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Dyslexia: Relevance of Concepts, Validity of Measurements, and Cognitive Functions

BY

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Abstract

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The thesis opens with an exposition of different uses of the term dyslexia. In that context its conceptual relevance is discussed. The empirical studies investigate a) different aspects of validity of cognitive and achievement instruments often used in diagnostic assessment of dyslexia, b) different cognitive profiles for adults with dyslexia, and c) the relationship between cognitive and achievement measures.

Study I demonstrated the factor structure of the Swedish WAIS-R to be in close agreement with results of comparable analyses on normal and clinical groups in many countries world-wide, giving strong support for the construct validity of the Swedish WAIS-R for a group of adults diagnosed with dyslexia. The results from the three-factor solution were interpreted in terms of theoretical constructs, notably those posited by Carroll (1993) and Horn (1989).

The cognitive profiles of a sample of Swedish adults diagnosed with dyslexia—when using the three factors, the ACID profile, and the four-category Bannatyne profile—all resemble closely the profiles observed for a wide array of U.S. samples of children and adults diagnosed with dyslexia or learning disabilities. Gender differences on Digit Symbol, favoring females, were substantial in magnitude for the present sample, consistent with a bulk of research on gender differences for samples of normal individuals and of those identified with learning problems.

In Study II, factor analysis of nine Swedish achievement tests often used for dyslexia assessment yielded five meaningful factors in a group of adults diagnosed with dyslexia. Factors appeared to measure decoding, visual speed, reading comprehension, reading fluency, and phonological ability. The relationship between the five achievement factors and WAIS-R variables was subsequently examined. The Visual Speed and Reading Comprehension factors each correlated significantly with four of six global WAIS-R scores (two of three IQs and two of three factor scores). Visual Speed tended to correlate significantly with nonverbal scores and Reading Comprehension with verbal scores. Although the Phonological Ability factor did not correlate significantly with any verbal or nonverbal global score, it did correlate significantly with the Freedom from Distractibility factor and with all its component subtests—Digit Span, Arithmetic, and Digit Symbol. Decoding (technical reading skill) showed no significant relationship to any WAIS-R variable studied. More surprisingly, the Reading Fluency factor failed to show significant relationships to the WAIS-R.

Study III examined the validity of The Word Chain Test, a frequently used instrument in Swedish screening and diagnostic assessments of dyslexia. Different sources of validity evidence were evaluated. In summary, the results failed to support validity both for the WRI-index and the Wordchain subtest, suggesting that the instrument seems to be of questionable value in screening or diagnostic assessment of dyslexia.

Keywords: Learning disabilities, learning disorders, specific learning difficulties, reading disability, reading disorder, WAIS-R

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To my beloved Rüya, my greatest gift

The present thesis is based on the following studies, which will be referred to in the text by their Roman numerals:

I. Alm, J., & Kaufman, A. S. (2002). The Swedish WAIS-R factor structure and cognitive profiles for adults with dyslexia. *Journal of Learning Disabilities, 35,* 321-333.

II. Alm, J., & Melin, L. (2003). *Achievement factors in dyslexia assessment: Relations to cognitive factors.* Manuscript submitted for publication.

III. Alm, J., Bringhammar, C., & Melin, L. (2003). *A validation study of the Swedish Word Chain Test.* Manuscript submitted for publication.

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INTRODUCTION

A historical background

In 1884, a German ophthalmologist named Berlin introduced the term "dyslexia" (Hallahan & Mock, 2003). The denotation then was "acquired reading disability," that is, loss of existing reading abilities. The first case study of developmental dyslexia, referred to as "congenital word-blindness", was published in the *British Medical Journal* in November 1896 by the English physician Pringle Morgan. He describes a boy who would be the smartest lad in school if instruction was entirely oral, according to the school-master who taught him for some years (as cited in Critchley, 1970). This first case study paints the classic picture of dyslexia: good general intellectual ability paired with a specific disability in learning how to read. These core defining characteristics hold even today as displayed by diagnostic and classification systems like *Diagnostic and Statistical Manual of Mental Disorders*, fourth edition (*DSM-IV-TR*; American Psychiatric Association, 2000) and *The ICD-10 Classification of Mental and Behavioral Disorders* (*ICD-10*; World Health Organization, 1992), thereby reflecting the classical definition of developmental dyslexia established by the Word Federation of Neurology in 1968 (Critchley, 1970):

> Dyslexia is a disorder manifested by difficulty learning to read, despite conventional instruction, adequate intelligence, and sociocultural opportunity. It is dependent upon fundamental cognitive disabilities which are frequently of constitutional origin.

In the classic definition the term "dyslexia" only denotes specific reading difficulties. In daily use the term dyslexia has, over time, broadened to also include specific difficulties in writing and spelling; sometimes even specific problems in mathematics are included (British Dyslexia Association, 2002, p. 67). In Sweden the term "dyslexia" is used quite ambiguously and often broadened to include all kinds of reading and writing difficulties. The terminology I encounter in most assessments, excluding psychological, is simply "reading and writing difficulties/dyslexia". In the formal diagnostic and classification systems of *DSM-IV-TR* and *ICD-10* the distinctions between specific difficulties in reading, writing, and mathematics are maintained. In *DSM-IV-TR* these disorders are subdivisions of the general diagnostic category “Learning Disorders”. In the original *ICD-10* (1992) the comprehensive term is “Specific developmental disorders of scholastic skills”. In the Swedish version of *ICD-10* (1997), that label has been changed to “Specific Developmental Disorder in Learning Skills”, indicating an influence from the *DSM-IV* terminology.

Reading disability is often accompanied by difficulties in spelling and writing and sometimes by problems in arithmetic calculations (Miles & Miles, 1992, preface). Miles (1992, p. 1) summarizes some of the more important indications of dyslexia as “lateness in learning to read, relatively weak spelling even after many hours of tuition, weak memory for disconnected items in series, such as the months of the year or visually or auditorily presented digits, and uncertainty over left and right.” He further states: “All or most dyslexics have mathematical difficulties of some kind….” In the foreword they say: “The central theme of this book is that the difficulties experienced by dyslexics in mathematics are manifestations of the same limitation which also affects their reading and spelling.” Thereby evidently viewing dyscalculia, more or less, as an unnecessary term.

Gradually it also became evident that the cognitive and neurological backgrounds to these difficulties also have other important implications for school, work, and social life (Bartlett & Moody, 2000; *DSM-IV-TR*, 2000; Frith, 1999; McLoughlin, Leather, & Stringer, 2002). As associated features and disorders, *DSM-IV-TR* mentions demoralization, low self-esteem, and deficits in social skills; it also indicates that adults with learning disorders may have significant difficulties in employment or social adjustment. There is also a higher prevalence of Learning Disorders (10%-25%) in groups diagnosed with Conduct Disorder, Oppositional Defiant Disorder, ADHD, Major Depressive Disorder, or Dysthymic Disorder.

There has been increased attention to and awareness of the many problems associated with dyslexia, the most important being low self-esteem and a persistent feeling of being stupid[1]. A broad cognitive assessment constitutes a basic part of a diagnostic assessment of dyslexia (Green & Moats, 1995; Educational Testing Service, ETS, 1999). The cognitive assessment also shows the individual’s learning strengths and weaknesses, and often provides a cognitive explanation to the problem. Further, it is

[1] Few things have been so rewarding in my professional career as being able, after a two-hour assessment of intelligence, to show the individual documentation that his or her intelligence is normal or even above normal. This two-hour assessment of cognitive functions often gives an immediate and considerable enhancement in self-confidence, an effect that I believe would be almost impossible to gain otherwise.

essential in building intervention programs to make both the teacher and the individual aware of his or her preferred style of learning. Dyslexia is a specific problem in learning that needs to be uncovered during an evaluation; that evaluation, at the same time, has to offer insights into the person's cognitive and behavioral integrities, which can be used to facilitate the individual's learning and compensation. To briefly summarize Chasty's crucial point (1994): "If this child cannot learn the way you teach, can you teach him the way he learns?"

In 1962 Dr Samuel Kirk introduced the term learning disabilities (LD) as an umbrella term for failure in basic academic areas and gave the following definition (Hallahan & Mock, 2003):

> A retardation, disorder, or delayed development in one or more of the processes of speech, language, reading, writing, arithmetic, or other school subject resulting from a psychological handicap caused by a possible cerebral dysfunction and/or emotional, or behavioral disturbances. It is not the result of mental retardation, sensory deprivation, or cultural and instructional factors.

In a further display of U.S. policy, obviously being a very important influence to other countries, Hallahan and Mock (2003) indicate that Gerald Ford, in 1975, signed a law that required school districts to provide free and appropriate education to all their students, including students with LD. When the law reached full implementation in 1977, the U.S. Office of Education put forth a definition of LD that remains, with minor changes, the same definition used today:

> The term "specific learning disability" means a disorder in one or more of the psychological processes involved in understanding or in using language, spoken or written, which may manifest itself in an imperfect ability to listen, speak, read, write, spell, or to do mathematical calculations. The term does not include children who have LD which are primarily the result of visual, hearing, or motor handicaps, or mental retardation, or emotional disturbance, or environmental, cultural, or economic disadvantage.

The U.S. Office of Education's regulations, even if not explicitly stated, did retain the general idea of the need for a severe discrepancy between achievement and intellectual ability for a LD diagnosis. In the 1997 reauthorization of the Individuals with Disabilities Education Act (IDEA), the federal law regulating special education for LD students still is an expression of Kirk's ideas expressed in 1962 (Hallahan & Mock, 2003). This law is currently under revision and will very likely eliminate the need for an ability-achievement discrepancy for diagnosing LD, will put more stress on intervention, and has response to intervention as one defining aspect of LD.

Since that first article by Dr. Pringle Morgan there have been a plethora of proposed definitions of dyslexia from scientists, clinicians, and different dyslexia organizations. The classic definition has been criticized on different grounds, but is still the definition that most often regulates dyslexia research and diagnostic assessments (*DSM-IV-TR*, 2000; ETS, 1999; *ICD-10*, 1992; Kaufman, 2002, p. 318). An example of the huge difference in perspectives is that a prominent researcher like Professor Margret Snowling (2000, p. 15) asserts that the World Federation of Neurology's definition has fallen out of use.

Currently, different definitions have been proposed where reference to normal intelligence or spared cognitive resources has been left out as a defining characteristic. The most forceful and persistent claims against normal intelligence as a defining part of dyslexia have been put forth by two well-known researchers—Keith Stanovich and Linda Siegel. In a great number of articles (e.g., Siegel, 1989, 1999; Stanovich, 1989, 1999) they have argued for their position, and these views have been very influential, especially in educational settings. One point of argument for leaving out intelligence stems from a predominating theory that defines dyslexia as a deficit in the phonological system. This theory states that the cognitive background of dyslexia is a defect in the processing and representation of speech sounds (Stanovich, 1988a, 1988b; see also Lundberg & Høien, 1989; Snowling, 2000). The line of arguments from that Phonological Deficit Hypothesis to the exclusion of intelligence is somewhat unclear. It seems to emanate from a long held opinion by these and other researchers that the problems of phonology were specific to the dyslexic group, as defined by a discrepancy between general ability and reading ability. It was then repeatedly demonstrated that the phonological problems were not specific to dyslexic readers, thus defined, but were also found in non-discrepant readers, often termed the "garden variety" group (Stanovich 1988b; Nicolson, 1996). These findings have then been used as one argument for removing intelligence as part of the definition.

