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IDENTIFICATION OF DYSLEXIA SUBTYPES BASED ON DEFICIENT READING AND SPELLING STRATEGIES

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ABSTRACT *In a sample of 345 fourth-graders (10-year-olds) living in Trondheim, Norway, 7.8% were identified as having dyslexic problems defined as a discrepancy between intelligence and reading/spelling achievements. An analysis of the reading and spelling functions was performed to investigate whether homogeneous subtypes could be identified. This was based on a combined developmental/ information-processing model. The assignment to different subgroups was made in accordance to the students' primary impairment either in the phonological or orthographic route or strategy. Even though broad subgroups of 'phonological' and 'morphemic' dyslexics could be found, these groups seemed to represent a dimensional rather than a categorical model. A 'mixed' subgroup also indicated a continuous distribution linking the extreme or typical cases of either subgroups. Individuals within a subgroup differed considerably from each other. A classification into broad dyslexic subgroups appears to provide insufficient information about dyslexic children. What is needed is a description of each individual child, indicating relative strengths and weaknesses on various dimensions.*

INTRODUCTION

Developmental dyslexia is typically defined as a reading and spelling disorder that cannot be accounted for by sensory or neurological damage, lack of educational opportunity, or low intelligence (Critchley, 1970). Exclusionary definitions of this kind are criticized because they imply that dyslexia cannot be diagnosed in a child with below average intelligence or in a child from a poor or unconventional background. The idea of a discrepancy between reading/spelling achievement and intelligence is also often included in definitions of dyslexia. Recently, several researchers have argued that serious conceptual problems arise from the use of discrepancy-based definitions (Fletcher et al., 1989; Siegel, 1989; Stanovich, 1991; Kamhi, 1992; Rack et al., 1992). Siegel (1989) asserts that intelligence should play no part in defining dyslexia, and Stanovich (1991) suggests that a discrepancy between reading ability and listening comprehension would be more relevant to use to identify dyslexic problems than a discrepancy between reading achievement and intelligence.

In spite of the controversy regarding the use intelligence-based definitions, the notion of a discrepancy between reading/spelling achievement and intelligence has been adopted by many researchers (Rutter and Yule, 1975, Thomson, 1984; Silva et al., 1985; Bjørgen et al., 1987). Hence, in the present study, dyslexia is defined as a severe difficulty with the written form of language, characterized by reading and spelling achievement well below that predicted on the basis of the child's intelligence and chronological age. No theoretical assumptions are involved in the use of the term.

Nevertheless, the identification of children with specific reading/spelling difficulties is only a starting point when studying dyslexia. Though no convincing explanation of dyslexia has emerged, dyslexia may be viewed as a delayed development of literacy acquisition or as an involvement of specific deficits preventing the child from a normal reading and spelling development (Stanovich et al., 1988). A large body of research has shown that dyslexic children display deficits in various aspects of phonological processing (Lundberg, 1982; Bradley and Bryant, 1983, Liberman and Shankweiler, 1985, Olson et al., 1989). Dyslexia may also be viewed as a unitary syndrome with a single cause (Vellutino, 1978) or a collection of homogeneous subtypes caused by several basic deficiencies. In the latter case, research has been conducted to investigate the occurrence of concomitant disabilities (Mattis, 1978) or to classify the dyslexic children in terms of differences in their actual reading/spelling performance per se (Johnson and Myklebust, 1967; Boder, 1973; Gjessing, 1977). These studies are based on the clinical inspection of psychometric data. More recent studies have used multivariate statistical techniques for dyslexic subtype identification (Satz and Morris, 1981; Vogler et al., 1989).

A well-known attempt at sub-typing within the clinical tradition was made by Boder (1973). On the basis of the observed reading and spelling patterns she identified three subtypes. Boder differentiated between a 'dysphonetic' group characterized by an inability to develop phonic skills, and a 'dyseidetic' group characterized by a deficit in the ability to perceive letters and whole words as configurations or visual gestalts. A third 'mixed' group comprised children characterized by problems that were typical of both the 'dysphonetic' and 'dyseidetic' groups. The largest group consisted of those with a phonic or language handicap. Boder's differentiation on the basis of reading/spelling patterns is quite similar to a Norwegian assessment procedure for diagnosing dyslexic children developed by Gjessing (1977, 1979). The equivalent terms in Gjessing's models are 'auditory' and 'visual' dyslexics.

Information-processing Theories

To differentiate among varieties of dyslexic children, some researchers have recently sought to explain the observed patterns of reading/spelling disorders in terms of information-processing models of basic reading and spelling functions. The 'functional architecture' of these models is influenced by experimental cognitive neuropsychological studies of acquired dyslexia in adults. Using the observed patterns of breakdown, attempts are made at drawing conclusions about the functions of normal reading/spelling processes. An early version of an information-processing model was set forth by Morton (1969), but later on elaborate models are found in various forms (Coltheart et al.1980; Morton, 1980; Seymour and Porpodas, 1980; Patterson et al., 1985; Ellis and Young, 1988; Høien and Lundberg, 1989; Seymour, 1990). These models are modular and are presented as flow charts. The models postulate the co-operating systems and processes which are involved in reading and spelling. An analysis of the reading and spelling performances gives information about the specific processes which are functioning inadequately. The theories, of modular information-processing models have thus led to the establishment of a psycholinguistic methodology involving test methods which are mapped on to the

model. Quite similar methods are developed by Seymour (1986) and Høien and Lundberg (1988, 1989). Seymour (1987a) refers to his method as the 'cognitive assessment procedure', while Høien and Lundberg describe their method as a process-analytical approach (Høien and Leegaard, 1991).

To explain the basic processes in reading and spelling, the traditional dual-route theory still dominates in neuropsycology. According to this theory, word recognition in reading is dependent on two processing systems. One is the grapheme-phoneme conversion system which utilizes knowledge of spelling-sound correspondences to translate the written word into an internal phonological representation. This is called the non-lexical or phonological route or strategy, and is used when sounding out unfamiliar words or nonsens words. The other involves direct access to the word's meaning and phonology on the basis of morphemes and orthographic pattern recognition. This is termed the lexical or orthographic route or strategy, and is used when reading irregular words and well-known words. To become a skilled reader both routes have to be acquired (Coltheart, 1978; Ellis and Young, 1988; Høien and Lundberg, 1989).

Likewise, the stored knowledge about spelling represents either knowledge about grapheme-phoneme correspondence rules (non-lexical, phonological route) or word specific knowledge (lexical, orthographic route). Spelling errors are seen as a breakdown in either or both of the two routes (Frith, 1980; Seymour and Porpodas, 1980).

However, it has been argued that the distinction between the two routes is artificial (Henderson, 1982). In both the so-called lexical analogy models (Glushko, 1979; Goswami, 1988) and the computational models (Van Orden, 1987) the distinction between the direct orthographic route and the indirect phonological route tends to be more blurred. Seidenberg (1988) claims that the dual-route theory does not specify how the processing mechanisms are actually operating. A connectionist model of the development of word recognition and naming has been described by Seidenberg and McClelland (1989). This model shows that the same system can be used for pronouncing irregular words and nonsens words. Modifications of the connectionist model have been suggested. These models stress the importance of phonological skills in learning to read and write (Adams, 1990; Hulme et al., 1991).

Despite the current attacks on the dual-route theory, several researchers still find that it provides a useful framework 'for the assessment of dyslexic problems (Høien and Leegaard, 1991; Seymour, 1990). Even if the two routes might be functionally interactive, they can be quite distinct conceptually. For the fluent readers the two routes seem to be well integrated, but for disabled readers the interaction of the two routes might not function in an adaptive way.

The Developmental Perspective

Information-processing theories have also been criticized for neglecting the normal course of reading/spelling development when studying developmental dyslexia.

