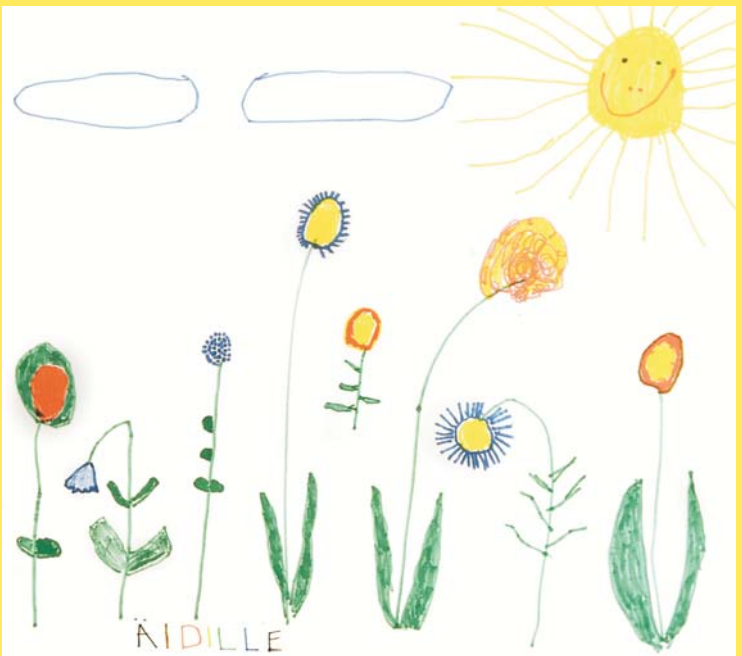
Anne Puolakanaho

Early Prediction of Reading

Phonological Awareness and Related Language and Cognitive Skills in Children with a Familial Risk for Dyslexia



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JYVÄSKYLÄ STUDIES IN EDUCATION, PSYCHOLOGY AND SOCIAL RESEARCH 317

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UNIVERSITY OF JYVÄSKYLÄ

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ABSTRACT

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Yhteenveto: Lukemistaitojen varhainen ennustaminen – Fonologinen tietoisuus, kielelliset ja kognitiiviset taidot lapsilla joiden suvussa esiintyy dysleksiaa
Diss.

This thesis explored the developmental connections from early phonological awareness and related language and cognitive skills to 2nd grade reading accuracy, fluency and specific reading disability, in the context of Finnish: a language with high orthographic regularity. The four studies presented addressed the following three main themes: emerging phonological awareness and its relationship to reading-related language and cognitive skills, links from these childhood skills to 2nd grade outcomes, and early prediction of an individual child's risk for dyslexia. The results are based on behavioural-level tasks and longitudinal assessment of nearly 200 children belonging to the Jyväskylä Longitudinal Study of Dyslexia. The findings indicated that emerging phonological awareness skills can already be measured at the age of 3.5 years using age-appropriate and language-modified tasks. In addition, phonological skills are predicted by prior verbal comprehension, language production and cognitive skills. Phonological awareness and related language and cognitive skills (e.g., pseudoword repetition, expressive vocabulary, verbal short term memory and rapid serial naming of objects) at the age of 3.5, 4.5 and 5.5 years were found to form a broader constellation of strongly interrelated and developmentally stable skills than has been previously suggested. In accordance with the phonological core hypothesis it was also shown that in the orthographically regular Finnish language, reading accuracy was relatively strongly predicted by early phonological and language abilities but considerably weaker links were found to reading fluency. A rough index for an individual child's risk for reading disability could be constructed using three key risk measures. An attempt is made to construct a conceptual framework of the paths leading to reading acquisition. A challenge for future studies lies in the investigation of the unique paths leading to fluent reading and in developing methods and programs for training fast and efficient decoding.

Keywords: reading accuracy, fluency and dyslexia, phonological awareness, language and cognitive skills, letter knowledge, longitudinal study, prediction, childhood

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Jyväskylä Longitudinal Study of Dyslexia (JLD)

KIITOKSET

Tämän väitöskirjatutkimuksen mahdollistitte te, tutkimushankkeessa mukana kulkeneet vanhemmat ja lapset. Kiitos sitkeästä jaksamisesta. Kiitän myös teitä hyvät työkaverit ja kollegat käytännön työn kentillä - olette avanneet silmiäni lukemisen moni-ilmeisyyteen. Kun kirjoitan tätä en vielä oikeasti ole tohtori, mutta siihen yritykseen ovat osaltaan rohkaisseet vastaväittäjäni Rauno Parrila ja esitarkastajani Usha Goswami. Kiitän teitä paneutumista väitöskirjaani. Tutkijan tiellä en varmastikaan olisi, ellen olisi puolivahingossa joutunut mukaan Heikki Lyytisen graduryhmään. Olen kiitollinen Heikille hänen ainaisesta valmiudesta maalata uusia unelmia tiedemaailman kartalle. Niistä olen inspiroitunut lukemattomia kertoja – ja lopulta oppinut myös kaivamaan jalkani tukevasti kiinni maan kamaraan. Timo Ahoselta olen aina voinut etsiä neuvoa ja erityisen arvokasta se on ollut silloin kun on pitänyt nähdä metsä puilta tai toisinpäin. Anna-Maija Poikkeukselle olen kiitollinen pitkäaikaisesta yhteisestä matkasta ja erityisesti paneutumisesta asioiden esittämiseen tiedetoimittajan tarkkuudella. Ilman Asko Tolvasta tutkimuksistani olisi varmasti tullut vaatimattomampia. Hänen tapansa keskustella ja miettiä sekä tilastollisia että sisällöllisiä kysymyksiä on ainutlaatuista! Matkalla on tullut eteen monta tutkimukseen ja teoreettisiin asioihin liittyvää kysymystä, joiden selkeyttämisessä olen aina voinut kysyä apua Paavo Leppäseltä, Kenneth Eklundilta, Minna Torpalta, Mikko Arolta ja Sini Hintikalta.

Välillä puurtaessani artikkeleiden maailmassa tunsin miltei muuttuvani painomusteeksi. Silloin pelastus löytyi tutkijaporukasta, heidän ystävyydestään ja erityisesti kyvystään rätkättää -eli nauraa ja naurattaa niin että vatsanpohjaa vihloo. Olen syvästi kiitollinen koko poppoolle ja erityisesti Paula Salmelle, Jarmo Hämäläiselle, Hanne Salmiselle, Nina Saineelle, Kirsti Eklundille, Annamaija Oksaselle, Manu Vesteriselle, Tomi Guttormille, Tarja Etelälahdelle, Kaisa Lohvansuulle, Annika Tanskaselle, Jarkko Hautalalle, Riitta Pennalalle, Riitta Hytöselle, Marja-Leena Laaksolle, Pirkko Leppäselle sekä Ritva Ketoselle. Valoa työhön ovat puhaltaneet uudet työtoverini LukiMat -hankkeen parissa, erityisesti Juha-Matti Latvala, Marika Peltonen, Anne ja Ville Mönkkönen sekä Anna Maija Stubb. Voimia ja uusia näkökulmia ovat tarjonneet elämääni sydänlämmöllä erityisesti ystäväni Anneli, Sari, Reijo, Ilmari, Irma, Marjo, Eija, Aila ja Jari.

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LIST OF PUBLICATIONS

This dissertation is based on the data presented in the following articles that are referred in the text using their Roman numerals (I-IV).

Study I Puolakanaho, A., Poikkeus, A.-M., Ahonen, T. Tolvanen, A., & Lyytinen, H. (2003). Assessment of three-and-a-half-year-old children's emerging phonological awareness in a computer animation context. *Journal of Learning Disabilities,* 36, 416-423.

Study II Puolakanaho, A., Poikkeus, A., Ahonen, T., Tolvanen, A., & Lyytinen, H. (2004). Emerging phonological awareness differentiates children with and without familial risk for dyslexia after controlling for general language skills. *Annals of Dyslexia,* 54, 221-243.

Study III Puolakanaho, A., Ahonen, T., Aro, M., Eklund, K., Leppänen, P.H.T., Poikkeus, A. , Tolvanen, A., Torppa, A., & Lyytinen., H. (in press, 2007) Developmental links of very early phonological and language skills to second-grade reading outcomes: Strong to accuracy but only minor to fluency. *Journal of Learning Disabilities.*

Study IV Puolakanaho, A., Ahonen, T., Aro, M., Eklund, K., Leppänen, P.H.T., Poikkeus, A. , Tolvanen, A., Torppa, A., & Lyytinen., H. (in press, 2007). Very early phonological and language skills: Estimating individual risk of reading disability. *Journal of Child Psychology and Psychiatry.*

CONTENTS

1 INTRODUCTION

Difficulties in achieving proficient reading skills in spite of adequate sensory ability, intellectual skills and schooling has been termed dyslexia or reading disability. This thesis presents findings regarding the behavioural-level predictors of dyslexia assessed before formal education has had an effect on them. The aim is to shed light on very early phonological awareness skills, to study their connections to other early language and cognitive skills and to explore their developmental stability as well as connections to later reading outcomes. Of special interest is the examination of the above mentioned dynamics in a regular language context. At the end of the 2nd grade Finnish children are at an interesting point in their reading and spelling development, since variation in both reading accuracy and reading fluency exists and it is already possible to identify children who manifest persistent difficulties in reading. Fluent reading is a necessity for every child in today's modern society, and for those who struggle in acquiring sufficient reading and writing skills, schooling becomes frustrating and may form a barrier to later learning. Early identification of children at risk for reading difficulties would offer a possibility for early intervention or planning alternative approaches to learning.

1.1 Early Prediction of Reading Skills and Dyslexia

From Past to Present and from Irregular to Regular Orthographies

Dyslexia was first described almost a century ago but real advances in understanding its cognitive phenotype has only come about during the last 30 years. Earlier theories about dyslexia focused on the assumed visual perceptual deficits (e.g., manifested in reversals). Vellutino (1979) demonstrated that reversal problems in dyslexia were restricted to processing print in one's own language, and were thus really linguistic in nature rather than visual. A compelling body of literature nowadays suggests that dyslexia is a genetically and environmentally transmitted linguistic disorder resulting from a core

phonological deficit (Grigorenko, 2005; Pennington, & Olson, 2005; Plomin & Kovas, 2005; Vellutino, Fletcher, Snowling, & Scanlon, 2004; Rutter & Maughan, 2005). The majority of the reading researchers agree with the phonological core deficit hypothesis, but some regard it as secondary to a more basic auditory impairment or as part of a general sensomotor deficit (review by Ramus, 2003). Recently Grigorenko described dyslexia in the following way**: "*Developmental dyslexia or specific reading disability is a set of common weaknesses in a number of cognitive processes forming the foundation for the mastery of reading and correspondingly, for developing literacy*"** (Grigorenko, 2005; p. 286). She estimates that in developed countries dyslexia affects approximately 5 to 9 out of every 100 individuals, across all ages. Although the manifestation and prevalence varies in different linguistic systems, there is a consensus that this condition is present in all languages and cultures.

Written language is a relatively recent cultural invention and scripts vary in their conventions of mapping words. A printed character in an orthography can represent a word, syllable or phoneme. The Finnish orthography is highly regular, i.e. each phoneme corresponds to just one grapheme and vice versa. On the other hand, English, from which the vast majority of reading research comes from, is orthographically an exceptionally irregular language compared to other European languages (Aro & Wimmer, 2003). It has been suggested that English speaking children use grapheme-phoneme correspondences for learning the basic principles of regular words but for reading irregular words they need to learn about orthographic rules and different types of decoding strategy (Nation, Angell, & Castles, 2007; Ehri, 2005; Wimmer, Mayringer, & Landerl, 2000). For Finnish speaking children all that is needed in order to read is to be accurate and fast in grapheme-phoneme mapping (Aro, 2006; Holopainen, Ahonen, & Lyytinen, 2002; Parrila, Aunola, Leskinen, Nurmi, & Kirby, 2005).

Isabelle Y. Liebermann (1973) suggested at the beginning of the 1970's that learning to read and write depends on the phonological domain of skills and especially on the degree to which the child is aware of the underlying phonological structure of the words, i.e. phonological awareness (see also Brady & Shankweiler, 1991). Awareness of the phonological structure of words was shown to predict reading success for children from different languages (e.g., Alegria, Pignot, & Morais, 1982; Bradley & Bryant, 1983; Liberman, 1973; Lundberg, Olofsson, & Wall, 1980; Tornéus, 1984). Studies also suggested that phonological awareness can be trained in young children (Content, Morais, Alegria, & Bertelson, 1982; Olofsson & Lundberg, 1983). Additionally, adults with literacy problems were shown to have difficulties with tasks requiring explicit understanding of the phonological structure of words, and adults' phonological awareness was noted to increase as individuals acquired further reading skill within an alphabetical orthography (e.g., Morais, Cary, Alegria, & Bertelson, 1979; Read, & Ryter, 1985). Since the findings of Bradley and Bryant (1978, 1983) connecting preschool rhyme awareness to later reading achievements, a whole body of research has been published concentrating on

phonological awareness, its operationalization, terminology[1] ,and associations with reading acquisition and dyslexia (e.g. Brady & Shankweiler, 1991; Jackson & Coltheart, 2004; Goswami, 2001).