In November 1996, a special issue of *Dyslexia*, Europe's leading scientific journal on dyslexia, was devoted to the question of dyslexia and intelligence. In that special issue and in later publications (Stanovich, 1999; Siegel, 1999) more elaborate arguments for excluding intelligence from the concept of dyslexia were given. In addition to the argument that phonological problems are found at all levels of intelligence (maybe for different reasons, as pointed out by Frith, 1999, and Nicolson, 1996, p. 196), other reasons for excluding intelligence from the definition are also offered: (a) intelligence is not relevant to the decoding process; (b) intelligence tests, themselves, are crude measures of a problematic concept; and (c) intelligence is irrelevant to intervention (Stanovich, 1999, p. 352). Stanovich states: “There is no evidence that low-IQ and high-IQ readers respond differently to treatment.” In defense of the classical view, Nicolson (1996) points out that Stanovich is mixing up symptoms with causes. Stanovich defines dyslexia in terms of reading, which obviously is a *symptom* of some cognitive problem in information processing with a possible neurological origin. As also pointed out by Frith (1999, p. 197), “on the one hand the absence of reading difficulties can be seen to be compatible with dyslexia, while on the other hand the presence of reading difficulties may have nothing to do with dyslexia. A definition of dyslexia in terms of performance on reading tests would get the diagnosis hopelessly wrong.” The dyslectic problem of reading is compatible with fever being one symptom of measles (as exemplified by Frith, 1999) or one symptom of malaria (as exemplified by Nicolson, 2001, p. 90). To define, research, diagnose, and intervene in terms of reading is much like defining, researching, diagnosing, and intervening on the level of fever in the cases of measles or malaria.

Those who argue in favor of eliminating intelligence tests from LD diagnosis indicate that research fails to support the notion that intelligence is a crucial factor in intervention. Their conclusion that, therefore, intelligence is not important for intervention is, indeed, surprising since intervention means new learning and intelligence obviously is strongly related to learning. In later years the issue of comorbidity has received much attention. Different additional diagnoses are needed in many cases of dyslexia (Hynd, 2002), thereby making stronger demands for qualified diagnosticians being able to conduct differential diagnosis and account for comorbid conditions.

Concepts and terminology

Science can be viewed as resting on three pillars: facts, theories and concepts. Machado, Lourenco, and Silva (2000) argue that whereas scientific progress requires a balance among investigations into these three areas, psychological research strongly favors factual investigations. They further argue that this situation is brought about by “the obsession of psychology with a narrow and mechanical view of the scientific method and a misguided aversion to conceptual inquiries”. In their review of current scientific psychology, the authors show evidence for an overemphasis on methodological issues in reviews, evaluations, and publications of psychological studies in scientific journals and a simultaneous lack in the requirements for clarity and scientific rigor concerning theories and, especially, their concepts.

This lack of conceptual clarity is exemplified in the area of dyslexia. As cited by Morrison and Siegal (1991), Cruickshank, as early as 1972, observed that more than 40 English terms had been used in the literature to refer to some or all of the children subsumed under the LD label. In a survey by Wassmouth (1983), the same number of different terms are enumerated. The terminology used to describe the syndrome of dyslexia and LD naturally mirrors the understanding of the concept. Dyslexia, in the beginning termed "congenital word blindness" (Hallahan & Mock, 2003), indicated from the start, a supposed genetic basis and a connection to the visual system. It further indicates the conception that the affliction is specific to reading. That idea of defining dyslexia just in terms of reading has been lingering until today. The more simplified term "word blindness" was used for a long time in Sweden and is still used, but nowadays quite infrequently.

Parallel to this, the expression "specific reading and writing difficulties" came into frequent use in Sweden. This terminology reflects the important observation that problems in learning to read often go together with problems in spelling and free writing. This term also reflects an understanding of dyslexia as just confined to problems in reading and writing. In Sweden the term "dyslexia" came into use in the early 1950s (Nationalencyklopedins Ordbok, 1995). The term gave a more scientific and medical flavor to the phenomenon, and suggested medical doctors as diagnostic resources. However, there was, and still is, no way to diagnose dyslexia on purely medical grounds, except by an anamnestic interview to ascertain that some typical pattern of the syndrome is evident. That is, however, only one part of a diagnostic assessment. A complete evaluation must also include a broad cognitive assessment coupled with assessment of different levels of reading, writing, spelling, and mathematics. To label a person as dyslexic only from an interview is obviously not acceptable.

The term LD denoted a specific deficit in learning underlying the symptoms of specific problems in learning how to read, write, and do mathematics. It was defined as a psychological processing problem, that is a problem in learning. The term learning disability or learning disabilities (LD) is currently the preferred term in the U.S. In England the preferred term is specific learning difficulties—SPLD, often written as SPLD/dyslexia (Alm, 2000; Nicolson & Fawcett, 2001, p. 142). The terms LD or SPLD are quite often used synonymously with dyslexia. To provide a clearer statement that it is a specific problem, as opposed to a general learning problem, the term "specific learning disabilities" has gained increased use in the U.S.

There have been different attempts to gain conceptual clarification (e.g., Fawcett & Nicolson, 2001; Frith, 1999). Fawcett and Nicolson argue that a conceptual confusion has arisen by looking at dyslexia mostly from a symptomatic level and thereby mixing up cause, symptoms and remediation. Fawcett and Nicolson (see Fig. 1) makes an analogy with the field of medicine. This analogy also indicates a lack of agreement on the causes of the affliction, as well as often missing important symptoms. The figure also points out that remediation should rest on a causal level more than on a symptomatic level.

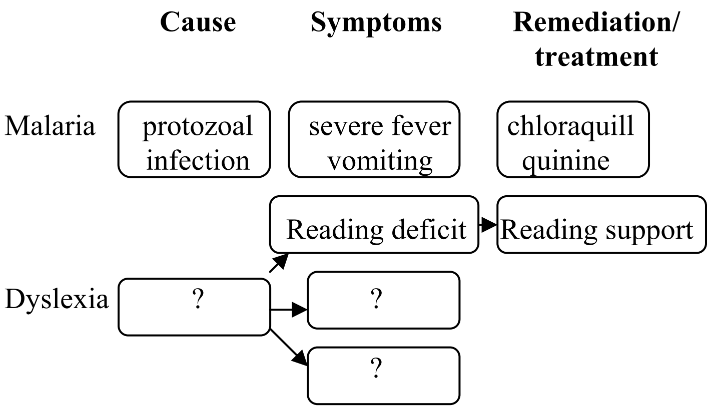

Fig 1. Targets for a causal analysis.

Frith argues that paradoxes in the definition of dyslexia have arisen because dyslexia has different levels with very different appearances (see Fig. 2), and that "dyslexia can be defined as a neuro-developmental disorder with a biological origin and behavioural signs which extend far beyond problems with written language. At the cognitive level, putative causes of the behavioural signs and symptoms of the condition can be specified".

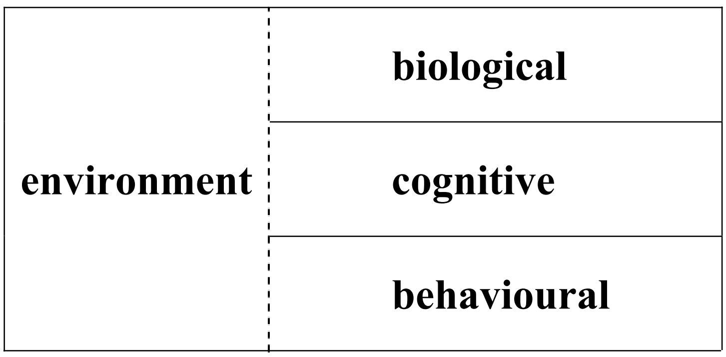

Fig. 2. The three-level framework.

Theories of dyslexia

Nicolson and Fawcett (2003) reviewed five current theories on dyslexia which are summarized here.

1) The Phonological Deficit Hypothesis (PDH) asserts that the underlying cause of reading problems in dyslexia is some abnormality in phonological processing—that is, breaking down a word into its constituent sounds. These difficulties cause problems in sound segmentation and also in word blending, both of which are critical for the development of reading and spelling (Bradley & Bryant, 1983; Lundberg & Høien, 1989; Stanovich, 1988b)

2) The Magnocellular Deficit Hypothesis emphasizes the person's difficulties in processing rapidly changing visual or auditory stimuli (Lovegrove, 1994; Stein, 1989, 1994; Tallal, Miller, & Fitch, 1993). Livingstone, Rosen, Drislane, and Galaburda (1991) have demonstrated that analysis of brains in the Orton dyslexia brain bank indicates significantly fewer magnocells in the visual and auditory pathways of dyslexic than non-dyslexic brains. This problem with slow processing could also serve as an explanation of the phonological problems experienced by individuals with dyslexia (Tallal et al., 1993). Stein and Tallal argue, independently, that dyslexic children have abnormal magnocellular pathways, and that this abnormality causes the reading problems.

3) The Double Deficit Hypothesis (e.g., Wolf & Bowers, 1997) argues that dyslexic children suffer from two crucial deficits: (a) Phonological processing problems and (b) Rapid processing problems, as measured by Rapid Automatized Naming (RAN) tests.

4) The Automatization Deficit Hypothesis (Nicolson & Fawcett, 1990) stipulates that the concept of an automatization deficit provides a coherent framework for the explanation of the range of problems shown by dyslexic children. Dyslexic children will have difficulties on any task that requires automatization of a skill. Even on tasks where they appear to be performing normally, they have to try harder to achieve the same results as non-dyslexic children. This theory of dyslexia has its inception in learning theory, a surprisingly new framework in dyslexia research, despite the fact that the umbrella terms for dyslexia are *(specific) learning disabilities* and *specific learning difficulties.*

5) The Cerebellar Deficit Hypothesis posits abnormalities in the cerebellum as an underlying causal factor of dyslexia (Nicolson, Fawcett, & Dean, 2001).

When considering the five theories together, the Phonological, Double Deficit, and Automatization theories view dyslexia from a *cognitive* level while the Magnocellular and Cerebeller theories operate on the *neurological* level.

Prevalence

One very fundamental problem in dyslexia research is the divergence in definitions. Research studies on dyslexia, with the disorder defined differently, means different inclusion and exclusion criteria. That problem reduces the value of many studies because research findings come from very different samples. Some "dyslexia" research is based simply on individuals with low achievement in reading and writing, while other studies add measures on phonological ability. The majority of studies use the classic definition from 1968 by also taking normal general ability into account, along with other cognitive deficits. Dyslexia is, in itself, a heterogeneous set of disorders, but with one consistent characteristic—*it involves a specific problem in learning to read* and write. Low achievement in reading and writing is often due to different environmental factors. Furthermore many other cognitive factors, besides phonological ability, are important determinants of learning how to read and of reading achievement (see e.g., reviews by Flanagan, Ortiz, Alfonso, & Mascolo, 2002, p. 61; McGrew & Flanagan, 1998, p. 38). With that in mind, it becomes hard to interpret research findings where dyslexia is defined in terms of low achievement on tests of reading and writing. Similarly, when deficits in phonology are added as a criterion for inclusion, the findings are likewise hard to interpret—for example, in studies of prevalence. The difficulties are further emphasized by Frith (1999) pointing out, that phonological problems in association with sociocultural disadvantage and low general ability are hard to interpret, stating that it is difficult "to diagnose phonological deficits in the presence of environmental disadvantage and low 'g'. In this case, poor test performance is over-determined." Also, in the context of several other competing theories, it is obviously inadequate to define dyslexia solely in terms of phonology. In light of these considerations, the classic definition of dyslexia still seems to be the best working definition. It includes different cognitive functions as causal candidates and excludes environment and low general ability as confounding variables.

