee letters Daardoor kon het effect van het aantal letters (drie of vier letters) op de benoemtijd bepaald worden, terwijl het aantal fonemen constant gehouden werd (drie fonemen) Een *omgekeerd* lengte-effect werd gevonden in alle drie de experimenten De reactietijd was langer voor woorden met drie letters Dit resultaat is strijdig met studies uit de literatuur die melden dat de reactietijd toeneemt met het aantal letters, en doet vermoeden dat de procedure waarbij woorden worden gesegmenteerd met behulp van een scheidingsteken, effecten teweegbrengt die geen rol spelen in het 'normale' lezen Daarom werd in experiment 4 een nieuwe techniek gebruikt om woorden in delen op te splitsen Deze keer werd geen scheidingsteken gebruikt Pseudowoorden werden in twee helften opgedeeld door een gelijktijdige overgang in kleur en grootte van de letters De taak van de proefpersoon was de pseudowoorden hardop te benoemen Kinderen uit de derde groep van het basisonderwijs namen deel aan dit onderzoek De pseudowoorden waren van het type CVC, CVCC en CCVC Onderzocht werd of beginnende lezers onset-rime-eenheden gebruiken Tevens werd nagegaan of kinderen hoog-frequente medeklinker-bigrammen als eenheid verwerken Ook deze resultaten gaven geen aanwijzingen dat onset-rime eenheden een rol spelen Evenmin wezen de resultaten erop dat kinderen hoog-frequente medeklinker-bigrammen als eenheid verwerken
Concluderend, de veronderstelling dat de parallelle vooruitgang tijdens training het gevolg is van een toename in de efficientie waarmee woorden en pseudowoorden in onset-rime structuren worden gedecodeerd, moet vooralsnog als niet aannemelijk worden beschouwd, aangezien er geen aanwijzingen zijn dat beginnende lezers deze subwoord-structuren gebruiken

In **hoofdstuk 4** wordt de mogelijkheid onderzocht dat de geconstateerde vooruitgang in leessnelheid tijdens training niet het gevolg is van verbeterde decodeervaardigheid, maar van een efficientere articulatorische programmering Volgens deze zienswijze zou het verschil in benoemtijd tussen lange en korte woorden en pseudowoorden het gevolg zijn van verschillen in decodeervaardigheid, en de vooruitgang zou het resultaat zijn van efficientere articulatorische programmering Deze zienswijze veronderstelt dat zwakke lezers problemen hebben met articulatorische programmering, anders valt moeilijk te verklaren waarom oefening zo'n enorme vooruitgang bewerkstelligt Tevens zou moeten blijken dat de tijd die nodig is om een articulatorische code van een pseudowoord te produceren niet samenhangt met het aantal te coderen grafemen De snelheidswinst was immers even groot voor lange als voor korte pseudowoorden Deze veronderstellingen werden getoetst door relatief goede en zwakke beginnende lezers met elkaar te vergelijken in de snelheid waarmee zij een articulatorisch programma van een pseudowoord construeren, en het effect van het aantal te

coderen grafemen op deze variabele te onderzoeken.
De resultaten gaven geen aanleiding te concluderen dat goede en zwakke lezers verschillen in de vaardigheid waarmee zij een articulatorische code produceren. Verder werd aangetoond dat relatief zwakke lezers even snel zijn als goede lezers als het gaat om het uitspreken van een inmiddels geïdentificeerd pseudowoord. Tenslotte bleek dat woordlengte, in termen van het aantal te coderen grafemen, een groter effect had op de reactietijd van zwakke, dan van goede lezers. Deze verschillen bleven echter beperkt tot de fase van het fonologisch decoderen.
Concluderend, de veronderstelling dat de vooruitgang tijdens training het gevolg is van een toename in de efficiëntie waarmee een articulatorisch programma van woorden en pseudowoorden wordt geconstrueerd moet vooralsnog als niet aannemelijk worden beschouwd. Integendeel, de resultaten wijzen erop dat de vooruitgang in leessnelheid het gevolg is van vooruitgang in decodeervaardigheid. Het raadsel van de evenwijdige vooruitgang is echter nog niet opgelost. Uit de literatuur blijkt dat decodeervaardigheid van essentieel belang is voor de leesontwikkeling, en dat verbetering in decodeervaardigheid samengaat met vooruitgang in leesvaardigheid. Desondanks is nog onbekend hoe, en welke cognitieve deelprocessen beïnvloed worden als decodeerprestaties verbeteren door oefening.

In **hoofdstuk 5** worden de belangrijkste bevindingen van dit proefschrift samengevat. De betekenis van de resultaten voor modellen van fonologisch decoderen en leesproblemen wordt besproken.
Het fonologisch decoderen van een letterreeks wordt opgevat als bestaande uit drie componenten: (a) het bepalen van de orthografische eenheden en het ophalen van de corresponderende fonologische eenheden uit het lange-termijn geheugen (orthografische omzetting), (b) het opslaan van deze klankeenheden in een tijdelijke geheugenbuffer, en (c) het samenvoegen van de inhoud van deze buffer in een echte fonologische representatie van de letterreeks. Het resultaat van evenwijdige vooruitgang in benoemtijd door training suggereert dat, in tenminste één van de componenten, de eenheden van verwerking het niveau van individuele grafemen en fonemen overschrijden. De experimenten uit hoofdstuk 3 geven geen steun aan de veronderstelling dat multi-grafeem eenheden worden gebruikt in de fase van orthografische omzetting. Integendeel, het gegeven dat een verschil van één grafeem tot een substantieel tragere benoeming leidt suggereert dat grafemen en fonemen de kenmerkende eenheden van verwerking zijn in de fase van orthografische omzetting. Multi-grafeem-eenheden spelen eerder een rol in de andere componenten van het fonologisch decoderen. Het idee wordt geopperd dat onsets en rimes, en wellicht ook gehele lettergrepen, een rol spelen in de tijdelijke opslag van fonemen, of bij het samenvoegen van de samenstellende klankdelen.
Beargumenteerd wordt dat kennis van de relatie tussen de verschillende componenten van decodeervaardigheid en leesprestaties niet alleen van belang is vanuit theoretisch oogpunt, maar ook kan bijdragen aan de ontwikkeling van (meer) effectieve behandelingstechnieken. Een aantal manieren waarop zulke kennis experimenteel kan worden verworven worden

besproken.
Tenslotte wordt geconcludeerd dat een trainingsprogramma waarbij decodeervaardigheden worden geoefend door het lezen van kort aangeboden woorden en pseudowoorden, een bijdrage kan leveren aan de behandeling van woordidentificatieproblemen van jonge, zwakke lezers. Suggesties voor de opzet van een dergelijk oefenprogramma worden gegeven in de laatste sectie van dit hoofdstuk.

References

Adams, M J (1979) Models of Word Recognition *Cognitive Psychology, 11*, 133-176

Adams, M J (1981) What Good is Orthographic Redundancy? in O J L Tzeng, & H Singer (Eds), *Perception of Print Reading Research in Experimental Psychology* (pp 197 221) Hillsdale, NJ Lawrence Erlbaum Associates

Adams, M J (1990) *Beginning to Read Thinking and Learning about Print* Cambridge MIT Press

Allington, R L (1978) Word Identification Abilities of Severely Disabled Readers A Comparison in Isolation and Context *Journal of Reading Behavior, 10*(4), 409-416

Allington, R L (1984) Oral Reading in P D Pearson (Ed), *Handbook of Reading Research* (pp 829-864) New York Longman

Anderson, J R (1983) *Architecture of Cognition* Cambridge Harvard University Press

Backman, J , Bruck, M , Hebert, M , & Seidenberg, M S (1984) Acquisition and Use of Spelling-Sound Correspondences in Reading *Journal of Experimental Child Psychology, 38*, 114-133

Baddeley, A (1986) *Working Memory* Oxford Clarendon Press

Bakan, P , & Alperson, B (1967) Pronounceability, Attensity, and Interference in the Color-Word Test *American Journal of Psychology, 80*, 416-420

Bakker, J J M (1972) *Constant en variabel* Unpublished doctoral dissertation, University of Amsterdam

Balota, D A , & Chumbley, J I (1985) The Locus of Word Frequency Effects in the Pronunciation Task Lexical Access and/or Production? *Journal of Memory and Language, 24*, 89-106

Barron, R W (1980) Visual and Phonological Strategies in Reading and Spelling in U Frith (Ed), *Cognitive Processes in Spelling* London Academic Press

Barron, R W , & Baron, J (1977) How Children Get meaning from Printed Words *Child Development, 48*, 587-594

Beck, I L , Perfetti, C A , & McKeown, M G (1982) Effects of Long-Term Vocabulary Instruction on Lexical Access and Reading Comprehension *Journal of Educational Psychology, 74*, 506-521

Bentin, S , & Frost, R (1987) Processing Lexical Ambiguity in Deep Orthography *Memory and Cognition, 15*, 13-23

Berg, R M van den, & Lintelo, H G te (1977) *AVI Analyse van Individualiseringsvormen* 's-Hertogenbosch Katholiek Pedagogisch Centrum

Biemiller, A (1977-1978) Relationship between Oral Reading Rates for Letters, Words, and Simple text in the Development of Reading Achievement *Reading Research Quarterly, 13*, 223-253

Blanchard, J S , & McNinch, G H (1980) Testing the Decoding Sufficiency Hypothesis A Response to Fleisher, Jenkins, and Pany *Reading Research Quarterly, 15*(4), 559-564

Bon, W H J van (1986) Commentaar op V H P van Daal, N C M Bakker, P Reitsma en D A V van der Leij Woordfrequentie, Repetitie en Emstige Leesproblemen in P Reitsma, A G Bus, & W H J van Bon (Eds), *Leren Lezen en Spellen, Ontwikkeling en Problemen* (p 46) Lisse Swets & Zeitlinger

Bon, W H J van, Kessel, A E G van, & Kortenhorst, E P M (1987) Beinvloeding van woordherkenningssnelheid door middel van Flash Cards In J Hamers, & A van der Leij (Red), *Dyslexie* Utrecht, the Netherlands (pp 87-94) Lisse Swets & Zeitlinger

Bond, G L , Tinker, M A , & Wasson, B B (1979) *Reading Difficulties Their Diagnosis and Correction* Englewood Cliffs Prentice Hall

Bouma, H , & Legein, C P (1980) Dyslexia A Specific Recoding Deficit? An Analysis of Response Latencies for Letters and Words in Dyslectics and in Average Readers *Neuropsychologica, 18,* 285-298

Bowey, J A (1990) Orthographic Onsets and Rimes as Functional Units of Reading *Memory and Cognition, 18*(4), 419-427

Bradley, L , & Bryant, P E (1983) Categoring Sounds and Learning to Read- A Causal Connection *Nature, 301,* 419-421

Briggs, P , Austin, S , & Underwood, G (1984) The Effects of Sentence Context in Good and Poor Readers A Test of Stanovich's Interactive-Compensatory Model *Reading Research Quarterly, 20,* 54-61

Brown, P , & Besner, D (1987) The Assembly of Phonology in Oral Reading A New Model in M Coltheart (Ed), *Attention and Performance 12*(pp 471-489) Hillsdale, NJ Lawrence Erlbaum Associates

Bruck, M (1988) The Word Recognition and Spelling of Dyslexic Children *Reading Research Quarterly, 23*(1), 51-69

Brus, B T , & Voeten, M J M (1972) *Een-Minuut Test, vorm A en B* Nijmegen Berkhout Testmateriaal

Bryant, P E , & Bradley, L (1980) Why Children sometimes Write Words which they do not Read in U Frith (Ed), *Cognitive Processes in Spelling* (pp 355-370) London Academic Press

Bryant, P E , & Bradley, L (1985) *Children's Reading Problems* Oxford Basil Blackwell

Byrne, B , & Shea, P (1979) Semantic and Phonetic Memory Codes in Beginning Readers *Memory and Cognition, 7,* 333-338

CELEX (1988) *Centre for Lexical Information, A User Guide* Interfaculty Research Unit for Language and Speech Nijmegen, the Netherlands

Ceprano, M A (1981) Context versus Isolation Methods of Word Instruction Efficiency Assessed by Paralleling Assessment Methods *Journal of Reading Behavior, 13*(4), 381-389

Coltheart, M (1978) Lexical Access in Simple Reading Tasks in G Underwood (Ed), *Strategies of Information Processing* (pp 151-216) London Academic Press

Cutler, A (1987) Speaking for Listening in A Allport, D G MacKay, W Prinz, & E Scheerer (Eds), *Language Perception and Production Relationships between Listening Speaking Reading, and Writing* (pp 23-40) London Academic Press

Cutler, A , Butterfield, S , & Williams, J N (1987) The Perceptual Integrity of Syllabic Onsets *Journal of Memory and Language, 26,* 406-418

Daal, V.H.P. van, Bakker, N.C.M., Reitsma, P., & Leij, D.A.V. van der (1986). Woordfrequentie, Repetitie en Ernstige Leesproblemen. in: P. Reitsma, A.G. Bus, & W.H.J. van Bon (Eds.), *Leren Lezen en Spellen; Ontwikkeling en Problemen.* (pp.40-45). Lisse: Swets & Zeitlinger.

Daal, V.H.P. van, & Reitsma, P. (1990). Effects of Independent Word Practice with Segmented and Whole Word Sound Feedback in Disabled Readers. *Journal of Research in Reading, 13*(2), 133-148.

Daneman, M. (1988). Word Knowledge and Reading Skill. in: M. Daneman, G.E. MacKinnon, & T.G. Waller (Eds.), *Reading Research: Advances in Theory and Practice. 6*(pp.145-175). London: Academic Press.