Because of this, Seymour has argued for an integration of the two types of theoretical models (Seymour and MacGregor, 1984; Seymour, 1990).

Several stage models for early reading and spelling acquisition have been put forth (Marsh et al., 1981; Frith, 1985; Seymour, 1990). Although the terminology of these models may differ, they are quite similar in their basic ideas. A well-known and elaborate model is outlined by Frith (1985), who has proposed three stages in reading development which are associated with three strategies or approaches:
  1) The logographic strategy which involves immediate recognition of familiar words according to graphic cues or guessing. Printed words are processed only as visual patterns, not as linguistic representations by applying alphabetic principles.
  2) The alphabetic strategy where letters are recognized in sequence and converted to sounds.
  3) The orthographic strategy where multi-letter units are recognized and combined in the identification of words.

These three strategies are assumed to emerge in the order given in that the accomplishment of the earlier stages is necessary for the achievement of the later stages. A similar sequence of development can also be observed in spelling, but the development occurs in different rates in reading and spelling. It is assumed that in spelling the alphabetic strategy may emerge first and influences the alphabetic strategy in reading. The orthographic strategy, however, emerges first in reading and is later transferred to spelling (Frith, 1985).

Seymour (1990) has proposed a variant of Frith's model in which logographic and alphabetic strategies may develop as concurrent rather than successive stages. The emergence of the orthographic strategy is supposed to occur progressively and is dependent on both the logographic and alphabetic strategies. Thus the orthographic system is seen as the product of a merger of the logographic and alphabetic systems, and the subsequent concurrent development of all three strategies is assumed.

In order to relate the developmental models to dyslexia it is necessary to translate the strategy concepts of the stage model to the format of information-processing systems. There have been a few attempts at postulating combined developmental/information-processing models. (Seymour and MacGregor, 1984; Stuart and Coltheart, 1988; Seymour, 1990). Since these models represent variants of the dual-route theory, the test methods developed within the information-processing framework are assumed to be appropriate for the investigation of the combined models.

Dyslexia Subtypes Based on Strategy Deficiencies

Dyslexic readers are characterizes by problems in recognizing single words. There is an increasing consensus that phonological processes play a crucial role in reading and spelling development (Olson et al., 1989). A lack of phonological sensitivity makes it therefore difficult to develop a proper "sight word recognition". There is also growing evidence that some dyslexic children may have visual/orthographic processing deficits (Stanovich, 1991). According to Seymour (1990) two types of underlying

impairment may restrict orthographic development in reading and spelling and, hence, produce two broadly-defined contrasting groups of dyslexic children. These two groups he refers to as 'phonological' and 'morphemic' dyslexia. In 'phonological' dyslexia the alphabetic-phonological development is impaired and this blocks progress towards the orthographic level in reading and spelling. Logographic development can still proceed. In 'morphemic' dyslexia the orthographic development is restricted. The subgrouping of 'phonological' and 'morphemic' dyslexia is based on the idea that the phonological and orthographic routes may be subject to different degrees of impairment. A predominant deficiency in the phonological strategy characterized by an impairment in spelling to sound knowledge will produce 'phonological' dyslexics. A predominant deficiency in the orthographic strategy reflects a problem in establishing a large sight vocabulary and hence will produce 'morphemic' dyslexics. The dual-route theory can in this way be applied in subgrouping dyslexic children.

The dual-route theory is influenced by neuropsychological studies of acquired dyslexia in adults, and investigations of acquired dyslexia have also sought to classify patients into syndrome categories (Shallice, 1981; Coltheart et al., 1980). A similar analysis has been made for developmental dyslexics (Temple and Marshall, 1983). Recently, it has been argued that the syndrome approach in acquired dyslexia is no longer a useful one, because the syndromes that were formerly thought to be unitary are fractionating, i.e. there are demonstrations of the same syndrome with different underlying causes (Coltheart, 1987).

Nor has the search for discrete subtypes among dyslexic children always proved to be successful (Vogler et al., 1989; Elbro, 1990; Høien and Leegaard, 1991). Instead of searching for homogeneous subtypes, as a categorical model would dictate, several researchers have adopted the notion of a dimensional model (Ellis, 1985; Stanovich, 1988). In a dimensional model the distribution of important test scores related to reading and spelling skills will be located fairly randomly in a multidimensional space. A categorical model, on the other hand, assumes that the children will fall into discrete classes or categories, i.e. there will be 'galaxies' of subgroups in the multidimensional space. A critical problem in a dimensional model is to find the most important dimensions or modules related to reading and spelling. Two relevant dimensions seem to be the grapheme-phoneme conversion system (or phonological strategy) and the word specific knowledge (or orthographic strategy) described in the dual-route theories (Ellis, 1985; Høien and Lundberg, 1989; Lundberg and Høien, 1990).

Purpose

Using a combined developmental/information-processing model the main purpose of the present study is to identify the deficient reading and spelling functions, and hence, the deficient reading and spelling strategies of dyslexic children defined as underachievers. In view of the conflicting evidence of dyslexic subtypes, an important question is whether it is possible to classify dyslexics into homogeneous subgroups or whether it is more appropriate to use a dimensional model.

For convenience, the study is divided into two phases. The first phase will report on the identification of dyslexic children. The second phase focuses on a method of experimental psycholinguistic techniques combined with individual case studies that are used to identify and interpret the deficient reading and spelling functions of dyslexic children. The method is based on the theory and models developed by Seymour (1986, 1990) and Høien and Lundberg (1989, 1991ab).

PHASE 1

This part of the study describes the criteria used to define and select the dyslexic children.

METHOD

Subjects

The screening sample consisted of 345 Ss, 177 boys and 168 girls. The students were selected from eight public schools in Trondheim, Norway. The schools were chosen randomly and covered a representative socio-economic range. Children in 17 ordinary school-classes (10-year-old children) participated in the study.

Instruments, Data Collection and Data Analysis

Group tests on reading, spelling and intelligence were administered during a single session to all children in the sample. Two tests were used for measuring the children's reading performances: (1) Reading Speed (Høien and Trana, 1978) and (2) Reading Comprehension (Solheim et al., 1984). Reading Speed tested speed of word reading measured by multiple-choice marking of appropriate figure drawings (400 items). Reading Comprehension consisted of twelve short stories each followed by four multiple chose questions (48 items). The standard scores of the two reading tests were summed to obtain a single measure of reading. A spelling test, Word Spelling (Asheim, 1964), measured the ability to write single words correctly (50 items).

The intelligence tests which were used are based on theories of hierarchical organization of cognitive factors which suggest that fluid intelligence may be identical with a general intelligence factor (Horn and Cattell, 1966; Undheim, 1981). Intelligence was measured by the following tests: (1) Matrices, (2) Picture Analogies, (3) Number Series. Neither of the intelligence tests required the children to read. To obtain a measure of general intelligence, standard scores on the three intelligence tests were summed. Except for the Word Spelling Test, the screening tests were administered as two parallel tests and were time restricted. All the screening tests have been used before in Norway to identify children with dyslexic problems (Bjørgen et al.,1987; Gjessing et al., 1988; Thygesen, in press).

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Specific reading and spelling difficulties (dyslexia) were defined as a level of reading and spelling achievement below that predicted on the basis of a child's age and intelligence. The predictions of reading and spelling achievement were based on regression equations, and the discrepancy scores were standard scores on the reading and spelling tests, minus regressed scores on the basis of the general intelligence measure. According to Rutter and Yule (1975) the appropriate difference between the observed and predicted performance levels was two standard scores.

