Varieties of reading disability
Phonological and orthographic word decoding deficits
and implications for interventions

Stefan Gustafson
PREFACE

This thesis is based on the following five studies, which will be referred to in the text by Roman numerals.


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1. INTRODUCTION

"And so to completely analyze what we do when we read would almost be the acme of a psychologist's achievements, for it would be to describe very many of the most intricate workings of the human mind, as well as to unravel the tangled story of the most remarkable specific performance that civilization has learned in all its history" (Huey, 1908/1968, p. 6).

Although written in the beginning of the last century, this sentence eloquently illustrates the challenge facing today's researchers examining reading and reading disabilities. Above all, it reminds us of the great complexity inherent in the process of reading. In order to be able to read and successfully comprehend even the simplest message, a large number of different sensory, perceptual, and cognitive operations have to be performed. The above quotation also highlights the fact that written language is a central aspect of society and that it is a cultural invention. Reading skills do not evolve spontaneously in human beings (cf. McGuinness, 1998), rather, reading is something that we must learn to do. Therefore, two basic societal requirements for the development of reading skills are that the surrounding society values these skills and that it supplies an adequate reading instruction.

Given the complexity of the process of reading, there are many different factors, internal as well as external to the individual, that can be assumed to influence the acquisition of reading. This also means that failure in learning to read can be the result of a complex interaction between different factors.

Though the examination of reading and its various components can be approached by studying the societal issues surrounding its acquisition, of specific interest to many researchers today are the internal mechanisms and processes that occur while a human is learning to read. Along these lines, many recent studies have attempted to isolate cognitive components associated with reading acquisition (e.g., Rack, Snowling, & Olson, 1992; Share & Stanovich, 1995; Wagner & Torgesen, 1987). Other studies have attempted to identify subgroups of reading disability based on cognitive skills directly related to the process of reading, that is, skill in using the two main word decoding strategies (Castles & Coltheart, 1993; Manis et al., 1996; Stanovich, Siegel, & Gottardo, 1997).

The general aim of the present thesis is to analyse variations in the word decoding skills of reading disabled children and to relate these differences to possible cognitive, developmental, and, to some extent, environmental
causes of reading disabilities. Increased knowledge concerning varieties of reading disability could have implications for educational interventions for different groups of reading disabled children.

2. DISABILITY RESEARCH AND READING DISABILITY

It is difficult to provide a precise definition of disability research since it is not a homogeneous field of research. My own view is that disability research covers a variety of possible theoretical perspectives and methodological approaches. Researchers come into the field of disability research with very different disciplinary backgrounds and research interests. For example, a micro–macro distinction can be made where some disability researchers will focus mostly on the abilities and disabilities of the individual, while others will focus more on environmental factors.

I will begin this section by discussing the notions of impairment, disability, and handicap (these concepts are related to the micro-macro distinction just mentioned). I will then discuss the concept of normality, which is another central concept in disability research. These concepts will be exemplified by, and discussed in relation to, research on reading disabilities.

2.1 Impairment, disability, and handicap

The relationship between the individual and the environment is central to the classification system proposed by the International Classification of Impairments, Disabilities, and Handicaps, or ICIDH (World Health Organization, 1980). In this system, a disease is assumed to cause one or more impairments, where an impairment stands for "any loss or abnormality of psychological, physiological or anatomical structure or function" (WHO, 1980, p. 47). A disability is defined as "any restriction or lack (resulting from an impairment) of ability to perform an activity in the manner or within the range considered normal for a human being" (WHO, 1980, p. 143). A handicap is defined as "a disadvantage for a given individual, resulting from an impairment or a disability, that limits or prevents the fulfilment of a role that is normal (depending on age, sex, and social and cultural factors) for that individual" (WHO, 1980, p. 143). Thus, in this classification system it is assumed that there is a cascading causation, where a disease causes impairment, impairment causes disability, and disability causes handicap.
The body affected by a disease is regarded as the starting point in this chain, whereas a handicap is described as a socialised situation:

"Handicap is characterised by a discordance between the individual’s performance or status and the expectations of a particular group of which he is a member... Handicap is thus a social phenomenon, representing the social and environmental consequences for the individual stemming from the presence of impairments and disabilities" (WHO, 1980, p. 29).

In ICIDH it is acknowledged that sometimes the causal link between the concepts may not hold, and that in some cases there might even be a causal relation in the opposite direction: "The experience of certain handicaps can engender, as part of illness behaviour, not only various disabilities but at times even the impairment of certain faculties" (WHO, 1980, p. 30).

Nordenfelt (1983/1997, 1993) acknowledged that the classification system provided by the ICIDH (WHO, 1980) has some merits and has proven fruitful for the discussion of concepts related to disabilities, but he also identified some conceptual problems associated with this system. Nordenfelt (1983/1997) argued that there is an unclear distinction between the two concepts of disease and impairments since they are described in very similar ways. According to Nordenfelt (1983/1997), there is also an unclear distinction between the two concepts of disabilities and handicaps, since many descriptions of particular disabilities are in fact value-laden.

Other critics of the ICIDH (WHO, 1980) have focused mostly on the definition of handicap. The Canadian Society for the ICIDH and the Quebec Committees (1989, 1990) have specifically objected to the normative aspects of normality inherent in the definition of handicap in ICIDH (WHO, 1980). According to those critics, the life habits of a specific individual should determine when a handicap arises rather than the vague cultural norms of what a person should be able to accomplish in a particular society. Nordenfelt (1987, 1993) wanted to go one step further in the definition of handicap and not only include life habits, which can be described as repeated or repeatable actions, but also other actions which are important for a particular individual. Nordenfelt (1987) thus proposed that the vital goals of individuals should instead be focused on in the characterisation of handicaps and disabilities.

Some of the problems of ICIDH should be eliminated in a new classification, ICIDH-2, which is planned to be published in 2001 (WHO, 1999). According to a preliminary version of ICIDH-2, the new classification system will include three dimensions: (1) body level; (2) individual level; and (3) society level. These dimensions will be named Body functions and structure,
Activities, and Participation, respectively (WHO, 1999). In ICIDH-2, "functioning" will be used as an umbrella term covering positive or neutral aspects of the three dimensions whereas "disability" will be used as an umbrella term for problems in these dimensions (WHO, 1999). Note that ICIDH-2 is currently undergoing field trials and might be subject to changes. In the present thesis, the terms impairment, disability and handicap will be used in accordance with ICIDH (WHO, 1980).

An inclusive view of disability research would be that research conducted on any of the three levels of analysis: impairment, disability, and handicap, could be regarded as examples of disability research. However, even if a particular study only involves one level of analysis, disability research would probably benefit from acknowledging the existence of the other two levels. Reducing complex phenomena like disabilities and handicaps to only one level of explanation might lead to unnecessary theoretical paradoxes, as well as unnecessary misunderstandings between people representing different disciplines, professions, or ideological views (see Frith, 1999, and section 7 in this thesis). A continuous debate between different research paradigms and multi-disciplinary research environments may help to facilitate a broader awareness of both individual and societal aspects of disabilities and handicaps.

The need to consider both individual and environmental factors when studying disabilities can be illustrated by a reading disability example. An exclusive neurological or genetic explanation of reading disability would certainly fail to account for all factors involved, such as the obvious socio-cultural influences on reading skills or the fundamental importance of educational activities in learning to read. However, it does not follow that biological and genetic factors would have no influence on reading acquisition, as some researchers have argued (e.g., McGuinness, 1998). A child is not born as either a good or a poor reader but children can be expected to vary in their potential for acquiring reading skills, just like they vary in their potential for acquiring other skills (cf. Olson et al., 1989). Therefore, the possibilities of neurological deficits or genetic influences in reading disability are empirical questions and should be regarded as such (see section 4 for empirical findings). A complex phenomenon like reading disability should not be reduced only to its biological aspects, but neurological and genetic findings could provide valuable complements to findings on the behavioural and environmental levels of analysis (Frith, 1999).

Of course, a finding that supports one specific explanation or cause of reading disability, by stressing a particular individual or environmental
factor, does not rule out other explanations of reading failure and should not be over-generalised to the whole population of poor readers. Thus, even if a genetic component is found in developmental dyslexia, it does not imply that there is a genetic component in all forms of reading disability. Within a group of reading disabled individuals there seem to exist substantial individual differences regarding the relative influence of genetic compared to environmental factors (Castles, Datta, Gayan, & Olson, 1999; Wadsworth, Olson, Pennington, & DeFries, 2000).

It should also be noted that neurological impairments are by no means fixed or resistant to treatment. Recent findings in the neurosciences provide evidence of brain plasticity not only in children, but also in adults who have suffered damage to the brain as a consequence of tumours (Seitz et al., 1995), or stroke (Chollet et al., 1991; Johansson, 2000). Findings also suggest that a stimulating environment may be critical for the outcome of interventions aimed at overcoming disabilities caused by acquired as well as congenital neurological impairments (Johansson, 2000; Mattsson, Sorensen, Zimmer, & Johansson, 1997; Schrott et al., 1992). Furthermore, even if a particular neurological impairment would be impossible to treat at a given time, the actions and opinions of the surrounding environment, such as political decisions and social and technological developments, would continue to affect the individual, directly or indirectly.

In the present thesis, the terms "reading disability" and "reading disabled children" will be frequently used. How then, are these concepts related to the concepts of disability and handicap? I would suggest that as soon as a reading disabled individual encounters demands on reading skills which exceed his or her current reading ability, the individual is handicapped in that particular situation. In the empirical studies of this thesis, the demands on reading skills are very pronounced, since a number of timed tests measuring word decoding skills and reading comprehension were administered. In a test situation, the possibility of using environmental compensatory strategies, such as asking for help or using technical aids, which could sometimes be used in real life situations, is also typically minimised. In other words, the focus of a test is on the reading disability and not on the handicap associated with this disability. The focus on internal abilities and the exclusion of many environmental factors influencing the lives of reading disabled children is a limitation of the present thesis (even though study IV included measures of print exposure). However, a general aim of these empirical studies is to learn more about different groups of reading disabled children in order to facilitate more adequate educational interven-
Disability research includes a wide variety of possible theoretical frameworks and methodological approaches. However, there are some common themes and concepts which often need to be addressed, explicitly or implicitly. For example, the interaction between the individual and the environment seems to be one such common theme in disability research. Another theme that will often enter the research process is the classification and definition of different disabilities. This can be exemplified by study I in the present thesis which critically examined the inclusion of IQ in the definition of developmental dyslexia. Additionally, the process of diagnosis and the effects of receiving a diagnosis are other related themes. For a comprehensive study of how children, parents, and teachers talk about and give meaning to the diagnosis of dyslexia, see a recent thesis by Zetterqvist Nelson (2000).

In this section, I will focus on another concept, normality, which seems to be one of the central concepts in disability research and also has a direct bearing on research and current debates in the field of reading disabilities. The concept of normality was introduced in western society by statisticians as late as in the 19th century (Davis, 1997). The statistical notion of normality relies on the assumption of the normal distribution of abilities, also known as the bell-shaped curve, with the majority of cases being positioned in the middle, or "normal", part of the distribution. This notion incorporates some paradoxes, which can be illustrated by research on reading disabilities. One such paradox is that since the bell-shaped curve is taken for granted in statistical analyses, then "norming the non-normal is an activity as problematic as untying the Gordian knot" (Davis, 1997, p. 14). If there is always a bell-shaped curve, it follows that there will always be some individuals situated at the lower end of the continuum, regardless of the general level of performance. Thus, a reader positioned at the lower end of the continuum in a society with a high general reading ability may be regarded as a normal reader in another society with a low general level of
reading ability. Furthermore, even if the general level of reading ability improves in a population, there will still be just as many statistically subnormal readers within that population.