Given the different definitions of dyslexia, the stated prevalence of dyslexia differs. *The International Book of Dyslexia* (Smythe, 1997, p. 238) shows numbers from 14 different countries around the world and the range of stated incidence is from 1% to 11%. According to the American Psychiatric Association (1994) the prevalence of Reading Disorder (dyslexia) in the United States is estimated at 4% of school-age children. The British Dyslexia Association estimates the prevalence to 4% (BDA, 1998). In Sweden the prevalence is estimated to 5-10% (Høien & Lundberg, 1992).

Diagnostic assessment of dyslexia

The classic definition states that dyslexia is caused by disturbances in basic cognitive processes. As stated by Frith (1999), the assessment of dyslexia should not only include measures of reading, writing, and intelligence, but also neuropsychological tests. A similar additional requirement is to measure information processing as well as cognitive strengths in diagnostic assessments of dyslexia (ETS, 1999). The leading test instrument for individual assessment of cognitive functions and intelligence has for several decades been the Wechsler scales.

A validation study examining the factor structure of the Swedish WAIS-R for adults with dyslexia was, therefore, a natural starting point for the thesis. Surprisingly, no validation study on the Swedish WAIS-R has been published. No previous investigation into the factor structure of the Swedish WAIS-R for normal populations, much less for different clinical groups, existed. After the factor structure of the Swedish WAIS-R had been investigated, the next step was to investigate if the cognitive profiles found in groups with dyslexia abroad also held for a Swedish adult group with dyslexia.

It was also interesting to find out about the factor structure of literacy tests often used to document the achievement part of the assessment and, subsequently, to relate these factors to cognitive factors.

Finally it was of interest to look into the validity of actual measures used in the assessment of dyslexia. For that purpose, the frequently used Word Chain Test was chosen.

Aims of the thesis

The general aims of the empirical studies included in this thesis were:

(a) to investigate the factor structure of the Swedish version of WAIS-R for an adult group with specific learning disabilities/dyslexia.

(b) to examine the cognitive profiles for a group of adults with specific learning disabilities/dyslexia

(c) to investigate the factor structure of achievement tests commonly used in dyslexia assessment in Sweden

(d) to examine the relationship between achievement and cognitive factors; and

(e) to examine the validity of a frequently used test in the screening and diagnostic assessment of dyslexia.

THE EMPIRICAL STUDIES

Method

Participants

The results of Study I are based on 88 adults with dyslexia. Study II includes 68 participants, 33 from Study I and 35 additional adult subjects with dyslexia. In Study III the 68 subjects from Study II were compared to a group of 64 adult subjects without dyslexic problems. The dyslexic and control groups in Study III had similar educational backgrounds, both with a median educational level of two years of senior high school and were comparable in age, with a mean age of 29.1 and 29.7 years respectively. There was a somewhat lower proportion of females in the dyslexic group than in the control group, 31% compared to 53%.

Measures

Both in Study I and Study II the Wechsler Adult Intelligence Scale-Revised, WAIS-R are discussed from different viewpoints. To familiarize the reader with the structure and terminology used, the following information could be helpful (see also Table 1, 2 and 3 below).

The WAIS-R consist of 11 subtests, six verbal and five non-verbal or performance subtests. Dr David Wechsler, the originator of the test, proposed the following basic composites. All subtests can be summarized to get a Full scale IQ (FIQ). The verbal and performance subtests can be summarized among themselves to give a Verbal IQ (VIQ) and a Performance IQ (PIQ) respectively. Different normative scales are used for subtests and the IQs. The subtest results are given in “Scaled scores”. Scaled scores have a mean (*M*) = 10 and a standard deviation (*SD*) = 3. The IQ scores as well as composite scores have a mean = 100 and a standard deviation = 15.

However, factor analytic investigations have often found a more complex factor structure. In these analyses the verbal scale often splits up into two factors, a Verbal Comprehension (VC) and a Freedom from Distractibility

(FD) factor. The VC factor can be seen as a more clearly unidimensional factor of higher verbal functions, while the FD factor can be seen as a measure of “lower” cognitive functions, such as short term and working memory and sequential ability. The factor, being sensitive to a number of clinical problems, is also a measure of behavioral components, such as attention and motivation. As is found in the Verbal scale, the performance subtests also give rise to a more clearly unidimensional non-verbal factor called Perceptual Organization, which includes only three of the five performance subtests.

From a clinical perspective another often used system for categorization is the one proposed by Bannatyne (1974) and further developed by Kaufman (1990, 1994, 2002). Bannayne splits the verbal scale into two different factors, a Verbal Conceptualization factor and a factor of Acquired Knowledge, the latter including subtests especially sensitive to enriched environment and school knowledge. Bannatyne also proposes a more clearly unidimensional performance factor called Spatial Ability, which includes the same subtests as the PO factor. A forth factor called Sequential Ability is composed of the two FD subtests and the Coding subtest from the performance scale.

Another often used categorization of WAIS-R subtests is the ACID-profil. The ACID profile is so-named based on the initial letters of the four subtests that compose it—*A*rithmetic, *C*oding/Digit Symbol, *I*nformation, and *D*igit Span. This profile has been found to produce characteristically low scores relative to the normative mean in many previous studies of samples of children, adolescents, and adults diagnosed with dyslexia or learning disabilities.

Study I

Introduction and aim

The most meaningful generalization regarding the factor structure of the original WAIS-R is that there are three dimensions that emerge for a wide variety of normal and special samples. The two main and omnipresent factors are Verbal Comprehension (VC) and Perceptual Organization (PO). A third, smaller, dimension has been assigned labels like Freedom from Distractibility (FD), Memory, Sequential Ability, and Number Ability, and has emerged alongside the two hypothesized dimensions in most factor analyses of normal and clinical samples of children, adolescents, and adults (Kaufman, 1979, 1990, 1994; Kaufman & Lichtenberger, 1999, 2000).

Similarly, samples of individuals with learning disabilities or dyslexia, and other samples with similar labels that are united by displaying academic problems despite normal intelligence, have yielded characteristic group profiles on Wechsler's scales, including the WAIS-R. From a factor-analytic perspective, the most typical profile for individuals with dyslexia has been PO > VC > FD (Gregg, Hoy, & Gay, 1996). Bannatyne's (1974) recategorization of Wechsler's subtests has also produced typical profiles for individuals with learning disorders. These samples invariably perform best on Spatial Ability (akin to PO) and worst on Sequential Ability (akin to FD), with the VC analog (Verbal Conceptualization) and the Acquired Knowledge grouping yielding intermediate scores (see e.g., Frauenheim & Heckerl, 1983; Kaufman, 1990, chap. 13; Sandoval, Sassenroth, & Penaloza, 1988). Although these patterns do not maintain for some specialized samples, such as college students with learning disabilities (Morgan, Sullivan, Darden, & Gregg, 1997; Salvia, Gajar, Gajria, & Salvia, 1988), they do seem to characterize most samples of adults with dyslexia. However, most data are based on U.S. samples, and none have been from Sweden.

In addition, samples of females and males with learning disabilities or dyslexia sometimes differ in their factor patterns or Bannatyne patterns because one of the three component subtests of Sequential Ability (and often of FD, when a three-subtest factor is interpreted) is known to yield large gender differences in favor of females: Digit Symbol (Kaufman, 1990; Vogel, 1990). Consequently, gender differences on the separate WAIS-R subtests were examined in this study, to help understand possible gender difference in the cognitive patterns for females versus males.

Therefore, the aims of this study were: (a) to analyze and describe the factor structure of the Swedish version of WAIS-R for a group of adult individuals with dyslexia, and relate these findings to factor-analytic studies on the U.S. standardization sample and on different clinical samples in the U.S.; (b) to examine profiles on various cognitive abilities (e.g., the three factor scores and the four Bannatyne categories) for an adult group with dyslexia and relate these results to previous research findings with a variety of samples of individuals diagnosed with learning disabilities or dyslexia; and (c) to investigate significant gender differences on individual subtests.

Method

Participants

Eighty-eight adults with dyslexia were tested on the complete Swedish WAIS-R. The group consisted of 55 males and 33 females with a median age of 29 years (range = 17-50 years). The educational backgrounds varied from less than nine years of compulsory school to the completion of university degrees with a median of senior high school education of maximum two years. The participants were referred from various private, municipal, and state organizations for the assessment of dyslexia.

Procedure

First, principal components analysis (ones in the diagonal) was conducted to determine objectively the number of factors to interpret as significant (i.e., those with eigenvalues greater than 1.0). Cattell's (1966) scree test was then applied to get a second objective criterion for deciding on the number of significant factors. Next, the 11 WAIS-R subtests were factor analyzed using exploratory maximum-likelihood factor analysis with varimax rotation, a method recommended and used, for example, in the factor analytic investigation of the Swedish WISC-III. The first unrotated factor from the principal components analysis was used to estimate the g-factor loadings.

Gorsuch (1983) and others have suggested that factor solutions should be evaluated not only according to empirical criteria but also according to the criterion of "psychological meaningfulness". Data were thus also interpreted in light of the research literature regarding different models for describing the WAIS-R. In their review of factor-analytic studies on the WAIS-R, Leckliter, Matarazzo, and Silverstein (1986) stressed that the main reason for factor analyzing a Wechsler battery is "to provide the basis for hypothesis testing by the examiner".

In addition to principal components and maximum likelihood factor analysis, cognitive profiles (VIQ-PIQ, composite scores of subtests allocated to the three factors, Bannatyne category scores, subtest scaled scores) for the present sample of adults with dyslexia were examined and compared to profiles reported in the literature for previous samples of adults with dyslexia. The cognitive profile analyses were conducted for the total sample, for individuals within the sample from different levels of educational background, and for separate groups of males and females.

Results

As shown in Table 1 half of the variance in the battery is accounted for by "g". All subtest loadings are above .50 with the highest loadings of .80-.81 obtained for Similarities and Comprehension, both measures of verbal reasoning ability (Kaufman, 1990).