RESULTS

Table I shows the psychometric characteristics of the screening tests for the total sample of 345 Ss. The coefficient of equivalence for the two reading tests were 0.82 and 0.86, and for the three intelligence tests the reliability varied from 0.62 to 0.70. The correlation between the two reading tests was 0.69, and between reading and spelling 0.69. The correlations for the three intelligence tests varied from 0.55 to 0.62.

Table I. Psychometric characteristics of the screening tests (N=345).

Tests	No. items	Total minutes worked	M	SD	Skew	Relia-bility*
1. Reading Speed	400	10	187	42.4	-.23	.82
2. Reading Comprehension	48	8	23	8.8	.09	.86
3. Word Spelling	50	–	36	9.4	-.71	–
4. Matrices	28	6	16	5.4	-.72	.67
5. Picture Analogies	30	6	20	4.9	-.67	.62
6. Number Series	24	6	12	5.0	-.25	.70

*Reliability is based on test-retest ("Coefficient of Equivalence")

The coefficient of equivalence between intelligence and reading was 0.57, and between intelligence and spelling 0.49. As the discrepancy scores used in the selection of dyslexic children were standard scores on reading and spelling tests, minus regressed scores on the basis of the general intelligence measure, the discrepancy score for reading was:

$Dif_R = z_R - (.57z_i)$, and for spelling:

$Dif_S = z_S - (.49z_i)$.

By using the same criteria as Rutter and Yule (1975), i. e., two standard scores difference between the observed and predicted performance levels, only 1.5% of the sample was found to have reading disability and 1.5% had spelling problems. This was a total of 2.6% with reading and/or spelling problems. To obtain a prevalence in accordance with estimates of dyslexia from other studies in Norway, the children who obtained a discrepancy score of 1.3 below the predicted level in reading (5.5%) and 1.5 in spelling (5.5%) were selected as children with dyslexic problems. This resulted in a group of 27 dyslexic children (7.8%), 63% of whom were boys and 37% girls.

PHASE 2

Phase 2 examines the deficient reading and spelling functions of dyslexic children in order to see whether the results are compatible with the subtype model based on strategy deficiencies. Furthermore, a few case-studies of dyslexic children will also be presented.

METHOD

Subjects

The dyslexic sample identified in Phase 1 consisted of 27 Ss, but because of a dropout of 2 boys with reading difficulties, only 25 Ss participated in the diagnosis of dyslexia. These comprised 11 Ss (8 boys and 3 girls) with both reading and spelling problems, 6 Ss (1 boy and 5 girls) with reading disorders only, and 8 Ss (6 boys and 2 girls) with spelling problems only.

Instruments

The dyslexic Ss were diagnosed by means of a process-analytical reading test battery (KOAS) devised by Høien and Lundberg (1989, 1991b). The test battery was designed to test the efficiency of the orthographic and phonological strategies or routes and was carried out by means of a microcomputer (IBM AT). The computer registered and calculated the correct score and the reaction time in percent. However, in the present study the experimenter recorded the response time by pressing a button on the keyboard. Because of this, the reaction time had to be used with caution. Only the reaction times of word length for Reading Words Orally and non-words are given when presenting the dyslexic case-studies. Unfortunately, the test battery of KOAS was not standardized for 4th grade. The standardization data could therefore not be used. The battery consisted of four tests, as follows:

(1) Reading Words Orally. The test consisted of 120 words systematically varied along the dimensions of length (3, 5 and 7 letters), frequency (high, low), and according to grammatical class (content and function words). The words were presented in lower case letters (size 32x16 pixels, Hercules), and each word was presented on the computer screen with an exposure time of five seconds. The examiner noted whether the response was correct or not by pressing a button on the keyboard. The button press ended the exposure of the word on the screen. Errors were also recorded. Because the reader is free to choose between the phonological and orthographic strategies, this test assesses the preference and efficiency of the decoding strategies.

(2) Briefly Exposed Words (Timed presentation). This test consisted of 72 words which varied systematically along the dimensions of length, frequency, grammatical class, and concrete vs. abstract meaning. Each word was presented for a short stimulus time (100 ms) where no eye movements were possible. The brief exposure time imposes constraints on using the phonological strategy and encourages the use of the

orthographic strategy. A poor result on this test indicates difficulty in using the orthographic strategy. As before, the examiner recorded the reading errors.

(3) Non-word Reading. The test was composed of 36 non-words varying in length (3, 5 and 7 letters) and phonological complexity. Each word was presented on the screen with an exposure time of five seconds. Reading errors were recorded. This test assesses the efficiency of the phonological strategy.

(4) Lexical Decision Task. Pairs of real word homophones were presented (eks. hjul-jul). The examiner read a sentence and the subject had to decide which of the two homophones fitted the context. In this task the child will have no benefit in using a phonological strategy. Failure here indicates a deficient orthographic route.

In addition to the four computer-based reading tests, the following tests were administered to the children:

(5) Text Reading. The children read a short narrative text aloud (Gjessing, 1979). The examiner recorded the reading rate and the accuracy of reading. Comprehension questions were also asked. The reading was tape-recorded for further analysis.

(6) Phonological Synthesis. Ten words and ten non-words varying in length and phonological complexity were presented. The examiner pronounced the phonemes of each item with intervals between successive segments of about one second. The task for the child was to name the word or non-word decomposed by the examiner.

(7) Phonological Analysis. The test consisted of two tasks: a) The child was presented orally with several words one at a time and was asked to pronounce the phonemes of each word. b) The examiner pronounced a word. Then the word was repeated, but this time with a syllable left out. The task was to name the missing syllable.

(8) Writing Non-words and Sentences from Dictation. The Ss were asked to write 20 non-words which varied in length and phonological complexity. The children were also asked to write sentences from dictation. The words in the dictated sentences varied according to how phonetical their spellings were.

DATA ANALYSIS AND ASSESSMENT PROCEDURE

According to models based on strategy deficiencies in reading and spelling, a strategy can be more or less impaired in dyslexic children. The relative efficiency of the strategies has been used for classification into dyslexic subgroups. A relatively mild orthographic impairment combined with a serious inefficiency in the non-lexical route will produce 'phonological' dyslexics. A relatively mild phonological impairment combined with an impairment in the lexical route will produce 'morphemic' dyslexics (Seymour, 1987ab).

Whole word reading is seen as a test of the efficiency of the orthographic strategy and non-word reading as a test of the phonological strategy. Therefore, the method of

contrasting the error rates between words and non-words was used as a basis of classification into the two subgroups of 'phonological' and 'morphemic' dyslexia (Ellis, 1985; Seymour, 1990). Analysis of linguistic dimensions and error classification gave further information about the preference and efficiency of the strategies. The efficiencies of phonological synthesis and analysis were also assessed.

Contrasting of Words and Non-words

A scattergram defined by a scale of whole word reading on one axis and a scale of non-word reading on the other was used to illustrate the distinction between the two strategies or routes in reading. Instead of contrasting the reading of non-words and low-frequency words as in Seymour (1990), the scales were operationally defined in terms of the distinction between error rates on Non-words and Briefly Exposed Words in the computer-based test battery. This was done because the Briefly Exposed Word test imposes constraints on using the phonological strategy, whereas in the Reading Words Orally test (with an exposure time of 5 seconds) the phonological strategy might assist the subject in reading the whole word. It is expected that in 'phonological' dyslexics non-word reading will be relatively less efficient than whole word reading. Reaction time will also be affected. In 'morphemic' dyslexics whole word reading will be the least efficient.

A similar procedure was adopted for spelling, with a scale of word spelling on one axis and a scale of non-word spelling on the other. The scales were operationally defined in terms of the distinction between the error rates of Word Spelling (the first 20 words) from the first phase of the study and Non-word Spelling (20 words) from the second phase. According to Seymour (1987b) a phonological disturbance should result in better spelling of words than non-words. The reverse pattern is assumed for 'morphemic' dyslexics.