This can be illustrated by a comparative study of reading literacy organised by The International Association for The Evaluation of Educational Achievement (IEA) (see Taube, 1995). Taking place in 1990/1991, this study used different measures to evaluate the reading skills of 9-year-old and 14-year-old children from 31 different countries. The results showed that when a composite measure of text reading ability was formed, Sweden ranked third highest among all countries both for the 9-year-olds and the 14-year-olds. The mean score of the top-ranked nation, Finland, was 569 for 9-year-olds, compared to the lowest mean score of 383 for Venezuela. Interestingly, differences also occurred between countries with similar economic resources and in the same geographic area. For example, the mean score of the Swedish 9-year-olds (539) were higher than that of the Danish 9-year-olds (475). In fact, the 25th percentile (i.e., 25% performed below this score) of the Swedish pupils was higher than the mean score of the Danish pupils (Taube, 1995). Thus, if a single bell-shaped curve, including both Swedish and Danish children, would be formed, more Danish than Swedish children would be found in the lower tail of the normal distribution. If separate distributions would instead be used, a Swedish pupil, located at the 5th percentile, for instance, would be expected to perform at a higher level than a Danish pupil also located at the 5th percentile.

Besides the statistical notion of normality, the concept can have a normative meaning. Now, what is considered normal is not based on statistical comparisons but on cultural and societal norms and values. As long as there are only quantitative and no identifiable qualitative differences between reading disabled individuals and "normal readers", the cut-off point between subnormal and normal will always be arbitrary to some extent. This means that the societal norms will affect what proportion of children will be categorised as reading disabled. Higher requirements would be associated with larger proportions of reading disability if the general level of reading ability is held constant. However, the general level of reading ability would also be affected by societal norms and values, for example, through the allocation of educational resources. How much resources are available for interventions might also affect what proportion of children will be categorised as reading disabled, because the identification of a "subnormal" group, like reading disabled children, may be associated with certain responsibilities for decision makers. There might be a resistance to
acknowledge that a large percentage of children are in need of extra resources if no such resources are judged to be available. Thus, according to Aaron (1997), the number of children who are identified as reading disabled may sometimes be the result of fiscal, rather than psychological, decisions. This also means that the number of children categorised as reading disabled may vary from year to year, depending on how much resources are allocated to a particular school district (Aaron, 1997).

No radical solution to these dilemmas will be provided in this thesis. The normal distribution will enter the statistical analyses as usual, and the term "normal readers" will also be used occasionally, with reference to the control groups included in the empirical studies. It seems difficult to completely avoid the concept of normality while conducting disability research. For example, disabled people who participate in disability research often do so because they differ from a given norm in some respect. However, while including these notions and statistical measures of normality, I fully acknowledge the difficulty and complexity of using them. In conclusion, what is considered normal and abnormal depends on both individual and environmental factors and what is considered abnormal in one particular society would be considered perfectly normal in other societies.

2.3 Environmental demands on reading skills

Given that a handicap arises partly as a result of environmental demands and that these demands can be expected to change over time, the current demands on reading skills in Sweden need to be discussed. The level of reading skills and the demands on these skills will interact to create the measurable qualification of a reading handicap. A related question, which will also be discussed in this section, concerns the secondary effects of reading disability, that is, what are the personal and social consequences of failing to acquire the level of reading skills required by society? A third question considers the implications of the rapidly developing information and communication technology for reading disabled individuals. This technology may further increase the societal demands on reading skills but should also offer new opportunities for compensation for reading disabled people. Although each of these questions could produce their own thesis, in the present work they will only be discussed briefly as background to the empirical studies, with the environmental demands being more or less taken for granted.
In school, reading is clearly one of the most fundamental activities. It is easy to overlook how much educational time and effort is usually spent on teaching children how to read and write and to continuously improve on these skills. Reading skills are fundamental in all theoretical subjects in school, since written language is a critical source of information and communication. Even when information is provided orally in school, written language in the form of note-taking is often used to preserve a more robust representation of what is said than the information that will be stored in memory upon hearing it. This illustrates one of the most remarkable benefits of written language compared to spoken language. Written language is more decontextualised, since it is not dependent on events occurring at certain places and times:

"A technology which allows the user to communicate with others from whom he/she is removed in space and time is certainly miraculous and has indeed had the most profound consequences for the living conditions of mankind. No wonder that mastery of such a remarkable system as written language has become a highly valued skill and prerequisite for success in our society" (Lundberg & Høien, 1997, p. 11).

The intense reading instruction that children receive in school reflects the high demands on reading skills of today's society. There are countless activities which include written language in some form. The nature of these activities and the motives behind participating in them vary considerably. For example, written language can be used as a source of information, as a tool for communication with others, as our "externalised memory", as a means of personal expression, as part of our work, as a social act when we read together with, or for, someone else, and it can be used for recreational purposes. These activities also vary in terms of the required levels of word decoding and comprehension skills (see section 3.1) and the possibilities of using compensatory strategies, such as asking for help or using technical aids. However, all of these different activities require that we have basic skills in reading and writing.

Purves (1990) emphasises that environmental demands on reading skills are not restricted only to the technical aspects of transforming strings of letters into words. The importance of cultural literacy is discussed in terms of membership or non-membership in a "scribal society" in which a number of assumptions about the world is shared. Purves (1990) here makes a distinction between the literate, who merely possesses basic skills in reading and writing, and the "scribe" who is a master of written language and not only knows how to read and write but also knows most of the specific
conventions of written language, as well as a body of texts which are valued by a particular scribal society. According to Purves (1990), scribes tend to manage society because they have control of the information and its flow. In the context of the rapidly developing information technology in the United States, he notes that: "the distinction between the literate and the scribe has come to take on increasing social and even economic weight, and it looks as if the gap will only widen" (Purves, 1990, p. 38).

Even though this analysis was based on the situation in the United States, the general idea that cultural literacy is critical for success in many areas of society and that written language can be used to exclude groups of people from being full members of various scribal cultures may apply to most literate societies, including Sweden. In many cases, to be a normal reader, or merely literate, might simply not be enough. In order to be a successful member of a particular field of society, the individual must also meet a number of demands which have to do with knowledge of the conventions and important texts of that scribal society (Purves, 1990). Thus, a distinction between normal readers and people with reading disabilities is a simplified way of categorising people according to level of reading skills. However, the importance of social and cultural aspects of written language does not lessen the importance of the more technical aspects of reading. It is possible that the technical skills are necessary but not sufficient requirements in reaching high levels of cultural literacy.

Since reading skills are of fundamental importance in our society, failure to acquire these skills might have negative secondary effects for the individual. A number of studies have examined the possible links between reading disability and various types of behavioural problems. In a study by Adams, Snowling, Hennessy, and Kind (1999), prosocial behaviour was positively correlated with reading ability, whereas conduct problems were negatively correlated. A modest, but statistically significant 4% of the variance in concurrent reading was accounted for by teachers' ratings of children's behaviour. In another study, the relationship between reading problems and antisocial behaviour was examined (Maughan et al., 1996). The results suggested that juvenile offending was most strongly predicted by poor school attendance. Reading problems only seemed to be indirectly related to risk for offending, via the poor readers' poor school attendance. This result is in line with a recent Swedish study concerned with the prevalence of reading disabilities among prison inmates (Samuelsson, Gustavsson, Herkner, & Lundberg, in press). The results of this study suggested that, in general, the observed reading difficulties among prison
inmates could be explained by their poor social and educational back-
grounds, rather than being caused by specific reading disabilities of constitu-
tional origin (i.e., developmental dyslexia, see section 4.1).

In correlational studies like these, however, it is not really possible to
determine the causal direction of the relationship. Problems of behaviour
might be a secondary effect of reading disability but there might also be a
causal link in the other direction, that is, problems of behaviour might lead
to reading difficulties. The exact nature of this relationship and its causal
direction does not seem to be clear at this point. It also seems that knowledge
is largely lacking concerning many other possible secondary effects of
reading disability, such as the educational and vocational situations of
people with reading disabilities living in Sweden.

General environmental developments may sometimes have profound
effects on specific disabilities and handicaps. For example, the rapidly
developing information and communication technology should offer new
possibilities for compensation for people with reading disabilities. Tools
such as scanners, speech synthesis, and speech–to–text conversion may
facilitate better access to text-based information and provide new bridges
between spoken and written language. Information and communication
technology also offers new possibilities of using computers for educational
purposes, through various types of programs for reading instruction. On the
other hand, as long as the information and communication is mainly based
on written language and there is limited opportunity of using compensatory
 technological tools, this technology also imposes new demands on reading
and spelling skills, and thus, might accentuate some of the negative aspects
of being reading disabled. Access to information and communication
channels seems to be one of today’s most central democratic issues, and this
issue could be even more critical for people with reading disabilities who are
in a vulnerable position because of their difficulties in using written

Reading and reading disabilities are complex phenomena which can be
analysed on several different levels of analysis; but even if the analysis is
restricted to the cognitive level, they are not clear-cut concepts. Different
reading activities can be expected to vary in terms of their specific cognitive
requirements. Some activities may require a very rapid and automatic
transformation of letters into words, while other reading tasks may put
higher demands on higher-level mental processes. The complexity of
transforming strings of abstract symbols (i.e., letters) into meaningful
entities (i.e., morphemes, words, and sentences) also implies that there are
several possible cognitive causes of reading failure. Thus, before going any further the cognitive process of reading needs to be examined in some detail.

3. MODELS OF READING

3.1 The two components of reading

The process of reading can be divided into two components: word recognition and comprehension (Aaron, 1997; Gough & Tunmer, 1986; Hoover & Gough, 1990). Word recognition (or word decoding) refers to the technical aspect of reading, that is, to transform written words into their corresponding sounds. However, the general purpose of reading is to gain meaning in what is written and this is the role of the second component, comprehension (or understanding). The process of understanding is an activity on a higher cognitive level where the reader makes use of personal experience, interpretations are made, and conclusions are drawn. This mental activity is similar to the mental activity engaged in listening to a text read by someone else (Aaron, 1997).

There is empirical support that these two components are to some extent independent of each other, such that one of the components can be selectively impaired while the other is more or less intact (Oakhill, 1982; Share & Stanovich, 1995; Stothard & Hulme, 1992). An example of impaired word recognition skills but intact comprehension would be developmental dyslexia (cf. Share & Stanovich, 1995). An extreme example of the opposite pattern, intact word recognition skills but impaired comprehension, would be the case of hyperlexia (Aaron, Franz, & Manges, 1990; Healy, 1982). However, there are also crucial dependencies between the two components. In order to be able to understand what is written, the words always have to be decoded. Thus, in a timed test of reading comprehension dyslexics would be expected to perform below normal even if their comprehension is intact. If the word decoding process in itself requires much effort, there should be less processing capacity left for accessing the meaning of what is written, thus, a deficit in comprehension.

There might also be more long-term secondary effects of impaired word decoding skills on higher–level, semantic abilities. Stanovich (1986) described such ”Matthew effects” in reading (from the Gospel according to St Matthew, 25:29) and explained how a low initial level of word decoding skill in children may have long-term negative effects on their verbal IQ. One reason for such negative effects is that word decoding difficulties may
negatively affect the motivation to read. If reading disabled children tend to avoid written language, there would be an increasing gap in reading ability between them and children without any reading difficulties. The vocabulary of reading disabled children would also be expected to grow at a slower rate due to their relatively limited exposure to written language. Thus, even if a child initially has a specific deficit in word decoding, there might be secondary snowballing effects of this specific deficit leading to more general difficulties (Høien & Lundberg, 1992; Stanovich, 1986). This should not be understood in a deterministic sense. Instead, it should be regarded as another reminder of the importance of early and appropriate interventions.