It has been suggested that poor performance in phonological awareness tasks may reflect ***poorly specified phonological representations and/or poor phonological processing skills*** at the cognitive level (Snowling, 2001; Swan & Goswami, 1997; Ramus, 2001; Rayner, Foorman, Perfetti, Pesetsky, & Seidenberg, 2001). The quality of phonological representations and phonological processing skills is thought to be manifested in a variety of tasks such as those involving phonological awareness, pseudoword repetition and naming (Bowey, 2001; Elbro & Jensen, 2005; Fowler, & Swainson, 2004; Ramus, 2001; Wagner et al., 1994). Further, it has been proposed that phonological representations undergo continuous restructuring in the mental lexicon during childhood (i.e. lexical restructuring model by Fowler, 1991; Metsala 1999a). Children with familial dyslexia are believed to have a higher risk for inaccurate lexical and sub-lexical representations (Leppänen, Richardson, Pihko, Eklund, Guttorm, Aro, & Lyytinen, 2002; Ramus, 2001; Szenkovits & Ramus, 2005).

The development of phonological skills is affected by the child's inherited neural capacities (e.g. Grigrorenko, 2005; Plomin & Kovas, 2005; Ramus, 2003; Rutter & Maughan, 2005) as well as language experiences in the environment (Walley, Metsala & Garlock, 2003). It is well documented that phonological awareness, especially phonemic awareness, predicts reading among preschool-aged children and that it develops reciprocally with letter knowledge and reading skills (e.g. Burgess & Lonigan, 1998; Wagner, Torgesen, & Rashotte, 1994; Morais 1991). However, the findings concerning very early phonological awareness skills and their developmental continuity as well as the connections to other language skills and later reading outcomes are sparse (but see Silvén, Poskiparta, & Niemi, 2004 for data from the Finnish language).

Emerging Phonological Awareness

The development of phonological awareness is generally described as a progression from shallow sensitivity to large phonological units through to a

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[1] Phonological awareness refers to the ability to perceive and attend to a word's sound structure, as opposed to its meaning, i.e. the term refers to understanding that oral language can be divided into smaller sound components. It is operationalized by multiple tasks that measure the ability to manipulate the sounds of spoken words. The tasks differ in cognitive task demands (e.g. identification, detection, blending and elision) and in the linguistic complexity of the items (e.g. words, syllables, rimes, onsets and phonemes). Several other terms have been used in the context of phonological awareness: Linguistic awareness (Liberman & Shankweiler, 1987), rhyme awareness (Bradley & Bryant, 1983), phonological sensitivity (Lonigan, Burgess, Anthony & Barker,1998), epilinguistic skills (Gombert, 1992) referring to early or emerging phonological awareness, metaphonological awareness (Gombert, 1992) referring to a more advanced and conscious level of phonological awareness skills. Phonemic awareness refers to the ability to isolate phonemic-size units from speech (for an overview see Brady & Shankweiler, 1991; Goswami, 2001).

deep awareness of small phonological units. Studies focusing on skills present before any formal reading experience offer valuable information about predictors of reading per se. Following the ideas of Jackson and Coltheart (2001), very early phonological skills might represent ***proximal causes*** of reading ability; i.e. if the early skills which are not as intertwined with the reading acquisition process as later skills succeed in predicting reading outcomes, they reflect true deficiencies at that cognitive processing level. On the other hand, if the early skills are shown to have reciprocal connection with the reading acquisition process, the association would reveal ***distal causes*** i.e. they are at least partly byproducts of reading acquisition.

Although a large body of studies have indicated that a variety of tasks can be used to assess phonological awareness around school entry (e.g. Lundberg, Olofsson, & Wall, 1980; Yopp, 1988), only a few of them have documented reliable and sensitive assessment of the skills of younger children (e.g., Chaney, 1998; Lonigan, Burgess, Anthony, & Barker, 1998). Table 1 in the Appendix lists the most prominent studies that have examined phonological awareness of children under four years of age and reported connections to their later reading achievements.

The phonological awareness tasks developed in the Jyväskylä Longitudinal Study of Dyslexia were influenced theoretically by Gombert 's (1992) view of developmental stage-like shifts in the quality of phonological awareness skills, and the lexical restructuring model (Fowler, 1991, and its extension by Metsala & Walley, 1998, and Metsala, 1999a). The latter model assumes that lexical items are gradually restructured from more holistic word-like forms into more segmental representations. Based on the earlier literature it was expected that before four years of age, children are generally able to master phonological units that are larger than a single phoneme. The principles guiding the construction of the measures were the following: 1) the tasks needed to cover the continuum from whole words to syllables to phonemes, 2) the cognitive demands of the tasks were appropriate to the children's age (e.g., identification or blending), 3) children's engagement, interest and the reliability of task presentation were ensured by using playful game-like elements in the tasks and embedding all the tasks in a computer animation program.

Other Predictors of Reading and Reading Disability

The findings of recent follow-up studies of children with a familial risk for dyslexia (e.g. Carroll & Snowling, 2004; Elbro, Bostrom, & Petersen, 1998; Pennington & Lefly, 2001; Snowling, Gallagher, & Frith, 2003; de Jong & van der Leij, 2003) as well as the pioneering longitudinal research by Scarborough (1989, 1990) and her meta-analyses of around 60 predictive studies of dyslexia from 1977 to 1996 (Scarborough, 1998; 2001) indicate that in addition to phonological awareness, the best preschool and kindergarten-age predictors of future reading achievement are the following: letter knowledge, short term memory, serial naming speed, pseudoword repetition and expressive vocabulary. Nonverbal skills like performance IQ, visual memory and motor

skills are also associated with reading scores but to a lesser extent (Scarborough, 1998; 2001).

The scattered findings prior to the age of four (e.g. Bryant, MacLean, Bradley, & Crossland, 1990; Gallagher, Frith, & Snowling, 2000; Scarborough, 1990; Snowling, Gallagher, & Frith, 2003) suggest that the bivariate correlations between early reading outcomes and preschool-age predictors are not markedly lower than those between reading and the same predictive measures assessed just before school entry at the kindergarten-age. However, typically these studies have not used a battery of simultaneously assessed predictive measures. Findings concerning some critical predictors such as rapid naming or phonological memory are mostly absent.

Close associations between the key predictors of reading have been typically observed at an early age (e.g. Chaney, 1998; Gallagher et al., 2000; Metsala, 1999a; Pennington & Lefly, 2001; Silvén et al., 2004). Phonological awareness has been found to be associated with prior skills such as vocabulary (Metsala, 1999b; Lonigan, Burgess, Anthony, & Barker 1998), articulation quality (Thomas & Senechal, 2004; Carroll, Snowling, Stevenson & Hulme, 2003), sensitivity to rhyme and alliteration (Bryant, MacLean, Bradley & Crossland, 1990.), awareness of morphemes and syntax, (Chaney, 1998), maternal interactional sensitivity (Silvén, Niemi, & Voeten, 2002), as well as parental involvement (Senechal & LeFevre, 2002). Among the predictors of reading, several latent factors correlating with each other have also been identified (e.g. Wagner et al., 1994). Although some studies exist in which Structural Equation Modelling has been applied to analyse the relations between predictive skills at the preschool age and later reading outcomes (Lonigan, Burgess, & Anthony, 2000; Storch, & Whitehurst, 2002), interrelations between different early skills (Carroll et al., 2003), and their developmental stability (Lonigan et al., 2000; Whitehurst, & Lonigan, 2001), a developmental modelling study based on a comprehensive battery of early measures applied longitudinally from the age of three to school age is lacking.

The Findings of the Jyväskylä Longitudinal Study of Dyslexia

The Jyväskylä Longitudinal Study of Dyslexia (JLD) has followed a group of children with and without a familial risk for dyslexia from birth to the end of the 3rd school year. The study has produced many findings that expand the previous literature. The JLD speech perception studies using neuro-physiological methods (i.e. ERP-studies) have indicated differences in the quality of speech processing between infants who do or do not have a familial risk from assessments just after birth and at the age of 6 months (Guttorm, Leppänen, Tolvanen, & Lyytinen, 2003; Leppänen et al., 2002). Children with and without risk were also found to differ in speech sound categorization assessed using the head turn-paradigm at the age of 6 months (Richardson, Leppänen, Leiwo, & Lyytinen, 2003). In analyses combining speech perception data and later behavioural measures, the neural processing of speech sound stimuli at birth , as measured using ERPs, was shown to predict later skills like

receptive language at the age of 2.5 and verbal memory at 5 years (Guttorm, Leppänen, Poikkeus, Eklund, Lyytinen, & Lyytinen, 2005). A further very recent analysis showed that the group of children who ultimately manifested reading problems differed in processing basic auditory stimuli in infancy (Salminen, Hämäläinen, Guttorm, Eklund, Lyytinen, & Leppänen, submitted, 2007).

The analyses using behavioural level measures have reported associations between childhood language development and mother-child interaction (Laakso, Poikkeus, & Lyytinen, 1999), child early intentional communication (Laakso, Poikkeus, Katajamäki, & Lyytinen, 1999), and symbolic play (Lyytinen, Eklund, & Lyytinen, 2003). At the age of 2.5 years, children with and without the risk differed in their number of vocalizations (Lyytinen, Aro, Eklund et al., 2004) as well as morphological skills and vocabulary development (Lyytinen, & Lyytinen, 2004). From this age onwards, several linguistic and cognitive measures were found to differentiate the at risk and control groups and predict children's later reading related skills (Lyytinen, Ahonen, Eklund, et al., 2001; Lyytinen, Aro, Eklund et al., 2004). The two groups of children have not been found to differ on home literacy experiences except that in the control group the parents reported more personal reading activities than the parents in the at-risk group (Torppa, Poikkeus, Laakso, et al., 2007a).

Parental teaching, on the other hand, was found to have an effect on the development of beginning reading (Torppa, Poikkeus, Laakso et al., 2007a). Recent articles involve identification of reading trajectories based on the early language and literacy measures (Lyytinen, Erskine, Tolvanen, Torppa, Poikkeus, & Lyytinen, 2006) and identification of developmental paths of reading based on profiles of word recognition and reading comprehension (Torppa, Tolvanen, Poikkeus et al., 2007b). In addition, heterogeneity among parents with a familial risk of dyslexia has been described with respect to deficiencies in speed and accuracy of reading (Leinonen, Müller, Leppänen, Aro, Ahonen, & Lyytinen, 2001), and to detection of sound stimuli (rise times), which was further connected to phonological and reading skills (Hämälainen, Leppänen, Torppa, Müller, & Lyytinen, 2005).

1.2 The Theoretical Framework Connecting Early Skills to Later Reading Outcomes

Focusing upon the main point of interest in this thesis, the early prediction of reading, it is relevant to reflect on theoretical accounts which model the core processes behind the development of predictive skills and later reading. Two decades ago McCelland and Rummelhart (1986) introduced the connectionist or parallel distributed processing framework, whose main principles are presented in Figure 1 (but see also recent extensions by Huzler, Ziegler, Perry, Wimmer, & Zorzi, 2004; Plaut, McClelland, Seidenberg, & Patterson, 1996).

This framework regards reading as a cognitively complex task that demands ***information processing at multiple sensory levels, i.e. at least at phonological, visual, semantic and context levels.*** Each level of processing is assumed to be simultaneously active and interactive, working in mutual coordination with each other - in concert **-** during a reading and spelling event. For example, at the orthographic level of processing the written symbols of the word 'cat' are detected by analysing the visual stimuli connected to it. At the phonological level of processing the word "CAT" is identified by analysing the different phonemes and blending them to form a word. Semantic processing connects the word 'cat' to animals and specific features like fur. The context processor connects the word 'cat' to contextual meaning like talking about the cat who ran away from the dog (Adams, 2001).