Denckla, M.B., & Rudel, R.G. (1976). Naming of Object-Drawings by Dyslexic and Other Learning Disabled Children. *Brain and Language, 3*, 1-15.

DeSoto, J.L., & DeSoto, C.B. (1985). Reading Achievement and Automatic Recognition of Words and Pseudowords. *Journal of Reading Behavior, 17*(2), 115-127.

Dixon, P., LeFevre, J., & Twilley, L.C. (1988). Word Knowledge and Working Memory as Predictors of Reading Skill. *Journal of Educational Psychology, 80*(4), 465-472.

Dommerholt, I. (1970). *Differentiele Zinnenleestest.* Groningen: H.D. Tjeenk Willink.

Dumont, J.J. (1984). *Lees- en Spellingsproblemen.* Rotterdam: Lemniscaat.

Dumont, J.J. (1990). *Dyslexie.* Rotterdam: Lemniscaat.

Dyer, F.N. (1973). The Stroop Phenomenon and its Use in the Study of Perceptual, Cognitive and Response Processes. *Memory and Cognition, 1*(2), 106-120.

Ehri, L.C. (1980). The Development of Orthographic Images. in: U. Frith (Ed.), *Cognitive Processes in Spelling.* London: Academic Press.

Ehri, L.C. (1987). Learning to Read and Spell Words. *Journal of Reading Behavior, 19*(1), 5-31.

Ehri, L.C., & Roberts, K.T. (1979). Do Beginners Learn Printed Words Better in Context or in Isolation? *Child Development, 50*, 675-685.

Ehri, L.C., & Wilce, L.S. (1979). Does Word Training Increase or Decrease Interference in a Stroop-task? *Journal of Experimental Child Psychology, 27*, 352-364.

Ehri, L.C., & Wilce, L.S. (1983). Development of Word Identification Speed in Skilled and Less Skilled Beginning Readers. *Journal of Educational Psychology, 75*, 3-18.

Ellis, A.W. (1984). *Reading, Writing and Dyslexia; a Cognitive Analysis.* London: Lawrence Erlbaum Associates.

Eriksen, B.A., & Eriksen C.W. (1974). Effects of Noise Letters upon the Identification of a Target Letter in a Non-Search Task. *Perception and Psychophysics, 16*, 143-149.

Fagan, W.T., & Eagan, R.L. (1986). Cues Used by Two Groups of Remedial Readers in Identifying Words in Isolation. *Journal of Research in Reading, 1*, 56-68.

Fayne, H.R., & Bryant, N.D. (1981). Relative Effects of Various Word Synthesis Strategies on the Phonics Achievement of Learning Disabled Youngsters. *Journal of Educational Psychology, 73*, 616-623.

Fiedorowicz, C.A.M. (1986). Training of Component Reading Skills. *Annals of Dyslexia, 36*, 318-334.

Fischer, F.W., Liberman, I.Y., & Shankweiler, D. (1978). Reading Reversals and Developmental Dyslexia: A Further Study. *Cortex, 14*, 496-510.

Fleisher, L.S., Jenkins, J.R., & Pany, D. (1979). Effects on Poor Readers' Comprehension of Training in Rapid Decoding. *Reading Research Quarterly, 1*(25), 30-48.

Forster, K I , & Chambers, S M (1973) Lexical Access and Naming Time *Journal of Verbal Learning and Verbal Behavior*, *12*, 627-635

Fredenksen, J R , & Kroll, J F (1976) Spelling and Sound Approaches to the Internal Lexicon *Journal of Experimental Psychology Human Perception and Performance*, 2(3), 361-379

Fudge, E (1987) Branching Structure within the Syllable *Journal of Linguistics*, *23*, 359-377

Gibson, E J , & Levin, H (1975) *The Psychology of Reading* Cambridge MIT Press

Glushko, R (1979) The Organization and Activation of Orthographic Knowledge in Reading Aloud *Journal of Experimental Psychology Human Perception and Performance*, *5*(4), 674-691

Goodman, G S , Haith, M M , Guttentag, R E , & Rao, S (1985) Automatic Processing of Word Meaning Intralingual and Interlingual Interference *Child Development*, *56*, 103-118

Goswami, U (1986) Children's Use of Analogy in Learning to Read A Developmental Study *Journal of Experimental Child Psychology*, *42*, 73 83

Gough, P B (1984) Word Recognition in P D Pearson (Ed), *Handbook of Reading Research* (pp 225-253) New York Longman

Greenberg, S N , & Vellutino, F R (1988) Evidence for Processing of Constituent Single and Multi Letter Codes Support for Multi Level Coding in Word Perception *Memory and Cognition*, *16*(1), 54-63

Guttentag, R E , & Haith, M M (1978) Automatic Processing as a Function of Age and Reading Ability *Child Development*, *49*, 707-716

Hand, D J , & Taylor, C C (1987) *Multivariate Analysis of Variance and Repeated Measures A practical Approach for Behavioural Scientists* London Chapman and Hall

Henderson, L (1982) *Orthography and Word Recognition in Reading* London Academic Press

Henderson, L (1985) Issues in the Modelling of Pronunciation Assembly in Normal Reading in K E Patterson, J C Marshall, & M Coltheart (Eds), *Surface Dyslexia Neuropsychological and Cognitive Studies of Phonological Reading* (pp 459-508) Hillsdale, NJ Lawrence Erlbaum Associates

Henderson, L , & Chard, J (1980) The Reader's Implicit Knowledge of Orthographic Structure in U Frith (Ed), *Cognitive Processes in Spelling* London Academic Press

Heuven, V J van (1980) Aspects of Dutch Orthography and Reading in J F Kavanagh, & R L Venezky (Eds), *Orthography, Reading, and Dyslexia* (pp 57 73) Baltimore University Park Press

Hogaboam, T W , & Perfetti, C A (1978) Reading Skill and the Role of Verbal Experience in Decoding *Journal of Educational Psychology*, *70*(5), 717-729

Holmes, B (1983) Europe and Canada in J Cameron, R Cowan, B Holmes, P Hurst, & M MacLean (Eds), *International Handbook of Educational Systems* Chichester Wiley

Horn, C C , & Manis, F R (1985) Normal and Disabled Readers Use of Orthographic Structure in Processing Print *Journal of Reading Behavior*, *17*(2), 143-161

Horn, C C , & Manis, F R (1987) Development of Automatic and Speeded Reading of Printed Words *Journal of Experimental Child Psychology*, *44*, 92-108

Jorm, A F , & Share, D L (1983) Phonological Recoding and Reading Acquisition *Applied Psycholinguistics*, *4*(2), 103-147

Juel, C (1980) Comparison of Word Identification Strategies with Varying Context, Word Type, and Reader Skill *Reading Research Quarterly*, *15*(3), 358-376

Juel, C (1988) Learning to Read and Write. A Longitudinal Study of 54 Children from First through Fourth Grades *Journal of Educational Psychology*, *80*(4), 437-447

Kay, J (1987) Phonological Codes in Reading Assignment of Sub-Word Phonology in A Allport, D G MacKay, W Prinz, & E Scheerer (Eds), *Language Perception and Production Relationships between Listening, Speaking, Reading, and Writing* (pp 181 196) London Academic Press

Klapp, S T , Anderson, W G , & Berrian, R W (1973) Implicit Speech in Reading Reconsidered *Journal of Experimental Psychology*, *100*, 368-374

Klein, G S (1964) Semantic Power Measured through the Interference of Words with Color-Naming *American Journal of Psychology*, *77*, 576-588

Kusters, E D M (1987) *Self-Corrections in Oral Reading Some Aspects of the Reading Process of Good and Poor Readers* Unpublished doctoral dissertation, University of Nijmegen, the Netherlands

LaBerge, D , & Samuels, S J (1974) Toward a Theory of Automatic Information Processing in Reading *Cognitive Psychology*, *6*, 293-323

LaHeij, W (1988) *Lexical Context Effects in Reading and Naming An Investigation of the "Semantic Relatedness Paradox"* Unpublished doctoral dissertation, University of Leiden, Utrecht Elinkwijk bv

Lesgold, A , & Resnick, L (1982) How Reading Difficulties Develop Perspectives from a Longitudinal Study in J Das, R Mulcahey, & A Wall (Eds), *Theory and Research in Learning Disabilities* (pp 155-187) New York Plenum Press

Levelt, W M J (1989) *Speaking From Intention to Articulation* Cambridge, Massachusetts MIT Press

MacKay, D G (1972) The Structure of Words and Syllables Evidence from Errors in Speech *Cognitive Psychology*, *3*, 210 227

MacLeod, C M (1991) Half a Century of Research on the Stroop Effect An Integrative Review *Psychological Bulletin*, *109*(2), 163-203

Manis, F R (1985) Acquisition of Word Identification Skills in Normal and Disabled Readers *Journal of Educational Psychology*, *77*(1), 78-90

Mann, V A , Liberman, I Y , & Shankweiler, D (1980) Children's Memory for Sentences and Word Strings in Relation to Reading Experience *Cognition*, *24*, 65-92

Mason, M (1975) Reading Ability and Letter Search Time Effects of Orthographic Structure Defined by Single-Letter Positional Frequency *Journal of Experimental Psychology General*, *104*, 146-166

Mason, M (1978) From Print to Sound in Mature Readers as a Function of Reader Ability and Two Forms of Orthographic Regularity *Memory and Cognition*, *6*, 568-581

Mason, M , & Katz, L (1976) Visual Processing of Non-Linguistic Strings Redundancy Effects and Reading Ability *Journal of Experimental Psychology General*, *105*, 338-348

Massaro, D W , Taylor, G A , Venezky, R L , Jastrzembski, J E , & Lucas, P A (1980) *Letter and Word Perception The Role of Orthographic Structure and Visual Processing in Reading* Amsterdam North Holland

McClelland, J L , & Rumelhart, D E (1981) An Interactive Activation Model of Context Effects in Letter Perception Part 1 An Account of Basic Findings *Psychological Review*, *88*(5), 375 407

McCormick, C., & Samuels, S. J. (1979). Word Recognition by Second Graders: The Unit of Perception and Interrelationships among Accuracy, Latency, and Comprehension. *Journal of Reading Behavior, 11*, 107-118.

McKeown, M.G., Beck, I.L., Omanson, R.C., & Perfetti, C.A. (1983). The Effects of Long-Term Vocabulary Instruction on Reading Comprehension: A Replication. *Journal of Reading Behavior, 15*, 3-18.

Mitchell, D.C. (1982). *The Process of Reading: A Cognitive Analysis of Fluent Reading and Learning to Read.* Chichester: John Wiley & Sons.

Monsell, S. (1987). Nonvisual Orthographic Processing and the Orthographic Input Lexicon. in: M. Coltheart (Ed.), *Attention and Performance. 12*(pp.299-323). Hillsdale, NJ: Lawrence Erlbaum Associates.

Newell, A., & Rosenbloom, P.S. (1979). Mechanisms of Skill Acquisition and the Law of Practice. in: J.R. Anderson (Ed.), *Cognitive Skills and their Acquisition.* (pp.1-55). Hillsdale, NJ: Lawrence Erlbaum Associates.

Newell, A., & Simon, H.A. (1972). *Human Problems Solving.* Englewood Cliffs, NJ: Prentice Hall.

Nijhoff, W.J., & Streumer, J.N. (1988). Netherlands. in: T.N. Postlethwaite (Ed.), *The Encyclopedia of Comparative Education and National Systems of Education.* Oxford: Pergamon.

Noordman-Vonk, W. (1979). *Retrieval from Semantic Memory.* New York: Springer Verlag.

Orden, G.C. van, Pennington, B.F., & Stone, G.O. (1990). Word Identification in Reading and the Promise of Subsymbolic Psycholinguistics. *Psychological Review, 97*(4), 488-522.

Pace, A.J., & Golinkoff, R.M. (1976). Relationship between Word Difficulty and Access of Single Word Meaning by Skilled and Less-Skilled Readers. *Journal of Educational Psychology, 68*(6), 760-767.

Pashler, H., & Baylis, G. (1991). Procedural Learning: 1. Locus of Practice Effects in Speeded Choice Tasks. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17*(1), 20-32.

Patterson, K.E., & Morton, J. (1985). From Orthography to Phonology: An Attempt at an Old Interpretation. in: K.E. Patterson, J.C. Marshall, & M. Coltheart (Eds.), *Surface Dyslexia: Neuropsychological and Cognitive Studies of Phonological Reading.* (pp.335-359). Hillsdale, NJ: Lawrence Erlbaum Associates.

Perfetti, C.A. (in press.). The Representation Problem in Reading Acquisition. in: P.B. Gough, L.C. Ehri, & R. Treiman (Eds.), *Reading Acquisition.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Perfetti, C.A. (1984). Reading Acquisition and Beyond: Decoding Includes Cognition. *American Journal of Education, 93*(1), 40-60.

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

Perfetti, C.A. (1986). Continuities in Reading Acquisition, Reading Skill and Reading Disability. *RASE, 7*(1), 11-21.

Perfetti, C.A. (1988). Verbal Efficiency in Reading Ability. in: M. Daneman, G.E. MacKinnon, & T.G. Waller (Eds.), *Reading Research: Advances in Theory and Practice. 6*(pp.109-143). London: Academic Press.