Although the two components, word recognition and comprehension, are related to each other, Aaron (1997) proposed that they can be used as a basis for categorising poor readers into three subgroups: specific reading disability or developmental dyslexia (associated with deficient word recognition but adequate comprehension), nonspecific reading disability (associated with poor comprehension but adequate word recognition), and generalized reading disability (associated with difficulties in both comprehension and word recognition). Aaron (1997) argues that this categorisation system is more outcome-based than traditional definitions of reading disability, due to the fact that the three subgroups suggest different remedial instructions.

Even if the purpose of reading is to understand what is written, there is strong evidence that the development of word recognition skills is the most foundational task in early reading acquisition (cf. Share & Stanovich, 1995). Difficulties in word decoding also seem to be the main problem for most at-risk and reading disabled children (Bruck, 1988; Perfetti, 1985; Share & Stanovich, 1995; Stanovich, 1986; Vellutino & Scanlon, 1987). As the general level of reading ability increases, the proportion of variance accounted for by word recognition decreases and the proportion accounted for by comprehension increases (Curtis, 1980; Daneman & Carpenter, 1980; Stanovich, Cunningham, & Feeman, 1984), however, word recognition continues to account for a substantial amount of variance in reading ability in adults as well (Cunningham, Stanovich, & Wilson, 1990; Liberman, Rubin, Duques, & Carlisle, 1985; Perfetti, 1985). Because of the importance of word recognition in early reading acquisition and in explaining reading difficulties in reading disabled children, this component will be focused in the present thesis, even though the empirical studies also included measures of the comprehension component.
3.2 A developmental model of word recognition

In the previous section it was stated that word recognition skills are fundamental in early reading acquisition. This is partly due to the fact that there are several ways of recognising words and that novice readers are not able to use the same word decoding strategies as skilled readers. Høien and Lundberg (1988) presented a stage model of the development of word recognition skills with the following sequence of stages: pseudo-reading, logographic–visual, alphabetic–phonemic, and orthographic–morphemic reading (see Figure 1).

![Figure 1: Stages of decoding development. As the child advances in development the dependence on context is decreased as indicated. Dotted lines indicate that a given strategy is still available although no longer dominating (Høien & Lundberg, 1988).](image)

In the pseudo-reading stage of this model, the child relies on contextual cues to read without paying much attention to print itself. For example, the child may guess that the word "milk" is printed on a milk carton but would typically give the same response even if a different word was written on it. In the next stage, the logographic–visual, printed words are processed as mere visual patterns. The alphabetic principle has not yet been mastered here and the child learns to read new words by increasing his or her "sight vocabulary". There is still a high reliance on contextual cues in this stage. As the number of words in the "sight vocabulary" increases, the load on
memory also increases, and a new strategy is eventually required to make progress in word decoding.

The transition to the alphabetic–phonemic stage requires that the child starts paying attention to the individual letters of words and their corresponding sounds. Thus, the task now is to break the alphabetic code. When children have learned to map graphemes with their corresponding phonemes, they are much less dependent on contextual cues because they will then be able to sound out words never seen before as well as words presented out of context. The alphabetic–phonemic strategy is more efficient than the strategies of previous stages because it utilises the basic principle of our writing system. However, since it requires that individual graphemes are converted into phonemes, it is a slow and rather strenuous process (Høien & Lundberg, 1988).

In the final stage, orthographic–morphemic decoding, the reader is able to process multi-letter units as unified patterns in his or her mental lexicon. At this point, word decoding has become instant, automatic, and no longer depends on grapheme–phoneme conversion. Høien and Lundberg (1988) stress that the orthographic–morphemic stage should not be confused with the more primitive visual–logographic stage. In orthographic–morphemic word decoding, all letters and letter positions are of critical importance, but they are organised in higher-order structures. According to Høien and Lundberg (1988), orthographic–morphemic processing builds upon sub-lexical information, and therefore it is misleading to use terms such as "whole-word reading" or "Chinese reading" for this type of reading. Chinese reading is also an inappropriate term because Chinese signs provide phonological as well as semantic information (McGuinness, 1998).

Children are assumed to pass through these stages of reading development in the same order, and a change from one stage to another is brought about by increasing task requirements (Høien & Lundberg, 1988). In the developmental model, a stage is regarded as the dominating strategy during a specific stage of development, although it builds on previous stages which are still available as back-up functions when the new strategy cannot be used (hence the dotted lines in Figure 1). For example, skilled readers using the orthographic–morphemic strategy might still use the alphabetic–phonemic strategy when reading unfamiliar words.

There are other stage models which propose the occurrence of similar changes in word decoding strategies during reading development. Thus, it is generally assumed that there is a gradual shift from more reliance on phonological word decoding to reliance on orthographic decoding in the
later stages of reading acquisition (Ehri, 1987; Ehri & Wilce, 1987; Frith, 1985; Juel, Griffith, & Gough, 1986). It is also suggested that poor readers rely on phonological information for word identification to a greater extent than do normal readers of the same age. Although an orthographic reliance is found in skilled young readers, their phonological skills continue to develop throughout childhood (Backman, Bruck, Herbert, & Seidenberg, 1984), suggesting that there is no clear dissociation between these word decoding skills (Aaron, Wleklnski, & Wills, 1993; Juel et al., 1986).

Thus, the stage models and findings concerning the relation between word decoding skills suggest that poor phonological word decoding would normally exclude skill in orthographic word decoding. Furthermore, skilled orthographic word decoding would frequently include skill in phonological decoding. A reading disabled child, suffering from phonological deficits, would experience difficulties in acquiring both phonological and orthographic word decoding skills (Stanovich, 1988a; Stanovich & Siegel, 1994). Considerable progress in reading might be made by relying on visual strategies and other intact mechanisms, with some reading disabled children learning to read by gradually increasing their "sight vocabulary" of printed words (Snowling & Hulme, 1989). However, this would correspond more to logographic than to skilled orthographic decoding. By learning to read in this way, the lexical system of the child would lack the complex set of connections between letters and sounds which characterises the lexicon of a reader in the orthographic stage of reading development (Høien & Lundberg, 1988; Seymour, 1986).

Bearing these general models in mind, it is important to not ignore individual differences in the development of word decoding skills (cf. Share & Stanovich, 1995). Some of these differences might be due to developmental aspects of word recognition, but it is also possible that differences in word decoding reflect different underlying cognitive deficits or differences stemming from environmental factors such as type of reading instruction or amount of print exposure (Manis et al., 1996; Stanovich et al., 1997; see also study III and IV of the present thesis).

3.3 Cognitive models of word recognition

Stage models of reading acquisition are related to dual-route models of word recognition. Ellis and Young (1988) have presented such a dual-route model, which describes two routes from print to meaning (see Figure 2).
The top left of this model deals with the recognition of spoken words. In this process, the auditory analysis system transforms the sound into a form that is recognisable by the auditory input lexicon. This lexicon contains representations of all words familiar in their spoken form. The meanings of words are contained in the semantic system and a heard word is not understood until it has triggered the activation of that word's semantic representation.

For written words there are two different routes to the semantic system. First, the visual analysis system identifies the letters of a word and notes each letter's position (this is assumed to be a strictly visual process). Words that are familiar in their written form are represented in the visual input lexicon, and skilled readers who have learned to recognise thousands of words have a representation for each of these words. When reading a familiar word, the representation of that word in the lexicon is activated, and the semantic representation of that word has to be activated in order to understand its meaning (Ellis & Young, 1988).

However, in order to be able to read unfamiliar words (i.e., words not represented in the visual input lexicon), the reader has to use an alternative
strategy. This alternate process also starts with the identification of the letters of words and their positions in the visual analysis system. The letters (graphemes) are then converted to sounds (phonemes). The output of this grapheme–phoneme conversion is an activation of phonemes at the phoneme level. Now the words can be articulated, either by speaking them out loud or by using inner speech. The words have now been converted to their auditory form and can be analysed in the auditory analysis system, as if the words had been heard. If the words are familiar in their spoken form, the representations in the auditory input lexicon are activated. Finally, the meaning of the word can be accessed by activating representations in the semantic system. Thus, by using this alternative route, words that are visually unfamiliar still can be understood if the reader has heard the word before and knows its meaning. Young or unskilled readers, not having many visual representations of words in their visual input lexicon, often rely on this process (Ellis & Young, 1988).

Reading disabled children would encounter difficulties following both the first and the second route of this model. If reading is a difficult task for the child and progress is slow, the visual input lexicon will expand at a slower rate than for normal readers. Furthermore, if the child has underlying phonological deficits (see section 4.1 of this thesis), he or she would experience difficulties in using the alternative, phonologically based route. Phonological deficits might impair grapheme–phoneme conversion as well as processing in the auditory analysis system.

Some comments should also be made concerning this model's relation to other theoretical concepts. In this model, the first route, from the visual analysis system to the visual input lexicon, is similar to both the visual–logographic and the orthographic–morphemic word decoding strategy suggested by Høien & Lundberg (1988). However, as pointed out by Høien and Lundberg (1988), orthographic–morphemic word decoding should not be confused with the more primitive visual–logographic strategy and it seems that in the model of Ellis and Young (1988), this distinction is not made. When using the concept of orthographic decoding in the present thesis, I refer to an advanced and automatic word decoding strategy; that is, one which builds on sublexical information. In this strategy all letters and letter positions are processed, but they are also organised into higher-order structures. Thus, the words still have to be decoded and orthographic decoding is only a "direct" route from print to meaning in the sense that it does not require that individual graphemes are converted into phonemes (Høien & Lundberg, 1988; Liberman, 1999; see also Ehri, 1992).
The second route, from the visual analysis system, via grapheme–phoneme conversion, to the auditory input lexicon, seems to be identical to the alphabetic–phonemic strategy described by Høien & Lundberg (1988). In the present thesis, this word decoding strategy will most often be referred to as phonological word decoding. Although this word decoding strategy is sometimes labelled the "indirect" route, there is evidence that phonological decoding can sometimes be very quick, perhaps even faster than the visual–orthographic route (Liberman, 1999; Lukatela & Turvey, 1994a; 1994b; Perfetti & Bell, 1991).

However, other models of visual word recognition have raised questions as to the necessity of a dual-route system. In the alternative, single-route models of reading, it is instead assumed that "there is a single, uniform procedure for computing a phonological representation from an orthographic representation" (Seidenberg & McClelland, 1989, p. 525). According to Seidenberg and McClelland (1989), written language (i.e., written English) is a quasiregular system; that is, a body of knowledge that is systematic, but still admits irregularities. It is argued that as a consequence of its quasiregular nature, knowledge of written language can be best represented by "weights on connections between simple processing units in a distributed memory network" (Seidenberg & McClelland, 1989, p. 525). In such a connectionist network, learning is conceptualised as modifying the weights on the connections between linguistic units by exposure to written language. Note that there is no need for any explicit rules in such a model of reading acquisition. Computer programs designed to simulate connectionist models of word recognition display implicit learning from the correspondences between letters and sounds in the sets of words that are presented to them. According to Seidenberg and McClelland (1989), their model was able to account for behavioural data that dual-route models had failed to explain. Seidenberg and McClelland (1989) thus argued that it was able to account for differences among words in terms of processing difficulty, differences in reading skill, and findings about reading acquisition. However, proponents of a dual-route model did not agree with that conclusion and instead argued that dual-route models could better account for all these findings (Coltheart, Curtis, Atkins, & Haller, 1993).

The purpose of this thesis is not to examine the relative strengths and weaknesses of dual-route and single-route models, therefore, I will not elaborate on the details here. Overall, it seems that both dual-route and single-route models have their specific merits and limitations. There have also been several attempts to modify both types of models to better account
for the empirical findings (Coltheart et al. 1993; Hulme, Snowling, & Quinlan, 1991; Luo, 1996; Taft, 1991), and a combined model has also been proposed (Bjaalid, Høien, & Lundberg, 1997).