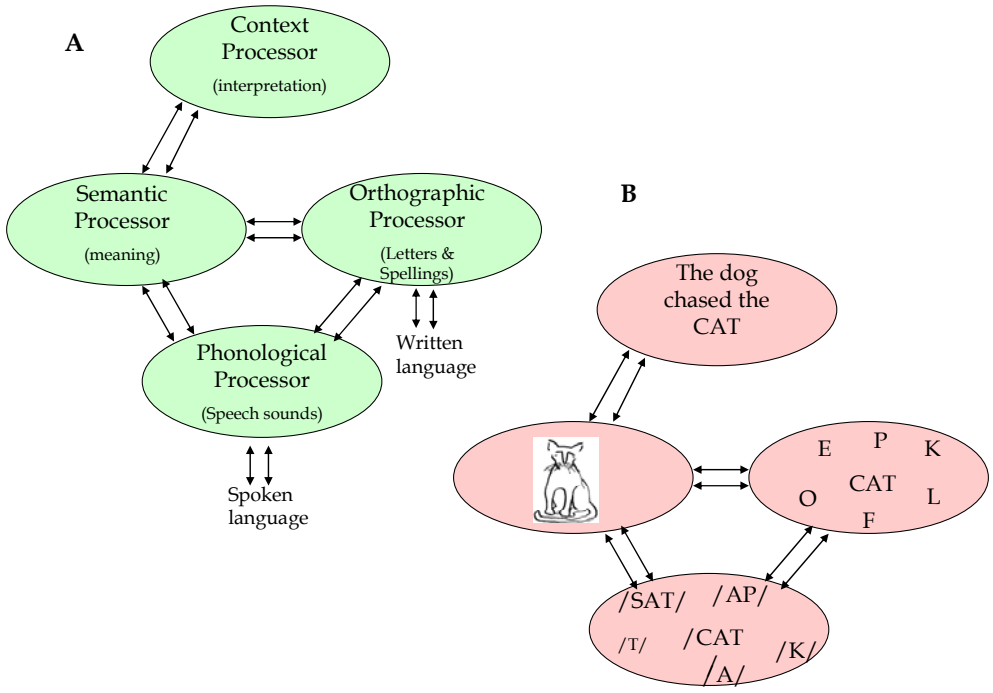


FIGURE 1 A Parallel Information Processing Model of Reading (A) And A View of How The Word " CAT" Might Be Read (B), Based On Ideas by Adams (2001)

As described in the preceding chapters, many predictors of early reading are identified in the literature, with some tapping phonological processing, some tapping semantic processing aspects (such as vocabulary and IQ) and some tapping orthographic processing skills (such as letter knowledge) (Nation, & Snowling, 2004). However, as noted by Ramus (2001) a certain behavioural level task is not usually able to capture the intended specific underlying processing skill purely but rather it taps several skills along with the one that it is predominantly designed to assess.

Taken together the models and findings presented in the literature (see the chapters above) claim that the core problem of dyslexia stems from deficiencies in phonological processing and the quality of phonological representations.

Performance on any task requiring access to phonological representations or processing of phonological information will thus be affected to a greater or lesser degree. Predictive links to reading are most commonly reported from the phonological domain of skills, however, tasks tapping orthographical or semantic processing have also been shown to have predictive links to the reading outcomes. In addition, associative links among the predictors are observed. It is noteworthy though, that reports on predictive associations to reading have nearly always concerned reading accuracy in orthographically irregular languages. The view of dyslexia as a genetically and environmentally transmitted linguistic disorder, along with the lexical restructuring hypothesis, offer wider developmental perspectives: these ideas suggest that environmental stimuli and/or biological restrictions have an extremely dynamic effect on a variety of language skills and their development. It is possible to capture a snapshot of this process in the early years of life – but only if we succeed in developing age-sensitive assessment procedures.

1.3 The Effects of the Language Regularity Context on the Achievement of Reading Accuracy and Fluency

Most reading-related studies originate from English speaking countries, despite the fact that English is an exceptionally irregular language in its grapheme-phoneme correspondence. Learning about the multiple correspondences between the written and spoken forms of words is a critical step in becoming a skilled reader in English. The Finnish language represents the other end of the continuum of regularity since its orthography is highly transparent. Grapheme -phoneme correspondences are extremely regular and symmetrical, and spelling is highly consistent with pronunciation. Each phoneme is represented by a corresponding single letter – with the exception of the /ŋ/ phoneme. However, due to its agglutinative-fusional nature, Finnish morphology is complex, and thus words are typically polysyllabic and long. A notable feature of Finnish phonology is the role of phonemic duration in changing word meaning (e.g., mato = worm, matto = carpet), which makes additional demands for accurate phonological coding (Aro, 2006; Karlsson, 1983). In the light of these language specific features it is evident that the major challenge for a beginning reader of Finnish is becoming accurate in grapheme-phoneme mapping in the early phase and being able to do this fluently and automatically in the later phase (Aro, 2006; Leppänen, Niemi, Aunola, & Nurmi, 2006; Lerkkanen, Rasku-Puttonen, Aunola, & Nurmi, 2004). It is likely that well-developed morphological skills and experiences of a rich language and literature environment further help the process of reading acquisition.

The findings in regular languages like Italian, Greece or Finnish have shown that in these language environments children can shift emphasis from reading accuracy to reading fluency during the first or second school years. In

contrast, in irregular language contexts like Danish or English, the emphasis remains on the acquisition of reading accuracy for several years (Goswami, 2002; Seymour, 2005; Wimmer & Mayringer, 2002). These differences lead to differences in the phenotype of dyslexia: in regular languages, soon after the first year of reading instruction dyslexic readers are recognized mainly by their dysfluent reading while in irregular languages, dyslexia is manifested as persistent accuracy problems both in reading and spelling.

Predictors of reading skills and reading problems are generally similar between different languages; however, some differences have been suggested. Although phonological awareness is known to predict the beginning reading phase (i.e., reading accuracy) in most alphabetic languages, phonological awareness does not appear to be as good a predictor of reading fluency. The weaker prediction of fluency has been reported mainly for orthographically regular languages (Holopainen, Ahonen, & Lyytinen, 2001; Wimmer & Mayringer, 2002), but it has been recently supported by findings from irregular language environments in older children too (Hogan, Catts & Little, 2005; Kirby, Parrila, & Pfeiffer, 2003).

The potentially strong role played by rapid naming skill as a predictor of reading fluency has lately had increased attention. In her review, Allor (2002) suggested that in most studies, findings have supported the link between rapid naming (RAN) and fluency in both typical and poor readers. However, the findings mainly come from irregular languages and concern reading accuracy. Recently Georgiou, Parrila and Papadopoulos (submitted, 2007) explored RAN in the orthographically regular Greek and irregular English languages during the first two school years, beginning at age five. Their analyses suggested that RAN is a reliable predictor of reading fluency (see also Savage & Frederickson, 2005), having a substantial influence on early reading development (see also Compton, DeFries, & Olson, 2001). Furthermore RAN may be a stronger predictor of reading in regular languages compared to irregular languages (see also Wimmer, Mayringer, & Landerl, 2000). Thus far studies using measures of RAN obtained before 5 years of age to predict both reading accuracy and fluency do not exist.

Letter knowledge has been highlighted as one of the most important pre-reading skills at preschool age and a predictor of both variance in normal reading and reading disability (e.g. Catts, Fey, Zhang, & Tomblin, 2001; Pennington, & Lefly, 2001; Wagner, Torgesen, & Rashotte, 1994). The few studies investigating the predictors of letter knowledge suggest that it is connected to cognitive precursor such as phonological sensitivity, phonological memory and rapid naming skills (de Jong &Olson, 2004; Torppa, Poikkeus, Laakso, Eklund, & Lyytinen, 2006). However, letter knowledge is also connected to environmental factors such as home-based letter teaching and mother's educational level (Torppa et al., 2006). No previous study, to the author's knowledge has examined whether early letter knowledge predicts reading accuracy and fluency in a similar fashion.

The reading development of English readers has often been described as a series of stages or phases (Frith, 1985; Ehri, 2005; Seymour, 2005). In each of

these theories phonology plays an important role in helping the child establish word –specific orthographic representations. Phonological recoding provides the bases for generalization, a self-teaching mechanism (Share, 2004) and the foundation upon which to build further learning about orthography (Nation, Angell, & Castles, 2007). Subsequent exposure with literature and further practice is thought to lead to fluent reading i.e. automaticity in retrieving word forms and meanings from printed words (Rayner et al., 2001).

In slight contrast, approaches such as connectionist models suggest that the cognitive system acts upon certain probabilistic principles of computation for implicit learning in both regular and nonregular languages (e.g. McCelland & Rummelhart, 1986; see also Huzler, Ziegler, Perry, Wimmer, & Zorzi, 2004; Plaut, McClelland, Seidenberg, & Patterson, 1996). In the latter types of approaches, a single processing mechanism operates over simple input and output representations connected via hidden units. The key assumptions are that the sets of distributed representations code phonological, orthographical and semantic information and that as a consequence of experience and learning, connection weights between these representations come to represent the statistical properties of the language being learned. Importantly, no part of the model deals exclusively with a certain class of words such as nonwords or exception words. Theories based on the neurobiological origins of reading are also now emerging (Dehaene, Cohen, Sigman, & Vinckier, 2005; Turkeltaub, Weisberg, Flowers, Basu, & Eden, 2005).

The Psycholinguistic Grain Size Theory by Ziegler and Goswami (2005) suggests that the cognitive strategies in learning to read – at least for skilled reading – may be very different in orthographically diverse languages. In corollary, the manifestation of dyslexia may also be different in these languages. The process of becoming a fluent reader in different languages, however, is not yet well-understood and remains open to test in Ziegler's and Goswami's theory.

1.4 Challenges in Developing Individual Screening Practices

A measure that shows a clear statistical difference between groups does not necessarily predict skills at the level that would be useful in the prediction of individual risk. To attain clinical relevance and sufficient individual predictive power, a measure needs to be both ***sensitive*** and ***specific*** **(**the issue related to a measure's predictive power and usability in clinical practice is addressed further in Appendix; Figure 3, Figure 4 and Table 5). To create the most sensitive indices of an individual´s risk of reading disability, statistical procedures combining several variables have been employed (e.g., Pennington and Lefly, 2001; Elbro et al., 1998). Only a few studies have attempted to implement empirically-derived indices into clinical screening practice. Catts, Fey, Zhang and Tomblin (2001) found that the performance of children with

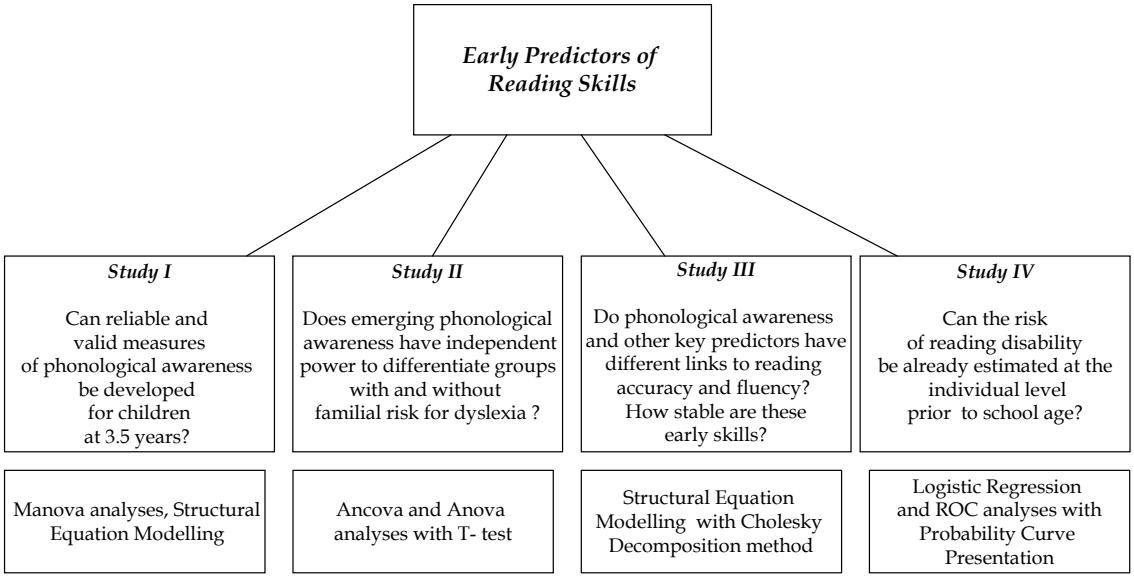
early language problems at age 5, in letter knowledge, sentence imitation, phoneme/syllable deletion and rapid naming had a significant contribution in predicting the risk of 2nd grade reading comprehension difficulties. Another significant contributor was maternal education. Risk indices such as those produced in by Catts et al., as well those by Pennington and Lefly (2001) and Elbro, Bostrom and Petersen (1998) do, however, have drawbacks. Most critically, they identify quite a large number of false positive cases in addition to true positive cases (i.e., children with reading disability). The challenge of current research is to find a clinically useful and parsimonious procedure to evaluate an individual child's risk for a reading disability. It is also important to be able to present a viable way to illustrate the risk.

2 AIMS OF THE THESIS

This thesis explored developmental links from very early phonological awareness at the age of 3.5 years through to 2nd grade reading skills, in the highly orthographically regular Finnish language. It had three main goals: ***first,*** to investigate emerging phonological awareness and its relations to other early reading-related language and cognitive skills; ***second,*** to study links from these early skills through to 2nd grade reading accuracy, fluency as well as to reading disability; and ***third,*** to explore the feasibility of early individual prediction of dyslexia.