Perfetti, C A , Beck, I , Bell, L C , & Hughes, C (1987) Phonemic Knowledge and Learning to Read are Reciprocal A Longitudinal Study of First Grade Children *Merrill-Palmer Quarterly*, *33*(3), 283-319

Perfetti, C A , Finger, E , & Hogaboam, T (1978) Sources of Vocalization Latency Differences between Skilled and Less Skilled Young Readers *Journal of Educational Psychology*, *70*(5), 730-739

Perfetti, C A , Goldman, S , & Hogaboam, T (1979) Reading Skill and the Identification of Words in Discourse Context *Memory and Cognition*, *7*, 273-282

Perfetti, C A , & Hogaboam, T (1975) Relationship between Single-Word Decoding and Reading Comprehension *Journal of Educational Psychology*, *67*, 461-469

Perfetti, C A , & McCutchen, D (1982) Speech Processes in Reading in N Lass (Ed), *Speech and Language Advances in Basic Research and Practice* 7(pp 237-269) New York Academic Press

Perfetti, C A , & Roth, S (1981) Some of the Interactive Processes in Reading and their Role in Reading Skill in A Lesgold, & C A Perfetti (Eds), *Interactive Processes in Reading* (pp 269-297) Hillsdale, NJ Lawrence Erlbaum Associates

Pring, L , & Snowling, M (1986) Developmental Changes in Word Recognition An Information-Processing Account *The Quarterly Journal of Experimental Psychology*, *38*(A), 395 418

Rayner, K , & Springer, C J (1986) Graphemic and Semantic Similarity Effects in the Picture-Word Interference Task *British Journal of Psychology*, *77*, 207-222

Reitsma, P (1983a) Printed Word Learning in Beginning Readers *Journal of Experimental Child Psychology*, *36*, 321-339

Reitsma, P (1983b) Word-Specific Knowledge in Beginning Reading *Journal of Research in Reading*, *6*(1), 41-56

Reitsma, P (1984) Sound Priming in Beginning Readers *Child Development*, *55*, 406-423

Reitsma, P (1988a) Reading Practice for Beginners Effects of Guided Reading, Reading While-Listening, and Independent Reading with Computer Based Speech Feedback *Reading Research Quarterly*, *23*(2), 219-235

Reitsma, P (1988b) Tussen Letter en Woord Het Effect van Oefening met Wisselrijen *Pedagogische Studieen*, *65*(9), 344-357

Reitsma, P (1990) Development of Orthographic Knowledge in P Reitsma, & L Verhoeven (Eds), *The Acquisition of Reading in Dutch* (pp 43 64) Dordrecht Foris Publications

Reitsma, P , & Dongelmans, J (1988) Het Effect van Oefeningen met Wisselrijen voor Leeszwakke Kinderen *Tijdschrift voor Orthopedagogiek*, *27*, 248-265

Reitsma, P , & Vinke, J (1986) Individuele Verschillen in Direct en Indirect Lezen in P Reitsma, A G Bus, & W H J van Bon (Eds), *Leren Lezen en Spellen, Ontwikkeling en Problemen* (pp 80 85) Lisse Swets & Zeitlinger

Rijnsoever, R J van (1988) *Spelling en Leren Lezen* Unpublished doctoral dissertation, University of Nijmegen, the Netherlands

Roth, S F , & Beck, I L (1987) Theoretical and Instructional Implications of the Assessment of Two Microcomputer Word Recognition Programs *Reading Research Quarterly*, *22*(2), 197-218

Rumelhart, D E , & Norman, D A (1978) Accretion, Tuning, and Restructuring Three Models of Learning in J W Cotton, & R Klatzky (Eds), *Semantic Factors in Cognition* Hillsdale, NJ Lawrence Erlbaum Associates

Samuels, S J , LaBerge, D , & Bremer, C D (1978) Units of Word Recognition Evidence for Developmental Changes *Journal of Verbal Learning and Verbal Behavior*, *17*, 715-720

Schadler, M , & Thissen, D M (1981) The Development of Automatic Word Recognition and Reading Skill *Memory and Cognition*, *9*(2), 132-141

Schreuder, R , & Bon, W H J van (1989) Phonemic Analysis Effects of Word Properties *Journal of Research in Reading*, *12*(1), 59-78

Seegers, G H J (1985) *Individuele Verschillen in Leesvaardigheid* Unpublished doctoral dissertation, Katholieke Universiteit, Nijmegen

Seidenberg, M S (1987) Sublexical Structures in Visual Word Recognition Access Units or Orthographical Redundancy? in M Coltheart (Ed), *Attention and Performance 12*(pp 245 263) Hillsdale, NJ Lawrence Erlbaum Associates

Seidenberg, M S , & McClelland, J L (1989) A Distributed, Developmental Model of Word Recognition and Naming *Psychological Review*, *96*(4), 523-568

Seidenberg, M S , Waters, G S , Barnes, M A , & Tanenhaus, M K (1984) When does Irregular Spelling or Pronunciation Influence Word Recognition? *Journal of Verbal Learning and Verbal Behavior*, *23*, 383-404

Seymour, P H K (1979) *Human Visual Cognition* New York St Martin Press

Seymour, P H K , & Porpodas, C D (1980) Lexical and Non-Lexical Processing of Spelling in Developmental Dyslexia in U Frith (Ed), *Cognitive Processes in Spelling* New York Academic Press

Shankweiler, D , & Liberman, I Y (1972) Misreading A Search for Causes in J F Kavanagh, & I G Mattingly (Eds), *Language by Ear and by Eye The Relationships between Speech and Reading* (pp 293-318) Cambridge M I T Press

Smith, F , Lott, D , & Cronell, B (1969) The Effect of Type Size and Case Alternation on Word Identification *American Journal of Psychology*, *82*, 248 253

Spoehr, K T , & Smith, E E (1973) The Role of Syllables in Perceptual Processing *Cognitive Psychology*, *5*, 71-89

Spring, C , & Capps, C (1974) Encoding Speed, Rehearsal, and Probed Recall of Dyslexic Boys *Journal of Educational Psychology*, *66*, 780-786

Spring, C , & Davis, J M (1988) Relations of Digit Naming Speed with Three Components of Reading *Applied Psycholinguistics*, *9*, 315-334

Stanners, R F , & Forbach, G B (1973) Analysis of Letter Strings in Word Recognition *Journal of Experimental Psychology General*, *98*, 31-35

Stanovich, K E (1980) Toward an Interactive Compensatory Model of Individual Differences in the Development of Reading Fluency *Reading Research Quarterly*, *1*, 33-71

Stanovich, K E (1981) Relationships between Word Decoding Speed, General Name-Retrieval Ability, and Reading Progress in First-Grade Children *Journal of Educational Psychology*, *73*(6), 809-815

Stanovich, K E (1982) Word Recognition Skill and Reading Ability in M H Singer (Ed), *Competent Reader, Disabled Reader, Research and Application* Hillsdale, NJ Lawrence Erlbaum Associates

Stanovich, K E (1986) Matthew Effects in Reading Some Consequences of Individual Differences in the Acquisition of Literacy *Reading Research Quarterly*, *21*(4), 360 406

Stanovich, K.E., Cunningham, A.E., & West, R.F. (1981). A Longitudinal Study of the Development of Automatic Recognition Skills in First Graders. *Journal of Reading Behavior, 13*, 57-74.

Stanovich, K.E., & West, R.F. (1979). The Effect of Orthographic Structure on the Word Search Performance of Good and Poor Readers. *Journal of Experimental Child Psychology, 28*, 258-267.

Stanovich, K.E., & West, R.F. (1989). Exposure to Print and Orthographic Processing. *Reading Research Quarterly, 24*(4), 402-433.

Staphorsius, G., Krom, R.S.H., & Geus, K. de (1989). *Frequenties van Woordvormen en Letterposities in Jeugdlectuur*. Arnhem: Cito.

Sternberg, S., Monsell, S., Knoll, R.L., & Wright, C.E. (1978). The Latency and Duration of Rapid Movement Sequences: Comparisons of Speech and Typewriting. in: G.E. Stelmach (Ed.), *Information Processing in Motor Control and Learning*. (pp.117-152). New York: Academic Press.

Sullivan, H.J., Okada, M., & Niedermayer, F.C. (1971). Learning and Transfer under Two Methods of Word-Attack Instruction. *American Educational Research Journal, 8*, 227-239.

Tinker, M.A., & McCullough, C.M. (1969). *Teaching Elementary Reading*. New York: Appleton Century Crofts.

Treiman, R. (1988). The Internal Structure of the Syllable. in: G. Carlson, & M. Tanenhaus (Eds.), *Linguistic Structure in Language Processing*. Dordrecht: the Netherlands: Reidel.

Treiman, R., & Chafetz, J. (1987). Are there Onset- and Rime-like Units in Printed Words? in: M. Coltheart (Ed.), *Attention and Performance. 12*(pp.281-298). Hillsdale, NJ: Lawrence Erlbaum Associates.

Treiman, R., & Danis, C. (1988). Short-Term Memory Errors for Spoken Syllables are Affected by the Linguistic Structure of the Syllable. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14*, 145-152.

Treiman, R., & Zukowski, A. (1988). Units in Reading and Spelling. *Journal of Memory and Language, 27*, 466-477.

Trommelen, M. (1984). *The Syllable in Dutch*. Dordrecht: Foris Publications.

Underwood, G., & Briggs, P. (1984). The Development of Word Recognition Processes. *British Journal of Psychology, 75*, 243-255.

Vellutino, F.R. (1979). *Dyslexia: Theory and Research*. Cambridge: MIT Press.

Vellutino, F.R. (1982). Theoretical Issues in the Study of Word Recognition: The Unit of Perception Controversy Reexamined. in: S. Rosenberg (Ed.), *Handbook of Applied Psycholinguistics*. (pp.33-197). Hillsdale, NJ: Lawrence Erlbaum Associates.

Vellutino, F.R., & Scanlon, D.M. (1987). Linguistic Coding and Reading Ability. in: S. Rosenberg (Ed.), *Advances in Applied Psycholinguistics*(2). Cambridge: Cambridge University Press.

Venezky, R.L. (1976). *Theoretical and Experimental Base for Teaching Reading*. The Hague: Mouton.

Wagner, R.K., & Torgesen, J.K. (1987). The Nature of Phonological Processing and its Causal Role in the Acquisition of Reading Skills. *Psychological Bulletin, 101*(2), 192-212.

Weijden, M. van der, & Willems, H. (1990). *Waarin Onderscheiden Lezers zich bij het Benoemen van Plaatjes?* Department of Special Education: University of Nijmegen.

West, R.E., & Stanovich, K.E. (1979). The Development of Automatic Word Recognition Skills. *Journal of Reading Behavior, 11*(3), 211-219.

West, R.E., & Stanovich, K.E. (1982). Source of Inhibition in Experiments on the Effects of Sentence Context on Word Recognition. *Journal of Experimental Psychology Learning, Memory, and Cognition, 8*, 385-399.

Weyters, T. (1983). *Positiewoordenboek van de Nederlandse Taal*. Lisse: Swets & Zeitlinger.

Wise, B.W., Olson, R.K., & Treiman, R. (1990). Subsyllabic Units in Computerized Reading Instruction: Onset Rime vs Postvowel Segmentation. *Journal of Experimental Child Psychology, 49*, 1-19.

Wolf, M. (1991). Naming Speed and Reading: The Contribution of the Cognitive Neurosciences. *Reading Research Quarterly, 26*(2), 123-141.

Wolf, M., Bally, H., & Morris, R. (1986). Automaticity, Retrieval Processes, and Reading; A Longitudinal Study in Average and Impaired Readers. *Child Development, 57*, 988-1000.

Appendices

Appendix 2.1: Two parallel versions of a list of 17 VC pseudowords used for the selection of subjects in the first and second training study.

List 1

ap	aat	ein	uis
ek	eel	eup	ijg
il	oof	iem	
on	uus	oek	
ur	aug	oup	

List 2

ak	aag	eip	uim
em	ees	eut	ijt
ir	oot	iek	
ol	uuf	oeg	
uf	aun	ous	

Appendix 2.2: Words and Pseudowords used as practice materials in training study 1.