Table 1
Varimax-rotated Factor Loadings of the Swedish WAIS-R for Adults with Dyslexia, Using Exploratory Maximum-likelihood Factor Analysis: Two-factor and Three-factor Solutions

WAIS-R Subtest	"g" Loadings	Two-factors I(V)	Two-factors II(P)	Three-factors I(VC)	Three-factors II(PO)	Three-factors III(FD)
VERBAL						
Information	**.76**	**.79**	.19	**.73**	.12	.38
Digit Span	.65	**.46**	.35	.32	.21	**.60**
Vocabulary	**.77**	**.96**	.09	**.91**	.07	.29
Arithmetic	**.75**	**.63**	.33	**.52**	.22	**.54**
Comprehension	**.80**	**.83**	.28	**.84**	.30	.14
Similarities	**.81**	**.60**	**.55**	**.62**	**.61**	.05
PERFORMANCE						
Picture Completion	.51	.09	**.62**	.09	**.64**	.07
Picture Arrangement	.68	.38	**.52**	.31	**.47**	.34
Block Design	**.74**	.28	**.80**	.20	**.74**	.35
Object Assembly	.64	.16	**.76**	.12	**.74**	.22
Digit Symbol	.60	.25	**.55**	.12	**.45**	**.48**
% of Total Variance	50.11	32.08	25.77	27.23	22.69	12.94

Note. N = 88. "g" loadings are unrotated first factor loadings from principal components analysis[2]. Unrotated loadings ≥ .70 and rotated loadings ≥ .40 in boldface. V = verbal factor, P = performance factor, VC = verbal comprehension, PO = perceptual organization, and FD = freedom from distractibility.

When two factors were extracted, a classic verbal and performance factor structure appeared with all Verbal subtests loading highest on the first factor (V) and all Performance subtests having their highest loadings on the second factor (P).

The three extracted factors were consistent with earlier findings from the American WAIS-R (Kaufman, 1990). The VC factor for the sample of Swedish adults diagnosed with dyslexia comprised all Verbal subtests except Digit Span and featured very high loadings (.73-.91) by Vocabulary, Comprehension, and Information; a PO factor defined by all Performance subtests, with its very highest loadings (.64-.74) by Picture Completion, Block Design, and Object Assembly; and a third FD factor with its highest loadings on Digit Span (.60) and Arithmetic (.54).

[2] In the original article published in *Journal of Learning Disabilities, 35,* 321-333 there is a misprint. The "g" loadings and the two factors solution are incorrectly subsumed under the same line.

As shown in Table 2 the mean values for subtest scaled scores for the sample of Swedish adults diagnosed with dyslexia are all below the normative mean of 10, some substantially below.

Table 2
Means and Standard Deviations (SDs) for Swedish WAIS-R Subtest Scaled Scores for Adults with Dyslexia

	Scaled score	
WAIS-R Subtest	*M*	*SD*
VERBAL		
Information	6.88	3.91
Digit Span	6.94	2.43
Vocabulary	7.30	3.41
Arithmetic	7.86	3.28
Comprehension	8.85	3.56
Similarities	8.31	4.04
PERFORMANCE		
Picture Completion	9.45	3.07
Picture Arrangement	9.74	3.16
Block Design	9.38	3.76
Object Assembly	9.07	3.53
Digit Symbol	7.10	3.16

Note. $N = 88$. These values are derived from age-based scaled score norms.

Similarly, as can be seen in Table 3, the mean standard scores on IQs, factors, and Bannatyne categories are all substantially below 100, with the mean Full Scale IQ equaling 87.

Table 3
Means and Standard Deviations for Swedish WAIS-R IQs, Factor Scores, Bannatyne Categories, and ACID Profile for Adults with Dyslexia

WAIS-R Score[3]	Score *M*	*SD*
IQ		
Full Scale	87.07	18.22
Verbal	85.57	17.82
Performance	93.07	18.03
Factor Score		
Verbal Comprehension	86.99	19.57
Perceptual Organization	95.80	16.71
Freedom from Distractibility	84.42	15.17
Bannatyne category		
Verbal Conceptualization	89.46	18.76
Spatial Ability	95.80	16.71
Sequential Ability	82.20	15.19
Acquired Knowledge	84.07	18.88
ACID Profile	79.81	17.51

Note. $N = 88$. ACID profile = standard score computed from sum of scaled scores on four subtests: Arithmetic, Digit Symbol, Information, Digit Span. The values in this table are derived from age-based scaled score norms.

The group had a mean Verbal-Performance (V-P) discrepancy of 7.5 points (1/2 *SD*), in favor of P-IQ, a difference that reached significance at the .001 level, using a *t* test for dependent samples [t (87) = 4.49]. Previous studies in the U.S. on individuals with dyslexia usually have found a P > V IQ discrepancy between 5 and 15 IQ points (Kaufman, 1990), similar to the present results.

Because education level is known to be associated with V-P IQ discrepancies, with higher levels of education often associated with V > P profiles and lower levels of education associated with P > V profiles (Kaufman, 1990, chap. 6), the V-P analysis was conducted for separate educational groups. Indeed, when subgroups from different educational backgrounds were analyzed separately (excluding seven subjects for whom educational data were unavailable), the picture gets more complex. The group with an education background of up to nine years of Swedish compulsory school ($n = 27$) had a significant ($p < .001$) mean P > V IQ discrepancy of 12.1 points. The group with 1-2 years of senior high school

[3] In the original article published in *Journal of Learning Disabilities, 35,* 321-333 there is a printing error, incorrectly saying “WAIS-R subtest”.

education ($n = 27$) had a significant ($p < .01$) mean P > V IQ discrepancy of 8.6 points, and for the group with an educational background of three years of senior high school or more ($n = 27$), the P > V difference was a non-significant 3.2 points. Thus, regardless of educational background, there was a P > V profile, but the magnitude of the discrepancy decreased notably with increasing education, failing even to reach significance for the most educated group.

V-P differences were also conducted separately for males and females. Both groups demonstrated P > V profiles that were significant ($p < .01$). The mean P > V difference was 5.8 for males and 10.3 for females. To determine whether the value of P > V was significantly larger for females than males, a t for independent samples was computed; the difference was not significant at the .05 level ($t(86) = 1.29$).

When considering the three-factor structure (see Table 3), the group diagnosed with dyslexia scored highest on the PO factor (about 96), followed by the VC factor (87) and FD factor (84). For this analysis, the VC factor was composed of Information, Vocabulary, Similarities, and Comprehension; the PO factor was composed of Picture Completion, Block Design, and Object Assembly (excluding Picture Arrangement, which loaded below .50, and Similarities, which is more associated with VC than PO factors, despite its nearly equal loadings in this analysis); and the FD factor was composed only of the Arithmetic—Digit Span dyad, the two subtests with the highest loadings on the third factor. The expected PO > VC difference and the expected PO > FD difference (based on previous research with samples diagnosed as having dyslexia) were significant ($p < .001$), according to Tukey's Honestly Significant Differences (HSD) post hoc test. The VC > FD difference was not significant at the .05 level.

These analyses were also conducted separately for the three educational groups described previously. At different educational levels, the same significant differences were found except for one: the educational level of three years of senior high school education and more, where the PO > VC discrepancy was not significant. The lack of significance for that particular comparison is consistent with the expectation of higher verbal ability for more educated groups, and with research findings for college students with learning disabilities (e.g., Morgan et al., 1997). In the separate analyses by gender, the same significant findings found in the whole group were also found for males and females, respectively.

In the interpretation of WAIS-R test protocols of individuals presumed to have dyslexia, the Bannatyne (1974) categories are often used (Kaufman, 1990). They consist of Verbal Conceptualization (Vocabulary, Comprehension, Similarities), Spatial Ability (Picture Completion, Block Design, Object Assembly), Acquired Knowledge (Information, Vocabulary,

Arithmetic) and Sequential Ability (Digit Span, Arithmetic, Digit Symbol). The present sample showed a profile usually found in groups of English-speaking adults with dyslexia (Kaufman, 1990, chap. 13), with the highest mean score on Spatial Ability (standard score = 96), followed by Verbal Conceptualization (89), Acquired Knowledge (84), and Sequential Ability (82). All pair-wise differences were significant (p < .005), according to Tukey's HSD post hoc test, with the exception of Acquired Knowledge versus Sequential Ability. Thus the overall profile for the sample of Swedish adults with dyslexia was:
Spatial > Verbal Conceptualization > Acquired Knowledge = Sequential.

When analyzing different educational levels and genders, the same pattern was consistently found, but without always reaching statistically significant levels when comparing adjacent categories. This pattern mirrors the results of Bannatyne analyses with a wide variety of Wechsler scales and age ranges for children and adults (Kaufman, 1979, 1990, 1994). College students with learning disabilities, who tend to score higher on the two categories composed of Verbal subtests (Verbal Conceptualization, Acquired Knowledge) than do other samples of individuals with learning disabilities, are an exception to the rule (e. g., Salvia et al., 1988). However, good performance on verbal tasks is not surprising for a group that has achieved well scholastically despite learning disabilities. Overall, the consistency of the Bannatyne pattern for a diversity of samples composed of individuals diagnosed with learning disabilities or dyslexia provides an aid during the assessment process when individuals with learning problems are referred for evaluation. However, similar Bannatyne patterns have been observed for individuals with other diagnoses, such as behavior disorders or emotional disturbance, making the characteristic pattern of limited value for differential diagnosis (Kaufman, 1990, 1994).

The ACID profile yielded a low standard score of 79.8 (see Table 3), reaffirming that this pattern is characteristic of adults with dyslexia and learning disabilities (e.g., Gregg, Hoy, & Gay, 1996; Katz, Goldstein, Rudisin, & Bailey, 1993), just as it is for children (Kaufman, 1979, 1994). As with the typical Bannatyne pattern, the principal exception to this research finding is for college students with learning disabilities, especially females (Kaufman, 1990, pp. 448-451).

To compare the different subtest scaled scores for males and females, t tests for independent samples were conducted with a Bonferroni correction for 11 simultaneous comparisons. To achieve a family-wise alpha level of .01, $p < .009$ was needed. The only subtest to achieve significance was Digit Symbol, which produced a mean scaled score of 8.55 for females versus a mean of 6.24 for males [t (86) = 3.53, p = .0007]. In contrast, none of the 10 other subtests even approached significance (all with p > .30). Female superiority on Coding and Digit Symbol is a well-validated cross-cultural research finding for children, adolescents, and adults, both with learning disabilities and without (e.g., Kaufman, 1990, pp. 154-156, 450-451; Vogel, 1990).

Discussion

The present factor analyses of the Swedish WAIS-R (see Table 1) were in striking consistence with results for the American WAIS-R obtained for a plethora of normal and clinical samples, including samples diagnosed with learning disabilities or dyslexia (Kaufman, 1990, chap. 8; Leckliter et al., 1986); they accord well with pertinent factors in the analyses for normal children and adolescents on the four-factor American WISC-III (Wechsler, 1991) and Swedish WISC-III (Wechsler, 1999), and they are quite congruent with the two-factor and three-factor solutions reported by Kaufman, Lichtenberger, and McLean (2001) for the four-factor WAIS-III (Wechsler, 1997).

What about the factor structure of the Swedish WAIS-R in a normal group? To investigate this structure, the correlation matrix for the Swedish standardization group of 227 cases (Wechsler, 1996, p. 17) was analyzed. First the data were analyzed using exploratory factor analysis in accordance with the procedures used in the previous analyses on the adult group with dyslexia.