The ***first*** goal is addressed in Studies I, II, and III. The challenge of Study I was to create a battery of phonological awareness tasks which are appropriate for children under four years of age, i.e., to build tasks in which both the cognitive and linguistic demands are suitable for the young children. Study II examined the predictive skills of 3.5-year-old children's emerging phonological awareness skills. Study III explored the connections of phonological awareness at the age of 3.5, 4.5 and 5.5 years to other key predictors of dyslexia (i.e., expressive vocabulary, rapid naming of objects, verbal short term memory, pseudoword repetition, phonological awareness, performance IQ, and familial risk status). The ***second*** goal is addressed in Studies III and IV. The third study examined predictive links from early skills to reading accuracy and fluency, whereas the fourth study highlighted the connection of early skills to reading disability. Parsimonious individual screening possibilities were the focus in the ***third*** goal and it was addressed in Study IV. The main research questions and methods of the studies are presented in Table 2.

TABLE 2 The Main Research Questions and Methods of Analysis in the Original Studies



3 METHODS

3.1 Participants

The offspring of families with and without reading difficulties (see Study II) formed the samples of the present studies. Data concerning children for whom the full data set was available and who had no sensory or diagnosed neurological deficiencies at the time of the analyses were included in the studies. The children were native Finnish speakers. The parents' educational distribution in the JLD sample was representative of the Finnish population, and no significant differences were observed in the parental education level between at-risk and control groups. From four successive age cohorts of the families invited for screening, a total of 214 families from the city of Jyväskylä and its surrounding communities in the Province of Central Finland joined the study prior to the birth of their children. Half of the participating families include a parent who has been diagnosed with dyslexia and who also reports similar problems among immediate relatives. The other half comprises families in which parents gave no personal or familial report of reading or spelling difficulties. The parents underwent extensive cognitive and literacy-based assessment (see Leinonen et al., 2001, for full details). An IQ below 85 in the Raven matrices (Raven B,C, and D matrices; Raven, Court, & Raven, 1992) was applied as the exclusion criterion. The JLD attrition rate was low, with 199 of 214 families continuing to participate in the project until the end of the 2nd grade. The samples of Studies I–IV are presented in Table 3.

TABLE 3 Subsamples of Studies I–IV

Studies in the dissertation	*N*	*Analysed samples*	*Gender*	
			Girls	*Boys*
Study I	91	Control group children	41	50
Study II	91	Control group children	41	50
	98	At-risk group children	50	48
Study III	92	Control group children	40	52
	106	At-risk group children	53	53
Study IV	46	Children with reading disability	22	24
	152	Children with no indication of reading disability	71	81

3.2 Methods and Tasks

The analyses, methods and tasks are presented in detail in each original article. Table 4 shows all the tasks used in Studies I–IV and their assessment phases.

TABLE 4 Assessment Phases and Tasks Used in Studies

Assessment phase	Tasks	Studies I	II	III	IV
	Early language and cognitive development				
14 months	MCDI[1]; Vocabulary comprehension		x		
18 months	RDLS[2]; Verbal comprehension		x		
2 year	MDI[3]		x		
2 year 2 months	Global language at 26 months		x		
3.5 year	Peabody Picture Vocabulary Test - Revised		x		
3.5 year	Inflectional morphology		x		
3.5 year	Sentence repetition - subtask from the NEPSY		x		
3.5 year	Comprehension of instructions - subtask from the NEPSY		x		
3.5 year	Productive naming-subtask from the NEPSY		x		
	Early phonological awareness				
3.5 year	Word-level segment identification from HepsKups	x	x	x	x
3.5, 4.5 and 5.5 year	Syllable-level segment identification from HepsKups	x	x	x	x
3.5 year	Synthesis of phonological units from HepsKups	x	x	x	x
3.5 and 4.5 year	Continuation of phonological units from HepsKups	x	x	x	x
4.5 and 5.5 year	Initial phoneme identification			x	x
4.5 and 5.5 year	Production of first phoneme			x	x
	Congitive skills related to reading				
3.5 and 5.5 year	Boston Naming Test		x	x	x
3.5 and 5.5 year	Rapid Serial Naming (RAN) of Objects			x	x
3.5 and 5.0 year	Digit Span task			x	x
5.5 year	Memory for Names - task from the NEPSY			x	x
5.0 year	Vocabulary subtask of the WPPSI-R			x	x
3.5 and 4.5 year	Pseudoword Repetition - task from HepsKups			x	x
5.5 year	Nonword Repetition - task from the NEPSY			x	x
3.5, 4.5 and 5.5 year	Letter naming - task			x	x
5 year	Performance IQ of the WPPSI-R			x	x
8 year	Performance IQ from the WISC-III			x	x
8 year	Verbal IQ from the WISC-III			x	x
	Reading accuracy and fluency				
2nd grade	Reading three and four syllabic words and nonwords			x	x
2nd grade	Spelling words (6 items) and nonwords			x	x
2nd grade	Reading nonword text 'Vinnittäjä tenkoja'			x	x
2nd grade	Reading text 'Jännittävät matkat'			x	x
2nd grade	Reading fluency, standardized test 'Lukilasse'			x	x

[1]MCDI=MacArthur Communicative Development Inventory

[2]RDLS=The Reynell Developmental Language Scales

[3]MDI=The Mental Development index of the Bayley Scales of Infant Development-II

4 SUMMARY OF THE RESULTS

4.1 Study I: Assessment of 3.5-Year-Old Children's Emerging Phonological Awareness in a Computer-Animation Context

The main aim was to explore whether emerging phonological awareness can be assessed reliably at the age of 3.5 years. Four computer animated tasks were created for assessing emerging phonological awareness. The findings indicated that by the age of 3.5 years children are already able to master tasks demanding identification, blending and continuation of phonological units. In line with earlier literature, children showed a much higher mastery in dealing with words and syllables than phonemes. The tasks were presented as a part of a computer animation story context which the children found motivating; refusals were extremely rare. The findings indicated that by using a playful assessment procedure as well as cognitively and linguistically appropriate stimuli in the tasks, emerging phonological awareness skills can be reliably assessed as early as 3.5 years.

4.2 Study II: Emerging Phonological Awareness Differentiates Children with and without Familial Risk for Dyslexia after Controlling for General Language Skills

Emerging phonological awareness was compared in two groups of 3.5-year-old children (at-risk group; n = 98 and control group; n = 91). A composite of the four computer-animated tasks explored in Study I was used as an index of emerging phonological awareness.

In both groups phonological awareness at the age of 3.5 years was predicted by early language skills and it was also associated with concurrent language. Phonological awareness at the age of 3.5 years was predicted by early language skills including verbal comprehension, vocabulary and inflectional

skills assessed between 14 and 26 months of age. Of the early measures, phonological awareness was especially strongly correlated to the verbal comprehension of 18 month-old children (using the Reynell Language Developmental Scales) and of 2-year-old children using the Bayley MDI. At least moderate associations were also found between phonological awareness and other concurrent language skills of receptive vocabulary (using the PPVT), productive vocabulary (using the Boston Naming Test), and morphological skills. Among the tasks that shared most variance with phonological awareness was the concurrent comprehension of instructions (a subtask of the NEPSY).

The difference in phonological awareness between the at-risk and control groups at the age of 3.5 years remained significant even when the effect of other language skills, such as productive and receptive vocabulary and mastery of inflections (measured both at earlier ages and concurrently) were controlled. The study indicated that phonological awareness skills are built upon earlier language skills, with verbal comprehension playing a particularly significant role.

4.3 Study III: Developmental Links of Very Early Phonological and Language Skills to Second-Grade Reading Outcomes: Strong to Accuracy but Only Minor to Fluency

The third goal was to build a predictive model of 2nd grade reading accuracy and fluency with predictors assessed at the age of 3.5, 4.5 and 5.5 years. The model was constructed using Structural Equation Modelling and it tested the connections of phonological awareness and other key predictors of dyslexia (expressive vocabulary, rapid naming of objects, verbal short term memory and pseudoword repetition) via letter knowledge to reading. The model also included familial risk status and performance IQ.

The predictors were significantly correlated with each other and formed a common core factor at each age, labelled Early Phonological and Language Processing Skill (EPLP). Phonological awareness intertwined with letter knowledge at the age of 5.5 years indicating reciprocal development by age. The EPLP factor was highly stable across the different developmental time points and was most strongly represented (with approximately equal weights) by phonological awareness at all three ages. From 3.5 years onwards, EPLP was strongly connected to reading and spelling accuracy and it predicted letter knowledge increasingly by age. The finding supports the phonological core deficit hypothesis and the view of emerging phonological awareness skills as the proximal cause of reading outcomes (Jackson & Coltheart, 2001) with regard to reading accuracy. However, the link between the EPLP latent factor and reading fluency was much weaker, and fluency was additionally explained by a unique link from early letter knowledge. Familial risk for dyslexia and performance IQ were connected to EPLP, but the strength of predictive links of

EPLP to both reading accuracy and letter knowledge were considerably higher than those of the former variables.

The study showed that relatively strong links to reading can be demonstrated by using the behavioural level assessment procedures as early as 3.5 years i.e., four years before the start of the formal schooling. Using these behavioural measures close to half of the variation in the 2nd grade reading skills could be explained. The prediction was at its highest at 5.5 years when the EPLP shared 55 % of the common variance with reading accuracy and 11 % with reading fluency. Letter knowledge added to the prediction of reading fluency so that the total variance explained in fluency was 33 %. In general, the findings suggested a stronger intertwining of early phonological and language skills and a broader developmentally stable constellation of interrelated skills than reported previously. In addition, because the at-risk and control group children differed on all predictors in the model and familial risk had a strong link to the EPLP skills at all ages, it can be concluded that familial risk predisposes children to slower or deficient skill development from a very early age. The relatively weak prediction from the early phonological and language core skills to fluency poses a challenge to the phonological core deficit hypothesis as the sole explanation for fluency problems.

4.4 Study IV: Very Early Phonological and Language Skills: Estimating Individual Risk of Reading Disability

The goal of this study was to explore to what extent an individual child's reading disability can be predicted and estimated with a parsimonious procedure from as early as 3.5, 4.5 and 5.5 years. Study IV used the same data set as Study III. The findings were based on the analyses of children who were identified as having a reading disability (RD; n=46) and those who had age-level reading skills (n= 152). The Logistic Regression Modelling -approach with the ROC (Receiver Operating Curve) -plot was used to explore what combinations of measures could be the most sensitive and specific in predicting an individual child's risk for a reading disability both within and across the three age phases. The study also explored ways to illustrate an individual child's risk in a clinically usable way.

The examination of the group identified with a reading disability revealed that for 7 children the accuracy measures alone contributed to becoming identified with RD whilst for 21 children the fluency measures alone contributed. For 19 children both types of measures contributed to becoming identified with RD. In this sample a child who had a familial history of dyslexia faced a reading disability nearly four times more often than a child without such family background. The results indicated that children with a high risk of reading disability can already be identified from the age of 3.5 years onwards, i.e., about five years before RD can be reliably diagnosed. The calculation of a

risk index based on logistic modelling which identifies the key measures and their weights at each respective age (i.e., familial risk status, Letter Naming, and Rapid Naming of Objects/ Phonological Awareness) offers a rough screening procedure for evaluating an individual child's risk for a reading disability. By carrying out similar assessments, practitioners could also use probability curves to ascertain individual children's risk status.

However, caution must be exercised. Although the sensitivity, specificity and total prediction probability rates reported in the current study imply that the risk indices derived from the logistic modelling have clinically useful discrimination power, the predictions not only identify the true positives (i.e., children with dyslexia), but also some children who later do not manifest severe reading disability ("false alarms"). Their proportion is dependent on the dyslexia criterion that is being used, on the set probability cutoff-level, and on the population onto which the prediction model is applied.

5 GENERAL DISCUSSION

The early identification of children at risk for a reading disability would be of great importance. The failure to achieve proficient reading skills will have long-lasting and widespread effects on the individuals, but it will also have effects at the societal level: it is generally estimated that around 20-30 % of children suffer from some sort of difficulty in acquiring reading skills, and for approximately 12 % of the children, the difficulties are more pervasive. In the general population the prevalence of familial risk of dyslexia is typically reported to be around 6 % (e.g., Grigorenko, 2005; Vellutino et al., 2004). This thesis explored the developmental links from very early phonological awareness and other key dyslexia predictors to 2nd grade reading skills, in the highly orthographically regular Finnish language. The data are derived from the Jyväskylä Longitudinal Study of Dyslexia involving 106 children with a familial risk of dyslexia and 92 children with no indication of familial risk. The results are based on analyses using behavioral level tasks administered to children between 14 month of age and the end of their 2nd grade of school (when the children were on average 9.5 years old).

First, findings concerning the assessment of emerging phonological awareness are summarized, and the associations between early phonological awareness and other reading-related early language and cognitive skills are described. ***Second,*** findings concerning associations between the above mentioned skills and 2nd grade reading accuracy, fluency and reading disability are discussed. The ***third*** topic of the discussion is the prediction of an individual child's risk for dyslexia. Related to these three themes, questions concerning the reliability and validity of the results and the implications of the findings are considered. ***Finally,*** the findings of the presented studies are set in the context of other empirical findings and theoretical accounts, and a preliminary conceptual model of reading acquisition pathways is drawn.