CVC words

was	kam	wit	dom	kaal	leuk	lief	boek
dag	tak	dik	rug	taak	reis	vies	boer
man	weg	pil	juf	taal	geit	wiel	hoek
pas	bel	mis	bus	veel	vuur	vijf	doel
kat	ver	kin	hut	heet	muur	pijn	voet
bal	zes	kom	dun	deel	huis	rijk	voer
pak	gek	zon	suf	week	tuin	lijf	soep
pap	les	vol	haar	leeg	buik	boom	koek
bak	nek	bos	jaar	meel	muis	hoog	hout
dak	pen	kop	paar	geel	vier	boos	touw
jas	rem	kok	naam	keel	tien	zoon	
nat	pet	pot	baas	teen	dier	rook	
zak	zin	bom	raam	zeep	diep	roos	
gat	vis	pop	maan	neus	ziek	doos	

CVCC words

vast	hark	melk	test	kort	wolk	kaars	lijst
kant	park	nest	niks	volk	hulp	taart	rijst
warm	ramp	rest	sint	vorm	rust	paars	soort
kans	vals	help	film	rots	punt	laars	poort
half	zalf	kerk	kist	post	jurk	naakt	hoorn
dank	gast	tent	lift	wolf	rups	feest	doorn
hart	damp	verf	mist	pomp	tulp	beest	woest
hals	kalm	merk	list	vork	kurk	geest	koest
kamp	balk	hert	gist	worm	munt	reeks	koers
bank	gans	mest	pink	pols	muts	beurt	roest
kalf	werk	heks	lint	golf	bult	buurt	
kast	best	vers	pils	vonk	haast	juist	
lamp	mens	helm	soms	bons	kaart	niets	
dans	berg	vest	dorp	fort	maart	fiets	

CCVC words

klas	grap	grot	krul	traan	dweil	spijt	groep
glas	knap	stof	spul	zwaan	stuur	grijs	groen
gras	snel	knop	klaar	blauw	schuur	groot	vloer
plan	stem	slot	vraag	flauw	bruin	droog	bloem
trap	fles	stok	slaap	vlees	fruit	sloot	broek
plat	spel	stop	graan	steen	fluit	stoom	proef
stam	plek	stom	kraan	bleek	kruis	school	snoep
klap	pret	klok	zwaar	steel	pluis	schoon	troep
stap	stil	blok	draak	zweet	brief	bloot	vrouw
slag	blik	stuk	smaak	kleur	spier	droom	stout
vlam	slim	vlug	dwaas	steun	griep	knoop	
vlag	bril	druk	graag	klein	vlieg	vroeg	
vlak	spin	brug	plaat	trein	stier	stoel	
knal	stip	kruk	staal	plein	prijs	broer	

CCVCC words

krant	glans	schelp	flets	grint	plots	slurp	triest
plant	klank	vlecht	schelp	drink	pronk	kluns	sliert
zwart	kwark	grens	prins	glimp	stolp	stunt	driest
dwars	knars	krent	flink	spits	plomp	snurk	grieks
gracht	flank	dwerg	flits	sport	brons	plaats	grijns
plank	slank	sterf	stift	storm	front	twaalf	troost
start	frats	klerk	stink	trots	krols	staart	proost
kwart	kramp	stelt	klink	schort	slons	spaans	kroost
drank	snars	plens	brink	plons	vlucht	vlaams	proest
klant	slecht	zwerf	twist	klomp	vrucht	steeds	knoest
stank	sterk	klets	drift	stomp	schurk	kreeft	
blank	scherp	snert	plint	klont	slurf	preuts	
krans	knecht	prent	krimp	spons	pruts	stuurs	
kwast	scherm	vlerk	print	knots	kluts	knuist	

CVC pseudowords

wan	has	ner	kol	rut	maaf	keen	buin
dar	zas	pes	zos	jun	kaat	teet	muin
mas	gak	res	naal	but	taat	zeet	viet
par	kag	pem	vok	huk	taan	neul	ties
kal	tan	zik	bor	dul	veek	leum	dies
bam	wes	vik	kos	sut	heef	reil	diek
pam	ber	wik	kof	haaf	deek	geik	zies
pag	vek	dil	pok	jaat	weel	vuun	liek
bap	zek	pir	bog	paak	keel	muun	viem
dap	ges	mil	pos	baak	meek	huin	wies
jak	len	kis	dos	raal	geek	tuil	vijk

pijm	book	zoot	doom	hoel	voen	houk
rijl	hoot	roon	boep	doer	soer	toup
lijg	boop	rool	boes	voek	koef	

CVCC pseudowords

wark	varm	kest	lers	hork	rons	jaast	bijst
barg	walf	remp	wirm	pork	lump	faals	pijst
malk	vank	vels	dink	gost	duns	laast	moont
nast	bans	demp	hirt	dorm	zulf	saart	soont
rast	hank	gest	kimp	holp	muns	faats	woost
varf	karf	lent	bilk	tont	hurt	neets	boost
haks	walk	kert	kilk	mork	must	peels	loest
vars	halp	velk	hilm	kork	vust	keeft	boelt
wans	talp	rets	gilf	mots	pust	beems	roeks
niks	kars	pemp	rist	torf	puls	leust	toest
falm	kemt	verk	mirt	tort	kurt	kuust	
pank	kens	jerk	nikt	pors	paant	tuilt	
pals	benk	reps	vost	fost	baast	miets	
gaps	kelf	hest	holf	molf	gaast	riets	

CCVC pseudowords

blak	vlar	glos	stul	braar	sneip	stijk	zwoen
slam	snar	plos	stur	praak	vruug	blijt	bloek
fras	kles	grop	klaap	slaup	smuuk	slook	koer
grat	vlem	spol	staap	staul	stuim	ploot	stoen
drak	grem	plok	klaak	green	bruif	stoon	troen
brag	knep	stor	vlaas	kreen	gruip	broon	sloet
kral	brel	prot	zwaat	greef	knuip	groos	schoel
spal	blek	krok	zwaap	bleew	truip	vroog	sloem
klar	plit	stot	klaaf	krees	plien	bloom	vloug
zwar	stim	grus	fraat	steuf	dwiel	brook	stoul
dwas	klig	trup	plaas	fleut	drieg	stoop	
tran	knil	stup	praas	vleig	driem	knoep	
spak	plis	vluk	spaat	greit	vriew	stoek	
gran	snil	stum	staam	preif	stijp	droek	

CCVCC pseudowords

stark	snart	glamp	grecht	flenk	stens	flins	frins
scharp	prant	plans	klent	steft	trest	zwirf	prink
knacht	vlark	knats	blenk	stenk	krest	zwirm	krils
scharm	flats	stalp	glens	klenk	kriest	spirt	vlicht
vlacht	brank	plamp	kwerk	kremp	dwirs	stirm	kront
dwarg	twast	frant	kremp	schert	kwist	stimp	plonk
starf	grant	prats	pselm	klemp	spilk	klint	kwort
klats	brats	zwert	prens	brens	schilp	plits	krons

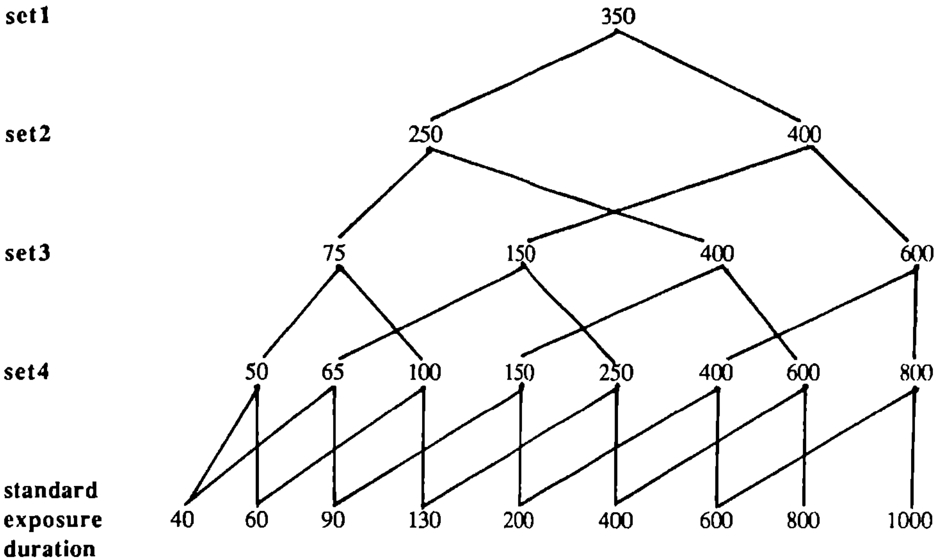
knors	flots	slorf	slunk	klaats	preets	griens	droenk
snors	droft	slorp	krunt	kraaft	vleums	briers	spoert
slocht	plont	drunk	stult	staars	stuunt	stijds	
grons	pront	stunk	stupt	traast	gruiks	knoost	
klork	vrocht	klunk	spuns	praast	smierk	sloort	
scholp	schork	flunk	pluts	speens	twielf	ploost	

Appendix 2.3: Frequency of occurrences of consonants in initial and final position in words and pseudowords in training study 1.

Consonant	words		pseudowords	
	initial	final	initial	final
b	36	0	38	0
d	27	0	25	0
f	14	18	14	23
g	28	16	27	13
h	18	0	18	0
j	5	0	5	0
k	62	67	61	76
l	10	25	11	26
m	14	24	15	26
n	8	28	7	23
p	44	40	46	39
r	15	19	15	16
s	73	83	70	89
t	20	108	21	99
v	34	0	33	0
w	11	4	11	2
z	13	0	15	0
	---	---	---	---
	432	432	432	432

Appendix 2.4: Determining the standard exposure duration for training experiment 1

Exposure durations (in ms) used for each set. On 80% or more correct, the exposure duration of the subsequent set was decreased according to the following scheme. In case of less than 80% correct answers, the exposure duration for the next set was decreased. Each subject started with an exposure duration of 350 ms.



set1	set2	set3	set4
mel	kur	ref	wer
san	bup	kig	lim
nas	tan	haf	tup
mef	der	zap	nof
vep	muk	wof	lar
beg	guf	hog	vam
zim	dif	kel	has
jot	bag	jep	dos
sog	vap	pog	pom
gar	tif	pig	ral

Appendix 2.5: Development and testing of the picture-word interference task employed in training study 1.

Introduction

The picture-word interference task should satisfy two basic requirements. First, with a group of normal third-grade readers, the task should be able to demonstrate that words and pseudowords interfere with picture naming. Second, in order to be certain that any possible interference effects can be attributed to automatic reading processes, and not to peripheral task aspects, the picture-word interference task should induce less, or no interference, in a group of children of comparable age but of low reading skill.

Earlier research has demonstrated that the magnitude of interference is modified by certain factors (see for review: LaHeij, 1988). Factors that are relevant with respect to the present study will be presented briefly. Words, in general, induce more interference on picture naming than pseudowords (Goodman, Haith, Guttentag, & Rao, 1985; Bakan & Alperson, 1967). Larger interference effect have been obtained for high-frequency words than for low-frequency words (Klein, 1964). Rayner & Springer (1986) found that when the superimposed distractor had the same initial letter as the actual picture name, interference was reduced. LaHeij (1988) reviewed a number of studies to the relation between interference effect and Stimulus Onset Asynchrony (SOA) between distractor and picture. He concluded that interference effects are at a maximum when the picture preceded the distractor, with a SOA between 0 and 100 ms.

In the present study, words and pseudowords were used. Picture naming latency with words and pseudowords were both compared with picture naming latency with consonant strings. Consonant strings were used as base-line in order to equate distractors as much as possible in terms of visual and linguistic characteristics. The words were semantically unrelated to the picture's name and had a high printed frequency count. Consonant strings, pseudowords and words matched in number of letters and initial letter. The initial letter of the picture name never matched the first letter of the distractor. Finally, presentation of the distractor preceded the picture. This may seem illogical because LaHeij's (1988) conclusion was that larger interference effects can be obtained without an SOA, or even with the picture slightly preceding the distractor. However, LaHeij's review concerned studies with adult subjects. The present study deals with young children. Although normal third-grade readers appear to process words automatically (Schadler & Thissen, 1981; Seegers, 1985; West & Stanovich, 1979), they are substantially slower than adults (Horn & Manis, 1987). Simultaneous presentation of picture and word has the risk of picture analysis being completed before automatic word processing can exert its influence to the full. In anticipation of this, a procedure was adopted in which the distractor preceded the picture by 150 ms.

Method

Subjects: Thirty-five children (12 boys, 23 girls) from a third-grade elementary school served as a sample of children with a normal reading development. Twenty-six poor readers (19 boys, 7 girls) from two schools for special education were also selected. The mean age of the normal readers was 9;1 years (*SD*=8 months) with a range of 7;9 to 10;5 years. The mean age of the poor readers was

9,2 years (*SD*=8 months) with a range of 7,10 to 10,9 years A standard reading achievement test, the Eén-Minuut-Test (Brus & Voeten, 1972), was administered The number of words read correctly by normal readers ranged from 26 to 80 with a mean of 52 1 (*SD*=13 2) This is a normal score for children of this age The number of words read correctly by poor readers ranged from 4 to 50 with a mean of 18 6 (*SD*=12 8) The poor readers performed at a reading level that is comparable to that of 'normal' readers at the end of grade one

Materials. Thirty-five pictures of common objects and animals were selected The names of the pictures consisted of one or two syllables (except the three-syllable word 'radio') A triplet of distractors, consisting of a word, a pseudoword, and a consonant string, was assigned to each picture Words were semantically unrelated to the picture Thirty-five high-frequency CVC words were selected from Staphorsius et al (1989) Their median printed frequency count was 65 occurrences per million (*M*=130, *SD*=155) In 18 words, the vowel consisted of two letters In the other 17 words, the vowel was represented by a single letter Pseudowords were derived from words by changing the last consonant Consonant strings were also derived from words by replacing the vowel(s) by consonant(s) An effort was made to make the consonant strings consist of phonotactically illegal consonant bigrams (e g tfb) However, that was not possible for all consonant strings In such cases, the least frequent positional bigram was chosen The first letter of the name of the picture never matched the first consonant of the distractor The complete list of stimuli can be found in Appendix 2 6

Apparatus A BBC microcomputer was used Line drawings were presented in white on a green background of a monochrome monitor The size of the pictures was 8 by 8 centimeters Distractors were typed in lower case in the standard available letter font of the computer A string of four letters measured approximately 1 1 by 0 4 cm Distractors were presented in the center of the pictures Naming latencies were measured by a voice-activated relay attached to the computer Latencies were measured accurately to the millisecond

Procedure A subject participated individually in a single experimental session, averaging 30 minutes The children were told that they would see a picture with a letter string superimposed Their task was to ignore the letters and to name the picture as quickly as possible Prior to the experiment proper, subjects were shown all the pictures to be used in this task (without distractors) and were asked to name them aloud This was to ensure that subjects knew the names of all pictured objects and animals Naming errors were rare, but when they occurred, the experimenter provided the correct label

Pictures were always paired to the same distractor triplet For each subject, presentation order of the (35*3) 105 trials was randomized with the restriction that a picture was not to occur twice within 3 trials Each trial started with a 50 ms beep followed by a fixation asterisk in the center of the screen (500 ms) Immediately after the fixation asterisk, the distractor appeared on the screen in the same location as the asterisk After 150 ms, the picture joined the distractor and both remained on the screen simultaneously until a response was made

Response latencies were determined for each trial Latency was defined as the time between the onset of the picture and the verbal response of the subject Following the subjects' response, the experimenter pressed a button on the computer keyboard to indicate whether the response was correct and whether it was the verbal response of the subject, and not some other auditory signal that triggered the voice-key. Experimental trials were preceded by 15 practice trials.