The empirical studies of the present thesis are rooted in dual-route theory. Therefore, in these studies it is generally assumed that there are two main word decoding strategies, a visual–orthographic and a phonological strategy. However, this should not be regarded as a theoretical statement against single-route models. Instead, single-route models can be regarded as alternative frameworks for interpreting the results.

3.4 Memory and reading

Memory is central in most cognitive processes and this also applies to the process of reading. The associations between memory and reading have been extensively studied (Baddeley, 1978; Brady, 1991; Gathercole, Willis, & Baddeley, 1991; Wagner & Torgesen, 1987). These studies have mainly focused on short term memory, or working memory, in relation to reading. The results generally show that reading disabled individuals perform below normal on measures of verbal short term memory, or working memory, which is in line with the hypothesis that reading disability is associated with phonological deficits (Baddeley, 1978; Estes, 1973; Wagner & Torgesen, 1987).

However, short term memory is not the only type of memory related to the process of reading. In the field of memory research there has recently been a great interest in findings concerning two different functions of the long-term memory store, referred to as implicit and explicit memory. Research has demonstrated a variety of striking dissociations between implicit and explicit memory, and that these two types of memory can be independent of one another (Cohen & Squire, 1980; Graf, Squire, & Mandler, 1984; Jacoby & Dallas, 1981; Warrington & Weiskrantz, 1968; 1970). According to Graf and Schacter (1985, p. 501): “Implicit memory is revealed when performance on a task is facilitated in the absence of conscious recollection; explicit memory is revealed when performance on a task requires conscious recollection of previous experiences”. Thus, implicit memory seems to be synonymous with unconscious memory, whereas explicit memory consists of conscious recollections.

The terms explicit and implicit memory also correspond to the use of two different types of tests. Explicit memory is revealed by traditional memory tests of recall or recognition in which subjects try to recall or recognise stimuli from a previous study. In implicit memory tests, the unconscious
influence of stimuli presented at study on performance at test is measured. The measure of interest in most implicit memory tests is priming effects. Priming occurs "when exposure to words, pictures, or other items facilitates subsequent processing of those items on tasks that do not make explicit reference to the prior study episode" (Schacter et al., 1990, p. 1079). In a test of implicit memory, it is of fundamental importance that the subjects are not using explicit memory strategies to solve the task; that is, they should not consciously recollect stimuli from the study phase. To achieve this objective, it is necessary to use reduced cues in some form. For example, the words used at study can be modified at test by removing the ending letters of the words so that only the first two or three letters of each word remain as cues (i.e., "ele__" for the target word "elephant"). The participants are then instructed to complete the word stems with the first word that comes to mind. The amount of priming can then be measured by observing how many of the words presented at study are later generated at test and comparing this number with a baseline; that is, the number of target words being generated from the word stems without any previous study of them. The difference between the study-test procedure for stem completion and baseline completion then constitutes the magnitude of priming. Word stem completion tests were used in study III and IV of the present thesis as measures of visual implicit memory.

A number of studies have demonstrated dissociations between implicit and explicit memory across a wide variety of tasks and conditions. Studies of amnesic patients generally show that, although they perform very poorly on explicit tests of memory, they perform remarkably well, and frequently at normal, on measures of implicit memory (Cohen & Squire, 1980; Graf et al., 1984; Warrington & Weiskrantz, 1968; 1970). Dissociations between explicit and implicit memory have also been observed in normal subjects (Jacoby, 1983; Jacoby & Dallas, 1981; Weldon & Roediger, 1987).

According to the multiple memory systems view (Squire & Cohen, 1984; Tulving & Schacter, 1990), the observed differences between implicit and explicit memory can be ascribed to different properties of hypothesised underlying separate memory systems. For example, Squire and Cohen (1984) argued that explicit recollection is a property of, and supported by, a declarative memory system which is involved in verbalisable knowledge such as the formation of new representations or data structures. Implicit memory, in turn, is attributed to a procedural system which is involved in skilled behaviour with no need for conscious recollection. It is assumed that different neural structures underlie performance on different tests tapping
the two kinds of memory and dissociations between implicit and explicit memory are explained by appealing to the different systems. Because these systems are thought to be largely independent, dissociations are to be expected.

Another multiple memory systems theory is the perceptual representation system (PRS) account (Schacter, Cooper, & Delaney, 1990; Tulving & Schacter, 1990). According to the PRS account, explicit memory tests are assumed to tap the episodic memory system. Perceptual priming, on the other hand, reflects operations of visual and auditory perceptual representation systems; that is, cortical regions that represent the form and structure of stimuli but not the semantic meaning and associating properties of words and objects. Thus, implicit memory is assumed to be presemantic and priming effects would be based solely on perceptual characteristics of the stimuli, not on semantic elaboration. Conceptually driven processes such as elaborating, organising, and reconstructing are assumed to belong to a third system: the semantic memory system. The great majority of studies of implicit memory have used tests involving visual processing, however, in a series of experiments Schacter and Church (1992) used two auditory implicit memory tests. The results were consistent with the hypothesis that a presemantic auditory perceptual representation system played an important role in observed auditory priming.

The hypothesised visual and auditory perceptual representation systems seem to correspond well to the visual and auditory input lexicons proposed in the dual-route model by Ellis and Young (1988). In study III and IV of this thesis, the possible interaction between the use of the two main word decoding strategies and the magnitude of visual and auditory priming, presumably tapping the perceptual representation systems, was examined. If the auditory and visual PRS are both impaired in reading disabled children, then these children should show less perceptual priming than normal readers for both auditory and visual information. Their relative performance would depend on which PRS, the visual or auditory, was most severely impaired. It should also be noted that, as shown in Fig. 1, there are links from the auditory and visual input lexicons to the semantic system. This suggests that even if the semantic system is functioning normally, an impaired input lexicon might lower the performance on a semantic test.
4. READING DISABILITIES

In recent years, the concept of developmental dyslexia has gained status in Sweden as well as in many other countries (Solvang, 1998). This motivates a thorough review of theories and empirical findings concerning developmental dyslexia. However, not all reading disabled children fit a traditional definition of dyslexia, which will be discussed in section 4.2. In this section, I will also critically discuss the assumption of specificity in developmental dyslexia and point to the problems of including overall intelligence in the classification of reading disabilities. Finally, in section 4.3, I will present an alternative classification, which is based on relative strengths in orthographic and phonological word decoding.

4.1 Developmental dyslexia

One basic distinction should first be made between developmental and acquired dyslexia. Developmental dyslexia refers to the problem of creating a new function (literacy) which has failed to develop normally. On the other hand, in acquired dyslexia the cognitive function has been impaired or lost as a consequence of neurological damage (Seymour & Bunce, 1994).

More than 100 years have passed since Pringle Morgan (1896) described a case of "congenital word-blindness". Since then, researchers have gained some knowledge about the causes and manifestations of congenital reading difficulties, which are now often referred to as developmental dyslexia. However, many questions still remain in this field of research. In fact, there is still no general agreement on the exact meaning of the concept of developmental dyslexia. The word dyslexia is put together by the two Greek words dys and lexia, which is translated as "difficulties with words". The term dyslexia has generally become accepted within the scientific community. Other synonymous terms are "word-blindness" and "specific reading disability". The term word-blindness is misleading because it suggests that dyslexia is primarily constituted by a deficit in vision, which is not the case (Aasved, 1989; Goldberg & Schiffman, 1972). It could also be too pessimistic because, even if dyslexics have reading difficulties, it is still possible for them to read and their reading skills could also be improved by means of adequate reading instruction. The term specific reading disability is somewhat impractical, simply because of its length.

There has been some debate as to the existence of any qualitative differences between dyslexics and poor readers in general, or if dyslexics are
simply at the end of a continuum of individuals representing different levels of reading skill (e.g., Bryant & Bradley, 1985). The basic distinction between dyslexics and poor readers is sometimes based on neurobiology. Thus, according to Vellutino (1978), dyslexia is a medical term, referring to a reading disorder that is due to some form of neurological dysfunction rather than to environmental factors. This statement is in line with the definition of dyslexia suggested by World Federation of Neurology in 1968:

"a disorder manifested by difficulty learning to read, despite conventional instruction, adequate intelligence and socio-cultural opportunity. It is dependent upon fundamental cognitive disabilities which are frequently of constitutional origin" (Critchley, 1970, p. 11).

This definition does not tell much about what dyslexia really is, however. Rather, it is dominated by excluding criteria. In spite of strong efforts, there is still no general agreement on a single, more operational definition of the term which would contain specific information of the etiology of dyslexia. Some controversies concerning the definition could stem from different levels of explanations in different theoretical accounts (Frith, 1999; Miles, 1995, see also section 7).

According to early accounts of dyslexia, it was constituted by low-level visual perceptual deficits (Bender, 1956; Birch, 1962; Orton, 1925; 1937). During this period, it was believed that dyslexia was caused by problems in visual organisation and visual memory. The types of reading errors which are frequently observed in dyslexia (i.e., reading b as d, as well as orientation and sequencing errors) were taken as evidence in support of visual perceptual deficits. However, such errors do not mean that dyslexics see or perceive the letters and words differently from other readers. Rather, it could instead be attributed to general difficulties in verbal processing; that is, in associating verbal labels with printed symbols (Vellutino, 1978).

Today, there is evidence that dyslexia is not primarily caused by deficits in vision (Aasved, 1987, 1989; Goldberg & Schiffman, 1972; Goulandris et al., 1998), and other studies also suggest that visual perception and visual memory are intact in dyslexia (Liberman, Shankweiler, Orlando, Harris, & Berti, 1971; Vellutino, Pruzek, Steger, & Meshoulam, 1973; Vellutino, Smith, Steger, & Kamin, 1975). For example, the observation that dyslexics seem to have erratic eye-movements when reading, such as repeating fixations and frequently jumping backwards in the text, can be regarded as a consequence of, rather than a cause of, reading problems (Rayner, 1985a; Vellutino, 1978).

However, the perceptual deficit hypothesis has experienced a renaissance in recent years. A number of neuropsychological findings suggest that the
magnocellular pathway of the visual system, which handles fast, low contrast stimuli, might be impaired in dyslexia, whereas the slow and relatively contrast insensitive parvocellular pathway might be intact (Lovegrove, Garzia, & Nicholson, 1990; Livingstone et al., 1991; Slaghuis & Lovegrove, 1984; Stein & Talcott, 1999). For example, Slaghuis and Lovegrove (1984) suggested that visible persistence of previous fixations makes reading difficult for dyslexics. It has also been suggested that reading disabled children show a perceptual deficit in handling rapidly presented auditory stimuli (Tallal, 1980; Tallal, Miller, & Fitch, 1993), but these results need not reflect auditory perceptual deficits and could be explained by an imperfect phonetic module (Liberman, 1999; Mody, Studdert-Kennedy, & Brady, 1997).

Today, most researchers seem to agree that phonological deficits constitute the main underlying cause of the word decoding difficulties in developmental dyslexia (Bruck, 1992; Elbro, Borstrøm, & Petersen, 1998; Fletcher et al., 1994; Rack et al., 1992; Stanovich & Siegel 1994; Wimmer, Mayringer, & Landerl, 1998). This is therefore in line with the definition proposed by Høien and Lundberg (1992, p. 37): "dyslexia is a disruption in the decoding of the written language, caused by a defect in the phonological system".

There is very strong empirical evidence that phonological skills are critical in learning to read (see Share & Stanovich, 1995, for a review). Phonological awareness, that is, the ability to explicitly reflect on the sound structure of language, has also proven to be a good predictor of early reading acquisition (Goswami & Bryant, 1990; Lundberg, Olofsson, & Wall, 1980; Wagner & Torgesen, 1987). Furthermore, a great number of studies have demonstrated that developmental dyslexics perform below normal on various measures of phonological processing (Rack et al., 1992; Snowling, 1981; Stanovich, 1988b).