Linguistic Analysis in Reading

The linguistic analysis can provide information about what strategy the child is using in reading and how effective the strategy is functioning. The reading performances of words in the computer-based reading tests were analysed along the dimensions of length (3, 5 and 7 letters), frequency (high, low), grammatical class (content and function words) and concrete vs. abstract meaning. It is assumed that readers who rely predominantly on the orthographic strategy will have relatively greater difficulty decoding abstract words, low frequency words and function words as opposed to concrete words, high frequency words and content words. Readers who rely on the phonological strategy will have relatively more problems decoding long words (Høien, 1987; Høien and Lundberg, 1989, 1991ab). It is expected that 'phonological' dyslexics may compensate for their difficulties by using the orthographic and/or the logographic route, and 'morphemic' dyslexics may rely on the non-lexical route (Seymour, 1986, 1987ab).

The testing of pairs of real word homophones (Lexical Decision Task) also gave information about strategy deficiency. Failure here indicates a deficient orthographic route (Høien and Lundberg, 1989), and hence is characteristic of 'morphemic' dyslexics.

Error Analysis in Reading

Error analysis involves classifying the reading errors into error categories which are related to the use of the different decoding strategies. However, it should be noted that error analysis is not without problems and sometimes it may be difficult to classify the reading errors into the appropriate error category.

Errors indicating an inefficient phonological strategy, and hence are characteristic of 'phonological' dyslexics, are phonological errors (the response word is phonologically similar to the target word, an example would be the Norwegian word "fisk-frisk"), incomplete reversal of letters (the sequence of letters is coded incorrectly, e.g. far-fra) and omissions and additions of letters (e.g. benk-benken). Confusion of letters like 'd-t' and 'k-g' may occur. Reading behaviour often tend to be uneven with repetitions of letters, syllables and words.

Errors indicating an inefficient orthographic strategy, and hence are characteristic of 'morphemic' dyslexics, are regularization errors (irregular words are read as if regular, e.g. deg-dei) and transposition errors (e.g. sol-los). Confusion of letters like 'd-b' may occur. Reading behaviour is often characterized as being slow, but phonetically accurate (Gjessing, 1977, 1979; Høien, 1987; Seymour, 1987ab; Høien and Lundberg, 1991b, 1989).

Visual errors (the response word is visually similar to the target word, e.g. solen-stolen) and derivational errors (the response and target word share the same stem, e.g. kjærlighet-kjærlig) appear primarily when the orthographic strategy is used in word retrieval, but indicate that this strategy is not functioning quite adequately. These errors may be found in both 'morphemic' and 'phonological' dyslexics (Seymour, 1987b).

Error Analysis in Spelling

Likewise, error analysis in spelling were performed for the spelling tests. Errors indicating an inefficient phonological strategy and hence are characteristic of 'phonological' dyslexics are illegal letter sequences (e.g. far-fra), omission of letters (e.g. sprette- srete) and addition of letters. Confusions of letters may occur (g-t, k-t, y-u, u-v). 'Phonological' dyslexics are also expected to have more errors classified as being phonetically inaccurate than accurate.

Errors indicating an inefficient orthographic strategy, and hence are characteristic of 'morphemic' dyslexics are visual errors (e.g. solen-stolen), regularization errors (e.g. hjelpe-jelpe, tog-tåg, stein-stæin), overcompensation (regular words are written as

regular ones (e.g. især-iser) and transposition errors. Confusion of letters like 'd-b' may occur. 'Morphemic' dyslexics show a preponderance of phonetically correct errors. Although the spelling may be phonetically well formed, difficulties in writing words of nonstandard sound-spelling structure (irregular words) is expected (Gjessing, 1977, 1979; Høien, 1987; Seymour, 1987ab).

Phonological Synthesis and Analysis

Phonological synthesis gives information about one of the subprocesses behind the phonological strategy in reading. However, phonological synthesis also depends on segmentation ability or analysis of words (Høien and Lundberg, 1989). These two tasks therefore give information about the efficiency of the non-lexical route.

Assignment to Dyslexia Subgroups

The children were classified as either being predominantly 'phonological' dyslexics or 'morphemic' dyslexics. A child would be classified as a 'phonological' dyslexic if both routes were impaired but the impact on the phonological route was more severe than on the orthographic route. A 'morphemic' dyslexic would have a relatively mild phonological disturbance. If the phonological and orthographic strategies were equally deficient, a child would be classified in a 'mixed' group (Seymour, 1987ab, 1990).

Procedure

To categorize the children into dyslexia subgroups, a qualitative assessment by two independent university researchers was performed, taking all the relevant data into consideration. The method of contrasting the error rate between words and non-words in reading and spelling was first considered. In the computer-based reading tests, the analysis of the linguistic dimensions and error analysis were performed according to the criteria imposed. The tape-recorded Text Reading was analysed with respect to reading behaviour, and Phonological Synthesis and Phonological Analysis were also taken into account to provide information about strategy deficiencies. Finally the spelling errors on Word Spelling and Writing Words from Dictation were analysed according to the criteria laid down.

Some of the dyslexic children were easy to classify, for others it was difficult. When the two researchers disagreed, they discussed the cases and agreed on the appropriate subgroups in which to assign these dyslexic children.

RESULTS

The reading/spelling results on the word and non-word dimensions will be presented first and compared to the qualitative assessment of strategy deficiencies in dyslexic children by the two researchers and, hence, to the assignment of dyslexia subgroups.

Thereafter, several case-studies will be described to illustrate the assessment procedure. Relevant data from all the tests will be included in the description of these dyslexic children.

Reading and Spelling Words and Non-words. Assignment to dyslexia subgroups.

In Figure 1 the reading results of all the 25 Ss are plotted on a surface showing the error levels in percent for reading Briefly Exposed Words and Non-words. The Ss who are located below the diagonal of the scatterplot are supposed to have relatively more problems with the phonological than with the orthographic strategy. The reverse is assumed for the Ss above the line. The scatterplot shows that the Ss do not fall into the discrete clusters predicted by the categorical or subtype model. They are scattered over the whole surface, except that there are no Ss who are extremely poor on whole word reading or non-word reading only.
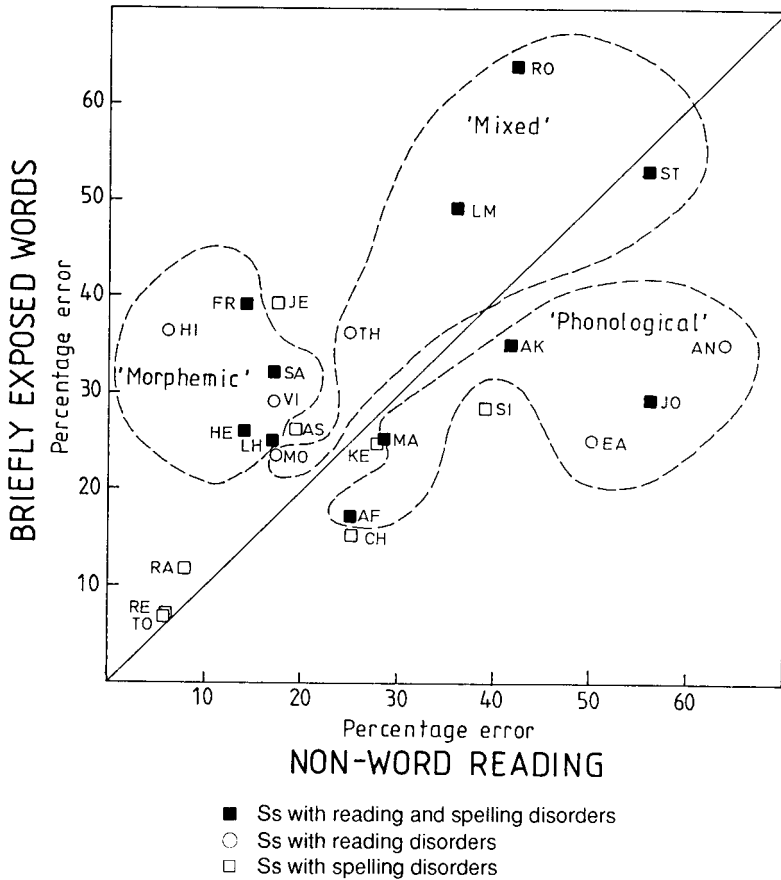