Results

Median picture naming latency was calculated for each distractor condition. Latencies of incorrect responses were not used. In addition, latencies of trials on which the timer was stopped by a sound other than the name of the picture, were eliminated. This resulted in a missing-value percentage of 12.3 (8.8% for normal readers, 17% for poor readers).

The pseudoword interference effect was defined as the delay in naming of pictures printed with pseudowords relative to naming of pictures printed with consonant strings. For each subject, the median latency of naming pictures with consonant strings was subtracted from the median latency of naming pictures with pseudowords. Similarly, the word interference effect was defined as the delay in naming of pictures printed with words relative to naming of pictures printed with consonant strings. For each subject, the median latency of naming pictures with consonant strings was subtracted from the median latency of naming pictures with words. Mean values are shown in Table A1.

Table A.1: Pseudoword interference (PWI) and Word Interference (WI) (in ms) for poor and normal readers, across subjects and across items (*SD* in parenthesis)

		PWI		WI	
			Poor readers		
across items	(n=35)	14.6	(92)	19.5	(92)
across subjects	(n=26)	-17.8	(236)	46.2	(280)
			Normal readers		
across items	(n=35)	60.4	(74)	104.6	(164)
across subjects	(n=35)	85.7	(88)	152.5	(113)

PWI: Latency on pictures with consonants subtracted from latency on pictures with pseudowords
WI: Latency on pictures with consonants subtracted from latency on pictures with words

Pseudoword interference and word interference were entered in analyses of variance with Reader Group (2) as between-subjects factor. Results with respect to pseudoword interference will be discussed first. The main effect of Reader Group was significant (Fs(1,59)=4.65, p<.05, and Fi(1,103)=6.28, p<.05). Within reader group analysis revealed that normal readers' picture naming was significantly delayed by a pseudoword distractor relative to a consonant string distractor (Fs(1,59)=18.98, p<.001, and Fi(1,103)=6.45, p<.05). This was not found for poor readers (F's<1).

The same pattern of results emerged with respect to word interference. The main effect of Reader Group was significant (Fs(1,59)=5.63, p<.05, and Fi(1,103)=4.64, p<.05). Within reader group analysis demonstrated that normal readers' picture naming was significantly delayed by a word distractor relative to a consonant string distractor (Fs(1,59)=19.99, p<.001, and Fi(1,103)=14.33,

$p < .001$). Again, this was not found for poor readers (Fs<1).

Discussion

The pattern of results is clear. Normal readers took longer to name pictures when distracting words or pseudowords were present than when consonant strings were printed in the pictures. Evidently, they were unable to suppress word and pseudoword processing, even if it was in their advantage to do so. Words and pseudowords were being processed automatically (Ehri & Wilce, 1983, Pace & Golinkoff, 1976). Poor readers on the other hand, had similar picture naming latencies under all experimental conditions, showing no sign of automatic processing.

Posthoc analysis revealed that, for normal readers, words tend to induce a larger interference effect than pseudowords ($F_s(1,59)=3.80$, $p=.056$, and $F_i(1,103)=3.92$, $p=.05$), suggesting that lexical factors attributed to the word interference effect.

The results are in accordance with other studies on this subject (Guttentag & Haith, 1978, Pace & Golinkoff, 1976, Schadler & Thissen, 1981, Seegers, 1985, Stanovich, Cunningham, & West, 1981). Normal third-grade readers appear to process words and pseudowords automatically, that is, without cognitive control. The poor readers of this age did not show any sign of automatic processing.

It was concluded that our implementation of a picture-word interference task could demonstrate the automatic processing of words and pseudowords by third-grade normal readers. In addition, no interference was observed in subjects of comparable age, but of low reading skill. With these results, the basic requirements for employing the task as a measuring instrument were fulfilled. The task was administered to the subjects of the training study prior to, and following training.

Appendix 2.6: Stimuli for the Picture Word Interference task used in experiment 1.

picture		letter string	pseudo word	real word	
auto	[car]	bmsk	boes	boek	[book]
bijl	[ax]	zvtk	zouk	zout	[salt]
bloem	[flower]	rkp	rop	rok	[skirt]
bril	[glasses]	tzsn	tees	teen	[toe]
emmer	[bucket]	ktnl	keen	keel	[throat]
fiets	[bicycle]	bdg	beg	bed	[bed]
fles	[bottle]	kps	kis	kip	[chicken]
hamer	[hammer]	jps	jap	jas	[coat]
huis	[house]	pts	pes	pet	[cap]
kam	[comb]	brkm	book	boom	[tree]
kast	[closet]	ptk	pok	pot	[pot]
kasteel	[castle]	mrsn	muin	muis	[mouse]
kerk	[church]	hkr	her	hek	[fence]
klok	[clock]	ngsl	neul	neus	[nose]
kruk	[stool]	grtk	geik	geit	[goat]
lamp	[lamp]	tsn	tan	tas	[purse]
mes	[knife]	rbsl	rool	roos	[rose]
molen	[mill]	lpm	lim	lip	[lip]
pan	[pan]	zmtp	zeet	zeep	[soap]
pistool	[pistol]	kbts	kaat	kaas	[cheese]
pomp	[pump]	wsl	wos	wol	[wool]
radio	[radio]	pfl	pif	pil	[pill]
schaar	[scissors]	msn	mas	man	[man]
sleutel	[key]	bgkr	biek	bier	[beer]
spijker	[nail]	bts	but	bus	[bus]
step	[scooter]	rtg	rut	rug	[back]
stoel	[chair]	bsr	bor	bos	[wood]
tafel	[table]	blr	ber	bel	[bell]
toeter	[horn]	pknl	paan	paal	[pole]
trap	[stairs]	ktl	kal	kat	[cat]
trui	[sweater]	bmtl	bool	boot	[boat]
vis	[fish]	znp	zop	zon	[sun]
vlag	[flag]	mtnp	maap	maan	[moon]
wiel	[wheel]	rbts	ries	riet	[reed]
zaag	[saw]	vbtm	voem	voet	[foot]

Appendix 2.7: Pseudowords used as practice materials in training study 2

CVCC Pseudowords

baaks	faarn	geets	jaalp	kuulm	naamp	pim	saans	tefs
baamp	faarp	gets	jaamp	kuuns	naans	pirp	saarf	teusp
baats	faats	geuns	jaams	laalf	naats	poem	saark	tielm
bems	famf	gijts	jaans	laalk	namf	poomp	saarn	tilf
biemp	faps	gilk	jaats	laalm	narf	pum	saam	tirf
bijks	farf	gimp	jaks	laamp	nam	puups	saats	tim
bimp	fam	girf	jarf	lam	narp	raalf	safs	tirs
birf	fats	girm	jam	lilf	nats	raalk	sats	toofs
bim	feelf	gim	jefs	lilp	neelf	raalm	seelk	toolf
birp	feerf	goelm	jets	lirf	neps	raans	seerm	toolk
bisp	fets	goomf	jilf	lirm	nijlk	raats	seump	toolm
boofs	feurf	goomp	jilk	lim	nijlm	rarf	seurk	toomp
books	fielm	goons	jimp	lirs	nilf	ram	sijlp	toops
boolf	fimf	goops	jins	loemp	nilk	reem	sijns	toorf
boolk	fimp	gom	jirf	loolf	nilp	reump	silf	toork
boolm	firf	guilm	jirm	loolk	nimp	reuns	silk	toorn
boolp	fim	guips	jim	loolm	nirf	reuts	simp	toors
bulf	fisp	gurs	jirs	loorf	nim	riens	sirf	tuilk
daalm	foerk	guump	jisp	loork	nirp	riers	sirm	tuns
daamf	foolf	haamp	jofs	loorn	noelk	rirf	sim	tuups
daamp	foolk	heump	jolm	luilf	noofs	rirm	sirs	vamf
daarn	foolm	hierp	joomp	luups	noolf	rim	soelm	vam
daam	foomf	hijlf	joorf	maamf	noolk	roemf	soofs	varp
dets	foomp	hilk	joork	maamp	noolm	roolf	soolf	veuns
dielk	foorf	himp	joorn	meufs	noolp	roolk	soolk	veups
doerk	foork	hirf	jorf	mielf	noomf	roolm	soolm	vijms
doolf	foorn	hirn	jom	mielk	noomp	roolp	soops	vijts
doolk	foors	him	juulp	mielm	noons	roorf	soots	vilp
doolm	foots	hirs	juuns	mijlm	nuilf	roork	sorf	vimp
doomp	fuilk	hoelm	juusp	mijts	nuilm	roorn	som	vim
duulf	fuump	hoolf	keemp	mimp	nuips	rorf	suiks	voems
duulk	fuurn	hoolk	keufs	mirf	nuurf	rom	suilf	vooks
duulm	gaalf	hoolm	keulm	mirm	nuurk	ruins	suimp	voolf
duuns	gaalk	hoomp	kieks	mim	nuurn	rulm	suns	voolk
duum	gaalm	hoosp	kijlk	molm	paamf	ruulp	taalk	voolm
duurs	gaalp	horf	kimf	moolm	paamp	ruurk	taamp	voomp
faaks	gaamf	huulf	kirn	moomf	peefs	saafs	taats	voons
faalf	gaamp	huurn	kirp	moomp	peufs	saaks	tafs	voots
faamp	gaats	jaafs	kirs	morf	peulm	saalf	talp	vuim
faaps	garf	jaalf	koolk	mom	peump	saalk	tam	waamp
faarf	gam	jaalk	koomf	muulm	pijks	saalm	tarp	waps
faark	geelm	jaalm	koons	muuls	pirm	saalp	tats	weem

weuks	wijrk	woemf	woons	zaafs	zaarn	zimp	zirs	zoorn
weumf	wijts	woolf	woots	zaamp	zaats	zims	zoern	zoors
wifs	wirn	woolk	wuilm	zaarf	zafs	zirf	zolm	zurn
wijlf	wirs	woolm	wuins	zaark	zarn	zirm	zoorf	zuulm
wijps	woelk	woomp	wump	zaarm	zeump	zirn	zoork	

CCVC Pseudowords

bleil	drel	flous	groum	kreil	sfes	snees	vlauk	zwif
bleim	drem	frar	gruil	kreim	sjaam	sneik	vlif	zwin
bleip	dren	freur	klijl	kreir	sjas	sneim	vlil	zwip
bleis	drep	frijn	klijm	kren	sjeis	snein	vlin	zwir
blel	drer	from	kloel	krer	sjen	sneip	vlir	zwis
bler	dres	frouk	kloen	krien	sjijm	sneis	vlis	zwof
bleum	drif	frum	kloes	krif	sjoek	sneuf	vluum	zwoof
bleus	drim	frep	kneif	krin	sjoen	sneuk	vreip	zwook
blouk	drin	froem	kneik	krir	sleif	sniek	vrim	zwool
bloun	drip	frol	kneil	kwoes	sleis	snool	vrus	zwoop
bluil	drir	froop	kneim	kwoom	slen	snoos	vruun	zwoos
bluis	dror	gneel	kneis	prar	sloef	snun	vruur	zwop
braun	dweel	gnees	knoef	praum	sloen	spaul	vruus	zwor
braup	dwef	gnies	knoek	praup	sloun	speif	wreip	zwos
brep	dweim	gnoek	knoem	preif	slous	speik	wrir	zwouf
brer	dweis	gnon	knoen	preil	smeip	speim	wroel	zwouk
brijl	dwen	greif	knoes	preip	smus	speip	wrool	zwuim
brijm	dwoem	greik	knouf	preul	snaam	trijl	wruun	zwuis
brijn	flaan	greil	knoul	proul	snaan	twes	zweik	zwun
dral	fleik	greim	knuim	proun	snaas	twip	zweil	zwuuf
dran	flien	gren	knuur	prous	sneef	twom	zweis	
drar	flool	grer	kreif	sfef	sneem	twook	zweus	

