Auditory ⇔ Visual Matching in Learning Disabilities: Intervention Studies from Finland and Sweden

Helsinki 2010

Research Report 315

Minna Törmänen

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Academic Dissertation to be publicly discussed, by due permission of the Faculty of Behavioural Sciences at the University of Helsinki, in Lecture room 5, Main Building, Fabianinkatu 33, on June 23rd, at 12 o'clock

Helsinki 2010

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ISBN 978-952-10-5770-0 (nid)
ISBN 978-952-10-5771-1 (pdf)
ISSN 1795-2158
Yliopistopaino
2010

University of Helsinki,
Faculty of Behavioural Sciences
Department of Teacher Education
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Abstract

The present thesis discusses relevant issues in education: 1) learning disabilities including the role of comorbidity in LDs, and 2) the use of research-based interventions. This thesis consists of a series of four studies (three articles), which deepens the knowledge of the field of special education. Intervention studies (N=242) aimed to examine whether training using a nonverbal auditory-visual matching computer program had a remedial effect in different *learning disabilities*, such as developmental dyslexia, Attention Deficit Disorder (ADD) and Specific Language Impairment (SLI). These studies were conducted in both Finland and Sweden. The intervention's non-verbal character made an international perspective possible.

The results of the intervention studies confirmed, that the auditory-visual matching computer program, called *Audilex* had positive intervention effects. In Study I of children with developmental dyslexia there were also improvements in *reading skills*, specifically in reading nonsense words and reading speed. These improvements in tasks, which are thought to rely on phonological processing, suggest that such reading difficulties in dyslexia may stem in part from more basic perceptual difficulties, including those required to manage the visual and auditory components of the decoding task. In Study II the intervention had a positive effect on children with dyslexia; older students with dyslexia and surprisingly, students with ADD also benefited from this intervention. In conclusion, the role of *comorbidity* was apparent. An intervention effect was evident also in students' *school behavior*. Study III showed that children with SLI experience *difficulties* very similar to those of children with dyslexia in auditory-visual matching. Children with language-based learning disabilities, such as dyslexia and SLI benefited from the auditory-visual matching intervention. Also comorbidity was evident among these children; in addition to formal diagnoses, comorbidity was explored with an assessment inventory, which was developed for this thesis.

Interestingly, an overview of the data of this thesis shows positive intervention effects in all studies despite learning disability, language, gender or age. These findings have been described by a concept *inter-modal transpose*. Self-evidently these issues need further studies. In learning disabilities the aim in the future will also be to *identify* individuals at risk rather than by deficit; this aim can be achieved by using research-based interventions, intensified support in general education and inclusive special education.

Keywords: learning disabilities, developmental dyslexia, attention deficit disorder, specific language impairment, language-based learning disabilities, comorbidity, auditory-visual matching, research-based interventions, inter-modal transpose

Helsingin yliopisto
Käyttäytymistieteellinen tiedekunta
Opettajankoulutuslaitos
Tutkimuksia 315

Minna Törmänen

Oppimisvaikeudet ja auditiivis-visuaalisen aistitiedon yhdistäminen: Suomessa ja Ruotsissa toteutetut interventiotutkimukset

Tiivistelmä

Erityisopetuksen oppilaiden määrä on kasvanut. Tilanne korostaa ennaltaehkäisevän ja varhaisen tuen merkitystä. Tämä tutkimus käsittelee ajankohtaisia kasvatustieteellisiä teemoja, kuten: 1) oppimisvaikeuksia ja niiden komorbiditeettia ja 2) interventioiden käyttöä. Tutkimus koostuu *neljästä* eri osatutkimuksesta (julkaistu kolmessa artikkelissa, I–III), luoden uusia erityispedagogisia näkökulmia. Interventiotutkimuksissa, jotka toteutettiin Suomessa ja Ruotsissa (N=242) tutkittiin auditiivisen ja visuaalisen aistitiedon yhdistämistä harjoittavan tietokoneohjelman (Audilex) käyttöä erilaisten oppimisvaikeuksien, kuten lukemis- ja kirjoittamisvaikeuksien, tarkkaavaisuushäiriöiden sekä kielenkehityksen häiriöiden kuntouttamisessa.

Osatutkimusten I–III mukaan oppilaat, joilla on oppimisvaikeuksia, hyötyivät ei-kielellisestä auditiivis-visuaalisen aistitiedon yhdistävästä interventiosta. *Osatutkimuksessa I* oppilaiden fonologiseen prosessointiin perustuvat lukemistaidot (nonsense-sanojen lukeminen ja lukunopeus) parantuivat. Voidaan olettaa, että lukivaikeuksien taustalla on häiriöitä havainnoinnissa, joita tarvitaan auditiivisen ja visuaalisen aistitiedon yhdistämisessä. *Osatutkimuksessa II* lukihäiriöiset oppilaat, myös lukioikäiset, hyötyivät kuntoutuksesta. Komorbiditeetti tuli esille, koska myös tarkkavaisuushäiriöiset oppilaat saivat hyviä tuloksia. Interventioefekti oli huomattavissa kaikkien oppilaiden positiivisessa koulukäyttäytymisessä. Kaksiosaisessa o*satutkimuksessa III* ilmeni, että lapsilla, joilla on kielenkehityksen häiriö, on hyvin samanlaisia ongelmia auditiivis-visuaalisen aistitiedon yhdistämisessä kuin lukihäiriöissä. Lisäksi osatutkimus III:n mukaan lapset, joilla on kielellisiä oppimisvaikeuksia, hyötyivät myös Audilex-kuntoutuksesta. Tutkimustulosten mukaan komorbiditeetti oli yleistä; tämä ilmeni lasten diagnooseista sekä tutkimusta varten kehitetyn lapsen kokonaiskehityksen arviointilomakkeista.