Figure 1. Scatterplot showing error levels in percent for reading Briefly Exposed Words and Non-words of dyslexic children (N=25)

However, one can find individuals who have relatively more problems with the phonological strategy, and therefore are typical examples of a 'phonological' dyslexic (JO). An example of a 'morphemic' dyslexic in reading is HI. There are also some Ss who seem to be equal deficient on both strategies (MA,MO), and there are some Ss who are extremely poor on both dimensions (RO,ST). According to the scatterplot, the proportion of phonological and orthographic strategy deficiencies in dyslexic children is approximately the same.
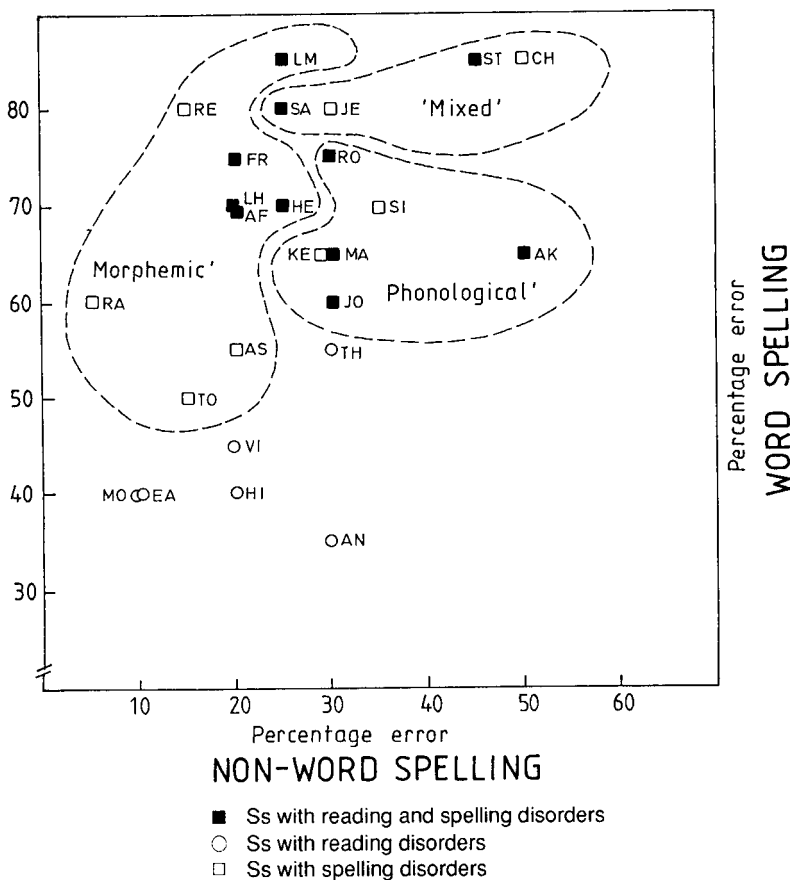

Figure 2 . Scatterplot showing error levels in percent for spelling words and non-words of dyslexic children (N=25).

The eight Ss with spelling problems only were also included in the analysis. As the scatterplot illustrates, three Ss (RA,RE,TO) are quite efficient readers. The other five Ss were more or less deficient in reading, even if they did not belong to the lowest 5.5% of the sample and thus were defined as dyslexics in reading. These Ss were

scattered among the other dyslexic Ss. It should be noted that due to the selection criteria, Ss with the same reading ability could be classified as being reading disabled or not, depending on their individual IQ scores.

The categorization into different dyslexia subgroups is also shown in the scatterplot. Six Ss (35%) were assessed to have predominantly phonological problems, six Ss (35%) to have predominantly orthographic problems, and five Ss (30%) to be about equally deficient in both routes. As regards reading ability, the results on the word and non-word dimensions and the qualitative assessment of dyslexia subgroups seemed to be comparable. It should also be noted that the Ss with the most severe impairments in both routes were all classified in the 'mixed' group.

In Figure 2 the spelling results of the 25 Ss are plotted showing the error levels in percent for spelling words and non-words. The result showed that the Non-word test in spelling was too easy compared to the Word Spelling test. Most of the children at this age were able to write the two and three letter non-words, which comprised 30% of all the non-words.

The five Ss with reading problems only were also included. Even though the performance of these Ss on the whole showed better results than the Ss identified as disabled spellers, they were nevertheless deficient spellers, with at least 35 % of the words being incorrectly spelled.

Concerning categorizatio... into different dyslexia subgroups in spelling, six Ss (32%) were assessed to have predominantly phonological problems, nine Ss (47%) to have predominantly orthographic problems, and four Ss (21%) belonged to the 'mixed' group. The least affected Ss (RA,TO,AS) were all classified as 'morphemic' dyslexics, and in the 'mixed ' group the children were all severely impaired. A few of the dyslexic Ss were assigned to different groups in reading and spelling (AF,SA,LM,RO). The scatterplot also showed that the three efficient readers with spelling problems only (RA,RE,TO) were characterized by inefficient orthographic strategy in spelling.

Case-studies

The results on the word and non-word dimensions and the assignment to different subgroups have been presented. However, the qualitative assessment confirmed the existence of heterogeneity among the dyslexic children, and that the assignment to three categories or groups may involve oversimplifications. To illustrate the assessment procedure and to give a more complete description of individual cases, some of the dyslexic children are described. The case-studies comprised six Ss, four Ss with reading and spelling problems, one child with reading disorders only, and one child with spelling problems only. They were chosen because they represented different intelligence levels and different sexes and were assigned to different dyslexia subgroups.

Table II. Error rates (percent) for Reading Briefly Exposed Words and Non-words, and of high- and low-frequency words for Reading Words Orally of members of dyslexic children.

Subject	Gender	IQ*	Briefly Exposed Words	Reading Words Orally Low-frequecy words	High-frequency words	Non-words
Reading and spelling problems						
JO	M	-.81	29	23	15	56
LH	F	1.25	25	15	12	17
ST	M	-1.80	53	37	18	56
SA	M	-.73	32	12	5	17
Reading problems only						
HI	F	.31	36	15	5	6
Spelling problems only						
CH	M	.12	15	5	7	25

* Standard scores

The error rates for reading Briefly Exposed Words and Non-words Reading are presented in Table II together with the summed standard scores on the three intelligence tests from Phase 1. The error rates of high and low-frequency words for Reading Words Orally are also presented here. In Table III the error rates of concrete/abstract words and content/function words for Briefly Exposed Words, and content/function words for Reading Words Orally is presented together with error rates of the reading of homophone words (Lexical Decision Task). In Table IV the percentages of errors for the spelling test in Phase 1 classified as being phonetically accurate or inaccurate are shown together with error rates of Phonological Synthesis and Phonological Analysis. Figure 3 shows the reaction time for reading 3, 5, and 7 letters word for Reading Words Orally.

Table III. Error rates (percent) of concrete/abstract words and content/function words for Briefly Exposed Words, of content/function words for Reading Words Orally, and for Lexical Decision Task of members of dyslexic children.