CCVCC Pseudowords

blarp	draats	dwirn	flolf	gleulp	klerp	klurs	kweurs	kwuuts
blelp	dralp	dwomp	flolp	glijmp	klilp	knens	kwielm	plaamp
blerm	drelp	dwoots	flork	glirs	klils	knerk	kwilp	plaks
blerp	dremp	dwulp	florp	glors	klirf	kneuts	kwins	plalf
blims	drerk	dwuuks	flors	gralp	klirm	knins	kwirk	plalp
blirs	drets	flaarp	fluilp	grurp	klirp	knirk	kwirp	plals
blolp	drips	flemp	fluirp	klalf	klirs	knirm	kwirs	plams
blork	drirp	flers	flurp	klalm	kloerm	knirn	kwolp	plaps
bluump	dromp	fleuns	frilf	klarf	klork	knits	kwons	plarf
braats	drorp	fleuts	frirp	klarm	klors	knoers	kwork	plarm
breers	drors	flijns	frorp	klarn	kluilp	knork	kworm	plarp
brerp	dwaans	flilp	glelp	klelk	kluks	knump	kworp	plelp
brolp	dwimp	flirp	glerk	klelp	klups	kwemp	kwors	plels
draans	dwirk	floens	glerp	klerm	klurp	kwerp	kwurs	plemp

plems	preets	slins	smimp	snins	stirp	trals	twolk	zwilf
plerf	prelp	slirf	smins	snips	stirs	trarf	twomp	zwilk
plerk	premp	slirk	smips	snirk	stols	trark	twops	zwilm
plerp	prerp	slirm	smirk	snirm	stoors	trarp	twork	zwils
plers	prers	slirs	smirm	snirp	stots	trars	twuulp	zwims
pleurk	preurs	sloets	smirp	snirs	stuilf	trelf	twuurp	zwins
pliems	prijlp	slols	smirs	snolp	stulk	trelk	twuuts	zwips
plijrs	prirp	sloms	smolp	snons	stulm	trelp	vlalp	zwirk
pliks	prolp	sloons	smork	snops	stuls	trels	vlaps	zwirs
plilm	promp	slops	smorp	snurp	stums	tremp	vlirp	zwits
plilp	proms	slork	smuilp	spalp	stuns	trems	vraks	zwoerf
plims	proorp	slors	smuns	sparp	stups	treps	vrarp	zwoks
plips	prorp	sluks	smurm	spemp	sturm	treulp	vrilk	zwolf
plirf	prors	slums	snalk	spers	sturp	trijls	vrolp	zwolk
plirk	pruilp	slups	snalp	spijns	sturs	trulf	vromp	zwomp
plirp	slaarp	slurm	snans	spimp	tjaalp	trulk	vruilp	zwons
plirs	slams	sluts	snarf	spirk	tjamp	trump	wralp	zwops
ploers	slarm	sluurt	snark	spirp	tjarp	truns	wrork	zwork
plolk	slars	smans	snarp	spoers	tjats	trurs	zwaks	zworm
plolp	slats	smats	snats	spolf	tjeps	twalp	zwalf	zworp
plorf	sleets	smeens	snemp	spolp	tjilf	twams	zwalm	zwors
plork	sleks	smeks	snens	spuums	tjirs	twark	zwalp	zwots
plorp	slems	smemp	snerp	stats	tjomp	twels	zwals	zwulp
plulp	slens	smens	sners	stens	tjuuts	twemp	zwans	zwump
plump	sleps	smerp	snets	stets	traks	twierm	zwaps	zwuns
pluulp	slers	smers	sneump	steurp	tralf	twijts	zwats	zwurk
pralk	sleurp	smielf	snilf	stijns	tralk	twilm	zweks	zwurs
pralp	slierp	smierp	snilp	stims	tralm	twirp	zwelk	zwuts
praps	slijlp	smilp	snimp	stirm	tralp	twoerk	zwens	

Appendix 2.8: High frequency words used in pre- and posttests for training study 2

CVCC words

berg	film	hulp	kant	melk	punt	tent	welk
best	haast	juist	kast	mens	rest	vast	werk
beurt	half	jurk	kerk	naast	rijst	verf	west
buurt	hals	kaart	kort	nest	rots	volk	zelf
dorp	hart	kalf	last	niets	rust	vorm	zorg
feest	heeft	kamp	maart	niks	soms	want	
fiets	help	kans	meest	post	soort	warm	

CCVC words

blik	fles	groen	klein	slaap	stam	stof	vlees
brief	fruit	groep	kleur	sloot	stap	stok	vlug
broer	glas	groot	knop	slot	steen	stop	vraag
bruin	graaf	grot	kraan	snel	stel	stuk	vroeg
draak	graag	klaar	plan	spel	stem	trap	zwaar
droog	graan	klap	plat	staan	stil	trein	
druk	gras	klas	plein	staat	stoel	vlak	

CCVCC words

blaast	droogt	klimt	plant	smaakt	sport	stopt	zwaars
blank	droomt	klomp	ploft	smeekt	staart	storm	zwart
breekt	drukt	klopt	plons	smelt	stamt	stuurt	zweeft
broers	dwars	knikt	plots	snapt	stapt	trekt	zweert
bromt	flink	krant	prent	snauwt	start	triest	zwemt
brons	flits	krast	prins	spaans	steekt	trots	zwerm
brult	graaft	kruipt	proeft	speelt	stelt	twaalf	
bruusk	grens	kruist	slaapt	spits	sterk	vliegt	
draagt	klant	kwart	sleept	spoelt	stikt	vraagt	
dreigt	klemt	plaats	slipt	spons	stookt	vriest	

Appendix 2.9: Sentences used for the Sentence Verification Task

Melk is klein	[Milk is small]
Vijf is meer dan zes	[Five is more than six]
De kat is een plant	[The cat is a plant]
Een kers is vlees	[A cherry is meat]
Het oor ruikt soep	[The ear smells soup]
Het jaar is van hout	[The year is made of wood]
De lift zakt heel hoog	[The elevator is descending very high]
Een sok is fruit	[A sock is fruit]
De bal heeft een hoek	[The ball has an edge]
De zee vliegt hoog	[The sea is flying high]
Het vuur is warm	[The fire is hot]
De broek is vies	[The pants are dirty]
De kraan lekt	[The tap is leaking]
Jos koopt een fles wijn	[Josh buys a bottle of wine]
De mat ligt voor de deur	[The mat is in front of the door]
Het boek is dik	[The book is thick]
In de boom zit een nest	[In the tree is a nest]
De ruit is van glas	[The pane is made of glass]
De peer is rot	[The pear is rotten]
De geit is van de boer	[The goat belongs to the farmer]
De pan is leeg	[The pan is empty]
An snoept van de taart	[Ann is sneaking pie]
Wim speelt met de bal	[Bill is playing with the ball]
De man loopt door de tuin	[The man walks through the garden]
Oom Jan rookt een pijp	[Uncle John smokes a pipe]
Gras is groen	[Grass is green]
De lamp is aan	[The lamp is burning]
De zaag is bot	[The saw is blunt]
De poes heeft een staart	[The cat has a tail]
In de muur zit een raam	[In the wall is a window]
In het park is het druk	[It is crowded in the park]
De tas is van leer	[The bag is made of leather]
De pen vlekt	[The pencil is staining]
De kok maakt soep	[The cook is making soup]
De man heeft een snor	[The man has a moustache]
De muis zit in de val	[The mouse is trapped]
De vaas is wit	[The vase is white]
Een koe geeft melk	[A cow gives milk]
Kaas is geel	[Cheese is yellow]
Ans zit op een stoel	[Ann is sitting on a chair]

Appendix 2.10: Development and testing of the picture-word interference task employed in training study 2

Introduction

This picture-word interference task is, in outline, similar to the task used in the first training study Differences will be discussed briefly Due to circumstances of organizational nature, poor readers did not participate in the testing part of the study The task was tested on 'normal' third grade children only Furthermore, distractors were printed in larger letters than in the previous picture-word interference task In order to increase the likelihood of obtaining significant effects, the number of pictures was raised to 48 In the previous picture-word interference task, 35 pictures were used Asynchroneous presentation of picture and distractor met with technical difficulties Therefore, picture and distractor were presented simultaneously Finally, pictures were presented in color Adding color reduced ambiguity regarding the correct picture label

Method

Subjects Thirty-two subjects (19 boys, 13 girls) from third grade of elementary school participated in this experiment Their mean age was 9,7 years (*SD*=6 months), with a range of 8,7 till 10,8 years They were qualified by their teachers as 'normal readers'

Materials Forty-eight pictures of common objects and animals were selected The names of the pictures consisted of one or two syllables Forty-eight distractor triplets were created, consisting, of (a) a word, (b) a pseudoword, and (c) a consonant string High-frequency words were selected from Staphorsius et al (1989) Their median printed frequency count was 30 occurrences per million (*M*=59, *SD*=75) The number of CVCC, CCVC, and CCVCC words within the set was 12, 12, and 24, respectively For each word, a pseudoword equal in length, orthographical structure and initial consonant, was created Finally, a consonant string, also equal in length and initial consonant to the word and pseudoword, was generated to complete the distractor set An effort was made to make the consonant strings consist of phonotactically illegal consonant bigrams (e g *gmjn*) That however, was not possible for all consonant strings In such cases, the least frequent positional bigram was chosen (CELEX, 1988) In this manner, 48 sets of three distractors were created The complete list of pictures and distractors can be found in Appendix 2 11

Apparatus An Apple IIGS computer was used Pictures were presented in color on a white background The size of the pictures was 15 by 15 cm Distractors were typed in black, lower case letters A four letter string measured approximately 3 by 0 7 centimeters Distractors were presented in the center of the pictures Naming latencies were measured by a voice-activated relay attached to 7 the computer Latencies were measured accurately to the millisecond

Procedure Subjects participated individually in a single experimental session, averaging 18 minutes The children were told that they would see a picture with a letter string superimposed Their task was to ignore the letters and to name the picture as quickly as possible Prior to the experiment proper, subjects were shown all the pictures to be used in this task (without distractors) and were asked to name them aloud. This was to ensure that subjects knew the names of all pictured objects and animals. Naming errors were rare, but when they occurred, the experimenter provided the correct label. Pictures were paired randomly with a distractor triplet. Presentation order of the (48*3) 144 trials was randomized with the constraint that a picture was not to occur twice within 24 trials. Each subject received a different randomization of the 144 trials. Each trial started with a 50 ms beep followed by a fixation asterisk in the center of the screen (500 ms). Immediately after the fixation asterisk, the picture and distractor appeared simultaneously on the screen in the same location as the asterisk. Both remained on the screen until a response was made. Response latencies were determined for each trial. Latency was defined as the time between the onset of the picture and the verbal response of the subject. Following the subject's response, the experimenter pressed a button on the computer keyboard to indicate whether the response was correct and whether it was the verbal response of the subject, and not some other auditory signal that triggered the voice-key. Experimental trials were preceded by 18 practice trials.

Results

Median picture naming latencies were calculated for each distractor condition. Latencies of incorrect responses were not used. In addition, latencies of trials on which the timer was stopped by a sound other than the name of the picture, were eliminated. This resulted in a missing-value percentage of 11.3. Pseudoword interference and word interference were determined in the same manner as in the previous picture-word interference task. Mean values are shown in Table A.2

Table A.2: Pseudoword Interference (PWI) and Word Interference (WI) (in ms) across subjects and across items (*SD* in parenthesis)

		PWI		WI	
across items	(n=48)	18.7	(49)	36.7	(79)
across subjects	(n=32)	36.5	(73)	62.0	(74)

PWI: Latency on pictures with consonants subtracted from latency on pictures with pseudowords
WI: Latency on pictures with consonants subtracted from latency on pictures with words

Pseudoword interference and word interference were entered in an analysis of variance. Effects of both pseudoword interference and word interference were significant ($Fs(1,31)=4.74$, $p<.05$, and $Fi(1,47)=11.96$, $p<.001$ for pseudoword interference, and $Fs(1,31)=6.87$, $p<.05$, and $Fi(1,47)=33.81$, $p<.001$ for word interference). This means that picture naming latency was significantly delayed by a superimposed pseudoword or word, in comparison with naming of pictures printed with consonant strings.

Discussion

Normal third-grade readers took longer to name pictures when distracting words or pseudowords were present than when consonant strings were printed in the pictures. Evidently, they were unable to suppress word and pseudoword processing, even if it was in their advantage to do so. Words and pseudowords were being processed automatically, that is, without cognitive control (Ehri & Wilce, 1983; Pace & Golinkoff, 1976). Posthoc analysis revealed that words tended to induce a larger interference effect than pseudowords ($Fs(1,31)=3.58$, $p=.068$, and $Fi(1,47)=4.60$, $p<.05$), suggesting that lexical factors attributed to the word interference effect.

It was concluded that this implementation of a picture word interference task is capable of demonstrating effects of automatic processing of words and pseudowords by third-grade normal readers. With these results, a basic requirement for employing the task as a measuring instrument was fulfilled.

Appendix 2.11: Stimuli for the Picture Word Interference task used in experiment 2.