The principal components analysis yielded two factors with an eigenvalue ≥ 1.0 (4.70, 1.67), with successive factors producing eigenvalues of 0.97, 0.78, 0.56, 0.50, 0.47, 0.40, 0.39, 0.30, and 0.27. The scree test supports a three-factor solution as the most meaningful. Based on previous research, and since the test manual provides for two scales─verbal and performance─varimax-rotated maximum likelihood solutions were examined for two factors and also for three factors.

Both the two- and three-factor solutions made much psychological sense. In the two-factor solution, all the verbal subtests had their highest loadings on the first factor, with loadings between 0.44 and 0.82. The lowest loading was by Digit Span followed by Arithmetic (0.50), with Vocabulary showing the highest loading. All performance subtests had their highest loadings on the second factor with a range from 0.48 (Digit Symbol) to 0.80 (Block Design).

In the three-factor solution, the Verbal Comprehension subtests (Information, Vocabulary, Comprehension, and Similarities) had the highest loadings on the first factor (0.71-0.80). The Perceptual Organization subtests (Picture Completion, Block Design, and Object Assembly) had their highest loadings on the second factor. The Freedom from Distractibility subtests (Digit Span and Arithmetic) had their highest loadings on the third factor

(0.45 and 0.50, respectively). The general (*g*) factor, derived from the first unrotated principal component, accounts for 42.7% of the total variance in the test battery.

To further investigate the best fit of different factor structures of the WAIS-R for the Swedish standardization group, further analyses were conducted, using confirmatory factor analysis. Four different models were tested: (a) a one-factor model, including all subtests in the battery; (b) a two-factor model with a verbal and performance factor, according to the division of subtests listed in the test manual; (c) a three-factor model, with a Verbal Comprehension factor (Information, Vocabulary, Comprehension, and Similarities), a Perceptual Organization factor (Picture Completion, Block Design, and Object Assembly), and a Freedom from Distractibility or FD factor (Digit Span and Arithmetic); and (d) a three-factor solution where Digit Symbol was included together with Digit Span and Arithmetic in the FD factor. The reason for the last model is that, as mentioned previously, Digit Symbol often shows an affinity to these two other subtests and has sometimes actually been included in the FD factor (Kaufman, 1979). As can be seen in Table 4 the outcome gave clear support for the three-factor model in which FD is composed of only two subtests (Model c).

Table 4
Goodness-of-Fit Indices of the Four Confirmatory Factor Models.

Models	χ^2	df	P	χ^2/df	RMSEA	CFI	GFI
Model a (1 factor)	407.05	44	.000	9.25	.191	.730	.750
Model b (2 factors)	130.75	43	.000	3.04	.095	.920	.900
Model c (3 factors I)	64.20	24	.000	**2.68**	**.086**	**.950**	**.940**
Model d (3 factors II)	91.12	32	.000	2.85	.090	.930	.930

Note. Values in **bold** indicate the best fit. RMSEA = Root Mean Square Error of Approximation, CFI = Comparative Fit Index, GFI = Goodness of Fit Index.

Now, how do you compare factor solutions for different groups? Are the factor solutions for the WAIS-R found in the original U.S. standardization sample and for different clinical groups in the U.S. similar or comparable to our findings for a clinical group of adults with dyslexia and for the Swedish standardization sample? The coherence can be estimated using different formulas, for example, a *coefficient of congruence* (Harman, 1976, pp. 343-344).

However, careful inspection of the loading matrices for different groups may reveal similarities and differences in factor structure sufficiently clear as to obviate the need for more formal procedures. If the groups generate the same number of factors, if almost the same variables load highly on the different factors, and if you can reasonably use the same labels to name factors for different groups, it is unnecessary to proceed to statistical comparison (Tabachnick & Fidell, 1989, p. 642). This is clearly the case when comparing the main findings from the U.S. (Kaufman, 1990, chap. 8; Leckliter et al., 1986) and our findings in the adult group with dyslexia and in the Swedish standardization sample.

This consistency attests (a) to the cross-cultural congruence of the Swedish WAIS-R with other versions of the WAIS-R, with Wechsler scales for children, and with the successor to the WAIS-R in the U.S., and (b) to the construct validity of the Swedish WAIS-R for adults diagnosed with dyslexia.

How Many Factors Should Be Interpreted?

All of the data in Table 1 are useful to interpret, rather than trying to decide whether the WAIS-R is a one-factor ("g"), two-factor (Verbal—Performance), or three-factor (VC, PO, FD) instrument. Really, it is all three of these, and all serve important functions.

The large "g" factor, accounting for 50% of the variance in the battery and composed of subtests which all had "g" loadings greater than .50, provides empirical support for the interpretation of Full Scale IQ, the most global score yielded by the WAIS-R, and for the third stratum ("general") in Carroll's (1993, 1997) Three-Stratum Theory of intelligence. The two-factor solution, which produced two robust dimensions, offers construct validation of Wechsler's assignment of subtests to either the Verbal or Performance IQ scale, as well as empirical support for the frequent interpretation of V-P IQ discrepancies by clinicians and researchers (Kaufman, 1990, chap. 9-11; Kaufman, 1994, chap. 4). The three-factor solution provides "purer" dimensions than those offered by the dichotomous Verbal and Performance IQs, and aids clinicians in the task of assigning theoretical interpretations to an IQ scale that had practical origins and was not especially rooted in any theory. The three factors accord well with three of the eight abilities that define the second stratum ("broad abilities") of Carroll's (1993, 1997) Three-Stratum Theory of intelligence (i.e., crystallized intelligence, fluid intelligence, and general memory and learning).

For example, Horn's (1985, 1989) expansion and refinement of the original Horn-Cattell fluid-crystallized distinction affords a theory-based interpretation of Wechsler's scales. As noted previously, the Verbal and Performance dimensions identified in the two-factor solution, as well as the Verbal and Performance IQs they reflect, are usually interpreted as measures of Gc and Gf, respectively. From that perspective, the VC and PO factors are likewise measures of Gc and Gf, with the PO factor (and Performance IQ) also measuring Horn's (1989) Broad Visualization (Gv) to a considerable extent (Horn & Hofer, 1992; Kaufman, 1994). The third factor, FD, measures Horn's factor of Short-Term Acquisition and Retrieval (SAR), sometimes referred to as short-term memory abbreviated as Gsm. That interpretation denotes the important role played by auditory short-term memory for success on Arithmetic and Digit Span, and the contribution made by visual short-term memory to success on the highly-speeded Digit Symbol subtest. Furthermore, each of these factors displays its own characteristic aging pattern across the adult life span when scores are based on a common norm and adjusted for educational attainment, and these aging patterns conform to the patterns associated with specific Horn abilities (Kaufman, 2000).

Even the dual loadings of some subtests accord well with Horn's theory. Similarities, for example, loaded substantially (.55-.62) on both the VC and PO factors in the two-factor and three-factor solutions. This pattern of loadings is consistent with its presumed duality of Gc and Gf components (Horn, 1985, 1989), and is generally consistent with its dual loadings observed on the American WAIS-R for separate groups of males and females, separate groups of African Americans and whites, adults ages 55-74, and several clinical samples such as medical patients and patients with brain damage (Kaufman, 1990, Tables 8.1 through 8.5).

The Gender Difference on Digit Symbol and Its Implications for Cognitive Patterns

The large gender difference on Digit Symbol, in favor of females, did not produce gender differences in cognitive profiles when evaluating either the ACID grouping of subtests or the Bannatyne recategorization. Nonetheless, it is instructive to examine the Bannatyne category scores for males versus females, despite the lack of statistical significance.

Group Versus Individual Differences in Cognitive Profiles

About one-third of the sample had all four ACID subtests among their lowest scaled scores and the same approximate proportion displayed the characteristic Bannatyne pattern. In view of the fact that these relatively low percents were obtained without even insisting on statistical significance, that similar results have been obtained with previous samples (Psychological Corporation, 1997), and that different clinical samples (e.g., emotionally disturbed; see Kaufman, 1990, pp. 451-452) sometimes display the so-called "dyslexic" Bannatyne pattern, it is clear that the group data are not necessarily generalizable to specific individuals within that group. Furthermore, low scores on the ACID subtests or on Bannatyne's Sequential or Acquired Knowledge categories can depend on many different cognitive and clinical factors, for example, problems with memory, attention, anxiety, motivation, numbers, sequences. To reach an analysis of interfering problems, observation, interview, and, sometimes, additional testing is needed.

When the sample of adults diagnosed with dyslexia was categorized by their educational level, the magnitude of the P > V profile was largest for the least-educated group (12.2 points) and smallest for those with the most formal education (3.2 points). These results are consistent with previous findings for typical individuals in the United States who differ in their educational levels; the Swedish individuals with dyslexia and the typical U.S adults both demonstrated an association between the number of years of formal schooling and their verbal ability. However, the individuals with dyslexia who had the highest education level still failed to display a V > P profile, suggesting an interaction between education level and the diagnosis of dyslexia.

Study II

Introduction and aim

Because the problems in reading, writing, and spelling are seen as dependent on different underlying cognitive disorders, it is of much theoretical and clinical interest to investigate the factor structure of reading and writing tests usually administered in standard diagnostic assessments of dyslexia. And because the most used cognitive batteries in assessment of dyslexia are the Wechsler scales, it is important both from a theoretical and clinical perspective to find out in which way the cognitive abilities measured by the Wechsler scales relate to the assessment of achievement in reading and writing—the other crucial part of a standard dyslexia assessment. The ultimate goal is to get a full understanding of the underlying relationships between cognition and academic achievement.

The aims of this study were: 1) to investigate the factor structure of commonly-used achievement instruments for the testing of reading and writing abilities in Swedish dyslexia assessments, and 2) to relate this factor structure to the factor structure of the WAIS-R.

Method

Participants

The factor-analytic study of the achievement tests is based on 68 cases, 33 of which have been evaluated on a full dyslexia assessment and the remaining 35 cases diagnosed with dyslexia from teachers with special education in testing for dyslexia and with considerable experience in the field, using the same kind of comprehensive structured interview, and assessment procedure of achievements on different levels of reading, spelling and writing, but without psychological assessment of cognitive functions. For this kind of study the two groups can be regarded as equivalent. For all nine achievement measures *t* tests for independent groups were made. The groups did not differ significantly on any of these measures, even without a Bonferroni correction for multiple comparisons.

The mean values in Stanines for each group for the normed achievement instruments were identical for four measures with a one-point difference for two measures, revealing a common pattern of below-average achievement on all measures of technical skills in reading and writing. On the contrary, their reading comprehension scores were in the normal range, consistent with the definition of dyslexia that implies poor technical skills but with no intrinsic problems in comprehension.

The group of 68 subjects comprised 47 males and 21 females. The mean age was 29.1 years with a standard deviation of 7.4 years (range 20-48 years). In the first group there were 22 males and 11 females with a mean age of 29.6 years (range 20-48 years). In the second group there were 25 males and 10 females with a mean age of 28.6 (range 20-46 years). The mean age for both groups was similar, as was the ratio of males to females, again justifying their combination into a single sample for the present factor analysis.

The educational backgrounds varied from less than nine years of compulsory school to the completion of a university degree with a median of senior high school education of maximum two years for both groups. The participants were referred from various private, municipal, and state organizations for the assessment of dyslexia.