5.1 Emerging Phonological Awareness and its Connections to Other Language and Cognitive Skills

Thus far studies have mainly focused on phonological awareness skills from the kindergarten age onwards and only scattered findings have shed light on very early phonological awareness. The present study addresses the possibilities of reliably assessing emergent phonological awareness and its relations to other important predictors of reading outcomes. Study I indicated that emerging phonological awareness can already be measured reliably at 3.5 years using age-modified tasks embedded in the playful context of a computer animation program. At the age of 3.5 years children mastered tasks in which they had to identify word or syllable–size phonological units, to blend them or to continue a given initial syllable. In line with earlier studies (e.g., Bryant, MacLean, Bradley & Crossland, 1990; Lundberg, Frost, & Petersen, 1988) conducted from the age of 4.5 years onwards, children also showed skills indicating access to phoneme-size units in tasks like identification of initial phonemes (Study III and IV). The various tasks employed here in the phonological awareness test batteries at the three age phases were closely correlated with each other (Study I, II and III). The intercorrelation between the tasks is supported by the structural analyses in prior modeling of phonological awareness (e.g. Anthony & Lonigan, 2004). Emerging phonological awareness at the age of 3.5 years was predicted by early language skills such as verbal comprehension at 18-months and language skills at the age of two years (Study II). The findings extended the previous empirical findings suggesting that several different types of tasks may tap emerging phonological awareness, and they are connected to earlier language skills.

The findings are in accordance with findings and theoretical assumptions presented in the existing literature: as toddlers, children show mastery in phonological awareness tasks with large phonological unit sizes and relatively low cognitive demands. When approaching school-age, children progress to mastery of tasks requiring explicit manipulation of phoneme size units (c.f., Gombert's (1992), developmental continuum from epiphonological to metaphonological awareness skills, and the assumptions of the lexical restructuring theory by Fowler, 1991; Metsala, 1999b; Metsala & Walley, 1998). Besides phonological awareness, this study also tool account of age-specific measurement demands by using the procedure suggested by Gathercole and Adams (1993) for the assessment of Digit Span. The early measures of children's language skills were consistently shown to have predictive validity (Study III and IV) which suggests that these skills can be measured reliably at an early age when adapted to an age-appropriate level. Thus, the observations on young children's inability to master tasks used with older children do not always reflect the lack of skills per se but rather point to challenges in assessing them.

Phonological awareness at 3.5 years was found to be predicted by early language skills such as verbal comprehension, vocabulary and inflectional skills

assessed between 14 and 26 months of age (Study II). Furthermore, at least moderate associations were found between phonological awareness and a variety of other language skills assessed at the same age e.g., receptive vocabulary (PPVT), expressive vocabulary (Boston Naming), inflectional morphology, and comprehension of instructions (a subtask of the NEPSY).

Phonological awareness and other key predictors of dyslexia, i.e. short term memory, RAN, expressive vocabulary and pseudoword repetition (assessed at 3.5, 4,5 and 5,5 years), shared a large amount of common variance and formed a latent factor labelled ***Early Phonological and Language Processing*** *(EPLP)* (Study III). Research on preschoolers and kindergarteners have shown that these skills are inter-correlated (e.g., Gallagher, Frith, Snowling, 2000; Pennington & Lefly, 2001) and form one (Lonigan, Burgess, & Anthony, 2000.; Storch and Whitehurst, 2002) or several latent factors (Wagner et al., 1994). However, modelling of the associative structure of these key skills in children under four years of age has been sparse until this time.

The findings of the present study are supported by those of Carroll, et al., (2003) whose data supported one latent factor solution at the age of 3 years 10 months, composed of syllable and rhyming skills, vocabulary, mispronunciation detection, articulation accuracy and letter knowledge. Dickinson et al. (2003) argued based on analysis of the subsequent reading achievement of children assessed at the age of 4 years 9 months that emergent literacy is predicted by a variety of oral-language skills and that key skills such as vocabulary, print knowledge and phonological awareness are all connected with each other. The findings of the present thesis suggest a strong intertwining of early skills and a broader constellation of interrelated skills than previously suggested.

The across-age modelling (Study III) showed that early phonological and language processing skills show a high degree of developmental stability at the early ages, when children are not exposed to formal teaching. Although the increase in absolute mean scores indicated that children's mastery of the skills increased by age, individuals tended to maintain their position with respect to each other. The SEM modeling also indicated that familial risk contributed to the development of early phonological and language ability equally at each respective age, i.e., from 3.5 years onwards. Although relative stability has been found in earlier studies with slightly older children (i.e. Wagner et al., 1994; Whitehurst & Lonigan, 2001), the finding of high stability prior to kindergarten and preschool age is a new finding. This novelty may be due to the use of a large battery of measures and the presence of adequate reliability.

The modelling in Study III also showed that a unique link emerged between phonological awareness and letter naming by the age of 5.5 years but not before. This finding is in accordance with claims about the reciprocal development of these two skills in the preschool years (Burgess & Lonigan, 1998; Hogan, Catts, Little, 2005; Holopainen, Ahonen, Tolvanen, Lyytinen, 2000; Wagner et al., 1994; Wimmer, & Mayringer, 2002). Via the EPLP factor, letter knowledge was associated with all other concurrently measured skills. With

increasing age the predictive link between EPLP and letter knowledge grew stronger: by the age of 5.5 years the measures forming the EPLP factor and letter knowledge shared around 50% of common variance. The latter finding underscores the intricate associations between phonological and orthographic processing in development (cf., recent findings in adult dyslexics by McCrory, Mechelli, Frith, & Price, 2005). One potential reason for the increased association by age may lie in the psychometric properties of the letter knowledge task at 3.5 and 4.5 years. At these ages differentiation in the lower end of mastery is difficult. Ziegler and Goswami (2005) have suggested in their Psycholinguistic Grain Size Theory that learning a language's orthography also produces changes in lexical representations and processing strategies which implicate these. Such processes might be reflected in the increasing associations between measures in the modeling.

The SEM analyses (Study III) add to the findings of earlier studies (e.g., de Jong & Olson, 2004) concerning the cognitive and language factors contributing to the development of letter knowledge. Letter knowledge was predicted not only by early phonological awareness but also by other language skills. The findings by Torppa, Poikkeus, Laakso, Eklund and Lyytinen (2006) using the same JLD sample showed that delayed letter knowledge at the age of 6 was associated at least partly with environmental factors such as parental letter name teaching and maternal educational level. Stephenson, Parrila, Georgiou, and Kirby (in press) also suggested that parental attitudes and child's task-focused behaviour might play a mediating role in the development of early reading related skills.

Concurrent links between phonological awareness and performance IQ (Study III) at the age of 5 years and the comprehension of instructions at the age of 3.5 years (Study II) indicate interesting unique connections (over and above those skills connected to EPLP- factor in Study III) between phonological awareness and measures tapping more general skills. These measures may share a common underlying cognitive component possibly related to general information processing efficiency. This possibility has also been suggested in previous literature (Tornéus, 1984).

In conclusion, the findings indicate that as early as 3.5 years, emerging phonological awareness skills and other language-related skills can be measured using age-appropriate and adapted tasks. Phonological awareness skills are built upon much earlier productive and comprehensive language skills and themselves undergo gradual change during development. Phonological awareness shares a lot of common variance with other key predictors of reading, it has a unique connection to more general cognitive skills and an increasingly strong link to letter knowledge with age. The findings of the present thesis suggest a stronger intertwining of very early phonological and language skills, as well as a broader constellation of skills with high developmental continuity than has been previously suggested.

5.2 Links from Early Skills to Reading Accuracy, Fluency and Reading Disability

The last two studies utilize the same predictive and outcome measures but whereas Study III uses Structural Equation Modelling (SEM) to model the intercorrelations between predictors of reading accuracy and fluency, Study IV employs Logistic Regression Approach to identify the key measures for prediction of reading disability. Thus, they offer a complementary view of the links between early skills and school age outcomes.

Reading Accuracy. The literature on predictive links between preschool and kindergarten phonological and language skills and the early phases of reading usually focus on reading accuracy (e.g., see the meta-analysis by Scarborough, 2001). The results of Study III showed that the predictors used typically with older children were also connected to reading outcomes when applied to a younger age group (especially 3.5-year old children). The key predictors – phonological awareness, short term memory, RAN, expressive vocabulary, pseudoword repetition, letter naming, familial risk of dyslexia, and performance-IQ – which have been reported in other languages (e.g. Carroll & Snowling, 2004; de Jong & van der Leij, 2003; Elbro, Bostrom, & Petersen, 1998; Gallagher, Frith, & Snowling, 2000; Pennington & Lefly, 2001) also had a predictive relationship to reading accuracy in Finnish, a highly orthographically regular language.

As described earlier, early phonological and language skills were correlated with each other and formed a common core factor (EPLP i.e. Early Phonological and Language Processing) representing underlying early ability. This early ability factor predicted around 50% of reading and spelling accuracy i.e. much above the level of IQ. Furthermore, analyses of developmental stability showed that this ability could already be tapped at 3.5 years. The subsequent age phases (4.5 and 5.5 years) did not make any significant contribution to the connection between early ability and reading accuracy. In the developmental literature it is generally assumed (Schaffer, 2006) that predictions become more accurate with increased age. However, the present analyses suggested no major changes in the course of development (the spurts or plateaus in prereading development suggested by Scarborough, 2001 were not observed). Interestingly, letter knowledge had no unique link to reading accuracy over early ability (EPLP), to which it was increasingly connected with age.

As noted in the preceding chapters there are strong claims in the literature that the core of dyslexia is phonological, that phonological representations and processing skills are underlying causes of reading success and failure, and that these underlying skills are best tapped by phonological awareness tasks. Study III showed that phonological awareness tasks best represented the EPLP factor and this was true across all three age phases. In addition, phonological awareness seemed to intertwine with letter knowledge at 5.5 years but not

before. These findings suggest that very early phonological awareness skills might reflect the ***proximal cause*** of the reading accuracy (c.f., Jackson, & Coltheart, 2001). The later phases of phonological awareness, on the other hand, may reflect distal causes of reading outcomes since they intertwine more with the literacy experience itself (e.g., learning of letter names). This study gives support for the assumptions of a phonological core in reading skills and reading disability but only regarding reading accuracy. As a corollary, it can be assumed that phonological deficits are the core reason for poor performance in reading accuracy at the 2nd grade.

Reading Fluency. By the end of the 2nd grade children exposed to orthographically regular languages such as Italian, Greek or Finnish have usually acquired basic reading skills and are relatively accurate decoders (Aro, 2006). From this phase onwards it is thus relevant to measure reading fluency i.e. fast and accurate decoding. The SEM modelling (Study III) indicated that early ability reflected by the EPLP factor had only a minor link with reading fluency; early abilities predicted less than 9% of variation in reading fluency. Letter knowledge increased the prediction up to 32% but the total prediction remained at a lower level than that for accuracy. If the reading accuracy in addition to the early skills (EPLP, letter naming, IQ) were taken into account in the prediction, 65% of fluency could be predicted. In line with Share´s (2004) view, the results showed that the fluency component of reading is only moderately connected to accuracy, i.e. becoming an accurate reader is not in itself sufficient for acquiring fluency skills in reading.

Reading Disability. A complementary view of the links between early predictors and 2nd grade reading outcomes was presented in Study IV, in which reading disability was predicted using a logistic regression approach. Based on the reading performance in four tasks tapping reading and spelling accuracy and four tasks tapping reading fluency skills, the children were divided into two groups: children with a reading disability (RD, n= 46) and children without a reading disability (nRD, n= 156). The children in the RD group mostly had problems with fluency (21 children) or with both fluency and accuracy (19 children). Only 6 children were identified as RD based on accuracy scores alone. Thus, the main proportion of children who were identified with a reading disability had problems with fluency.

In line with other studies (de Jong & van der Leij, 2003; Catts et al., 2001; Pennington & Lefly, 2001), the results showed that RAN, letter naming and phonological awareness formed the most powerful combination of measures in predicting RD. In addition to these measures, another significant predictor was familial history of dyslexia. A combination of three measures turned out to form a relatively sensitive index of individual risk for RD. The findings of the earlier presented studies (Study III and IV) might seem contradictory but actually they are based on two different analysing methods and research procedures: the first study is seeking the shared common variance between the measures while the latter study is seeking for the most powerful combination of measures in predicting group level difference.

Interestingly, rapid naming turned out to be a significant predictor of RD (Study IV) although it did not have any unique associations (over and above the EPLP factor) to the continuous variables of accuracy or fluency (Study III) and it shared the least common variance with the EPLP factor. The RAN measure's emergence as a significant predictor of RD vs. nRD group membership (instead of vocabulary, for instance) may be understood on the basis of RD diagnosis being heavily dependent on fluency scores in the Finnish language. i.e., a majority of children with RD were either slow, or slow and inaccurate readers rather than inaccurate alone. Thus, in line with a study by Georgiou, Parrila, & Papadopoulos, (submitted, 2007) the results gave some support for the special connections between early rapid naming skills and reading fluency.