In order to obtain evidence for a causal relationship between phonological processing skills and reading ability, longitudinal intervention studies have been conducted. It has been shown that training in phonological (or phoneme) awareness can improve the phonological awareness and the reading skills of young children (Ball & Blachman, 1988; Lundberg, Frost, & Petersen, 1988; Schneider, Ennemoser, Roth, & Kuspert, 1999; Torgesen, Morgan, & Davis, 1992). Other studies indicate that phonological interventions in which the phonological tasks are explicitly linked to the orthography of written language might be even more effective for beginning readers (Bradley & Bryant, 1983; Cunningham, 1990; Hatcher,
Hulme, & Ellis, 1994). However, it should be noted that the reported effect sizes on reading ability were not always large and a number of methodological shortcomings have been identified in these intervention studies (Troia, 1999). The intervention studies have also typically been conducted on either young children with no apparent reading difficulties or on children who were in an early stage of reading development. Thus, these studies have not been specifically directed at those children most in need of intervention, that is, children who have lasting and severe difficulties in acquiring reading skills. The purpose of study V in the present thesis was to examine the effects of a phonological intervention on children in grade 4 with established reading difficulties.

In the introduction, I stated that the existence of neurological and genetic factors in developmental dyslexia is an empirical question and now I will present some of the main empirical findings.

Studies on autopsied brains of dyslexics have resulted in two main findings. The first deals with cerebral asymmetry. The planum temporale, a region on the upper surface of the temporal lobe, is asymmetric (of different sizes in the two hemispheres) in approximately two-thirds of the whole population (Galaburda, 1999). On the other hand, in most autopsied dyslexic brains, the planum temporale was found to be symmetric (Galaburda, 1994; Galaburda et al., 1985). This finding has also been replicated by studies employing magnetic resonance imaging (MRI) on living dyslexics (Hynd et al., 1990; Larsen, Høien, Lundberg, & Ødegaard, 1990; Morgan & Hynd, 1998). For example, in the study by Larsen et al. (1990), symmetric plana temporale were found in 70% of the dyslexic subjects, whereas only 30% of the controls exhibited symmetry. Larsen et al. (1990) also reported that all dyslexics with pure phonological deficits in reading had symmetric plana temporale.

The second main finding from autopsy studies is the presence of minor cortical malformations, termed ectopias, in dyslexic brains (Galaburda et al., 1985). Such brain "warts" have been found in both auditory and visual areas of the perisylvian cortex, including the classical Broca’s and Wernicke’s language areas (Galaburda, 1994). Galaburda (1994, p. 136) suggests that "symmetry in the presence of ectopias, as is the case in dyslexic brains, is likely to be associated with fundamental changes in the functional properties of networks participating in perceptual and cognitive activities.” However, the exact locations and numbers of ectopias varied between the dyslexic brains, suggesting that, even if dyslexia has a neurological basis, individual variations in the severity and manifestations of the difficulties are to be expected. Interestingly, animal studies on "learning disabled"
ectopic mice demonstrate that the presence of neurological malformations does not imply that environmental factors cease to be important. On the contrary, the learning abilities of ectopic mice were significantly improved if they were reared in enriched environments (as compared to standard cages). In fact, ectopic mice reared in enriched environments seemed to compensate for their neurological impairments and performed on par with enriched non-ectopic mice on a complex spatial task (Schrott et al., 1992).

The pioneers in the field of reading disability research have already hypothesised that dyslexia is heritable (cf. Pringle Morgan, 1896). A large number of empirical studies support this hypothesis (Cardon et al., 1994; DeFries & Light, 1996; Hallgren, 1950; Olson et al., 1989; Pennington, 1991). Studies using data from identical and fraternal twins have obtained heritability estimates (the amount of variance in reading that can be attributed to genetic factors), of 50-60% (DeFries & Fulker, 1985; DeFries & Light, 1996; Pennington, 1991). Several studies have localised a gene for reading disability on chromosome 6, but other possible localisations have also been identified (Cardon et al., 1994; Fagerheim et al., 1999; Grigorenko et al., 1997). The different proposed localisations might suggest genetic heterogeneity in developmental dyslexia. Fagerheim et al (1999, p. 1) state that: "genetic heterogeneity is likely and could provide some explanation for the high frequency of dyslexia, but has not yet been clearly shown. Furthermore, the complexity of the reading process also suggests that many genes may be involved." Of course, what is inherited is not reading disability or dyslexia itself. There can be no specific "reading genes" solely devoted to the process of reading, because reading is a cultural artefact, just like driving a car. The functions that are in fact inherited are more basic cognitive and perceptual abilities which are critical for the process of reading. Behavioural–genetic studies suggest that phonological ability is the most likely mediator of genetic influences on reading skill. A lower but significant heritability has also been found for orthographic decoding skills (Olson et al., 1989; Stevenson, 1991).

To summarise, developmental dyslexia seems to be constituted by difficulties in transforming the code of the written language into comprehensive entities. These difficulties in word decoding are assumed to be caused mainly by phonological deficits which impair the acquisition of both phonological and orthographic word decoding skills in the dyslexic child. Higher mental activities, such as understanding, are not assumed to be directly affected in dyslexia, but deficient word decoding skills might lead to an impaired reading comprehension. There is strong evidence of underlying
neurological and genetic factors associated with dyslexia, but they will always interact with environmental factors in the development of reading skills.

4.2 Reading disabilities including comprehension deficits

In the previous section, many findings concerning developmental dyslexia have been discussed. This type of reading disability is also sometimes referred to as specific reading disability. However, not all reading disabled people fit a specific and narrow definition of the causes and manifestations of reading difficulties. Not all reading difficulties are caused by congenital, neurological impairments that specifically disturb the phonological system and result in problems with word decoding. Also, whereas biological factors seem to be associated with developmental dyslexia, other types of reading disability might be more strongly associated with environmental factors, such as limited exposure to written language or inadequate reading instruction. Furthermore, cognitive deficits other than deficits in phonological processing, as well as a more general developmental delay, may also lead to reading difficulties. The manifestations of these types of reading disability need not be restricted to word decoding deficits, but could also include the other component of reading: comprehension (Aaron, 1997, see also section 3.1).

In the framework suggested by Aaron (1997), there are three basic types of reading disability. Developmental dyslexia, or specific reading disability, is constituted by deficits in word recognition but with intact comprehension. In addition, there are two types of reading disability which include comprehension deficits: those who have specific deficits in comprehension but intact word recognition skills and those who have problems with both comprehension and word recognition.

Although research on reading disabilities seems to have focused on developmental dyslexia, some recent studies have examined the group of poor readers characterised by specific comprehension deficits (Nation & Snowling, 1998a; 1998b; Oakhill, 1982; Stothard & Hulme, 1992). These studies have shown that poor comprehenders have adequate phonological skills but weak receptive language skills and a low verbal IQ (Stothard & Hulme, 1992), show less contextual facilitation than normal readers, who, in turn, show less contextual facilitation than dyslexic children (Nation & Snowling, 1998a). They also tend to have difficulty in reading words that are typically read with support from semantics (Nation & Snowling, 1998b). From these studies, it should be clear that children with specific deficits in
comprehension differ from dyslexic children in many aspects. In fact, they often show an opposite pattern of results compared to dyslexics (e.g., Nation & Snowling, 1998a).

However, if we turn to the group of globally poor readers, who have difficulty with both word decoding and comprehension, the relation to developmental dyslexia becomes more complicated. Globally poor readers are sometimes referred to as garden-variety poor readers (Stanovich, 1988b), and the term itself illustrates the heterogeneity of this group. Because of the lack of any specific deficits, it is very difficult to provide any precise definition of this type of reading disability.

There is also an ongoing debate concerning the issue of specificity in developmental dyslexia. Since there is now strong evidence that developmental dyslexia is characterised by poor word recognition skills mainly caused by phonological deficits (see section 4.1), it could be argued that all poor readers who fulfil these criteria should be included in the dyslexic category, regardless of whether they have other difficulties (see Stanovich, 1996). However, the call for a more inclusive definition of developmental dyslexia has often been associated with a more specific critique, focused on the inclusion of the concept of intelligence in the definition (Stanovich, 1996; Siegel & Himel, 1998). According to traditional IQ-discrepancy based definitions, there has to be a discrepancy between the IQ score and the reading ability in order for a poor reader to be categorised as dyslexic. The discrepancy criterion can be criticised on several grounds, however (see study I of this thesis). For example, there is only a moderate correlation between reading ability and intelligence, and the causal relation between the two concepts is not clear (Aaron, 1997; Stanovich, 1986, 1996). Furthermore, reading disabled children with high and low IQs perform very similar on various measures related to reading (Ellis, McDougall, & Monk, 1996; Fletcher et al., 1994; Samuelsson et al., 1999; Stanovich & Siegel, 1994).

However, it should be noted that even if the concept of intelligence is kept out of the definition, it is still not clear just how specific the reading difficulties have to be in developmental dyslexia, or what the requirements on higher level processes should be. Comprehension is more directly related to the process of reading than is the broader concept of intelligence. Therefore, it is quite possible to both criticise the IQ-discrepancy criterion and simultaneously propose that a classification of reading disability should be based on the two components word decoding and comprehension (cf. Aaron, 1997).
4.3 Surface and phonological types of reading disability

Another basis for identifying subgroups of reading disability is to examine the relative strength in using the two main word decoding strategies: orthographic and phonological. Contrary to discrepancy-based classifications, this classification is very closely linked to the process of reading itself (see section 3).

The terms surface and phonological dyslexia were originally used to describe cases of acquired dyslexia, that is, specific difficulties in using one of the two word decoding strategies as a consequence of brain injury or disease. Some acquired dyslexics, termed phonological dyslexics, show a selective difficulty in using the phonological word decoding strategy while their orthographic word decoding skills are nearly intact (Dérouesné & Beauvois, 1979; Patterson, 1982). Other cases, termed acquired surface dyslexics, are characterised by selectively impaired orthographic word decoding in the presence of nearly intact phonological word decoding (Newcombe & Marshall, 1985; Shallice & Warrington, 1980).

Related to these cases of acquired dyslexia, cases of developmental surface dyslexia (Coltheart et al., 1983; Holmes, 1973; Samuelsson, 2000; Samuelsson, Bogges, & Karlsson, 2000) and developmental phonological dyslexia (Snowling & Hulme, 1989; Temple & Marshall, 1983) have been reported. If surface and phonological types of reading disability were rare and exceptional in the whole population of reading disabled individuals, this classification might not be very useful. However, Castles and Coltheart (1993) developed a regression-based method to identify surface and phonological subgroups in the population of reading disabled children. From this study and other studies using similar procedures, it is clear that the relative skills of using orthographic and phonological word decoding vary considerably among reading disabled children (Castles & Coltheart, 1993; Manis et al., 1996; Stanovich et al., 1997).

Although the regression-based method for identifying phonological and surface types of reading disability seems promising, there are still some critical questions that remain to be answered in this field of research. One question regards the causes of the differences. It seems that the phonological subtype could be explained by underlying deficits in the phonological system, while the surface subtype might reflect a general developmental delay rather than resulting from a cognitive deficit (Manis et al., 1996; Samuelsson, Finnström, Leijon, & Mård, 2000; Stanovich, et al., 1997). Recent behavioural-genetic studies also suggest that the two subgroups differ
in terms of heritability (Castles et al, 1999; Gayan, Forsberg, & Olson, 1994). Significant heritability of reading deficits was found for both subgroups, but the genetic contribution was much larger in phonological dyslexics than in surface dyslexics (Castles et al., 1999). These results support the hypothesis that there is a stronger environmental contribution in the surface type of reading disability. The possible cognitive and environmental causes of the phonological and surface types of reading disability were examined in the third and fourth study of the present thesis.