Pictures:

appel	[apple]	heks	[witch]	pijp	[pipe]
auto	[car]	hert	[deer]	potlood	[pencil]
ballon	[ballon]	hoed	[hat]	slang	[snake]
banaan	[banana]	ijsje	[icecream]	sleutel	[key]
beker	[mug]	jurk	[dress]	spook	[ghost]
bel	[bell]	kaas	[cheese]	stoel	[chair]
bloem	[flower]	kasteel	[castle]	teve	[television]
boek	[book]	kikker	[frog]	uil	[owl]
bril	[glasses]	kip	[chicken]	varken	[pig]
bus	[bus]	klok	[clock]	vis	[fish]
cadeau	[gift]	kok	[cook]	vlag	[flag]
druiven	[grapes]	kopje	[cup]	vlieger	[kite]
fietser	[cyclist]	lamp	[lamp]	vliegtuig	[plane]
fles	[bottle]	mond	[mouth]	wortel	[carrot]
hamburger	[id]	oor	[ear]	zaag	[saw]
handschoen	[glove]	pet	[cap]	zon	[sun]

Distractors: In order: consonant string, pseudoword, word with English translation between brackets.

bdfn,burp,balk	[beam]	bwst,blum,blok	[block]
bdmkl,buufs,baard	[beard]	djmkb,dwum,drank	[drink]
bhdv,blel,brug	[bridge]	dmh,dets,darm	[gut]
bkvrz,boolk,beest	[beast]	dvps,dwes,drop	[licorice]
bpfjl,brarp,brons	[bronze]	frdh,funs,film	[film]
brlkd,blims,brand	[fire]	fvkns,foelf,feest	[party]

gdsr,gimf,gans	[goose]
gjmn,gnos,gras	[grass]
gtnml,glorf,grens	*[border]*
gvpjr,glcum,graan	[corn]
hkmn,hosp,hark	[rake]
hzgrp,hieks,haard	[hearth]
kgdwp,knons,kwast	[brush]
kghr,kwaf,kruk	[stool]
kgvwm,klurs,klomp	[clog]
knjlr,kwirp,krans	[wreath]
kpftr,klirn,krent	[current]
ksbnp,kielp,koets	[couch]
kwdsgb,kwoens,kreeft	[lobster]
kzhjm,knous,kruik	[jar]
ldgf,lam,lift	[elevator]
pbknh,plerf,prent	[picture]
pgkdw,prolm,plant	[plant]
pjlwh,pliek,plein	[square]
plkrz,prem,plank	[plank]
ptkgr,plam,prins	[prince]
pwdntj,pliemp,plaats	*[town]*
sbghn,snulm,spons	[sponge]
sghw,sfup,spek	[bacon]
sgtbn,stuls,speld	[pin]
shdr,sjes,stam	[trunk]
sjknb,slork,stang	[bar]
slmjg,slouk,stier	[bull]
smlkg,snalp,storm	[storm]
snklw,smems,slurf	[trunk]
snltm,sluum,steen	[stone]
swmjrk,sneulf,staart	[tail]
twrdfs,tjaam,twaalf	[twelve]
vgrkms,vluurp,vriend	[friend]
zgtf,zirs,zand	[sand]
zvtps,zwuls,zwart	[black]
zwstpf,zweurt,zwaard	[sword]

Appendix 2.12: Number correct and naming latency (in ms) on pre and posttest of the Pseudoword Reading task, split by Orthographical Structure (*SD* in parenthesis)

Group		CVCC/CCVC		CCVCC		*M*	
		Number Correct (max=40)					
	pretest	25.1	(7.8)	23.0	(7.5)	24.1	(7.3)
FC (n=20)	posttest	35.7	(3.4)	34.9	(3.7)	35.3	(3.3)
	pretest	25.3	(6.8)	23.0	(7.8)	24.2	(6.9)
RA (n=21)	posttest	34.8	(4.1)	34.4	(4.7)	34.6	(4.3)
	pretest	23.7	(6.3)	24.6	(7.8)	24.2	(6.3)
NT (n=21)	posttest	28.0	(6.6)	27.1	(6.5)	27.5	(6.3)
		Latency					
	pretest	2089	(870)	2410	(878)	2244	(876)
FC (n=20)	posttest	1690	(645)	1940	(845)	1815	(740)
	pretest	2514	(783)	2674	(834)	2590	(781)
RA (n=21)	posttest	2300	(977)	2615	(1070)	2458	(1017)
	pretest	2195	(702)	2354	(789)	2273	(729)
NT (n=21)	posttest	1981	(791)	2171	(785)	2076	(775)

FC: Flash Card group. RA: Reading Aloud group. NT: No Training group

Appendix 2.13: Number correct and naming latency (in ms) on pre- and posttest of the Pseudoword Reading task, split by Frequency of Presentation and Orthographical Structure (*SD* in parenthesis)

Group	Orth.struct		Frequency of Presentation 8		4		1	
					Number Correct (max=10)			
FC (n=20)								
	CVCC/CCVC	pretest	6.00	(2.2)	6.50	(1.7)	6.50	(2.4)
	CVCC/CCVC	posttest	9.50	(.7)	8.95	(1.2)	8.50	(1.5)
	CCVCC	pretest	5.65	(2.5)	5.85	(2.3)	5.65	(2.5)
	CCVCC	posttest	9.20	(.7)	9.05	(1.0)	8.35	(1.8)
RA (n=21)								
	CVCC/CCVC	pretest	5.86	(2.0)	6.52	(2.4)	6.43	(2.2)
	CVCC/CCVC	posttest	9.10	(1.1)	8.48	(1.4)	8.43	(1.4)
	CCVCC	pretest	5.33	(2.6)	6.14	(2.4)	5.57	(2.2)
	CCVCC	posttest	8.90	(1.3)	8.29	(1.6)	8.48	(1.4)
					Latency			
FC(n=20)								
	CVCC/CCVC	pretest	2041	(908)	2159	(813)	1955	(884)
	CVCC/CCVC	posttest	1496	(599)	1653	(731)	1776	(722)
	CCVCC	pretest	2731	(1086)	2232	(1006)	2290	(1007)
	CCVCC	posttest	1915	(1031)	1921	(786)	1902	(1836)
RA (n=21)								
	CVCC/CCVC	pretest	2593	(892)	2615	(904)	2375	(846)
	CVCC/CCVC	posttest	2367	(1068)	2219	(1010)	2277	(919)
	CCVCC	pretest	2688	(964)	2590	(812)	2668	(785)
	CCVCC	posttest	2533	(1096)	2669	(1135)	2643	(1032)

FC: Flash Card group. RA: Reading Aloud group.

Appendix 2.14: Number correct and naming latency (in ms) on pre- and posttest of the Word Reading task, split by Orthographical Structure (*SD* in parenthesis)

Group		CVCC/CCVC		CCVCC		*M*	
		Number Correct (max=32)					
	pretest	28.0	(2.7)	24.9	(3.9)	26.4	(2.9)
FC (n=20)	posttest	30.1	(1.5)	28.9	(2.7)	29.5	(1.8)
	pretest	26.8	(3.9)	25.1	(5.1)	25.9	(4.3)
RA (n=21)	posttest	28.3	(6.9)	27.1	(7.0)	27.7	(6.9)
	pretest	28.2	(2.2)	26.0	(3.1)	27.1	(2.3)
NT (n=21)	posttest	29.3	(2.1)	27.7	(3.2)	28.5	(2.4)
		Latency					
	pretest	1322	(824)	1756	(1104)	1477	(927)
FC (n=20)	posttest	1085	(433)	1490	(722)	1257	(567)
	pretest	1527	(834)	1851	(926)	1674	(864)
RA (n=21)	posttest	1417	(781)	1869	(892)	1568	(787)
	pretest	1098	(391)	1523	(661)	1290	(557)
NT (n=21)	posttest	1036	(384)	1322	(535)	1152	(469)

FC: Flash Card group. RA: Reading Aloud group. NT: No Training group

Appendix 2.15: Decision latency (in ms) of correct responses on pre- and posttest of the Sentence Verification task, split by semantically true and false sentences (*SD* in parenthesis)

Group		True sentences		False sentences	
	pretest	4147	(1284)	5458	(1459)
FC (n=20)	posttest	3593	(1180)	4681	(1214)
	pretest	4712	(1387)	5849	(1521)
RA (n=21)	posttest	4334	(1262)	5607	(1577)
	pretest	3803	(759)	5049	(1212)
NT (n=21)	posttest	3573	(1006)	4457	(1566)

FC: Flash Card group. RA: Reading Aloud group. NT: No Training group

Appendix 3.1: The list of 144 CVC words used in experiment 1, 2 and 3 of chapter 3, consisting of 48 single-letter vowel CVC, 48 homogeneous digraph vowel CVC, and 48 heterogeneous digraph vowel CVC words.

nut	bot	kaal	poos	geit	bout
mes	kol	keet	neer	beuk	koel
zot	zes	vuur	rook	roep	saus
kus	zin	taal	teer	paul	zien
rot	fit	baas	duur	dauw	feit
vet	pet	kuur	boos	fout	piet
rum	tin	pook	kaas	pauw	tuin
zak	rus	doof	haat	hoek	reis
vis	gat	noot	boot	kuil	niet
kik	bek	mees	kool	zeil	muis
tel	rap	zuur	hees	zeis	zout
put	pil	pees	zoon	teil	kous
gil	gek	guur	maat	buis	gauw
bar	fut	vaat	poot	keur	voet
was	por	raam	teen	pauk	ruim
vel	hik	zaak	roos	duif	ziek
pas	kil	vaas	goot	paus	vies
nar	kat	kaak	beek	nier	koek
rok	ver	muur	reep	reuk	touw
tor	tol	boon	paal	toer	deuk
dor	bus	geel	huur	deur	geul
bos	kar	buur	deeg	mouw	boer
kas	puk	wees	puur	keus	wies
hut	duf	veel	haak	hout	vuil

Appendix 3.2: The list of pseudowords used in the lexical decision task of experiment 3 in chapter 3.

w*oos	ve*es	zut	n*ur	d*euf	we*us
m*uut	roo*p	kes	b*ir	r*aup	hie*t
g*eet	nuu*t	vas	k*os	h*iek	nui*t
p*aak	zee*k	kek	tu*n	n*oer	zeu*t
to*ol	taa*r	tan	vo*r	ro*uk	rou*m
ku*us	nit	rop	gi*k	da*uk	
da*af	zos	b*er	pa*r	ke*is	

Appendix 3.3: The list of pseudowords used in experiment 4 of chapter 3, consisting of 140 CVC (66 homogeneous digraph CVC, and 74 heterogeneous digraph CVC), 95 CVCC, and 100 CCVC pseudowords.
The pseudoword is placed in the first column; the log positional bigram-frequency in positions 1-2, 2-3, and 3-4 are placed in column 2, 3 and 4, respectively.

CVC: Homogeneous vowel digraph

jaal	10.379	13.851	9.620	gaak	11.438	13.850	10.868
jaas	10.379	13.850	9.641	gaam	11.438	13.850	10.986
jaak	10.379	13.850	10.869	heem	11.580	13.267	10.013
jaam	10.379	13.850	10.986	heep	11.579	13.267	10.412
jaan	10.379	13.850	10.994	heek	11.578	13.267	11.140
huuk	10.382	9.503	9.838	waam	11.614	13.850	10.986
roon	10.482	13.231	9.514	geem	11.736	13.267	10.013
roop	10.482	13.230	9.907	geep	11.736	13.267	10.412
hook	10.649	13.230	9.782	geek	11.736	13.267	11.140
vaam	10.659	13.850	10.986	geer	11.736	13.267	12.945
goon	10.871	13.230	9.513	meem	11.779	13.267	10.013
gook	10.870	13.230	9.782	meep	11.778	13.267	10.412
goop	10.870	13.230	9.907	meek	11.778	13.267	11.140
keem	11.002	13.267	10.013	took	11.872	13.230	9.782
keep	11.002	13.267	10.412	toop	11.872	13.230	9.907
keen	11.002	13.267	12.848	toor	11.872	13.230	13.072
laal	11.145	13.850	9.620	deem	12.003	13.267	10.013
laas	11.144	13.850	9.640	deep	12.002	13.267	10.412
laak	11.144	13.850	10.868	deek	12.002	13.267	11.140
laam	11.144	13.850	10.986	deer	12.002	13.267	12.945
laar	11.144	13.850	13.640	naal	12.241	13.850	9.620
veem	11.184	13.267	10.013	naas	12.241	13.850	9.640
veep	11.184	13.267	10.412	naak	12.241	13.850	10.868
veek	11.184	13.267	11.140	naan	12.241	13.850	10.993
daak	11.219	13.850	10.868	weem	12.274	13.267	10.013
daam	11.219	13.850	10.986	weep	12.274	13.267	10.412
zeek	11.228	13.267	11.140	weel	12.274	13.267	11.918
zeel	11.228	13.267	11.918	haam	12.434	13.850	10.986
moon	11.341	13.230	9.513	doon	12.508	13.230	9.513
mook	11.340	13.230	9.782	maam	12.600	13.850	10.986
moop	11.339	13.230	9.907	voon	12.712	13.230	9.513
moor	11.339	13.230	13.072	vook	12.712	13.230	9.782
gaal	11.438	13.850	9.620	voop	12.712	13.230	9.907

CVC; Heterogeneous vowel

jauk	10.379	9.146	9.838	veis	11.184	9.670	10.267
viem	10.426	13.289	10.013	veuk	11.184	10.506	9.837
viep	10.425	13.289	10.412	dauk	11.220	9.146	9.837
viek	10.425	13.289	11.140	zeuk	11.228	10.506	9.837
vien	10.425	13.289	12.848	moep	11.339	12.600	10.412
roen	10.482	12.600	12.848	moel	11.339	12.600	11.918
giem	10.519	13.289	10.013	moen	11.339	12.600	12.848
giep	10.519	13.289	10.412	gauk	11.438	9.146	9.837
gien	10.519	13.289	12.848	heuk	11.579	10.506	9.837
houk	10.649	9.947	9.837	wauk	11.615	9.146	9.837
hoem	10.649	12.600	10.013	miem	11.691	13.289	10.013
hoep	10.649	12.600	10.412	miel	11.690	13.289	11.918
hoel	10.649	12.600	11.918	geuk	11.736	10.506	9.837
vauk	10.659	9.146	9.837	meuk	11.778	10.506	9.837
wiem	10.691	13.289	10.013	toem	11.872	12.600	10.013
wiep	10.690	13.289	10.412	toep	11.872	12.600	10.412
wien	10.690	13.289	12.848	toek	11.872	12.600	11.140
kouk	10.788	9.947	9.837	toel	11.872	12.600	11.918
koem	10.787	12.600	10.013	deis	12.003	9.670	10.267
koep	10.787	12.600	10.412	nauk	12.241	9.146	9.837
tiem	10.818	13.289	10.013	weuk	12.274	10.506	9.837
tiep	10.817	13.289	10.412	hauk	12.434	9.146	9.837
tiek	10.817	13.289	11.140	doem	12.508	12.600	10.013
gouk	10.871	9.947	9.837	doep	12.508	12.600	10.412
goem	10.871	12.600	10.013	doer	12.508	12.600	12.945
goep	10.871	12.600	10.412	mauk	12.601	9.146	9.837
goek	10.871	12.600	11.140	voem	12.712	12.600	10.013
goel	10.871	12.600	11.918	voep	12.712	12.600	10.412
goen	10.871	12.600	12.848	voek	12.712	12.600	11.140
goer	10.871	12.600	12.945	voen	12.712	12.600	12.848
hiem	10.877	13.289	10.013	niem	12.909	13.289	10.013
hiek	10.877	13.289	11.140	niep	12.909	13.289	10.412
hien	10.877	13.289	12.848	niek	12.909	13.289	11.140
liem	10.927	13.289	10.013	niel	12.909	13.289	11.918
liek	10.927	13.289	11.140	nien	12.909	13.289	12.848
keis	11.002	9.670	10.267	ziem	13.472	13.289	10.013
lauk	11.145	9.146	9.837	ziep	13.471	13.289	10.412