Test instruments

The following test instruments were used: The Swedish Alphabet, Madison's 60 Word Spelling Test (untimed), Madison's 23 Word Decoding Test (untimed), Madison's simple Text 1 for reading aloud (untimed), Madison's more advanced Text 2 for reading aloud (untimed), Madison's Boris 1 (measuring both reading speed and reading comprehension), Word Chains (believed to measure the abilities of word decoding and word identification), and Letter Chains (believed to measure visuo-motor speed). The Boris 1 test for silent reading consists of 1940 words in 7 pages. For the assessment of reading comprehension there are parentheses, at even intervals, consisting of three words or expressions where the correct alternative is to be marked. There are 55 parentheses with around 34 words in between. Word Chains is a very frequently used test that demands rapid reading of word chains (three words without space in between). The task is to separate the words by making dividing lines between them. There are a total of 120 word chains and the time limit is three minutes. Letter Chains consists of 80 capital letter chains like KSBBSOOFE where lines are to be drawn between pairs of similar letters. The time limit is 90 seconds.

Procedure

First, principal components analysis (ones in the diagonal) was conducted to determine objectively the number of factors to interpret as significant (i.e., those with eigenvalues greater than or equal to 1.0). Cattell's (1966) scree test was then applied to get a second objective criterion for deciding on the number of significant factors. Next, the nine achievement tests were factor analyzed using exploratory maximum-likelihood factor analysis with varimax rotation.

Gorsuch (1983) and others have suggested that factor solutions should be evaluated not only according to empirical criteria but also according to the criterion of "psychological meaningfulness." Data were thus also interpreted in light of clinical experience and expert opinion (Madison, 1996; S. Madison, personal communication, February 20, 2002). There is a lack of Swedish factor-analytic validation research on instruments for the assessment of literacy achievement and even international research is limited. To determinate the appropriate number of factors, the results from the empirical tests together with psychological meaningfulness were used.

Composite scores on the achievement factors were then correlated with WAIS-R IQs and WAIS-R composite scores (based on analyses conducted by Alm & Kaufman, 2002; Study I) for the portion of the sample that was given *both* the WAIS-R and the achievement tests (i.e., the 33 adults in the first group).

Results

Factor Analysis of Achievement Test Scores

Varimax-rotated exploratory maximum-likelihood solutions were examined for three factors, four factors, and five factors to determine which one was the most sensible in terms of psychological theory and clinical practice.

The five-factor solution made much psychological sense (see Table 5). The first factor was a Decoding or Technical Reading Skill factor with loadings of .50 to .82 by Madison's 23 Word Decoding Test, Madison's simple Text 1 for reading aloud, and Madison's more advanced Text 2 for reading aloud. A second Perceptual (Visual) Speed factor emerged with loadings above .65 by Word Chains and Letter Chains. A third Reading Comprehension factor had a single loading > .40, a .74 loading by Boris 1 Reading Comprehension. The fourth factor was a Reading Fluency factor with loadings >.45 by Boris 1 Reading Speed and the Word Chains test. The fifth factor was defined by loadings between .49 and .78 by the Alphabet, Madison's 60 Word Spelling Test and Madison's 23 Word Decoding Test. This factor is best described as a Phonological Ability factor.

Table 5
Varimax-rotated Factor Loadings of Nine Achievement Tests for Adults with Dyslexia, Using Exploratory Maximum Likelihood Factor Analysis: Five Factor Solution

	Factors				
Tests	I(D)	II(VS)	III(RC)	IV(RF)	V(PA)
Alphabet	.10	.02	.17	-.06	**.49**
Spelling 60 Word	.39	.22	.01	.11	**.78**
Oral Reading 23 Words	**.59**	-.02	.32	.18	**.51**
Oral Reading Text 1	**.50**	.01	.12	.05	.11
Oral Reading Text 2	**.82**	.09	-.08	.20	.24
Reading Speed[a]	.17	.01	.20	**.66**	-.03
Reading Comprehension[a]	.12	.14	**.74**	.24	.23
Word Chains	.24	**.67**	-.12	**.46**	.37
Letter Chains	-.03	**.90**	.17	-.07	.01
% of Total Variance	16.86	14.87	8.6	8.88	15.15

Note. N = 68. Loadings ≥ .40 are boldfaced. D = decoding; VS = visual speed; RC = reading comprehension; RF = reading fluency; PA = phonological ability. [a]Test instrument Boris 1.

The five factor solution has the assets of (a) including meaningful loadings on at least one factor by all achievement tests in the factor structure, and (b) identifying a clearly-defined speed factor formed by Boris 1 Reading Speed and Word Chains. Word Chains, like the Boris 1 test, is a highly speeded measure, offering good support to the meaningfulness of this important dimension (Reading Fluency) that is otherwise excluded when only three or four factors are interpreted.

Correlations of Achievement Scores with Cognitive Measures

Correlations between the WAIS-R scores and the five achievement factors were analyzed for the 33 individuals who were assessed both on the full WAIS-R and on the nine achievement tests. For the correlational analysis, the .01 level of significance was used to avoid interpretation of correlations that might reach significance by chance alone, a common occurrence when the liberal .05 level is used with correlations obtained for a relatively small sample and when numerous coefficients are analyzed.

The Phonological Ability factor had four significant correlations at the .01 level (.44-.54), all associated with the FD factor—namely, the FD factor score and each of its component subtest scores. Short-term memory and sequential ability, as measured by the FD factor, are both important ingredients in learning the alphabet, developing the ability to spell correctly, and learning to decode words (Gathercole & Baddeley, 1993, p. 131).

The more general Decoding or Technical Reading Skill factor—with more demand on orthographic skills and measured by three untimed tests of single word decoding and oral reading of two texts of different complexity levels—did not correlate significantly with any of the cognitive measures in the WAIS-R. Orthographic processing is not that well understood and few, if any, standardized tests exist that measure that aspect of reading (Flanagan et al., 2002). That is to say, the cognitive processes involved in technical word decoding are not well covered by the WAIS-R.

The Reading Fluency factor, formed by Boris 1 Reading Speed and Word Chains, also failed to correlate significantly with cognitive factors measured by WAIS-R. For reading fluency, the demands on orthographic processing ability become even more decisive and the aspect of automaticity gets more pronounced. Again the orthographic processing ability does not seem to be measured by the WAIS-R. The Digit Symbol subtest, with its demands on fast visual processing does not tap the specific orthographic aspect and is a more general measure of visual-motor speed.

The Reading Comprehension factor correlated significantly with many different cognitive scores on the WAIS-R, but not with performance IQ, the PO factor score, or the Digit Symbol subtest. The results reflect the complex cognitive structure behind reading comprehension, tapping verbal reasoning, vocabulary, long- and short-term memory, and sequential ability. The Reading Comprehension factor, as expected, showed its highest correlations with the verbal and sequential measures (verbal IQ, Verbal Comprehension Index, and Freedom from Distractibility Index).

The Perceptual (Visual) Speed factor, formed by Word Chains and Letter Chains, correlated significantly with Full Scale IQ, PIQ, PO, FD, and Digit Symbol, but *not* with VIQ or VC. Based on this pattern of correlations, this factor seems highly related to visual-spatial ability and holistic processing. The low correlations with Digit Span and Arithmetic also indicate that the factor mostly involves visual-spatial (simultaneous) processing rather than sequential processing.

Discussion

No validity research on Swedish literacy achievement tests, using a factor-analytic approach, could be found in the literature. Surprisingly, even in international research there are few studies with a similar approach.

Knowing the underlying dimensions of literacy tests is obviously critical for many reasons: a) to provide full coverage of relevant dimensions in literacy assessment, b) to be able to relate dimensions in reading and writing to cognitive functions, and c) to propose appropriate interventions.

The five-factor solution is—besides taking all data into account—the solution that is best supported by reading research and clinical experience (S. Madison, personal communication, January 10, 2003). According to the dual-route theory of reading (Humphreys & Evett, 1985; Morton, 1979), there are two functionally independent means of processing words and getting access to lexicon: the orthographic, or direct, route and the phonological, or indirect, route. By the orthographic strategy you get a direct access to lexicon by recognition of the spelling or even the visual form of the word. If you do not recognize the spelling of the word, then you have to decode the word letter by letter and sound by sound. The dual-theory has similar bearings on spelling, and reflects different stages in learning to read (Frith, 1985), where the two last stages are alphabetic-phonemic reading and orthographic-morphemic decoding. These general theories give support for a factor structure where these two routes can be identified. This structure is best manifested in the four and five factor solutions. The double-deficit theory of reading disability, with its stress on fluency and automaticity, is also accounted for in the five-factor solution where a fluency or speed factor is identified.

The psychometric CHC theory (McGrew & Flanagan, 1998) gives us an interesting taxonomy for the relationship between cognitive and literacy factors. The Phonologic Ability factor can be found as a distinct factor subsumed under the broad Auditory Processing factor, but also related to short-term memory (Gathercole & Baddeley, 1993). The Decoding (orthographic ability) factor is not well covered in the existing CHC theory reflecting a lack in the breadth of processes subsumed under visual processing. The Reading Comprehension factor is of considerable complexity, although to analyze its different content is not within the scope of this study. From the analysis of our nine tests, it clearly stands out as a factor of its own. The consistent Perceptual (Visual) Speed factor formed by Word Chains and Letter Chains is again of much interest. The Word Chain test is based on the assumption that reading or word decoding is well measured by the ability to read words without space in between. That assumption is contrary to the very basic insights from the linguistic perspective of reading stating: "All literate societies try to represent key features of their oral language in their written language. So, for example, we have letters to represent the basic units of sound, usually referred to as *phonemes*. And we have spaces between words to represent *juncture*. Juncture is the property of sound that permits us to discriminate between *I* *scream* and *ice cream* or *my skis* and *mice keys*" (Pearson & Stephens, 1994, p. 24).

The achievement factor with the most significant correlations to scores on the WAIS-R is Reading Comprehension. Its significant correlations with VIQ, VC and FD are consistent with the many findings of strong relationships among Crystallized Intelligence, Working Memory, and Reading Achievement as demonstrated by reviews of existing research (Flanagan et al., 2002, p. 61; McGrew & Flanagan, 1998, p. 38). Significant correlations between working memory and reading comprehension are reported in many earlier studies; see, for example, Engle, Cantor, and Carullo's (1992) review of earlier findings as well as their own results in support of this relationship.

The Reading Fluency factor did not correlate significantly with any of the WAIS-R variables. The importance of fluency in the reading process has been much stressed in papers proposing a Double-Deficit Hypothesis in explaining reading problems (Wolf, 1999; Wolf & Bowers, 1999). The standard way of measuring fluency is by Rapid Automatized Naming (RAN) and is an aspect not covered by the WAIS-R or by other major cognitive batteries (Flanagan et al., 2001; McGrew & Flanagan, 1998). Reading Fluency is dependent on the ability to automatize the alphabetic sign-sound connection and on the memory for visual patterns of the written language—orthography (Aaron, 1995) in words and syllables. Deficiencies in the ability to automatize reading and writing skills are obviously predominant in dyslexia, but dyslexia has also been proposed to be a more general deficit in automatizing primitive skills in general (Nicolson & Fawcett, 1995). The WAIS-R has three subtests that are partly dependent on Osgood's automatic level of cognitive functioning (Kaufman, 1990), namely Digit Span, Picture Completion, and Digit Symbol. The specific ability of making decoding automatic is, however, not covered by the WAIS-R, according to the present correlational analyses.