Another question that needs to be addressed in future studies concerns the stability of the subgroups over time. If a large number of children would move from one subgroup to the other when repeating the subgrouping procedure after some time, this would cast doubts on the reliability and validity of this classification procedure (cf. Stanovich et al., 1997).

5. OBJECTIVES

The general aim of the present thesis is to describe and analyse individual differences among reading disabled children. In order to be able to develop adequate and more individually adapted educational interventions, there is a need to gain more knowledge concerning varieties of reading disability.

A critical evaluation of the validity of current definitions and classifications of reading disability and a search for theoretically and empirically sound classifications would be a necessary first step in the analysis. The aim of such an evaluation would be to identify which aspects of reading disability could be used as a basis for classification, and which aspects do not seem to offer a good foundation for this purpose. I agree with Aaron (1997) in that one criterion should be that the classification is outcome-based and that it suggests different interventions for different groups of poor readers. Thus, study I of the present thesis is a critical examination of traditional definitions of dyslexia which are based on the discrepancy between intelligence and reading ability. This theoretical study is also an attempt to identify alternative classifications of reading disability.

The possible causes of critical variations among reading disabled children then need to be examined. Different causes may suggest different interventions. Here, the complexity of reading disability necessitates that developmental (see section 3.2), cognitive (see sections 3 and 4), and environmental (see section 2.3) aspects are considered in the analyses. Developmental aspects of word decoding skills are focused in study II of this thesis. Study III examines the possible associations between implicit memory and word
decoding skills. Study IV examines both cognitive and environmental factors potentially associated with orthographic and phonological word decoding skills.

Finally, the validity of the proposed classification system and the resulting subgroups of reading disabled children should be examined. A direct way of assessing whether the proposed classification is outcome-based or not is to conduct a longitudinal intervention study. Therefore, in study V of the present thesis, differences between groups in the effectiveness of a phonological intervention is examined.

Variations in the effectiveness of a particular intervention, interpreted in light of possible causes of different varieties of reading disability, could provide suggestions for more adequate interventions for different groups of reading disabled children. Although the primary purpose of the present thesis is to gain more knowledge concerning varieties of reading disability, the empirical findings may also have theoretical implications for the more general fields of reading research and cognitive psychology. This should be regarded, however, as an additional bonus of conducting research in the field of reading disabilities, rather than the main objective of the present thesis.

6. SUMMARY OF THE STUDIES

6.1 Study I

In this article the inclusion of the concept of intelligence in the definition of dyslexia was critically examined. A number of theoretical problems and practical consequences of such an inclusion were discussed.

According to the IQ discrepancy criterion, an individual should only be regarded as dyslexic if there is a discrepancy between his or her actual reading ability and the potential reading ability as estimated by the IQ score. Furthermore, the actual reading ability has to be below normal, whereas the IQ score has to be within or above the normal range (Aaron, 1997).

We identified several problems and paradoxes associated with the IQ discrepancy criterion. First, we pointed out that intelligence is a fuzzy concept in itself. There is little general agreement on what mental capabilities should be included in the concept (Sternberg, 1990; Sternberg & Detterman, 1986). Secondly, intelligence is only moderately correlated with reading ability, and the causal direction between the two variables is not clear (Aaron, 1997; Stanovich, 1986, 1996). Thirdly, we pointed to groups that
will be excluded from the dyslexic category even if they also have word decoding deficits stemming from underlying phonological deficits. These groups included dyslexics who are able to compensate for their word decoding deficits (Snowling & Nation, 1997), poor readers with low IQ (Siegel, 1988; Stanovich, 1996), children from low socio-economic backgrounds (Siegel & Himel, 1998), and children with very low birth weight (Samuelsson et al., 1999).

We also identified groups that will be included in the dyslexic category, even if the cause of their reading difficulties is completely different from the underlying phonological deficits assumed to be causally related to dyslexia. Thus, groups who are poor readers because of limited experience with written language would be at risk of being classified as dyslexics even if they have no underlying constitutional or cognitive deficits (Samuelsson et al., in press; Stanovich & West, 1989; Svensson, Lundberg, & Jacobson, in press; Vellutino et al, 1997). Our final, critical remark on the IQ discrepancy criterion was that poor readers of high and low IQs do not seem to differ on a number of measures related to the process of reading (Ellis, McDougall, & Monk, 1996; Fletcher et al, 1994; Stanovich & Siegel, 1994). This finding implies that the discrepancy criterion is not an outcome-based definition and does not suggest any particular intervention for different groups of poor readers (cf. Aaron, 1997).

Many of these problems and paradoxes stem from the fact that the cause of the reading difficulties is completely ignored in the IQ discrepancy definition of dyslexia (Tønnessen, 1997). In this article we refer to a large number of empirical studies which have provided evidence for the critical role of phonological deficits in dyslexia (cf. Share & Stanovich, 1995). This suggests that the status of the phonological system should be focused on in classifications of reading disabilities.

In conclusion of this study, two alternative classifications of reading disability were suggested. One is based on the two components of reading: word recognition and understanding, where understanding is a more specific concept than IQ and also more closely related to the process of reading (Aaron, 1997). Another, more outcome-based classification would be to examine the reliance on, as well as the skill in using, the two main word decoding strategies: orthographic and phonological decoding. The way that a child decodes words seems to be related to the effectiveness of a particular training program (see study V of this thesis).
6.2 Study II

The general purpose of this study was to examine the development of phonological and orthographic word decoding skills in young readers. The study examined the relation between word decoding skills and reading comprehension for children who varied both in chronological age and in their level of word decoding skill.

According to most models of acquisition of word decoding skills, children first become proficient in using phonological decoding and then shift gradually toward using orthographic decoding (Ehri, 1987; Høien & Lundberg, 1988). In order to assess the relative contribution of phonological and orthographic skills in text reading it is not sufficient to study skills in decoding words presented in isolation. In the present study, we therefore examined the relative contribution of orthographic and phonological decoding skills to reading comprehension.

Sixty 8-year-old children, termed novice readers, and sixty 10-year-old children, termed experienced readers, were randomly selected from ten different schools. In contrast to the other empirical studies of the present thesis, these children had no apparent reading difficulties. However, variations in their reading skills were at the focus of the study. Thus, within each age group, new groups of children were formed based on their level of phonological and orthographic word decoding skills.

The test battery included two measures of reading comprehension (Malmquist, 1977), which were used to form an index of the critical dependent variable, and measures of orthographic and phonological word decoding (Olofsson, 1999; based on the design of Olson, Kliegl, Davidson, & Foltz, 1985).

The results replicated previous findings that children rely mainly on phonological word decoding early in their reading development, and that there is a gradual shift to more reliance on the orthographic word decoding strategy (Ehri, 1987; Frith, 1985; Juel et al., 1986). The results of multiple regression analyses revealed that phonological and orthographic decoding skills together accounted for 62% of the variance in reading comprehension for novice readers and 45% of the variance in reading comprehension for experienced readers. Orthographic word decoding skill was a significant predictor of reading comprehension, both for novice and experienced readers. Phonological word decoding skill was a significant predictor of reading comprehension only for novice readers.
The finding that orthographic decoding predicted reading comprehension for novice readers indicates that some novice readers had already begun to acquire orthographic skills in their word decoding. When a new regression analysis was performed on less skilled novice readers only (i.e., the 30 children who performed below the median on reading comprehension), orthographic word decoding was no longer a significant predictor of reading comprehension.

There were also statistically significant interactions between level of word decoding skill and reading skill (i.e., the groups of novice and experienced readers) on reading comprehension, both for orthographic and phonological word decoding. The differences in reading comprehension as a function of both orthographic and phonological decoding skills were larger for novice readers than for experienced readers. Thus, in younger and less skilled readers, variations in word decoding skills seem to be more important in explaining differences in reading comprehension than in more experienced and skilled readers.

The results were interpreted as supporting the general core of developmental models (cf. Høien & Lundberg, 1988), in which there is a gradual shift from phonological to orthographic decoding of words. It was also suggested that the link to reading comprehension in this study helped to generalise models of the development of word recognition skills to text reading and reading comprehension. Finally, the finding that phonological word decoding skill was a strong predictor of reading comprehension for novice readers, especially for those who performed below the median on reading comprehension, suggested that phonological training should also be considered for children who have already received one or two years of formal reading instruction in school.

6.3 Study III

The third article combined recent findings regarding surface and phonological subtypes of reading disability, as well as findings in memory research suggesting visual and auditory perceptual representation systems (PRS) in implicit memory. The general purpose was to examine how visual and auditory priming for words interact with skill in using the orthographic and phonological word decoding strategies.

Most models of the development of word decoding skills suggest that both phonological and orthographic information is involved in word recognition (Castles & Coltheart, 1993; Ehri, 1987; Seidenberg & McClelland,
However, it is possible to identify children who show better phonological than orthographic word decoding skills, and vice versa. An impaired phonological, relative to orthographic, word decoding ability is labelled phonological dyslexia, and the opposite pattern is labelled surface dyslexia (Castles & Coltheart, 1993). Dual-route models of reading explain dissociations between phonological and orthographic skills by proposing that in phonological dyslexia, the sublexical route (which relies on grapheme–phoneme conversion) is selectively impaired. In surface dyslexia, the lexical route from print to meaning is assumed to be selectively impaired (Coltheart et al., 1993; Castles & Coltheart, 1993). Single-route models have proposed that phonological dyslexia can be explained by phonological weaknesses, affecting the use of orthography to phonology conversions (Seidenberg & McClelland, 1989; Manis et al., 1996). Surface dyslexia has been accounted for by suggesting a general delay in learning how orthography maps phonology (Manis et al., 1996).

Study III attempted to answer two questions related to subtypes of reading disability. First, is it possible to gain independent evidence that orthographic and phonological word decoding skills can be simultaneously impaired (Manis et al., 1996)? Second, is it possible to identify an underlying cognitive deficit in surface dyslexia (Castles & Coltheart, 1993; Ellis, McDougall, & Monk, 1996)?

In order to answer these questions we turned to recent findings in the field of memory research, which have revealed striking dissociations between different memory systems and dissociations between the visual and auditory word form systems in implicit memory (Schacter et al., 1990). According to the PRS account (Schacter & Church, 1992; Tulving & Schacter, 1990), traditional explicit tests of retention, such as recall or recognition, are assumed to tap the episodic memory system, whereas implicit memory represents priming of pre-semantic perceptual representation systems. Schacter et al. (1990) provides evidence of a functional dissociation between visual and auditory priming in a letter-by-letter reader. Their findings suggest that visual perceptual priming taps a visual word form system, while auditory priming taps an auditory word form system. Thus, we hypothesised that children with a surface type of reading disability would show less visual compared to auditory priming for words. Phonological type children would be expected to show less auditory compared to visual priming. Children with both orthographic and phonological word decoding deficits would be expected to show low levels of both visual and auditory priming.
Thirty-six children with reading disabilities participated in the study and they were 9 to 15 years old. Most had been diagnosed as developmental dyslexics and all received special instruction in reading at the time of the study. Since IQ scores were not available for all children, the term "poor readers" was used instead of "dyslexics".

Orthographic and phonological word decoding skills were assessed by two timed pen and paper tests (Olofsson, 1999; Olson et al., 1985) and three subgroups of children were identified by means of a standard score procedure. Discrepancy scores between orthographic and phonological skills were first calculated. Based on a cut-off score of one standard deviation above or below the mean, six children were low in phonological, relative to orthographic, skill (the phonological subgroup). However, one child was excluded from this subgroup because of an orthographic skill clearly below the mean. Five children were low in orthographic, relative to phonological, skill (the surface subgroup). Twenty-five children did not dissociate in their word decoding skills and were denoted the mixed subgroup. Comparisons with age-matched controls revealed that the subgroups were at least two years behind in orthographic decoding, phonological decoding, or both.