	Briefly Exposed Words Concrete	Abstract	Content	Function	Reading Words Orally Content	Function	Lexical Decision Task
Reading and spelling problems:							
JO	22	28	25	33	13	25	40
LH	22	28	25	25	15	12	35
ST	50	50	50	56	23	32	35
SA	22	44	33	31	10	7	45
Reading problems only:							
HI	22	50	36	36	12	8	23
Spelling problems only:							
CH	11	6	8	22	2	10	25

JO was a boy at the lower end of the normal range of IQ (-.81). He had reading and spelling problems and was classified as a 'phonological' dyslexic. The impairment of the orthographic route was indexed by a high error rate in word reading for Briefly Exposed Words (29%). However, error rate in Non-word Reading was even higher (56%). Thus, even if both routes were impaired, the phonological route seemed to be the least efficient. JO's reading disclosed that he had relatively greater difficulty decoding abstract versus concrete words and function versus content words. He made derivational errors, visual errors and transposition errors. These results provided evidence of an orthographic involvement. But there was also evidence of an involvement of the phonological route. Word length produced an effect, and a number of his errors were incomplete reversals of letters. His reading behaviour disclosed that he was able to read short words in a wholistic way. When decoding longer words he tended to use the grapheme-phoneme translation system, but he had severe problems with phonologically complex words.

Table IV. Error rates (percent) for spelling classified as phonetically accurate or inaccurate, for Phonological Synthesis and Phonological Analysis of members of dyslexic children.

| | Spelling Test | | Phonological Synthesis | | Phonological Analysis | |
	Ph. Accurate	Ph. Inaccurate	Words	Non-words	Letters	Syllables
Reading and spelling problems						
JO	55	45	10	50	6	33
LH	73	27	10	20	18	20
ST	–	–	60	80	12	67
SA	55	45	0	20	6	27
Reading problems only						
HI	54	46	10	30	12	47
Spelling problems only						
CH	32	68	40	70	12	60

His non-word reading was slow (3098 ms) and the sequences of letters were often coded incorrectly. The exposure time for each non-word was five seconds, but JO often did not give a response within the time limit, a typical pattern found in many dyslexics with phonological impairment. This was supported by the finding that phonological synthesis for non-words was affected (50% error rate). His spelling was characterized by both phonetically accurate (55% error rate) and phonetically inaccurate errors (45% error rate), indicating impairments in both routes. His low score (40% error rate) on the lexical decision task (homophone words) also reflected a problem with the orthographic route. However, the phonological route seemed to be the most impaired.
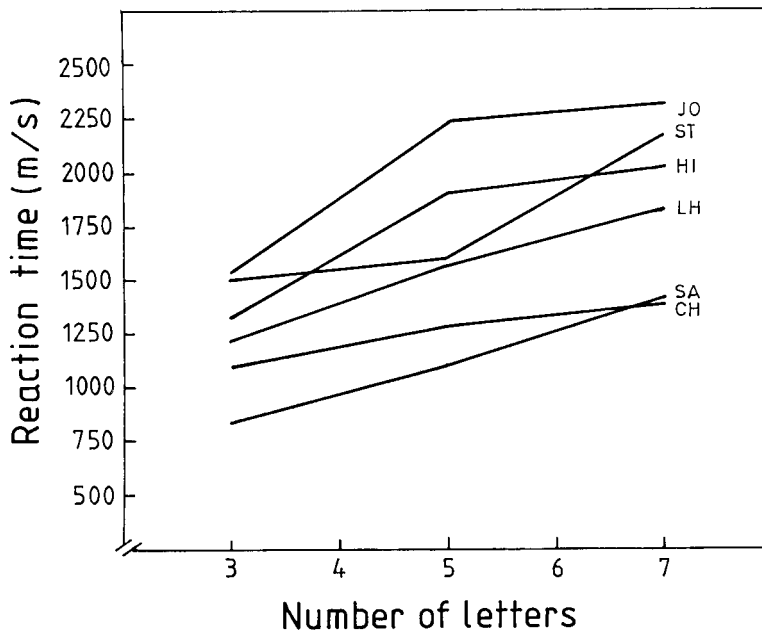
Figure 3. The reaction time for Reading Words Orally (3, 5, and 7 letters word) of the six dyslexic case-studies.

Subject LH

LH was a girl above average in intelligence (1.25) classified as a 'morphemic' dyslexic in reading and spelling. The orthographic route (25% error rate for briefly exposed words) was relatively more deficient than the phonological route (17% error rate for Non-words). LH's reading disclosed only small differences in grammatical class and high versus low frequency words. Length was more affected. She made mostly regularization errors and visual errors. Her reading behaviour was characterized by a phonic attack, reading letter-by-letter or letter groups. She sometimes also guessed when reading the short words. These results indicate that she is predominantly relying on a phonological strategy when reading. Non-word reading involved a somewhat slow response (3060 ms). However, she made few mistakes. Phonological synthesis and analysis involved no serious impairment. Her spelling errors also supported the finding of a predominantly orthographic impairment. The spelling errors were often phonetically accurate, but she had severe problems with the spelling of irregular words.

Subject ST

ST was below average ability (-1.8), and the most impaired of the dyslexic Ss presented. His reading and spelling performances showed evidence of severe disturbances in both routes. Due to this, he was classified in the 'mixed' group. ST's reading disclosed a difference in grammatical class and frequency. Length had also an influence. He made many errors in reading, especially phonological errors, incomplete reversals of letters and visual errors. He also exhibited confusion about letter identities. His reading behaviour was characterized by repetitions, especially for phonetically complex words, which he often misspelled. These results indicate that he is utilizing both routes when reading, and that neither of them is efficient. His non-word reading was somewhat slow (2521 ms). For long words he did not always respond within the time limit. He also had severe problems with phonological synthesis and analysis, indicating an inefficient phonological route. His spelling was severely impaired, and he refused to write many of the words presented. Because of this, the percentage of errors classified as phonologically accurate or inaccurate are not given. Even if the low score on the Lexical Decision Task reflected a problem with the orthographic route (35% error), several of the dyslexic Ss scored lower on this task than ST, indicating that his memory for correctly written words might be better than his phonological strategy. It could also be that his phonological impairment blocked the progress to the orthographic level in spelling. His poor handwriting obviously made it more difficult for him to spell correctly.

Subject SA

SA was a boy at the lower end of average ability (-.73). He had severe spelling problems, but his reading was also impaired. The orthographic route seemed to be the least efficient in reading. This was indexed by a higher error rate in word reading (32% error rate) than in non-word reading (17% error rate). He was classified as a 'morphemic' dyslexic in reading. The analysis of the effects on the linguistic factors revealed a difference on abstractness of meaning, word frequency and word length. His errors could be classified as regularization errors, visual errors, derivational errors, and confusions over letter identities. His reading behaviour was slow but fairly accurate. These results indicate that he is using both routes to assist word retrieval. Even if non-word reading was better than word reading, he also showed some impairments on this task, and his response time was somewhat slow (2566 ms). His spelling errors disclosed that both the orthographic route and the phonological route were impaired. Hence, he was classified in the 'mixed' group in spelling. His spelling errors were characterized by both phonetically accurate (55% error rate) and inaccurate errors (45% error rate). A low score on the lexical decision task (45%) reflected his problems with the orthographic route. He also exhibited confusion of letters (b/d,v/f), the same letters which he tended to confuse in reading. His poor handwriting probably made it harder for him to spell correctly.