Theoretical accounts have been presented arguing on behalf of the relative independence of rapid naming skills with other phonological and language processes (Wolf, Bowers, & Biddle, 2000; Swanson, Trainin, Necoechea, & Hammill, 2003). In their review, Wolf and her colleagues (Wolf et al, 2000) maintain that although naming speed includes aspects of phonological processing, it also includes a complex ensemble of subprocesses which may be semantic, motoric, memory and attentional and which have precise timing requirements within and across all components. The underlying processes required for completion of a RAN task are thought to resemble the processes underlying fluent reading.

Based on her observations of clinical samples and ideas of cognitive development Bates, (2004) also offers ideas of the role of rapid naming skills in the reading process. She argues that at birth every child possesses 'starter´ skills (e.g., object and social orientation, cross-modal perception, sensor-motor precision and computational power). These skills converge at later developmental milestones that correlate with language and may influence the ensuing language development. Thus, performance in RAN may reflect the quality of these starter skills, and the stressed condition of "rapidness" might reveal breakdowns of underlying information processing systems – either between different processing abilities or within the whole neural system. RAN's specific link with the reading difficulties may therefore be associated with neural timing mechanisms or effectiveness in areas of information processing.

In conclusion, the findings of this thesis show that at least in regular orthographies such as Finnish, early phonological and language skills predict only a minor part of fast and efficient reading at the 2nd grade. The findings suggest that the strongest contributors to reading fluency problems are compromised development of early phonological and language abilities (EPLP), letter knowledge and rapid naming skills, as well as familial risk for dyslexia. These measures presumably tap the underlying phonological, orthographical and semantic-contextual processing skills (Adams, 2001; McCelland & Rummelhart, 1986) as well as specific elements of timing (Wolf et al., 2001) and/or effectiveness of information processing (Bates, 2004). It is notable that behavioural level tasks always include several of these underlying information processing subskills although they might stress some of them (Ramus, 2001). In

the light of these accounts it is suggested that reading fluency problems are best understood as ***ineffectiveness*** of jointly orchestrated phonological, orthographical and semantic-contextual information processing **(**c.f., Neural Network Processing Ability noted by McCelland & Rummelhart, 1986).

5.3 Individual Prediction Possibilities

A key issue for clinical screening practice is whether it is possible to determine the critical ages and measures for the identification of an individual child's risk for a reading disability. It is also important to be able to present a parsimonious assessment procedure and a way to illustrate the risk. The analyses in Study IV indicated that an individual child's risk for a reading disability could be evaluated as early as the age of 3.5 years i.e., five years before the determination of RD at the 2nd grade. Logistic Regression Modelling produced indices of risk consisting of three measures at the three age phases. At the age of 3.5 and 5.5 years, the index comprised familial risk status, RAN and letter knowledge. At 4.5 years, the combination forming the risk index was the same except that it included phonological awareness instead of RAN (note that RAN was not included in the 4.5-year task battery). Probability curves were presented as a method for determination and illustration of an individual child's risk of RD.

The results are in line with the literature that has identified RAN, letter naming and phonological awareness as the key predictors of dyslexia (de Jong & van der Leij, 2003; Catts et al., 2001; Pennington & Lefly, 2001). The use of knowledge about the familial risk of dyslexia in combination with early measured key predictors increased the sensitivity of the risk indices of the present study to a level slightly above that which has been reached in earlier studies. The risk indices also maintained their discriminative ability when the classification analyses were conducted with a weighting procedure that took into account the fact that the proportion of children at risk is smaller in the general population than in the present sample.

Although the prediction rates of the age-specific risk indices were relatively high and yielded clinically usable levels, the prediction procedures also produced "false alarms", i.e., pre-school children who were predicted to have an RD at school-age, which then did not manifest. Such prediction procedures can also produce a number of "misses", where a child who does develop an RD is not detected through early risk indices. The predictions are more accurate if they are applied to a population where the prevalence of dyslexia is higher, as is the case with families who are identified as having a risk of dyslexia. In addition, the prediction accuracy is dependent on the set dyslexia criterion, which was quite strict in the present study: children's score had to fall under a set criterion in at least four of eight reading outcomes.

The cut-off points used in the screening process are always based on a common agreement. Especially when one wants to identify a large proportion

of true positives, the number of false positive cases is also greater near the cut-off point. The question about where to set the cut-off point is not solved solely by the metric properties of risk indices. It is an educational -political issue which leads to multiple questions that need to be solved. For example, what amount of resources do we have? Do we try to support all children, those with the most severe risk, or something between these end tails? To what extent do we provide individual vs. group level support? How does the early education infrastructure sustain support for children at risk or does it need to be developed? What systems-level changes need to occur?

One reason for misidentification in the form of false positives may have resulted from the predictors being less sensitive in predicting reading fluency. If researchers manage to find more sensitive early predictors of reading fluency, prediction rates could be improved. More sensitive methods for the assessment of phonological processing, e.g., neurophysiological measures like ERP, would also likely improve predictions. Dynamic behavioral assessment procedures (suggested by Byrne, Fielding-Barnsley, & Ashley, 2000; Swanson, & Howard, 2005) in which grapheme-phoneme learning gains are measured, may also offer more sensitive methods for prediction. Recently Compton, Fuchs, Fuchs, and Bryant (2006) presented a comparison of logistic regression analyses and a classification tree analysis in the prediction of 2nd grade reading disability using not only 1st grade language measures (such as sound matching, rapid digit naming and oral vocabulary) but also word identification fluency level and amount of gain observed in five weeks of schooling. Their findings suggested that the dynamic measurement procedure and the classification tree analysis together produced the most sensitive and specific indices for a reading disability. However, the usefulness of the procedure for clinical practice needs to be carefully considered since the monitoring process demands a great deal of resources and the analysing method is complex.

Another reason for misidentification is comforting: early skills are not the only determinants of future reading status- developmental changes are possible and they do occur. Some of the children identified at early time points as having below average preliteracy skills do catch up with their peers given time. Conversely, from this data a few individuals were present whose reading difficulties were difficult to predict using the produced risk index (i.e., they had average early skills). It has been shown that factors like motivation (Poskiparta, Niemi, Lepola, Ahtola,& Laine, 2003), early literacy experiences, parental support and reinforcement (Torppa et al., 2007a), early intervention (Poskiparta, 2002), competent teaching (Torgesen, 2005) and also an individual's learning rate or responsiveness to instruction (Byrne, Fielding-Barnsley and Ashley, 2000) moderate the individual developmental paths leading to reading outcomes.

The individual patterns in predictive skills suggests that different developmental paths may exist that lead to dyslexia (e.g., Lyytinen et al., 2006, Torppa et al., 2007b). Not only may different phenotypes of dyslexia exist, but diverse set of genes with diverse activation mechanisms producing dyslexic

problems (e.g. Grigorenko, 2005; Plomin & Kovas, 2005). The large individual variation and commonly occurring "false alarms " at the screening phase make it necessary in the process of drawing a plan for individual preventive/remedial actions that a a much broader scale of language, cognitive skills and familial risk of dyslexia be mapped. In addition, as Compton et al., (2007) suggest it would be wise to create learning environments in which literacy learning gains can systematically be observed (e.g., "Literate"; Lyytinen, Ronimus, Alanko, Taanila, & Poikkeus, in press, 2007; Hintikka, Aro, & Lyytinen, 2005).

Remedial programs have been shown to have a reasonable efficacy in improving reading at the early phases i.e. in reading accuracy (a review by Bus, & Van IJzendoorn, 1999). The most effective of them combine training of phonological awareness with speech processing and grapheme knowledge (e.g. Lundberg, Frost, & Petersen,1988; Poskiparta, 2002; Tornéus, Hedström, & Lundberg, 1991; Schneider, Roth, & Ennemoser, 2000). Several studies have ended up noting that there are treatment resistant children or the gains of the intervention are not long lasting (Byrne & Fielding-Barnsley 2000; Poskiparta, 2002; Torgesen, 1998; Scarborough, 2001). As indicated in the present thesis, the later process of fluent reading demands additional skills that we thus far know surprisingly little of.

The usefulness of the types of programs described above may therefore be limited in improving reading fluency. Fluency training is typically concentrated on repeated reading with the repetition of words or passages (a review by Kuhn, & Stahl, 2003; see also Wise & Snyder, 2003). Studies have in general indicated that fluency training has word specific effects but low transfer to untrained words (Thaler, Ebner, Wimmer, & Landerl, 2004). Although there are programs which aim to improve naming skills by teaching strategies to improve retrieval of names and elaborating vocabulary (e.g. Wolf, Miller, & Donelley, 2000), no programs exist, to the author's knowledge, where efficiency in the joint processing of phonological, orthographic and semantic-contextual information (see chapter 5.2) is trained directly. It is also obvious that reading experience and frequency of practice are important factors (see Cunningham & Stanovich, 2001) in shaping fluent reading skills.

In conclusion, based on the presented procedure for early identification of children at risk, a rough index for an individual child's risk for reading disability can be constructed as early as the age of 3.5 years. The problem with the risk index is that it identifies not only children who will have problems with reading but also "false alarms". The prediction accuracy of individual risk could be improved by using a learning environment where the gain or learning rate is possible to assess. Investigation of skills and paths leading to fast and accurate decoding and the development of training methods for fluency are challenges for future studies. These findings would also improve the prediction possibilities for an individual child's risk. In addition, future studies need to follow the development of reading skills from early phases to later fluency.

5.4 A Model of the Reading Acquisition Path from Birth to School Age

In the final chapter an attempt is made to set the present findings in the context of prior theoretical accounts and empirical findings by constructing a conceptual framework of the paths leading to reading acquisition. In the light of the specific features of the Finnish language, which includes highly transparent grapheme-phoneme correspondence, most beginning readers of Finnish have a relatively easy task in the early phase of acquiring accurate decoding and recoding skills. However, the polysyllabic and agglutinative-fusional morphology (Aro, 2006) of Finnish make the next steps, advanced reading with fast, accurate and automatic decoding and good reading comprehension, challenging. Compared to reading acquisition models of irregular orthographies, the Finnish reading model is simpler, since there is no special need for learning irregular orthographic patterns.

The findings presented in this dissertation suggest that reading accuracy is strongly associated with earlier language abilities. However, reading fluency is at least partly based on different subskills that were only moderately identified in this study. The following figure describes the major developmental paths towards reading acquisition that seem evident, highlighting some special issues concerning the Finnish language context (see Figure 2). The roots of reading skills can already be traced in infancy through auditory speech perception abilities (Leppänen et al. 2002; Richardson et al., 2003) or tone perception (Salminen, et al., submitted, 2007). These abilities set restrictions on the subsequent development of productive and comprehensive language skills (Guttorm et al., 2005). From toddlerhood onwards, language skills can be assessed using behavioural age-modified tasks (the present thesis). These skills develop in interaction with social partners and objects in the environment (Laakso et al., 1999a; 1999b; Torppa et al., 2006) and the child's inherited capacities.

The level of underlying processing skills (e.g., phonological, orthographic, semantic and context information processing as well as efficacy/timing mechanisms) is difficult to tap because behavioural level tasks always represent several of these skills and their connections. The processing skills have their bases in the genetic background, brain development and the developmental organization of early cognition (described as starter skills by Bates, 2004). These underlying processing skills form the bases for pre-reading skills, which in turn, mediate future reading acquisition (the present thesis) but possibly also have feedback loops back to underlying information processing skills (Ziegler & Goswami, 2006). Orthographic skills such as the letter knowledge and (parental) teaching exposure seem to be additional important mediating factors in the reading acquisition process (Silvén, Niemi, & Voeten, 2002; Torppa et al., 2007a).

Different underlying information processing skills are critical in different developmental phases (seen as bolded arrows in Figure 2). Reading and spelling accuracy is especially influenced by phonological processing skills, but reading fluency demands efficacy in phonological, semantic and orthographic information processing. Becoming accurate saves information processing capacity as well as allows for the development of fluency and comprehension rich vocabulary, good command of semantic and pragmatic features, knowledge about morphological structure and literacy experiences are also likely to help to recode the long and morphologically agglutinate words of Finnish (Aro, 2006; Silvén, Ahtola, & Niemi, 2003; see, Berends, & Reitsma, 2006) and to develop reading comprehension skills (see, Muter, Hulme, Snowling, & Stevenson, 2004).