Explicit memory was examined by free recall, both for visually and auditorily presented words. Visual implicit memory was assessed by a word stem completion test and auditory implicit memory was assessed by an auditory identification test. A letter matching test (Posner et al., 1969) was used to control for possible differences in visual perception, and a verbal fluency test was included to control for possible semantic differences.

No differences in visual perception or verbal fluency were found between the subgroups and there were no differences on the measures of visual and auditory explicit memory. However, in accordance with our predictions, the results provided evidence of a double dissociation, such that surface type children showed more auditory than visual priming, whereas the phonological subgroup produced more visual than auditory priming. The mixed subgroup showed low levels of both visual and auditory priming. The findings of this study therefore suggest that visual and auditory implicit memory are candidates to provide independent support for underlying cognitive deficits in subgroups of poor readers. Since perceptual priming is not mediated by explicit retrieval strategies, the results suggested that deficits in either phonological or orthographic word decoding reflect underlying cognitive weaknesses rather than strategic differences. The impaired auditory priming in the phonological subgroup is consistent with the view that the phonological type of reading disability is associated
with underlying phonological processing deficits. The impaired visual priming found in the surface subgroup suggests that one of their primary problems might be located in the visual word form system.

In conclusion, the results showed that it is possible to dissociate orthographic from phonological word decoding deficits, and that both routes can be simultaneously impaired.

6.4 Study IV

The fourth study built on the results found in study III. One goal was to replicate the finding of an interaction between visual and auditory priming and orthographic and phonological word decoding skills. In addition to cognitive measures, we also included measures of print exposure in this study. Print exposure could very likely affect the development of word decoding skills (Castles et al., 1999; Clay, 1987; Stanovich et al., 1997). In particular, it has been suggested that surface dyslexia may result from less severe phonological deficits in combination with limited exposure to print (Castles et al., 1999; Stanovich et al., 1997).

A different method for the subgrouping procedure was used as compared to study III. In study IV, we used a method based on regression analysis developed by Castles and Coltheart (1993) and modified by Manis et al (1996) and Stanovich et al (1997). In this subgrouping procedure, two regression analyses are first performed on control subjects, with the two variables being orthographic and phonological word decoding skill. The regression lines with confidence intervals are then superimposed on the corresponding scatter plot of the reading disabled subjects. Surface and phonological type subjects are those subjects who fall below the confidence limit of the relevant scatter plot.

Previous studies indicate that the choice of control group is critical for the outcome of this procedure. It has been argued that comparisons should be made with younger, reading-level matched controls rather than with age matched controls (Manis et al., 1996; Stanovich et al., 1997). Findings also suggest that when reading-level controls supply the regression lines instead of age matched controls, the number of surface type subjects is reduced (Manis et al., 1996; Stanovich et al., 1997).

In study IV, both age matched controls (29 children, with a mean age of 11 years, 0 months) and reading-level controls (26 children, with a mean age of 8 years, 11 months) were used for comparison. Fifty-three reading disabled children with a mean age of 11 years, 2 months participated in the study. The
reading disabled children all received special instruction in reading because of reading difficulties at the time of the study. Children with gross neurological impairments, sensory deficits, and children who did not speak Swedish as their first language were excluded from the sample.

The test battery included measures of reading ability (Malmquist, 1977), listening comprehension, visual and auditory explicit memory (i.e., free recall), visual and auditory implicit memory (i.e., stem completion and word identification), arithmetic, computerised tests of orthographic and phonological word decoding (Olofsson, 1999; Olson et al., 1985), and semantic and phonological verbal fluency. In addition to the cognitive measures, a questionnaire containing 10 items about reading habits and print exposure were completed by the children.

The results of the regression-based subgrouping procedure revealed that when the age matched controls supplied the regression lines, 11 phonological type, 30 surface type, and 12 mixed type subjects were identified. When the regression lines were instead supplied by the reading-level controls, the number of phonological type subjects increased to 18, the number of surface type subjects decreased to 10, and the number of mixed type subjects increased to 25. These results replicate previous findings that the choice of control group is critical when using this subgrouping procedure and that the number of surface type subjects is reduced when comparisons are made with reading-level matched controls instead of age matched controls (Manis et al., 1996; Stanovich et al., 1997). Thus, the pattern of orthographic and phonological word decoding skills found in surface type children is more similar to the pattern of younger children than that found in age matched children. This, in itself, suggests that the surface type of reading disability might be characterised as a developmental delay.

The results of the cognitive measures revealed that the entire sample of reading disabled children performed below age matched controls on measures of reading skills, explicit memory, listening comprehension, arithmetic, and semantic verbal fluency. Thus, this sample of reading disabled children would not satisfy a narrow definition of developmental dyslexia. Comparisons between the individual subgroups revealed that phonological type children only showed a specific deficit in phonological word decoding. Surface type children performed below the other groups on most cognitive measures, including visual priming for low frequency words, and they also reported fewer books at their homes (suggesting an association to limited print exposure). A highly significant correlation was also obtained between orthographic decoding and the number of books at
home. This pattern of results supported the hypothesis that the surface type of reading disability can be characterised as a general developmental delay, and that environmental factors might contribute more to this type of reading disability than to the phonological type.

6.5 Study V

The purpose of this longitudinal intervention study was to examine the effects of a strictly phonological intervention on the reading skills of reading disabled children in grade 4 (i.e., 10-11 years old). In addition to the examination of average improvements in reading, we examined possible explanations of differences in the effectiveness of the intervention.

Previous intervention studies have shown that phonological training can improve the phonological awareness and reading skills of young children (Bradley & Bryant, 1983; Hatcher et al., 1994; Lundberg, et al., 1988). However, the children who participated in these studies were quite young (7 years old at the most). Therefore, these interventions have not been directed towards children who experience lasting difficulties in acquiring reading skills and who are subject to special instruction for reading in school. In study V we wanted to examine whether strictly phonological training would also be effective for older children who were in need of special instruction for their reading difficulties.

We selected 33 children in grade 4 who received special instruction in reading according to our phonological training program (the phonological training group). Three control groups were also included in the study: 16 poor readers in grade 4 who would continue to receive regular special instruction during the intervention (grade 4 controls), 16 subjects who were matched with the two previous groups on reading ability, but who were two years younger (grade 2 controls), and finally, 83 children in grade 4 with no apparent reading difficulties (normal readers).

The children in the phonological training group received instruction according to a strictly phonological program (Gustafson & Samuelsson, 1998) over two semesters. The training program included seven different types of phonological exercises: rhymes, position analysis, subtraction or addition of sounds, segmentation, blending, and accentuation. The phonological training was carried out by nine experienced special instruction teachers in the children's normal school settings.

On three occasions (before, in the middle of, and after the intervention), the experimenter visited the schools and administered a comprehensive test
battery to all participating children. The test battery consisted of measures of reading ability (Malmquist, 1977), orthographic and phonological word decoding skills (Olofsson, 1999; Olson et al., 1985), phonological awareness, visual perception, and semantic memory.

The results replicated findings that phonological training improves the phonological awareness of children (Lundberg et al., 1988; Hatcher et al., 1994). However, the increase in phonological awareness was only accompanied by an increased reading ability for some children. Interestingly, the differences in response to the intervention seemed to be related to the use of word decoding strategies. The results of three separate regression analyses indicated that orthographic, but not phonological, word decoding contributed to text reading performance for children who resisted the intervention and failed to improve their reading skills (this held true before, during, and after the intervention). Thus, it seems that in order to benefit from a strictly phonological intervention, the child has to rely on the phonological word decoding strategy to some extent. In order for a phonological intervention to be successful for resistant children, it might be necessary to include explicit links between sounds and letters in the training program (see Bradley & Bryant, 1983; Hatcher et al., 1994).

6.6 Summary of the findings

In the first study, a number of serious problems resulting from the inclusion of IQ in the definition of developmental dyslexia were identified. We proposed that a classification of reading disability should acknowledge the causes of reading disability and that it should be outcome-based; that is, it should provide a basis for suggesting relevant interventions for different groups of poor readers (cf. Aaron, 1997). One of the proposed models was based on the two components of reading: word recognition and comprehension (Aaron, 1997). The other alternative was based on the two main word decoding strategies: orthographic and phonological word decoding. Different aspects of these word decoding strategies were analysed in the remaining four empirical studies of the thesis.

The second study examined developmental aspects of phonological and orthographic word decoding skills. This study replicated previous findings that there is a gradual shift from phonological to orthographic word decoding (Ehri & Wilce, 1987; Juel et al., 1986). The results of regression analyses also suggested that this shift could be generalised to text reading. However, since phonological word decoding contributed to text reading
performance for novice readers, we suggested that phonological interventions might also be considered for children with one or two years of formal reading instruction.

The third and fourth study examined the relationship between orthographic and phonological word decoding skills and visual and auditory implicit memory for words. In the third study, a double dissociation was obtained, revealing that surface type children showed more auditory than visual priming, whereas the phonological subgroup produced more visual than auditory priming. These results suggested that visual and auditory implicit memory may provide independent support for underlying cognitive deficits in the surface and phonological types of reading disability.

The fourth study did not reveal such a double dissociation. However, it should be noted that a different, regression-based subgrouping procedure was used in study IV. A slightly different sample of reading disabled children and slightly different word decoding tests were also used. The results of study IV suggested that the phonological type of reading disability might be characterised by specific deficits in phonological decoding. The general pattern of results here also suggested that the surface type might be characterised as a general developmental delay. The results revealed a visual implicit memory deficit in surface type children, but only for low frequency words. The results also showed that surface type children tend to report fewer books in their homes, suggesting that there might be a stronger environmental contribution in this type of reading disability.

Finally, the results of study V suggested that the relative reliance on orthographic and phonological word decoding in text reading has implications for the effectiveness of an educational intervention. The results showed that poor readers who received a strictly phonological intervention improved their phonological awareness, but this did not generally transfer to improved text reading. Instead, there was considerable individual variation in reading progress among the poor readers. Some children seemed to benefit from the intervention, while other children did not show any improvement in text reading (in spite of a steady increase in phonological awareness). Only one difference between improved and resistant readers was found: where improved readers seemed to rely on both orthographic and phonological word decoding in text reading, resistant readers seemed to rely only on orthographic word decoding. Note that this difference between improved and resistant readers concerned the relative contribution of the two word decoding strategies to text reading performance and not the relative skill in using the two strategies. Therefore, the resistant
readers of study V should not be confused with those that exhibit the phonological type of reading disability examined in study III and IV.

7. DISCUSSION

7.1 General discussion

In the first study, we critically examined the inclusion of general intelligence in the definition of developmental dyslexia. Based on recent findings, as well as from our own empirical studies, it was concluded that this procedure of classifying reading disabled children into dyslexic and non-dyslexic categories should be replaced by classifications which better acknowledge the manifestations, as well as the causes, of different reading disabilities (cf. Tønnessen, 1997).

There is strong empirical evidence that developmental dyslexia is associated with phonological deficits (e.g., Bruck, 1992; Rack et al., 1992; Stanovich & Siegel, 1994), stemming from underlying neurological impairments (Galaburda et al., 1985; Larsen et al. 1990). The primary manifestation of phonological deficits in reading seems to be poor word decoding skills (Perfetti, 1985; Share & Stanovich, 1995; Stanovich, 1986; Vellutino & Scanlon, 1987). These findings seem to provide a more solid basis for a definition of developmental dyslexia than the discrepancy between intelligence and reading ability (cf. Siegel, 1988; Stanovich, 1996).