Subject HI

HI was a girl of average ability (.31) classified as a 'morphemic' dyslexic. Even though she was identified as having reading disorders only, she still had some spelling impairments, and 40% of her words were spelled incorrectly. The orthographic route was most disturbed, and this was indexed by a higher error rate on word reading (36% error rate) than non-word reading (6% error rate). A 'morphemic' dyslexic is expected to show a reliance on the phonological route. Her reading was sensitive to variation in length, and her reading errors were regularization errors, derivational errors, incomplete reversal of letters and some visual errors. Her reading behaviour was characterized by a letter-by-letter approach or by reading letter groups. Short words were read in a wholistic way. This indicates that she primarily relied on the phonological route when reading. But her reading was also sensitive to variation of concreteness of meaning and frequency, suggesting that the orthographic route is used as a back-up strategy in word retrieval. Even if she had few errors in non-word reading, her reaction time was somewhat slow (2532 ms). Phonological synthesis and analysis were also somewhat impaired, suggesting that this route was not fully efficient after all. Besides, HI's spelling errors revealed an inefficient phonological route, and 46% of the errors were classified as being phonetically inaccurate. Perhaps these errors could be explained by the deficient phonological analysis of words.

Subject CH

CH was a boy of average intelligence (.12) with spelling impairments only. Both his word and non-word writing were severely impaired. The spelling errors were phonetically inaccurate (68%), and he confused the letters g/k and p/b. The absence of a proper phonological base seemed to block the progress to the orthographic level in spelling. Because of this, he was classified as a 'phonological' dyslexic, having predominantly a deficient phonological route. Even though he was not classified as reading disabled, his non-word reading was impaired, especially with regard to long words and decoding complex letter structures. Phonological synthesis and analysis were also severely deficient. His error level (25%) on the lexical decision task supported the finding that the orthographic route probably was the least deficient.

Comments

The six cases described had all more or less phonological strategy deficiencies. Even HI, who was the only individual with a low error rate on non-word reading, had a somewhat slow reaction time on non-word reading, and her spelling was characterized by some defect in the phonological route. All of the children had impairments in the orthographic route. This was expected for reading, as the selection of the dyslexic Ss was based on tests of word recognition and reading. Thus, the subgrouping of 'phonological' and 'morphemic' dyslexia can be based on the idea that the phonological and orthographic routes may be subject to different degrees of impairment, and that the assignment to the dyslexic subgroups can be done by reference to their primary impairment either in the phonological or orthographic

route. JO and CH could therefore be viewed as examples of 'phonological' dyslexics. CH had obviously adopted a compensatory strategy in reading, while JO was still relying on the grapheme-phoneme channel. LH and SA could be classified as 'morphemic' dyslexics with a relatively larger impairment in word reading than non-word reading. These children tended to rely on the phonological strategy when the orthographic strategy failed. However, in spelling SA was assigned to the 'mixed' group. ST's reading and spelling performance was very poor, and the impairment of the phonological and orthographic routes seemed to be of equal severity.

However, even if all the dyslexic children in the sample could be viewed as either a 'phonological', a 'morphemic' dyslexic or belonging to a 'mixed' group, the individual within a subgroup nevertheless differed considerably from each others. The study therefore confirms the <u>heterogeneity</u> of dyslexic children, and the groups seemed to represent a dimensional rather than a categorical model.

DISCUSSION

The main purpose of the present study was to identify and interpret the deficient reading and spelling functions of dyslexic children and investigate whether homogeneous subtypes could be found. It should be noted that selection criteria for the identification of dyslexic children differ within previous studies. As the definition of dyslexia in terms of a discrepancy between intelligence and reading and spelling achievement is adopted by many researchers (Thomson, 1984; Silva et al., 1985; Bjørgen et al., 1987), our selection procedure to identify dyslexic children appears to be reasonable. It should be noted that the procedure does not exclude children with low intelligence from being defined as dyslexics.

The decision as to the cut-off point used for estimating the number of children with dyslexia is necessarily somewhat arbitrary. By using the same criterion as Rutter and Yule (1975) in the Isle of Wight Studies, i.e., a difference of two standard scores between the observed and predicted performance levels, the prevalence of specific reading and spelling retardation in the present study was found to be low (2.6%). Therefore, the criterion was altered such that 7.8% of the sample was identified as dyslexic children, of whom 5.5% (1.3 standard score difference) were reading disabled and 5.5% (1.5 standard score difference) had spelling problems. This is in accord with the Dunedin study in New Zealand (Silva et al., 1985) where a 1.5 standard score difference between the observed and predicted reading levels was adopted, and 4.2% of the sample were identified as reading retarded. The prevalence of dyslexia in this study is also in accordance with estimates of dyslexia found in other studies in Norway, showing the same excess of boys (Bjørgen et al.,1987; Gjessing et al.,1988; Thygesen, in press). The different prevalence results in the present study and the Isle of Wight Studies may be a function of differences between research methods and samples used.

The results of the present study do not provide strong support for the identification of homogeneous subtypes among the dyslexic sample. This was evident for the word and non-word dimensions and also for the qualitative assessment. Even if the two

broad subtypes of 'phonological' and 'morphemic' dyslexics could be identified, these groups seemed to represent a dimensional rather than a categorical model. The subtype model predicts that the dyslexics on the word and non-word dimensions would cluster at different locations, the 'phonological' dyslexics showing predominant impairment on the non-word dimension, and the 'morphemic' dyslexics having impairment on the whole word dimension and a low or moderate impairment on the non-word dimension. Instead, the dyslexics were scattered over the whole surface in the scatterplot, suggesting a continuous variation on both dimensions. However, typical examples of the two subtypes were found, but they were rather extremes on a continuous distribution. The 'mixed' subtype that was found also indicates a continuous distribution, linking the extreme or typical cases of either subgroups. The prevalence of 'mixed' subtypes in other studies supports the evidence of a somewhat continuous distribution. However, it could be argued that the study comprised too few dyslexics, and that a larger sample of dyslexics would show a tendency of clusters of cases. The study should therefore be replicated with a larger sample. It should also be noted that classification of this kind is difficult and depends on the criteria used. Because of this, classification into dyslexia subgroups should be treated with some reservation. All the same, it gives an indication of the relative efficiency of the reading and spelling strategies.

Theoretical frameworks suggest that individual differences occur on various dimensions (Ellis, 1985; Fletcher and Morris, 1986). It follows therefore that one should examine the most important dimensions along which dyslexic children can be characterized.

There is now common agreement that phonological awareness is an important factor in early reading and spelling success. Phonological awareness refers to the conscious access of the phonemic level of the speech stream, and to the ability to cognitively manipulate the sound structure of spoken words (Lundberg, 1982 ; Bradley and Bryant, 1983; Olson et al., 1989). There is also evidence indicating that there is a developmental trend toward word-recognition via direct, visual access at more advanced stages of reading, leading to an integrated nature of reading in the fluent reader (Stanovich, 1986). The fact that Norwegian words are characterized both by regular spelling (words in which the letter-sound correspondence are predictable) and irregular spelling (spelling that is not predicted from the rules of spelling-sound correspondence) also suggests that the lexical and non-lexical dimensions are important when assessing developmental reading/spelling disorders. A comment should also be made on Norwegian teaching methods in beginning reading. A combination of whole word and phonic reading is the standard method in Norwegian schools. Thus, the method of contrasting the word and non-word dimensions as suggested by Ellis (1985) and Seymour (1990) to illustrate phonological and orthographic strategy deficiencies seems to be a reasonable and relevant method to use when diagnosing dyslexic children in Norway. The contrasting of the reaction times of words and non-words reading is also considered to be useful to demonstrate the efficiency of the two strategies (Seymour, 1990). This was not done in the present study.

However, the distribution of cases on a scatterplot will of course depend on the specific tests used and the age of the children. Seymour (1990) investigated the reading of non-words and low-frequency words, but the cases tended to fall below the diagonal of the scatterplot. The present study used the reading of non-words and briefly exposed words, and the reading disabled children were equally distributed on the plot. However, in spelling, the non-word test seemed to be too easy compared to the word spelling test. At this age, most of the children were able to write the two and three letter non-words. All the same, the method of contrasting words/non-words seem to be useful to assess strategy efficiency, but must be supplemented with an assessment and description of each individual child, indicating relative strengths and weaknesses on various dimensions. This may also be a profitable approach to find effective remediation of dyslexic children.