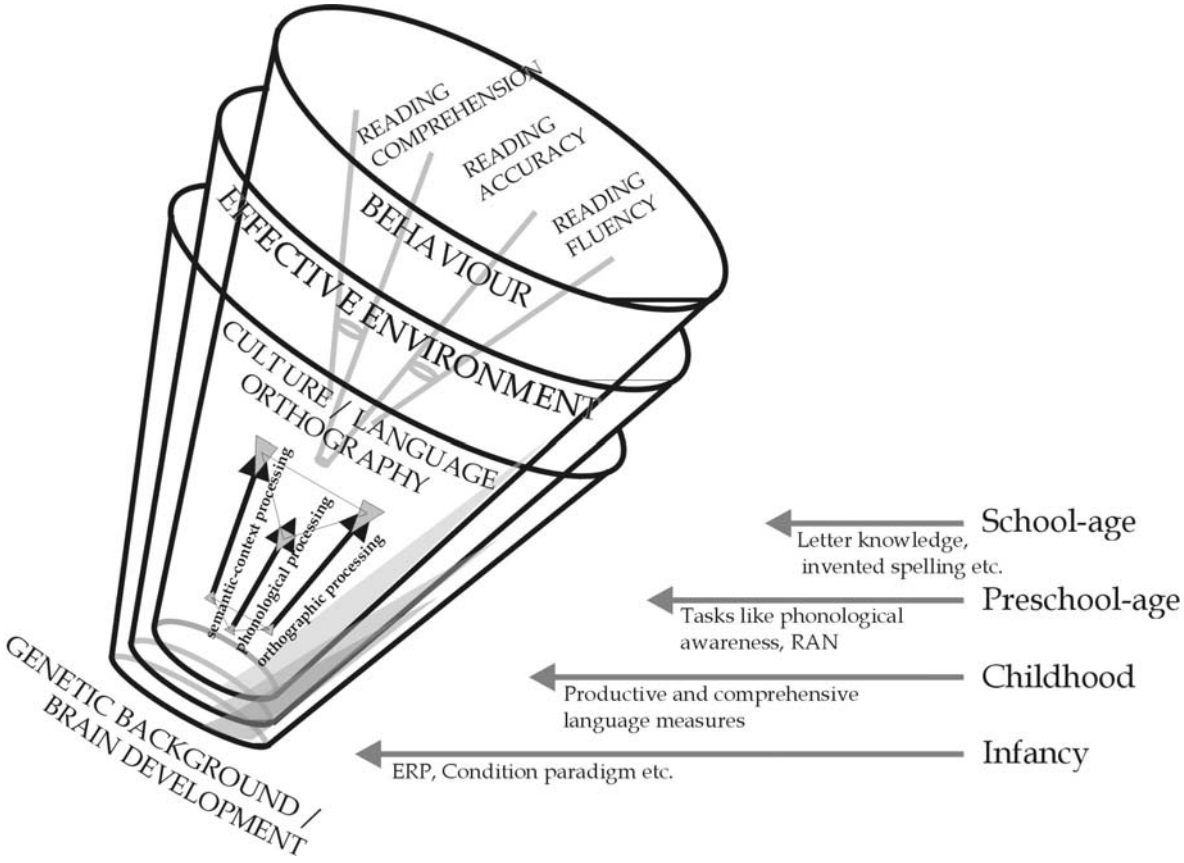


FIGURE 2 The Conceptual Model of Reading Acquisition from Birth to School Age

Importantly, the quality of language environment (Laakso et al., 1999a, 1999b ; Lyytinen, 2003) and inherited capacities shape the phonological representations throughout. Different mechanisms of individual-environment interaction (evocative, reciprocal and active as suggested by Rutter, Dunn, Plomin, Simonoff, Pickles, Maughan, et al., 1997) as well as reading experience and frequency of practice (e.g. Deahene et al, 2005; Cunningham & Stanovich, 2001; Stephenson, et al., 2007) also mediate the reading acquisition process. The

effectiveness of information processing may show individual variation both at the broad and more narrow levels (IQ would be an example of the former and RAN an example of the latter). This variation may lead to different trajectories in the manifestation of reading disabilities (e.g. Catts, Hogan, & Fey, 2003: Compton et al, 2006; Lyytinen et al, 2006; Torppa et al., 2007) as well as individual differences in compensatory mechanism (Bates, 2004).

6 CONCLUSIONS

I am grateful – as all Finns are – to Mikael Agricola for his pioneering translations into Finnish of two remarkable books: the ABC book published in 1543 and the New Testament published in 1548. He was the one who decided to use a nearly perfect correspondence in the marking of phonemes with graphemes. The modern Finnish orthography bears a very close resemblance to that presented by Agricola and because of that it is one of the most regular languages in the world. Finnish appears to be one of the easiest languages to learn to read in the initial phase of reading acquisition. Evidence for this fact comes from the recent cross-linguistic PISA studies (OECD, 2004) which have constantly demonstrated Finnish children's superior skills in reading and writing. However, at the individual level, reading difficulties do exist among both Finnish children and adults. Somewhat surprisingly, the language specific effects on reading performance have only recently been the focus of reading research.

This dissertation illuminates twofold findings concerning the predictors of reading accuracy and fluency. First, the predictors of reading accuracy are similar across orthographies. Difficulties in accuracy can be predicted at an early age and well described training programs are available. Second, the early phonological and language measures were not overly good predictors of the fluency problems which are the most common characteristic amongst Finnish dyslexic readers. Unfortunately we know little about efficient training programs for improving reading speed. A future challenge is to explore the early predictors of reading fluency which can also improve the prediction of individual risk. The presented procedure for the early identification of children at risk for reading disability is successful to a certain extent and after further development it could become parsimonious enough to implement into a child's preschool policy and practice.

Reading difficulties have long-standing effects for all individuals in societies with educational systems that stress literature-based learning practices. Most important of all is to support the child to realize his or her full capacities - not only a set of cognitive skills considered relevant for academic

success – which allows him or her to uncover individual strengths and creativity. Therefore, broad and alternative approaches to learning should be a part of every day care and school settings.

YHTEENVETO

Lukemistaitojen varhainen ennustaminen – Fonologinen tietoisuus, kielelliset ja kognitiiviset taidot lapsilla joiden suvussa esiintyy dysleksiaa

Lukemisvaikeudella voi olla kauaskantoisia ja laaja-alaisia yksilöllisiä seuraamuksia. Lukemisvaikeuden yleisyyden vuoksi sen vaikutukset ulottuvat kuitenkin yhteiskunnalliselle tasolle. Tässä tutkimuksessa perehdyttiin varhaisiin lukemiseen liittyviin valmiuksiin ja tutkittiin onko lukemisen taitoja ja lukemisvaikeutta mahdollista ennakoida jo leikki-iässä.

Tutkimuskirjallisuuden perusteella tiedetään, että monet esiopetusikäisten lasten kielelliset ja tiedon käsittelyyn liittyvät (kognitiiviset) taidot ennustavat myöhempiä lukemisen ja kirjoittamisen taitoja. Lukutaitoa ennustava tutkimus on keskittynyt pääosin englannin kieleen, joka on kirjoitusjärjestelmältään poikkeuksellisen epäsäännönmukainen kieli. Suomen kieli edustaa nykyeurooppalaisten kielten toista ääripäätä, sillä sen kirjoitusjärjestelmä on erityisen säännönmukainen ja kirjainten ja äänteiden vastaavuus yksiselitteinen ja johdonmukainen. Onkin arveltu, että lukutaitoa edeltävät taidot olisivat säännönmukaisissa kirjoitusjärjestelmissä erilaisia kuin epäsäännönmukaisissa. Suomalaiset lapset tyypillisesti saavuttavat peruslukutaidossaan hyvän lukemisen tarkkuuden (kykyä lukea oikein sanoja ja lauseita) ja sujuvuuden tason (kykyä lukea riittävällä nopeudella) toisen luokan lopulla, sen sijaan useimmilla englanninkielisillä lapsilla ei tässä kouluvaiheessa yksittäisten sanojen lukeminenkaan ole vielä virheetöntä. Aikaisemmissa tutkimuksissa on tunnistettu useita taitoja, jotka ennakoivat lukemisen tarkkuutta. Ennakoivien taitojen yhteyttä toisiinsa ja kehityksellistä pysyvyyttä on kuitenkin tutkittu vähän. Aiemmat tutkimukset ovat suurelta osin keskittyneet leikki-ikäisiä vanhempiin eli vähintään esiopetusikäisiin ja sitä vanhempiin lapsiin. Ei tiedetä, mikä merkitys hyvin varhaisilla taidoilla on suomen kielessä ja ennakoivatko samat taidot sekä lukemisen tarkkuutta että sujuvuutta.

Tässä väitöskirjatutkimuksessa selvitettiin, missä määrin jo leikki-ikäisten (3–5-vuotiaiden) lasten kielelliset ja kognitiiviset taidot ennustavat lukemisen tarkkuutta, sujuvuutta sekä lukemisen ja kirjoittamisen vaikeutta (dysleksiaa) toisen kouluvuoden lopulla. Lisäksi selvitettiin lapsen yksilöllisen dysleksiariskin ennakoimisen mahdollisuutta. Erityisenä tarkastelun kohteena oli varhainen fonologinen tietoisuus eli tietoisuus puhutun kielen äänneosista. Tutkimuksissa selviteltiin fonologisen tietoisuuden suhdetta tunnettuihin lukemista ennakoiviin kielellisiin ja kognitiivisiin taitoihin. Väitöskirjassa mallinnettiin polkua varhaisista kielellisistä ja kognitiivisista taidoista tarkkaan ja sujuvaan lukutaitoon. Tutkimustulokset perustuvat lähes 200 lapsen taitojen 10-vuotiseen seurantaan Jyväskylän yliopistossa toteutetussa ”Lapsen kielen kehitys ja suvuittain esiintyvä lukivaikeuksien riski ” -tutkimushankkeessa. Puolella lapsista esiintyi lähisuvussa dysleksiaa.

Väitöskirjatutkimuksen osana kehiteltiin uudenlaisia fonologisen tietoisuuden arviointimenetelmiä leikki-ikäisille. Ikävaiheeseen soveltuvia menetelmiä ja tehtäviä käyttäen voitiin todeta, että jo 3,5 vuoden ikäiset kykenivät tunnistamaan sanasta tavun kokoisia äänneyhdistelmiä, yhdistelemään niitä ja jatkamaan merkitykselliseksi sanaksi. Esiopetusikään mennessä 4,5- ja 5,5-vuotiaana lapset kykenivät erottelemaan sanoista äänteen kokoisia osasia. Varhaista fonologista tietoisuutta ennustivat aiemmin, jo 14–26 kuukauden iässä, arvioidut kielelliset taidot (mm. puheen ymmärtäminen, tuottaminen ja taivutusten hallinta). Fonologinen tietoisuus oli yhteydessä myös muihin varhaisiin kielellis-kognitiivisiin lukemista ennakoiviin taitoihin kuten kielelliseen muistiin, sanavarastoon, epäsanojen toistamiseen ja nimeämisen sujuvuuteen jokaisessa ikävaiheessa (3,5, 4,5 ja 5,5 vuotta). Nämä taidot muodostivat varhaisen ydinkyvyn (Fonologisen ja kielellisen prosessoinnin faktori), jota edusti vahvimmin fonologinen tietoisuus. Tutkimus osoitti, että edellä mainitut taidot liittyvät kiinteämmin toisiinsa kuin aikaisemmin on todettu ja yksilölliset erot ovat erittäin pysyviä jo 3,5-vuotiaasta lähtien. Suvussa esiintyvällä lukemisvaikeudella oli yhteys kielellis-kognitiivisten ja kirjaintuntemuksen taitojen hallintaan jo leikki-iässä.

Varhainen fonologis-kielellinen kyvykkyys ennusti yli puolet toisen luokan lopulla arvioidusta lukemisen tarkkuudesta. Tulokset viittaavat siihen, että suomen kielessä samoin kuin kirjoitusjärjestelmältään vähemmän säännönmukaisissa kielissä fonologisen prosessoinnin pulmat muodostavat merkittävän syyn lukemisen tarkkuuden pulmiin. Varhainen fonologis-kielellinen kyvykkyys ennusti sen sijaan heikosti (noin 11 %) toisen luokan lukemisen sujuvuutta. Lukemisen sujuvuutta kyettiin ennustamaan paremmin (noin 32 %), kun ennustajiin lisättiin kirjaintuntemus, mikä viittaisi siihen, että lukemisen sujuvuuden pulmat eivät selity yksistään fonologisen tiedonkäsittelyn puutteilla. Väitöskirjassa esitetään näkemyksiä lukemissujuvuuden pulmien mahdollisista taustatekijöistä.

Ennakoivista taidoista fonologinen tietoisuus oli vahvimmin yhteydessä lukemisen tarkkuuteen jo 3,5 vuoden iästä lähtien. Yleinen kognitiivinen kyvykkyys ennusti jonkin verran lukemisen tarkkuutta, mutta merkittävästi heikommin kuin fonologinen tietoisuus ja varhainen fonologis-kielellinen kyvykkyys. Esikouluikään mennessä fonologisen tietoisuuden ja kirjaintuntemuksen kehitys kietoutui yhteen. Tutkimus osoitti, kuten aikaisemmin on arveltukin, että nämä taidot kehittyvät vastavuoroisesti kouluiän kynnyksellä heijastaen paitsi fonologisia ydintaitoja myös kirjoitusjärjestelmään tutustumista. Varhaiset leikki-iän fonologisen tietoisuuden tehtävät ilmensivät siten puhtaammin fonologisia ydintaitoja kuin myöhemmän ikävaiheen tehtävät.