The conceptual problems and confusions in this field of research might, in part, stem from the fact that different causes of reading disability interact with one another. For example, environmental factors will always influence the reading skills of a particular child, regardless of whether this child is dyslexic or not. It seems questionable to exclude a child from the dyslexic category just because this child happens to be unfortunate in other respects as well, such as having a poor socio-economic background or by having inappropriate reading instruction in school (see the definition by The World Federation of Neurology cited in section 4.1). Also, it is not clear just how specific the cognitive deficits have to be in order for a child to be categorised as dyslexic. A child with multiple problems would certainly need extra educational resources in order to promote his or her reading skills. Additionally, as long as the problems include underlying phonological deficits, such a child would be expected to benefit from training programs designed for dyslexic children. An intervention focused on improving cognitive abilities (i.e. phonological awareness) would not preclude other simultane-
ous interventions aimed at other possible causes of the child's reading difficulties. The main problem with this seems to be distinguishing between different causes of reading difficulties. This calls for valid diagnostic tools focused on the specific deficits associated with developmental dyslexia.

The need to consider the multi-dimensional nature of reading disabilities has been emphasised by several researchers (Frith, 1999; Lundberg & Høien, 1997; Van der Leij, 1997). The three-level framework proposed by Frith (1999) will be used in the following discussion concerning varieties of reading disability.

Frith (1999) suggests that a framework of dyslexia should include three levels of analyses: biological, cognitive, and behavioural. At all three levels, interactions with environmental factors occur. The biological level includes neuro-anatomical and genetic factors, the cognitive level refers to proposed causes related to information-processing mechanisms (i.e., cognitive hypotheses and theories), and the behavioural level refers to behavioural observations, such as test performance. Frith (1999) suggests that if these different levels of analyses are acknowledged, many misunderstandings and apparent paradoxes concerning the definition of reading disabilities disappear (see sections 4.1 and 4.2). The framework proposed by Frith (1999) bears similarities to the multi-dimensional model of impairments, disabilities, and handicaps previously presented in section 2.1 (WHO, 1980), and acknowledges the inherent complexity of the concept of reading disability (cf. Huey, 1908/1968).

On the behavioural level of analysis, the results of the present thesis suggest that variations in orthographic and phonological word decoding skills seems to be a useful basis for classifying varieties of reading disability (see study III and IV). Contrary to classifications based on the IQ-discrepancy criterion, this method is very closely associated with the process of reading itself. The distinction between surface and phonological types of reading disability also seems useful in generating new hypotheses concerning the influence of biological, cognitive, and environmental factors in different types of reading disability (see below). The results of study V suggest that behavioural observations should not be restricted to assessments of phonological and orthographic word decoding skills but should also include observations of the relative reliance on these two word decoding strategies in text reading.

On the cognitive level of analysis, the results of study III suggest that the surface type of reading disability might be associated with an underlying cognitive deficit in the visual perceptual representation system (Schacter et
al., 1990). These results do not reveal whether this deficit is constituted by poorer, and perhaps less distinct, visual representations or if the problem is associated with difficulties in accessing these representations (or even both types of problems). The existence of structural deficits and/or process deficits in the visual perceptual representation system of reading disabled children could be the subject of future empirical studies.

The results of study IV do not fully support the finding of a general deficit in the visual perceptual system of children with a surface type of reading disability. In study IV, surface type children showed reduced visual priming only for low frequency words. This result in itself indicates that environmental factors, such as exposure to print, might need to be taken into consideration in an explanation of the surface type of reading disability (Castles et al., 1999; Stanovich et al., 1997). Limited print exposure would be expected to have more pronounced negative effects on the perceptual representations of words that are seldom seen.

This interpretation was in part supported by the questionnaire data of study IV. Surface type children reported fewer books at their homes than both mixed type subjects and reading-level matched controls. Early, informal literacy socialisation can be expected to influence the general attitude towards reading (Gottfried, Fleming, & Gottfried, 1998), and a relatively limited exposure to print during childhood might result in delayed reading development (Braten, Lie, Andreassen, & Olaussen, 1999; Leseman & de Jong, 1998). Supporting this, study IV also revealed a highly significant correlation between the orthographic decoding variable and the reported number of books at home.

The results presented in studies III and IV regarding possible causes of the surface type of reading disability are not conclusive. However, they do suggest that the nature of the visual perceptual representation system, as well as the relationship between the visual PRS and print exposure, should be examined more closely in future research. It should also be noted that the results of both studies are in line with the hypothesis that the surface type of reading disability can be characterised as a general developmental delay (Manis et al., 1996), and that environmental factors, such as print exposure, are important in explaining this type of reading disability (Castles et al., 1999; Stanovich et al., 1997).

The failure in study IV to replicate the finding of impaired auditory priming in the phonological type of reading disability in study III might stem from differences in the samples of reading disabled children. In study III, most of the children had been diagnosed as dyslexics, suggesting specific
phonological deficits (see section 4.1). In study IV, the sample included a number of children who had more global deficits (see section 4.2) due to the fact that they performed below age matched controls on measures of semantic verbal fluency, explicit memory, and arithmetic. These results seem to be in line with the general idea behind the phonological-core variable differences model proposed by Stanovich (1988b), which states that where developmental dyslexics might have specific reading difficulties stemming from underlying phonological deficits, there is a continuum of the degree of specificity, and therefore, other reading disabled children have more general language and cognitive difficulties. However, the model by Stanovich (1988b) was based on the comparison of IQ-discrepant and non-discrepant reading disabled children and IQ was not assessed in our studies. In a more recent study, Stanovich and Siegel (1994) recognised that comparisons based on IQ did not reveal any distinct differences between groups within the word recognition module (see also Fletcher et al., 1994).

On the biological level of analysis, both behavioural–genetic and neurological findings provide links to behavioural findings and cognitive hypotheses regarding surface and phonological subgroups. Behavioural–genetic studies suggest that both phonological and orthographic decoding skills are heritable, but also that phonological skill shows higher heritability (Olson et al., 1989; Stevenson, 1991). In line with this, Castles et al. (1999) observed significant heritability of reading deficits for both surface and phonological dyslexics, with the genetic contribution being much larger in phonological dyslexics. These findings suggest that there is a stronger environmental contribution in the surface type of reading disability than in the phonological type.

Neurological findings, such as the tendency for symmetric plana temporale (see Galaburda et al., 1985; Larsen et al. 1990), are consistent with the existence of phonological deficits in developmental dyslexia. Also, the magnocellular deficit hypothesis suggests auditory as well as visual lower-level processing deficits in developmental dyslexia (Livingstone et al., 1991; Lovegrove et al., 1990; Slaghuis & Lovegrove, 1984). The magnocellular deficit hypothesis would be able to account for phonological and surface types of reading disability by assuming that the visual, as well as the auditory, magnocellular system can be selectively impaired (cf. Stein & Talcott, 1999).

To summarise, there are hypothesised cognitive factors associated with the phonological subtype (although the exact nature of these proposed phonological deficits is not clear at this point), as well as hypothesised
cognitive and environmental factors underlying the surface subtype. Findings on the biological level of analysis seem to be consistent with the distinction between phonological and surface types of reading disability. It also appears that this classification system has already proven useful for suggesting new hypotheses about varieties of reading disability.

However, it should be noted that both phonological and orthographic word decoding skills seem to be continuous and normally distributed variables and that arbitrary cut-off points are used to separate phonological type, mixed type, and surface type subjects from each other. Therefore, it is not suggested that these subgroups are discrete and homogeneous (see Murphy & Pollatsek, 1994; Stanovich et al., 1997) and findings should be interpreted with caution, especially due to the fact that it has yet to be demonstrated that the resulting subgroups are stable over time.

In addition to biological, cognitive, behavioural, and environmental aspects of reading disabilities, I would like to suggest that the developmental aspect also needs to be considered because the behavioural manifestations, as well as the underlying cognitive abilities, will continuously change over time. In young children, especially, dramatic changes in terms of their reading-related skills are to be expected within only a year or two (see section 3.2). This was evident in study II of the present thesis, where age differences of only two years seemed to produce marked differences, both in the skill of using and the reliance on the two main word decoding strategies.

Returning to the discussion of interventions, clearly, the multi-dimensional nature of reading disabilities suggests that there is no single, uniform "cure" for all types of reading disabilities (cf. McGuinness, 1998). The strong evidence of phonological deficits in developmental dyslexia and the positive effects of phonological interventions (see section 4.1) suggest that this type of training should be considered for many children. However, the results of study V show that a strictly phonological intervention is not appropriate for all reading disabled children. An examination of the relative reliance on the two main word decoding strategies may be essential in suggesting educational interventions for children with established reading disabilities. It should be noted here that the training program used in study V was strictly phonological and that children seem to benefit from educational activities explicitly linking sounds to letters (Bradley & Bryant, 1983; Cunningham, 1990; Hatcher et al., 1994). Still, it remains to be demonstrated that this positive effect applies to all reading disabled children.

The results of study IV and V show that children who receive special instruction for reading in Sweden as a group do not fit a narrow definition
of developmental dyslexia because they also perform below normal on semantic and explicit memory measures. These global deficits in children who receive special instruction in reading suggest that research on reading disabilities should not be restricted to developmental dyslexia. For example, it is not yet clear what effects a phonological intervention would have on dyslexics compared to garden-variety poor readers (note that the intervention studies referred to in section 4.1 were not specifically directed to developmental dyslexics). The reported positive effects of phonological interventions (e.g. Ball & Blachman, 1988; Lundberg et al., 1988; Torgesen et al., 1992) were constituted by average improvements that might reflect "hothouse effects" for children who were delayed in their reading development rather than improved reading skills in dyslexic children with more severe reading difficulties (Olson, Wise, Ring, & Johnson, 1997; Torgesen, Wagner, & Rashotte, 1997; Van der Leij, 1997).

7.2 Further research

The findings presented in the present thesis need to be replicated and examined in more detail in future studies dealing with varieties of reading disability. Another regression-based study, in which the subgrouping procedure is repeated using the same sample of reading disabled children, should be performed to examine the stability of the resulting subgroups over time. In comparison to study IV, this study should include more detailed measures of print exposure (i.e., questionnaire data in combination with more indirect measures of print exposure such as an author recognition test or a title recognition test). Such a study should also include several measures of phonological processing skill to facilitate a more detailed examination of the possible phonological deficits in the phonological type of reading disability.

In order to examine individual differences in the use of word decoding strategies in text reading, eye-movement tracking seems to be a promising online technique (Rayner, 1985b). Measures of eye-movements could perhaps be used in combination with measures of orthographic and phonological word decoding skills in the classification of subgroups.

A longitudinal intervention study, where subgroups are defined prior to interventions, should be valuable in the search for more effective training programs. This would be due to its better adaptation to the specific needs of different groups of reading disabled children. Several different interventions should be included in such a study and the differences in effect sizes between
subgroups should be focused in the analysis of the results. At least some of the methodological pitfalls identified by Troia (1999) should be avoided when designing such an intervention study (the experimentally ideal condition might be very hard to obtain in ordinary school settings). For example, better control of potentially confounding teacher effects should be achieved.

7.3 Conclusion

In final conclusion, it is clear that reading disabled children constitute a heterogeneous group. Also, the inclusion of IQ does not seem to offer an appropriate basis for the classification of reading disabilities. The present thesis demonstrates that the relative skill in using the phonological and the orthographic word decoding strategies may provide a useful basis for identifying subgroups of reading disabled children. It seems that the phonological type of reading disability is characterised by specific deficits in phonological processing. The surface type of reading disability seems to be characterised by more global deficits, suggesting a general developmental delay (possibly also associated with environmental factors). When designing educational interventions for reading disabled children it seems important to examine the relative reliance on phonological and orthographic word decoding in text reading. Thus, interventions should acknowledge what the child is already attempting to do when reading.
8. REFERENCES


Rayner, K. (1985b). The role of eye movements in learning to read and reading disability. Reading and Special Education, 6, 53-60.