The analysis of the reading and spelling functions of the dyslexic cases demonstrated the number of ways reading and spelling performances may develop in dyslexic children and the various impairments that can occur in these children. A classification into broad dyslexic groups therefore does not provide sufficient information about dyslexic children. A strategy can be more or less deficient, mostly in combination with the inefficiency of the other strategy. This is in line with Berninger et al. (1991) who suggest that teaching word recognition has both visual or orthographic and linguistic or phonological requirements. The assignment of dyslexic children to different subgroups was done by reference to their primary impairment in either the phonological or orthographic route. Thus, the term 'morphemic' dyslexia means that the orthographic strategy was the most disturbed. However, nothing further could be implied about the status of the other functions or the strategic compensation adopted by the child. It has been assumed that the impairment of one route might result in a reliance on the less impaired route (Seymour, 1986). Thus, phonological dyslexics should be characterized by a tendency to rely on the orthographic route. This strategy of compensation was not always adopted by the dyslexic children in our study. At the age of 10, most of the children seemed to rely on the phonological route for word retrieval, using the orthographic strategy as a back-up procedure. However, CH and SI could be viewed as an example of 'phonological' dyslexics who compensated by relying on the orthographic route in reading.

In view of the dyslexic case-studies, the question arises whether the results support the developmental lag hypothesis or the deficit hypothesis. The first theory holds that some children have a delayed development of cognitive skills needed for literacy development, whereas the deficit hypothesis suggests that specific deficits will hinder the child from a normal reading/spelling development (Stanovich et al., 1988). According to Frith's (1985) developmental model it is expected that at the third and last stage the orthographic strategy will emerge first in reading and than be later transferred to spelling. This pattern was evident in three dyslexic children (RE,RA,TO) with spelling problems only and might therefore support the developmental lag theory with respect to these children. Another possibility is that they might have analytic visual processing disorders as described by Seymour (1987b) which are associated with a good reading/poor spelling pattern.

According to Stanovich et al. (1988) the developmental lag model is useful as theories of the mild reading disorders within the normal variation, whereas a specific deficit model is more appropriate to use with respect to the specifically disabled reader defined on the basis of IQ/reading dissociation. Since the dyslexic children in this study were defined in this way, it should therefore be expected that a specific deficit is involved. Many studies of specific reading/spelling disorders support the deficit theory (Trites and Fiedorowicz, 1976; Bradley and Bryant, 1983; Olson et al. 1989; Lundberg and Høien, 1990).

Most of the dyslexic case-studies in the present study also seemed to supported the deficit model. All of the dyslexic children had more or less evidence of phonological deficits. Even the three 'morphemic' dyslexics (RA,RE,TO), with spelling problems only, had spelling errors which revealed an inefficient phonological route. Another example is LH, a 'morphemic' dyslexic who showed a slow reaction time in reading non-words. This result is in line with Seymour (1986), who found that all the subjects in the dyslexic sample gave some evidence of inaccuracy or reaction time delays in reading non-words. There was also some evidence that a few of the dyslexic children were relatively competent readers despite their phonological impairment (CH, SI). This raises questions about the necessity of going through the reading stages in the order proposed by Frith (1985), and how phonological awareness might impair reading (Bradley & Bryant, 1983). The development of the orthographic route therefore seems to be dependent on other factors than those mediated by the phonological route. One might also ask if these children actually relied on a combination of orthographic and logographic strategies in reading. If so, this support Seymour's (1990) variant of the developmental model where concurrent development of the logographic and orthographic systems might occur. However, in these two children spelling was impaired in both routes. Spelling competence, therefore, seems to be dependent on the efficiency of both routes. The fact that some of the dyslexic children were classified in different subgroups in reading and spelling also indicated a somewhat different development for reading and spelling. Nor were all the children with reading disability identified as spelling disabled, and vice versa. Besides, it was suspected that poor handwriting might influence the spelling performances of some of the children.

The finding that the dyslexic children were more or less deficient in both routes may also support Stanovich's (1986) developmental version of the specificity hypothesis. According to this hypothesis, the dyslexic children are characterized by a phonological deficit upon entering school. This deficit makes it difficult for the child to understand the alphabetic principles and leads to less exposure to reading experience. This prevents the development of the rapid and precise orthographic representations in the mental lexicon. The reading failure has motivationally negative effects which lead to even less exposure to reading and writing. A comment should also be made on the possibility that there may be a small group of dyslexic children with a core problem in orthographic processing. Recently, Stanovich (1991) states that some children seem to have severe problems in accessing the lexicon on a visual/orthographic basis.

The search for subtypes tends to be interpreted as if the different subgroups stand for something permanent and unchangeable. Longitudinal case-studies of dyslexic

children should therefore be undertaken to investigate if strategy deficiencies are stable in these children, and whether they can be classified as being predominantly 'phonological' or 'morphemic' dyslexics over a period of several years. Such studies could throw light on the question of whether dyslexia can be viewed as a delayed development or if specific deficits prevent the child from a normal reading/spelling development.

Studies should also be undertaken to investigate whether the dyslexic subgroups of Boder (1973) and Gjessing (1977) are comparable to the subgroups based on strategy deficiencies. According to the subtype classification within the clinical tradition (Boder, 1973) most of the dyslexic children are classified as 'dysphonetic' (67%), and only a minor proportion of the children are 'dyseidetic' (10%) dyslexics. It seems reasonable to think that 'morphemic' and 'dyseidetic' dyslexics and 'phonological' and 'dysphonetic' dyslexics are parallel order for Seymour and Boder terms. Our result showed that 35% in reading and 32% in spelling were classified as 'phonological' dyslexics, and 35% in reading and 47% in spelling were 'morphemic' dyslexics. The rest belonged to the 'mixed' group. This indicates that the two assessment procedures differ. This result, however, was more in line with the Norwegian assessment procedure of Gjessing et al. (1988) who found that about 40% of the children belonged to the 'auditory' dyslexic group. Gjessing's 'visual' group comprised about 30% of the children, and the combined 'auditory-visual' group 10%. In his dyslexic sample he also included a group of children with emotional and educational dyslexia (20%), and he states that several of these children resemble the 'visual' subgroup, but most of them were ambiguous with respect to subgrouping. In the present study these problems were not investigated, and most probably the emotionally and educationally handicapped children were classified in the 'mixed' or 'morphemic' group. It should be noted that classification of this kind is difficult and depends on the criteria used.

A comment should also be made on the term 'morphemic' dyslexia. The term suggests that an individual is using orthographic knowledge to read words and not immediate word recognition. However, this subgroup is expected to show a deficiency in whole word reading, i.e., the specific words have not become part of the reader's print lexicon. The term 'morphemic' therefore does not give a precise description of this dyslexia subgroup. On the other hand, it may be difficult to distinguish a whole word strategy from a morphemic strategy.

The methods and theories used in the present study are based on a combined developmental/information-processing model. This approach has only recently been adopted as a guide for research on dyslexic children. There is currently no clear agreement about theories of development and the cognitive architecture involved in reading and spelling. The information-processing models are to a certain degree speculative and the dual-route theory has recently been challenged on theoretical grounds. Seymour (1990) also suggests that the developmental stages in reading acquisition will depend on the interaction of individual factors and teaching methods. All the same, this procedure seems to be a promising method for the understanding of developmental dyslexia. Systematic experimental investigations together with longitudinal studies are still needed to test the validity of the theories.

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