The Decoding or technical reading skill factor also had no significant correlations with WAIS-R variables. Orthographic processing does not seem to be related to WAIS-R scores for the present group of adults with dyslexia tested on both the achievement tests and the WAIS-R.

In contrast, the Phonological Ability factor did correlate significantly with the FD factor and all its component subtests. Learning the alphabet, the letter-sound correspondence, and the correct sequence of the letters are main requirements for mastering the skill that underlies this achievement factor. The significant correlations suggest that memory and sequential ability, measured by all three FD subtests, are crucial aspects of phonological ability.

The Perceptual (Visual) Speed factor correlated significantly with nonverbal measures on the WAIS-R, but not verbal variables. From this analysis, it seems evident that this factor is best described as a measure of visual-motor speed and is primarily related to simultaneous processing, a skill that has been shown to relate closely to Wechsler's Perceptual Organization subtests in factor analyses of both normal children and those with learning disabilities (Kaufman & McLean, 1986, 1987).

In view of CHC theory, probably the leading psychometric theory on cognitive functions, the results from the correlational analysis support prior analyses of the WAIS-R in relation to reading and writing abilities and point to the following possible conclusions: (1) the important orthographic decoding factor found in the achievement test battery is largely independent of the cognitive functions measured by the WAIS-R (the orthographic processing ability is hard to relate to the existing factors in the CHC model as well as to factors in the WAIS-R); (2) learning to decode words is initially very dependent on auditory processing ability that is not specifically covered by the WAIS-R; (3) the important aspects of working memory are measured by the WAIS-R, and its importance for basic decoding ability, as well as reading comprehension, is suggested by our analyses; and (4) the great importance of crystallized intelligence for reading comprehension is much supported.

To establish the stability of our findings, future research on normal readers are highly relevant.

Study III

Introduction and aim

The Word Chain Test (WCT) is a frequently used instrument in Swedish screening and diagnosis of dyslexia. It is a recommended instrument in the guidelines for certifying dyslexia to allow students extra time on the Swedish National University Aptitude Test (see e.g., Högskoleverket, *National Agency for Higher Education,* 2002). As described in the manual (Jacobson, 1993, 1997), the test has two parts—Wordchains and Letterchains. The Wordchains test consists of 120 chains of the following type "gulgrynute" (yellowgrainout) and "seochtyg" (seeandstuff). The length of each word varies from two to seven letters. The words are nouns, verbs, adjectives, and numerals, and all words are supposed to be in the children's vocabulary (Jacobson, 1995, p. 261). The task is to draw lines between the three words joined together. The test is described as a fast and simple group test for measuring word decoding or word recognition (Jacobson, 1993, 1997). In school and clinical situations it is commonly used as an individually-administrated tool for diagnostic assessments, a use strongly supported by the National Agency for Higher Education (2002).

The Letterchains test is made up of 80 chains of the following type: "KSBBSOOFE" and "DSIIYLLKE". The task here is to draw lines between pairs of identical letters. Except for the reading requirements, the Letterchains test involves the same demand characteristics as the Wordchains—that is, scanning letter sequences and making pencil markings (Jacobson, 1995, p. 261). The purpose of Letterchains is to measure "motor-perceptual speed" (Jacobson, 1997, p. 4) and "to control for the visuo-motor components and speed factor involved in the Word Chain Test" (Jacobson, 1995, p. 261). Low scores on both tests might, for example, indicate general slow pace or some visual weakness. The administration time for Wordchains is three minutes and for Letterchains 90 seconds.

The Word Chain Test was first published in 1993. In a revision of the manual in 1997, a Word Recognition Index (WRI) was introduced, whereby the results from Wordchains and Letterchains are combined to a common value according to the formula: WRI = 100 x (No. of Word Chains - No. of Letter Chains) / No. of Letter Chains. WRI has been shown to be a good indicator of dyslexic problems, especially for somewhat older pupils and for adults (Jacobson, 1997, p. 2), and a "WRI below approximately 10-20 for teenagers and older indicates specific reading disabilities" (Jacobson 1997, p. 27). Furthermore, according to Jacobson (1995, p. 265), the WRI "seems to be a quick and reliable way of identifying individuals with poor word decoding ability. A WRI under 10 in adults seems to be a good indicator of dyslexia, on conditions that the number of word chains processed is below a certain limit." About the Word Chain subtest the manual states, that: "The test is also suitable as a screening test to identify individuals with reading difficulties or dyslexia" (Jacobson, 1993, 1997, p. 4). At the same time, the author observed that: "Many dyslexic individuals seem to have a slow processing speed also in the Letter Chain Test. Low scores on both tests could indicate a general low processing speed." The latter observations, if correct, indirectly indicate a potential threat to the usefulness of the WRI. That concept is also pointed out in the revised manual (1997, p. 13), where a table displays correlations between Wordchains and Letterchains for different grades. These correlations indicate a shared variance of .35-.40 in grades 6-9, suggesting a common underlying speed factor at these ages.

The Word Chain Test is designed to assess word decoding or word recognition (Jacobson, 1993, 1997). The creative idea demonstrated in test construction is to eliminate the spaces between words, which makes the test suitable for group administration. Unfortunately that also becomes a major threat to construct validity. A basic component in word decoding is that there should be spaces between words to represent *juncture,* a fundamental insight from the linguistic research on reading (Pearson & Stephens, 1994, p. 24). Because the procedure of eliminating spaces between the words is taking away a fundamental part of word decoding, it is important to show that the instrument is a valid measure of word decoding despite this questionable procedure.

The Wordchain subtest consists of 120 chains with three words in each. In choosing stimulus words, a crucial aspect in respect to test validity is to exclude words that become new real words if the examinee reverses them. When inspecting the 120 wordchains, 41 words were found which, if totally reversed, become new words. The first page, consisting of 40 wordchains (about the mean for grade 5), has as many as 19 words with these characteristics. This seems an unnecessary threat to the diagnostic validity of the test, especially since reversals is one aspect of the problems of dyslexic individuals (Critchley, 1970 p. 29; Learner, 2002, p. 447; Madison, 1996, pp. 25-26; Thomson, 1990, p. 170; Witting, p. 76). Again, it is important to determine whether the Word Chains Test is valid for the assessment of dyslexia, despite its inclusion of numerous reversible words.

All wordchains are made up of three words, which is explicitly told to the examinee during administration. One way to reduce possible extraneous influences—namely, using the strategy of just looking for the middle word—would have been to use four words or simply vary the number of words from item to item. Such a change has been partially done for grade 4 and upwards, in a new test called Reading Chains. This new test consists of Word Chains, Letter Chains, and a new subtest called Sentence Chains (Jacobson, 2001).

As stated in the *Standards for Educational and Psychological Testing* (American Educational Research Association, American Psychological Association, & National Council on Measurement in Education, AERA, 1999), validity is a unitary concept and is the degree to which all the accumulated evidence supports the intended interpretation of test scores for the test's proposed purpose. In accordance with these guidelines, the aim of this study was to make a further examination of the validity of the Word Chain Test and the WRI-index. In line with current views and terminology on validity as stated in the same Standards, validity support is discussed in terms of: (1) theoretical evidence based on test content, (2) theoretical evidence based on response processes, and (3) empirical evidence based on relationships to other variables. This study evaluated the third aspect of a test's validity by providing empirical evidence of the Word Chain Test's relationship to the diagnosis of dyslexia. This evidence concerned the test's sensitivity and specificity in correctly distinguishing children diagnosed with dyslexia from a control sample.

Method

Participants

The LD group consisted of 68 adults with dyslexia. Of these 33 had been diagnosed as having dyslexia on the basis of a full dyslexia assessment. The basic diagnostic foundation was the classic definition of Dyslexia from World Federation of Neurology in 1968 (Critchley, 1970). Added to that definition were problems detected in information processing (ETS, 1999). The diagnostic decisions were based upon the integrated results from structured interview, a broad cognitive assessment and from achievements on different levels of reading, spelling and writing. Diagnostic decisions were not based on any formula for discrepancy between intelligence and reading ability. The remaining 35 cases were diagnosed with dyslexia from teachers with special education in testing for dyslexia and with considerable experience in the field, using the same kind of comprehensive structured interview, and assessment procedure of achievements on different levels of reading, spelling and writing, but without psychological assessment of cognitive functions. The two groups were given the Word Chain Test as a measure of training progress.

The group of 68 subjects comprised 47 males and 21 females. The mean age was 29.1 years with a standard deviation of 7.4 years (range 20-48 years). In the first group there were 22 males and 11 females with a mean age of 29.6 years (range 20-48 years). In the second group there were 25 males and 10 females with a mean age of 28.6 (range 20-46 years). The mean age for both groups was thus similar, as was the ratio of males to females. The educational backgrounds varied from less than nine years of compulsory school to the completion of a university degree, with a median and mean education level for both groups of two years of senior high school. The participants were referred from various private, municipal, and state organizations for the assessment of dyslexia.

The control group consisted of 64 individuals, with Swedish as their first language and without self-reported present or earlier reading or writing difficulties, from the Uppsala municipal adult education program at Cederbladsskolan. Their mean age was 29.7 years, with a age span of 20-48. The group consisted of 30 males and 34 females. The educational background varied from less than nine years of compulsory school (one person) to ‘post-gymnasium' education with a median of two years of senior high school education.

Procedure

When evaluating the value of a test as a screening or as a diagnostic instrument it is essential to calculate the sensitivity, specificity and the positive predictive value for the instrument (Altman, 1991; Bland, 2000; Daniel, 1999). The *sensitivity* of a test instrument is the proportion of positives (i.e., of those having the disorder) that are correctly identified. The *specificity* is the proportion of negatives that are correctly identified by the test. The *positive predictive value* (PPV) is the proportion of individuals with positive test results (in our case of those having test results indicating dyslexia) who are correctly diagnosed (i.e., are dyslexic). The *negative predictive value* (NPV) is the proportion of individuals with negative test results that are correctly diagnosed (i.e., are not dyslexic).

The sensitivity and specificity of the Word Chain Test for accomplishing its proposed use as an indicator of dyslexia were measured on the basis of test results for a dyslexic sample and a control group. To investigate this aspect of concurrent validity of the Word Chain Test, a hit and miss analysis was used to evaluate Wordchains and the WRI. A hit and miss analysis identifies four subgroups: true positives, true negatives, false positives, and false negatives (Crocker & Algina, 1986, pp. 268-269). According to the manual (Jacobson, 1997, p. 27) a WRI below approximately 10-20 for "teenagers and older" indicates a specific reading disability.

Results

Table 6 shows the results for the group with dyslexia when using 20 as the more liberal WRI cut-off level. WRI identified 21 individuals at risk, that is, 30.9% of the sample scored ≤ 20. If requirements are qualified to also make demands on a simultaneous low result on Wordchains (≤ Stanine 3), the number is reduced to 27.9% (19 out of 68 correctly identified).