CVCC

sorm	9.942	10.439	9.744	roms	10.482	10.807	9.877
sork	9.942	10.438	10.420	gilk	10.519	9.445	9.550
sonk	9.942	10.778	9.893	gilf	10.519	9.445	10.684
sons	9.942	10.778	11.204	gink	10.519	11.331	9.892
bams	10.031	9.383	9.877	horm	10.649	10.438	9.743
balf	10.031	10.105	10.684	hork	10.649	10.438	10.420
barm	10.031	10.367	9.743	hons	10.649	10.778	11.203
bark	10.031	10.366	10.420	homs	10.649	10.807	9.877
bans	10.031	11.929	11.203	vams	10.659	9.383	9.877
lets	10.179	10.850	10.915	valf	10.659	10.105	10.684
lenk	10.179	11.513	9.892	varm	10.659	10.366	9.743
lerm	10.179	11.654	9.743	vank	10.659	11.929	9.892
lerk	10.179	11.653	10.420	vans	10.659	11.929	11.203
kams	10.217	9.383	9.877	wilk	10.691	9.445	9.550
karm	10.217	10.366	9.743	wilf	10.691	9.445	10.684
kark	10.217	10.366	10.420	wink	10.691	11.331	9.892
kilk	10.241	9.446	9.550	wins	10.691	11.331	11.203
kilf	10.241	9.445	10.684	korm	10.788	10.438	9.743
kins	10.241	11.331	11.203	kork	10.787	10.438	10.420
pams	10.275	9.383	9.877	konk	10.787	10.778	9.892
palk	10.274	10.105	9.550	kons	10.787	10.778	11.203
palf	10.274	10.105	10.684	koms	10.787	10.807	9.877
parm	10.274	10.366	9.743	tilk	10.818	9.445	9.550
pank	10.274	11.929	9.892	tilf	10.817	9.445	10.684
pans	10.274	11.929	11.203	tink	10.817	11.331	9.892
bets	10.282	10.850	10.914	tins	10.817	11.331	11.203
belk	10.282	11.401	9.550	gorm	10.871	10.438	9.743
belf	10.282	11.401	10.684	gork	10.871	10.438	10.420
benk	10.282	11.513	9.892	gonk	10.871	10.778	9.892
bens	10.282	11.513	11.203	gons	10.871	10.778	11.203
borm	10.329	10.438	9.743	hilk	10.877	9.445	9.550
bork	10.328	10.438	10.420	hilf	10.877	9.445	10.684
boms	10.328	10.807	9.877	hink	10.877	11.331	9.892
jalk	10.379	10.105	9.550	hins	10.877	11.331	11.203
jalf	10.379	10.105	10.684	lins	10.927	11.331	11.203
jarm	10.379	10.366	9.743	kelf	11.002	11.401	10.684
jark	10.379	10.366	10.420	kenk	11.002	11.513	9.892
hulf	10.381	9.519	10.684	kens	11.002	11.513	11.203
hunk	10.381	9.921	9.892	larm	11.144	10.366	9.743
huns	10.381	9.921	11.203	lark	11.144	10.366	10.420
vilk	10.426	9.445	9.550	lank	11.144	11.929	9.892
vilf	10.425	9.445	10.684	vets	11.184	10.850	10.914
vins	10.425	11.331	11.203	velk	11.184	11.401	9.550
rons	10.482	10.778	11.203	velf	11.184	11.401	10.684

venk	11.184	11.513	9.892	dark	11.219	10.366	10.420
verm	11.184	11.653	9.743	zets	11.228	10.850	10.914
verk	11.184	11.653	10.420	zelk	11.228	11.401	9.550
dams	11.221	9.383	9.877	zenk	11.228	11.513	9.892
dalk	11.219	10.105	9.550	zens	11.228	11.513	11.203
dalf	11.219	10.105	10.684	zerm	11.228	11.653	9.743

CCVC

bruk	8.951	9.144	9.838	plap	9.298	10.317	9.418
bref	8.951	9.165	9.436	vlem	9.370	8.912	10.013
brem	8.951	9.164	10.013	vlep	9.370	8.912	10.412
brep	8.951	9.164	10.412	vluk	9.370	9.028	9.837
brap	8.951	9.555	9.418	vlur	9.370	9.028	10.311
brop	8.951	10.035	9.907	vlon	9.370	9.078	9.513
bris	8.951	10.517	10.267	vlik	9.370	9.605	9.388
slef	8.985	8.913	9.436	vlis	9.370	9.605	10.267
sles	8.984	8.912	9.513	snil	9.530	8.664	9.401
slem	8.984	8.912	10.013	snis	9.530	8.664	10.267
slep	8.984	8.912	10.412	snef	9.530	9.432	9.436
sluk	8.984	9.028	9.837	snes	9.530	9.432	9.513
slur	8.984	9.028	10.311	snep	9.530	9.432	10.412
slon	8.984	9.080	9.513	blef	9.649	8.912	9.436
kles	9.068	8.912	9.513	bles	9.649	8.912	9.513
kluk	9.067	9.028	9.837	blem	9.649	8.912	10.013
klon	9.067	9.078	9.513	blep	9.649	8.912	10.412
klis	9.067	9.605	10.267	bluk	9.649	9.028	9.837
vruk	9.144	9.144	9.837	blur	9.649	9.028	10.311
vres	9.144	9.164	9.513	blon	9.649	9.078	9.513
vrem	9.144	9.164	10.013	blop	9.649	9.078	9.907
vrep	9.144	9.164	10.412	blis	9.649	9.605	10.267
vrap	9.144	9.554	9.418	blap	9.649	10.317	9.418
vral	9.144	9.554	9.620	blas	9.649	10.317	9.640
vras	9.144	9.554	9.640	tres	9.877	9.164	9.513
vron	9.144	10.035	9.513	trep	9.877	9.164	10.412
vrop	9.144	10.035	9.907	tral	9.877	9.554	9.620
vril	9.144	10.517	9.401	tras	9.877	9.554	9.640
plef	9.299	8.912	9.436	tron	9.877	10.035	9.513
ples	9.298	8.912	9.513	trop	9.877	10.035	9.907
plem	9.298	8.912	10.013	trik	9.877	10.517	9.388
plep	9.298	8.912	10.412	tris	9.877	10.517	10.267
plur	9.298	9.028	10.311	dref	10.199	9.164	9.436
plon	9.298	9.078	9.513	dres	10.199	9.164	9.513
plok	9.298	9.078	9.782	drem	10.199	9.164	10.013
plik	9.298	9.605	9.388	drep	10.199	9.164	10.412
plis	9.298	9.605	10.267	dras	10.199	9.554	9.640

dron	10.199	10.035	9.513
drok	10.199	10.035	9.782
drik	10.199	10.517	9.388
dris	10.199	10.517	10.267
kwap	10.539	10.571	9.418
kwas	10.539	10.571	9.640
kwef	10.539	10.675	9.436
kwes	10.539	10.675	9.513
kwem	10.539	10.675	10.013
kwep	10.539	10.675	10.412
twap	10.670	10.571	9.418
twal	10.670	10.571	9.620
twas	10.670	10.571	9.640
twef	10.670	10.675	9.436
twes	10.670	10.675	9.513
twem	10.670	10.675	10.013
twep	10.670	10.675	10.412
stis	10.984	8.719	10.267
stur	10.984	9.118	10.311
stas	10.984	10.019	9.640
stes	10.984	10.146	9.513

Appendix 3.4: The list of words used in experiment 4 of chapter 3, consisting of 30 CVC (15 homogeneous digraph CVC, and 15 heterogeneous digraph CVC), 30 CVCC, and 30 CCVC words.
The word is placed in the first column; the log positional bigramfrequencies in positions 1-2, 2-3, and 3-4 are placed in column 2, 3 and 4, respectively.

CVC; homogeneous vowel

maar	12.60	13.85	13.64
voor	12.71	13.23	13.07
naar	12.24	13.85	13.64
door	12.50	13.23	13.07
daar	11.22	13.85	13.64
veel	11.18	13.26	11.91
geen	11.73	13.26	12.84
meer	11.77	13.26	12.94
weer	12.27	13.26	12.94
heel	11.58	13.26	11.91
gaan	11.43	13.85	10.99
waar	11.61	13.85	13.64
jaar	10.37	13.85	13.64
vaak	10.65	13.85	10.86
paar	10.27	13.85	13.64

CVC; heterogeneous vowel

niet	12.90	13.28	13.22
toen	11.87	12.60	12.84
doen	12.50	12.60	12.84
hier	10.87	13.28	12.94
zien	13.47	13.28	12.84
huis	10.38	10.76	10.26
leuk	10.17	10.50	9.83
vier	10.42	13.28	12.94
gauw	11.43	9.14	12.94
boek	10.32	12.60	11.14
hout	10.64	9.94	11.14
deur	12.00	10.50	10.31
fijn	8.71	10.50	10.30
boer	10.32	12.60	12.94
vijf	10.42	12.60	12.94

CVCC

want	11 61	11 92	11 40	melk	11 77	11 40	9 55
zelf	11 22	11 40	10 68	hulp	10 38	9 51	8 64
soms	9 94	10 80	9 87	last	11 14	10 06	8 64
werk	12 27	11 65	10 42	nest	9 72	9 65	8 64
vast	10 65	10 06	10 42	rest	9 58	9 65	8 64
best	10 28	9 65	10 42	rust	9 22	8 93	8 64
dorp	12 50	10 43	8 41	dank	11 22	11 92	9 89
mens	11 77	11 51	11 20	kort	10 78	10 43	9 89
denk	12 00	11 51	9 89	help	11 58	11 40	8 64
kant	10 21	11 92	9 89	hart	12 43	10 36	8 64
warm	11 61	10 36	9 74	punt	9 01	9 92	8 64
niks	12 90	8 79	9 12	hals	12 43	10 10	8 42
berg	10 28	11 65	8 48	kerk	11 00	11 65	10 42
kans	10 21	11 92	11 20	kamp	10 21	9 38	8 36
half	12 43	10 10	10 68	volk	12 71	9 33	9 55

CCVC

snel	9 53	9 43	11 91	plat	9 29	10 31	9 41
klas	9 06	10 31	9 64	stof	10 98	8 60	8 82
stuk	10 98	9 11	9 83	blik	9 64	9 60	9 38
vlug	9 37	9 02	8 66	stam	10 98	10 02	10 98
stil	10 98	8 72	9 40	knop	8 22	7 36	9 90
glas	8 73	10 31	9 64	slot	8 98	9 08	9 89
druk	10 20	9 14	9 83	stok	10 98	8 60	9 78
stem	10 98	10 14	10 01	klap	9 06	10 31	9 41
vlak	9 37	10 31	10 86	stap	10 98	10 02	9 41
gras	8 80	9 55	9 64	stop	10 98	8 60	9 90
plan	9 29	10 31	10 99	plek	9 29	8 91	11 14
fles	8 37	8 91	9 51	slag	8 98	10 31	9 19
spel	8 70	9 87	11 91	slim	8 98	9 60	8 50
trap	9 87	9 55	9 41	brug	8 95	9 14	8 66
grot	8 80	10 03	9 41	stom	10 98	8 60	8 81

Curriculum Vitae

Karel van den Bosch, geboren op 28 april 1959, behaalde in 1975 het MAVO diploma aan de Breitner MAVO te Amsterdam, en in 1977 het HAVO diploma aan de rijksscholengemeenschap 'Brocklede' te Breukelen. De opleiding tot leerkracht voor het basisonderwijs aan de 'Bouman Academie', te Amsterdam, werd in 1980 afgesloten met een diploma. In datzelfde jaar begon hij de studie psychologie aan de Universiteit van Amsterdam. Het kandidaatsexamen werd in 1983 behaald. In 1984 en 1985 was hij werkzaam aan het Instituut voor Woordblindheid en Andere Leerproblemen (IWAL), te Amsterdam. In 1984 volgde hij een stage aan het Max Planck Institut für Psycholinguistik te Nijmegen. Hij was daar werkzaam in het afasieproject. In 1986 volgde hij het bijvak Sociaal Wetenschappelijke Informatica. Onder supervisie van Prof. dr. J.J. Elshout deed hij onderzoek naar de relatie tussen spellingstrategieën en leesvaardigheid. In augustus 1986 behaalde hij het doctoraalexamen psychologische functieleer. Van 1987 tot 1991 was hij werkzaam als AIO aan de Katholieke Universiteit Nijmegen. Deze dissertatie is de weerslag van het onderzoek dat is verricht in die periode.