Suurimmalla osalla lapsista (45 %:lla) lukemisvaikeus ilmeni sujuvuuden pulmina tai sekä tarkkuuden että sujuvuuden pulmina (40 %:lla), ja vain 15 %:lla lapsista lukemisvaikeus ilmeni yksistään lukemisen tarkkuuden pulmina. Yhdistämällä tietoa useasta eri ennustajasta (kirjaintuntemus, nopea nimeäminen / äännetietoisuus sekä tieto suvussa mahdollisesti ilmenevästä lukemisvaikeudesta) voitiin lapsen yksilöllistä lukemistaitoa ja lukemisen vaikeutta en-

nustaa jo 3,5 vuoden iästä lähtien. Todennäköisyyskuvaajien avulla voidaan havainnollistaa yksilöllisiä taitoja ja lukivaikeusriskin suuruutta. Ennusteseulojen käytössä kannattaa olla varovainen, sillä parhaimmillaankin ne tuottavat myös ”vääriä hälytyksiä”, eikä niillä tunnisteta kaikkia, joilla kouluiässä ilmenee pulmia. Ennusteseulan herkkyyttä voidaan pyrkiä parantamaan muun muassa kehittämällä oppimisympäristöjä, joissa oppimista voidaan seurata ja mitata samanaikaisesti.

Väitöskirjatutkimuksen tulokset osoittivat, että leikki-iän fonologisten ja kielellisten taitojen avulla voidaan ennakoida toisen luokan lukemisen tarkkuutta. Tämän lukemisen osa-alueen ongelmiin on olemassa harjaannuttamisohjelmia, joista tehokkaimmissa yhdistyvät fonologisen tietoisuuden ja kirjaintuntemuksen harjoitteet. Suomalaisilla lapsilla lukemisen pulmat ilmenevät toisen luokan lopulla useammin hitaana, sujumattomana lukemisena kuin lukemisvirheinä. Tällä hetkellä lukemisen sujuvuuden harjoittelusta on saatavilla vähän tutkimukseen perustuvaa tietoa. Tulevaisuuden tutkimuksen haaste on kehittää menetelmiä lukemisen sujuvuuden pulmien varhaiseksi tunnistamiseksi ja sujuvuuden pulmien kuntouttamiseksi, mikä edistäisi myös yksilöllisen lukemistaidon ja -riskin ennustamismahdollisuuksia.

Tiivistäen tutkimuksen keskeisenä havaintona oli, että lukemisen vaikeuksia voidaan ennakoida jo leikki-iästä lähtien. Lukemisen alkuvaiheen pulmien korjaamiseksi riittää toisinaan varhainen tuki ja intensiivisempi harjoittelu. Osalle eivät nämä toimet riitä, vaan tarvitaan yksilöllisesti suunniteltua harjoittelua ja kuntoutusta. Joillekin lukemisen pulmat jäävät lapsuuden muistoksi, mutta lukemisen vaikeus voi olla myös sitkeää. Jälkimmäisen tyyppisen vaikeuden kuntouttamiseen sopivia harjoitusohjelmia ollaan vasta kehittämässä.

Koulun arjessa sitkeän lukemisen vaikeuden haasteeseen voidaan vastata tarjoamalla riittävän pitkäaikaista yksilöllistä tukea ja toteuttamalla yksilöllisiä opetussuunnitelmia. Koulussa olisi tarpeen kehittää sellaisia oppimista tukevia ympäristöjä, joissa lukemiseen ja kirjoittamiseen perustuvan oppimisväylän ohella opitaan esimerkiksi kuuntelun, keskustelun ja tekemisen kautta ja käytetään monipuolista taito- ja taideaineiden tarjontaa tukemaan oppilaan kehityspotentiaalien löytämistä. Kaikki lapset oppivat, mutta eivät samoja menetelmiä ja väyliä käyttäen.

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APPENDIX

TABLE 4 Very Early Predictors of Reading Outcomes

Follow up study	***Sample***	***Early age***	***Early predictor***	***Final assessment phase and outcome measure***
Bryant, MacLean, & Bradley, 1990; Bryant, MacLean, Bradley, & Crossland, 1990	follow up of 65 children	3;4 4;7	vocabulary (BPVS), Reynell Expressive and Receptive Language Scale, rhyme and alliteration oddity, joint rhyme/alliteration choice, phoneme deletion, phoneme tapping, IQ, mother's education level	6;7 word reading; understanding of words and simple sentences
Carroll & Snowling, 2004	17 children with speech difficulties 17 children with and 17 without familial risk of dyslexia	3;11	phonological processing (mispronunciation detection, expressive phonology and nonword repetition), phonological awareness (initial phoneme and syllable matching), phonological learning and word learning	6;1 children without risk were compared with the other two groups
Chaney, 1998	follow up of 41 children	3;8	Preschool Language Scale, phonological awareness (judging adequacy and correcting misarticulated phonemes, initial sounds, judging rhyming, phonological play and phoneme synthesis), structural, metalinguistic and print awareness, letter knowledge	7;3 (1st grade) nonsense word reading, word identification and comprehension
Hindson, Byrne, Fielding-Barnsley, Newman, Hine, & Shankweiler, 2005	17 weeks follow up of 101 children with familial risk of dyslexia and 68 children without risk	4;6	phonemic awareness (phoneme identity and blending, sensitivity for rhyme), word span, memory for sentences, nonword repetition, articulation rate, expressive vocabulary, syntax, block design, letter naming	group difference and intervention outcomes of a) phonemic awareness b) progress in training c) concepts about print
Locke, Hodgson, Macaruso, Roberts, Lambrecht-Smith, & Guttentag, 1997	30 children with familial risk of dyslexia and 28 children without risk	1;2 3;7	auditory discrimination, rhyme production, initial consonant deletion, producing sound associated with consonant letters	6;4 (1st grade) group difference
Lonigan, Burgess, & Anthony, 2000	developmental links based on 96 children and 97 children were modelled using SEM	3;4 5;0	phonological sensitivity (several measures e.g. blending and elision of syllables; rhyme and alliteration oddity), oral language (e.g.. receptive and expressive vocabulary, grammatics), letter knowledge, environmental print	age 4;8: concept about print phonological sensitivity, letter knowledge. age 6;0: earlier mentioned measures and word reading

Oloffson & Niedersoe, 1999	205 children were screened by the speech therapist's in the childhood	3 years 6 years	language factor (vocabulary, pronunciation accuracy, speech comprehension, sentence construction, morphology), receptive and expressive language factors (e.g. sentence repetition, naming and working memory) and language awareness.	age 8 to11 2nd grade word reading 3rd and 4th grade sentence reading
Silvén, Poskiparta, & Niemi, 2004	63 children followed and divided into 3 categories of readers: precocious, emergent, and nonreaders	1;0 2;0 3;0 4;0 5;2 6;2	vocal expressions, different morphological features (e.g. nouns and verbs already at 2 years onwards), quantity of expressed words, phoneme awareness difference in multiple measures (e.g. at 3 years onwards identification of two rhyming words)	7;3: before the 1st grade differences between the groups
Scarborough, 1989;1990	34 children with familial risk of dyslexia and 44 children without risk	2.5 years 3 5 years	utterance length, syntactic complexity and pronunciation accuracy object-naming and receptive vocabulary object-naming, phonological awareness, letter knowledge	age 8 (2nd grade) reading outcomes
Snowling, Gallagher & Frith, 2003	development al paths of 56 children with familial risk of dyslexia and 29 children without risk	3;9	expressive vocabulary (naming), expressive language, phonological awareness (nursery rhyme knowledge, phoneme deletion, rhyme oddity), nonword repetition, short term memory (digit span and recalling sentences), letter knowledge, IQ	age 6: language, phonological awareness and grapheme – phoneme skills; age 8: reading comprehension and word-level literacy
Thomas & Senechal, 2004	80 normally developing children (43 were followed up to age 8 years)	3;1	phoneme discrimination, judgement and recognition , articulation of letters and letter knowledge (at age 3 and 4), phoneme matching and categorization, word identification (at age 5 and 6) and phoneme segmentation and deletion (at age 8)	age 8 (2nd grade) decoding and producing phonemes /r/ and /m/ and pseudowords
Wood & Terrell, 1998	30 children followed	4;4	segmentation of sentences, segmentation and blending of syllables, onset/rime and phonemes, rhyme detection, phoneme deletion, letter knowledge	at the end of 5 (1st - 2nd grade) school terms: word recognition and spelling skills

TABLE 5 Terminology Used in Individual Prediction

Terms and concepts	Descriptions
Sensitivity	The probability of a test finding a disability among those who have the disability or the proportion of people with the disability who have a positive test result. Calculated as true positives/ (true positives + false negatives)
Specificity	The probability of the test finding NO disability among those who do NOT have the disability or the proportion of people with disability who have a negative test result. Calculated as true negatives/ (true negatives + false positives)
Positive Predictive Value (PPV)	The percentage of people with a positive test result who actually have the disability. Calculated as true positives/ (true positives + false positives)
Negative Predictive Value (PPV)	The percentage of people with a negative test result who do NOT actually have the disability. Calculated as true negatives/ (true negatives + false negatives)
ROC-curves	The ROC –curve is a plot of the True Positive- rate (sensitivity) against the False Positive-rate (1-specificity) for all cutoff points of a predictor
Area under ROC, i.e., Prediction probability	The ROC scores (area under ROV) can be interpreted as expressing the measure's overall *prediction probability* of a disability. The score is a reflection of how good the test is at distinguishing between children with and without disability. Values vary from .50 to 1.0. In general values greater than .80 are thought to be good/useful and values greater than .90, excellent
Goodness of the predictor	The goodness of the predictor is determined by its ability to "catch" the children with the disorder (True Positives) and to "avoid" false alarms (False Positives). However, predictions always identify not only true cases but also false cases. These two accounts are inversely related and by changing the cutoff - point (Y-point) of the predictor the rate of both true cases and false alarms shift

Note. See Greiner, Pfeiffer, & Smith, 2000; Grunkemeier, & Jin, 2001; Obuchowski, 2003

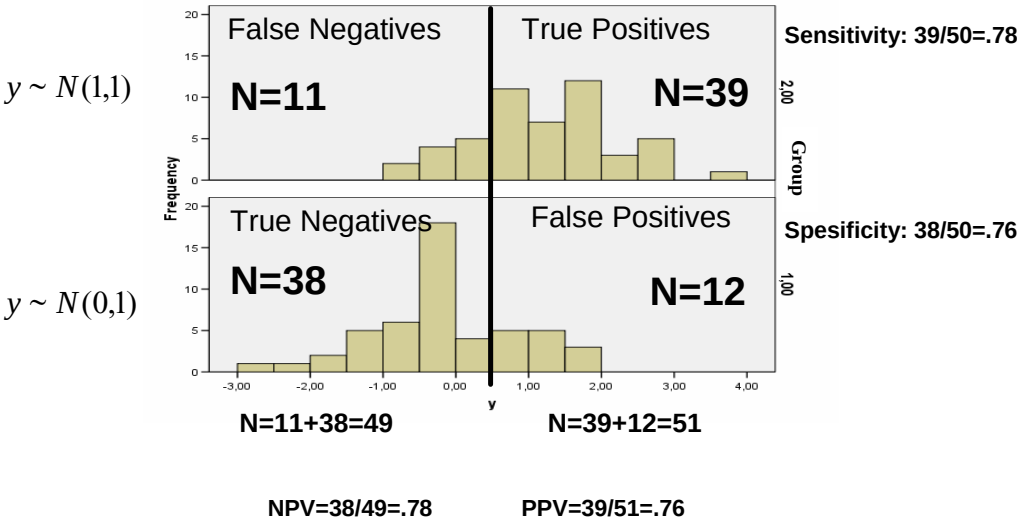
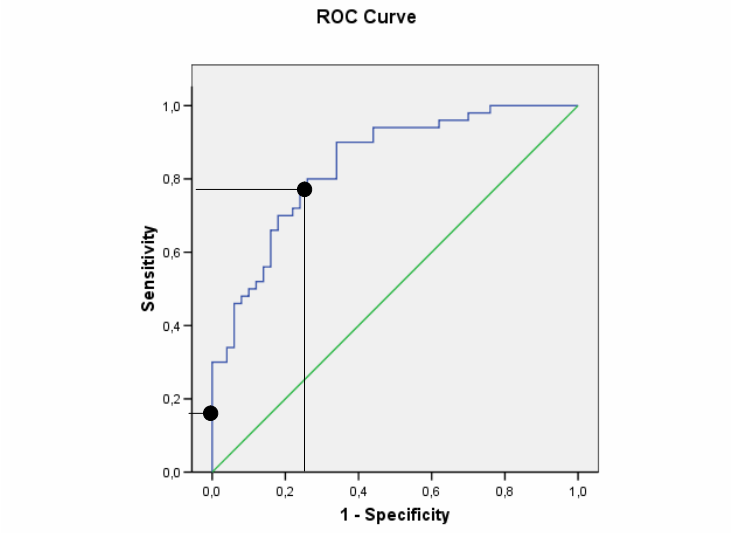


FIGURE 3 Example of the Classification Results



Note: If 76 % of true positives are identified it also produces 22 % of false positive cases.

FIGURE 4 Example of ROC-curve