Table 6
Outcome of the WRI

	Group		
WRI-index	Dyslexia	Control	Total
Indicating dyslexia	21	4	25
Not indicating dyslexia	47	60	107
Total	68	64	132

The Word Chain Test originally consisted of just the Wordchain subtest. Letterchains was later supplemented to partial out visuo-motoric speed as an explanation for a low score on Wordchains. In an additional step, the WRI was introduced. If we return to the initial idea by just looking at the outcome of the Wordchain subtest, there is an unexpected and dramatic increase in test sensitivity as is shown in Table 7.

Table 7
Outcome on the Word Chain Subtest

Wordchains	Group		Total
	Dyslexia	Control	
Indicating dyslexia	48	28	76
Not indicating dyslexia	20	36	56
Total	68	64	132

The Wordchains by itself correctly identified 48 out of 68 individuals with dyslexia (70.6%) who obtained scores ≤ Stanine 3. Consequently, the WRI seems to be an unnecessary and even detrimental addition that diminished sensitivity by more than 50%. If Letterchains is used as a screening instrument, which is against the idea of the test, that subtest alone identifies 43 individuals (63.2%) as having scores ≤ Stanine 3. Summing up, Letterchains is almost as good an indicator of dyslexic problems as the Wordchains, and each one separately identified more than twice as many individuals as the WRI.

In the control group of 64 individuals with Swedish as their first language and no reported current or earlier reading problems, 28 individuals scored below or equal to Stanine 3 on the Wordchain subtest. That result indicates that about 44% of the control sample would be identified as showing indications of decoding problems—even though the entire control sample was known *not* to have reading difficulties. The result of this analysis is a true negative rate of .56, indicating serious lack of specificity to reading problems. In other words 44% were falsely identified as having decoding problems. On the other hand, the WRI, being normally distributed (Lilliefors $p > .20$), only identified four individuals (6%) as having values ≤ 20, thereby having a true negative rate of .94. So while the Wordchain subtest had good sensitivity coupled with poor specificity, the WRI demonstrated the opposite result: high specificity coupled with poor sensitivity. There were no significant gender differences on the WRI-index or on Wordchains in the dyslexic and the control groups.

Finally we examined the *positive predictive value* (PPV) both for the WRI-index and the Word Chain subtest. As seen above, the estimated prevalence of dyslexia is 4% for the U.S. and the U.K. and 5-10% for Sweden. Using 5% as estimated prevalence gives a PPV of 0.21 for the WRI-index and 0.08 for the Word Chain test. The meaning of this data is that only 21% of those with a WRI-index ≤ 20 are dyslexic and only 8% of those with results ≤ Stanine 3 on the Word Chain subtest are dyslexic. Thus the great majority of those showing indications of dyslexia are not dyslexic. The NPV both for WRI and the Word Chain subtest are 0.96, showing that if a test result is “negative”, that is, showing no indication of dyslexia you can be quite certain that the person does not have dyslexia. Taken together, these findings do *not* support the validity of the Word Chain Test for identifying adults with dyslexia.

Discussion

The sensitivity of the WRI (30.9%) for dyslexic problems is low, not even half as good as the separate subtests taken by themselves. Even though the specificity of the WRI seems to be high, this study finds no support for the further use of this index for screening or diagnostic assessment of dyslexia. An earlier factor-analytic study gives some clarification on the background of this negative finding (Study II). In that study, little or no support could be found for supporting the notion that the two parts of the Word Chain Test measured different factors. A consistent finding was that Wordchains and Letterchains primarily formed a factor of their own, interpreted as a measure of Perceptual (Visual) Speed (see Study II). In a further correlational analysis with the Wechsler Adult Intelligence Scale—Revised (WAIS-R; Wechsler, 1981) this Perceptual Speed factor was found to be significantly related to Full Scale IQ, Performance IQ, Perceptual Organization Index, Freedom from Distractibility Index, and to Digit Symbol scaled score, but *not* to Verbal IQ or Verbal Comprehension Index. These findings support the interpretation of the factor as primarily a measure of Perceptual Speed. That interpretation, of course, directly affects the WRI, which, from that perspective, fails to give any fruitful information.

The sensitivity of the Wordchain subtest (70.6%) is paired with the good, but seemingly undesired, sensitivity of 63.2% for Letterchains. That finding also indicates, somewhat in line with Jacobson’s (1995, p. 266) own observations, that both subtests could primarily be measures of Perceptual (Visual) Speed, which, in turn, is very sensitive to dyslexic problems. The problem with the use of Wordchains as a separate subtest is its low specificity (.56). Letterchains was added to control for psychomotoric speed—not as a measure of dyslexic or reading problems. Therefore, the theory, construction, and interpretation of the test need to be reconsidered. The findings from the present investigation of sensitivity and specificity, along with the factor-analytic results, give further support for previous findings that processing speed, perceptual speed, and psychomotor speed are all important dimensions of the dyslexia syndrome (summary of research by Kaufman, 1994, p. 215).

GENERAL DISCUSSION

Main findings

The first study supported the factor structure of the Swedish WAIS-R for individuals with dyslexia, in accord with the main findings from the many factor-analytic investigations of the original U.S. version of WAIS-R, both for normal and clinical groups (see the reviews and summaries of diverse WAIS-R factor analyses by Kaufman, 1990, and by Leckliter, Matarazzo, & Silverstein, 1986). Typical cognitive patterns were found for the three factors and for the Bannatynes categories. Also an ACID-profile could be identified. Again, findings for the Swedish sample were entirely consistent with results using the American WAIS-R.

The second study examined the factor structure of literacy tests often used in Swedish assessments of dyslexia. Five factors were identified: Decoding or Technical Reading Skill, Perceptual (Visual) Speed, Reading Comprehension, Reading Fluency and a Phonological Ability factor. These factors were then related to cognitive factors measured by the WAIS-R. The Visual Speed factor tended to correlate significantly with nonverbal scores whereas the Reading Comprehension factor correlated significantly with verbal scores. The Phonological Ability factor correlated significantly with the Freedom from Distractibility factor and with all its component subtests—Digit Span, Arithmetic, and Digit Symbol. The Decoding factor showed no significant relationship to any WAIS-R variable studied and that was also the case for the Reading Fluency factor.

The third study examined the validity of the frequently-used Word Chain Test. An empirical investigation on the sensitivity and specificity of the test indicated serious lack of sensitivity to dyslexic problems for the WRI and a striking lack of specificity for the Wordchains subtest, if used separately. The Wordchains subtest by itself was more than twice as sensitive to proposed interpretations than the WRI. That was also true for Letterchains, even though that was not the intention of the test. A reasonable interpretation of the findings is that the WRI seems to be a meaningless addition to the test. Also, because Wordchains and Letterchains have about the same sensitivity to dyslexic problems, the theory, construction and interpretation of the whole test need to be reconsidered.

Directions for future research and final reflections

This thesis indicates a great need for clarifying the concept of dyslexia as well as validating the instruments used in the screening and diagnostic assessment of dyslexia. When summarizing the last three decades of work on dyslexia, it appears that the enormous efforts by professionals to try to clarify the concept have not been very successful. This lack of success may be a result of the failure of the leading researchers in the field to distinguish between the symptomatic and causal levels of dyslexia. That failure has also resulted in much published research being difficult to interpret, and with some leaders in the field coming up with many unwarranted conclusions. If the root (the concept) is weak we obviously cannot expect the fruits (research findings) to be otherwise.

The conceptual confusions have had an enormous practical impact on the individual and on society. They have made the social institutions and authorities so bewildered that they refrain from giving any guidance as to appropriate and professional identification of dyslexia. Still, after considerable and continuous pressure from institutions, organizations, and individuals, the natural acting body of the National Swedish Board of Health and Welfare has withdrawn from saying anything about definition and proper diagnostic procedures. This outcome is surprising since they themselves are in charge of the translation and publication of the Swedish version of the ICD-classification system. Today, there are no general Swedish standards or guidelines for the documentation of dyslexia. The lack of any authorization for issuing certificates paves the way for injustice. The controversies in the definition of dyslexia make almost any documentation of dyslexia defendable in light of some opinion somewhere. This "wild west condition" also has detrimental effects on intervention because there is a strong connection between the quality of assessment and the quality of intervention. The same lack of standpoint or position on a disorder shared by several percent of the school children is also shown by the Swedish Board of Education.

The National Agency for Higher Education, pressed from international requirements, has issued a list of certified diagnosticians. Their requirements for diagnostic assessment of dyslexia are based mainly on achievement on reading tests with the additional requirement of measuring phonology, along with an explicit recommendation to use the Word Chain Test.

The lack of policy and guidelines for professional diagnosis of dyslexia is alarming, since behavioral diagnoses often have implications just as important as somatic diagnoses. While it is axiomatic to develop diagnostic instruments with utmost sophistication in the field of physical diseases, the instruments used in behavioral diagnostic assessments are amazingly neglected and deficient. Social resources for constructing and validating basic instruments for the clinical identification of disorders that possibly afflict more than 5% of the Swedish population (about 500,000 individuals) are lacking. The field is much lagging behind, and thereby opening up for unscientific methods and unprofessional decisions.

Decisions with serious consequences for the individual and for society are often based on tools not properly normed, standardized, or validated. A recent example is the Swedish version of the WAIS-III, our leading instrument for assessing intelligence and cognitive functions for adolescents and adults in clinical practice. That instrument is used for diagnostic decisions on mental retardation and learning disabilities, yet it is not normed for the Swedish population. The norms for the U.S. population are used, because of lack of money. Nobody would be satisfied to use U.S. geological or geographical maps to describe the Swedish landscape. Psychological measures must be standardized for the population it is going to be used for. It must also be validated for Swedish conditions as well as shown to be reliable for the Swedish individuals.

Some clarification of the concept of dyslexia has been provided by Frith (1999) and by Nicolson and Fawcett (2001). At the same time, their conclusions are implicit in the classic definition of dyslexia, which speaks of dyslexia as a problem in learning to read due to deficits in certain cognitive processes and being of a constitutional (i.e., biological) origin.

Much research is needed on the psychometric qualities of instruments used in important clinical investigations. There is also a lack in the regulations that determine who can use particular test instruments for diagnostic purposes. Here a first requirement must obviously be that anyone using such instruments at least has some education on test theory, psychometrics, test knowledge, and test administration.

The three studies described in this paper all address the crucial issues discussed here. In Study I, one commonly-used test has been given empirical support for its validity with a population of individuals with dyslexia (the WAIS-R). However, in Study III, a different widely-used test received no support of being valid for its intended use (the Word Chain Test). In Study II, the constructs that underlie commonly-administered achievement tests were clarified based on their relationships to each other and to measures of cognitive ability. The results of all three studies combine to: (a) enhance clinical understanding of an array of instruments used frequently in Sweden for the diagnosis of dyslexia; (b) increase knowledge of the psychometric properties of these tests, especially their validity for their intended purposes; (c) elucidate interrelationships among the instruments and, hence, among the constructs that underlie each test; (d) contribute to a theoretical as well as practical understanding of these key constructs; and (e) help move the field of dyslexia, and its assessment, forward—not just in Sweden, but internationally as well, because better understanding of the definition and assessment of dyslexia are applicable to the world-wide controversies that exist during the first decade of the 21st century.

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