Tarkasteltaessa tutkimusten tuloksia voidaan yllättäen todeta, että Audilex-interventiosta ovat hyötyneet kaikki oppimisvaikeusryhmät, myöskään kieliympäristö, oppilaiden sukupuoli tai ikä eivät vaikuttaneet positiivisiin tuloksiin. Käsite ”inter-modal transpose” pyrkii kuvaamaan tätä mielenkiintoista ilmiötä, joka luonnollisesti vaatii jatkotutkimuksia.

Yleisesti huomion arvoisena tutkimustuloksena voidaan pitää myös auditiivisen ja visuaalisen aistitiedon yhdistämistä harjoittavan intervention käyttömahdollisuuksia eri maissa ja kieliympäristöissä. Tulevaisuuden tavoitteena voidaan pitää oppimisvaikeusriskin varhaista tunnistamista käyttämällä interventioita sekä tehostettua ja erityistä tukea.

Avainsanat: oppimisvaikeudet, lukemis- ja kirjoittamisvaikeudet, tarkkavaisuushäiriöt, kielenkehityksen häiriöt, kielelliset oppimisvaikeudet, komorbiditeetti, auditiivisen ja visuaalisen aistitiedon yhdistäminen, Audilex, interventiot, tehostettu tuki

Acknowledgements

This study was carried out in University of Helsinki at the Faculty of Behavioural Sciences at Department of Teacher Education in Special Education Section, and in Sibelius Academy at the Music Education Department. I am privileged having an opportunity to perform a cross-disciplinary and multicultural research.

I would like to thank several people who have contributed and supported me in this endeavor. First of all I am deeply grateful to all children and adolescents from Finland and Sweden for their participation. I also owe my gratitude to all Finnish and Swedish teachers and school principles for their co-operation.

I would like to owe my gratitude to my supervisor Adjunct Professor Marjatta Takala and Professor Jarkko Hautamäki for providing me with excellent working facilities and stimulating scientific atmosphere. I am also grateful for everything that I have learned from you concerning good science. My warm thanks to Adjunct Professor Marjatta Takala for your advice, support, and the freedom to develop my own ideas. I extend my appreciation to Professor Jarkko Hautamäki raising a number of wise and critical comments, which had valuable impact on the whole content; I am thankful for your contribution. I cordially thank my co-author Adjunct Professor Nina Sajaniemi for fruitful collaboration and for your commitment to our shared project. Your vast knowledge in neuropsychology, valuable comments and suggestions has widened my perspectives.

I would like to express my gratitude to The Music Education Department of the Sibelius Academy, my first steps in scietific world have been very important. I am greatly indebted to Professor emeritus Kai Karma for sharing his cross-disciplinary knowledge of music education and special education. I also owe my warm gratitude to Professor emerita Marjut Laitinen for her encouragement.

I am deeply indepted to all my colleagues in Special Education Section who believed in me, shared their expertice with me and supported, assisted and stimulated me during different stages of my Dissertation. I sincerely thank Adjunct Professor Elina Kontu for your continuous and devoted collaboration and invaluable expert comments throughout the whole process. I am also pleased for our shared interest towards music in special education. I wish to thank Eira Suhonen, PhD for the insightful scientific discussions that boosted my motivation. I owe my warm thanks for your support and care during my work.

I like to thank my co-author Professor Raija Pirttimaa for your interest and valuable expertise. I am very grateful to Professor emeritus Erkki Komulainen for sharing your statistical expertise with me. I also owe my gratitude to Vice-Rector of University of Helsinki, Professor Kimmo Kontula for your interest and kind support during these years.

My special thanks goes to my fellow researchers from SE group (*Supported Education*), and LSO group (*Lasten Stressinsäätely ja Oppiminen*). It is wonderful to work with such intelligent scientists. Your proficiency, enthusiasm and inspiration set great expectations for our future collaboration. I also want thank my fellow students from Special Education Section and from Sibelius Academy, especially Sara Sintonen, PhD.

The official reviewers, Professor Hannu Savolainen from University of Eastern Finland and Professor Mats Myrberg from University of Stockholm, Sweden are sincerely thanked for their careful review of this thesis. I am also grateful to Professor emerita Ulla Lahtinen, who kindly agreed to be the opponent in the public defense. I acknowledge Marlene Broemer from the Language Center of Helsinki University for proofreading my thesis.

This study was supported by grants from the Finnish Cultural Foundation, the Otto A. Malm Foundation and University of Helsinki, Department of Applied Sciences of Education, Special Education.

I am also very grateful to my wonderful friends from different phases of my life. Thank you all for being there for me, and for bringing joy to my life. Special thanks belongs to Auli Malimaa for sharing her unique attitude towards life and profound knowledge of wellness; without Herbalife this Dissertation would not have exist.

Finally, I wish to give my deepest thanks to my family for supporting me in so many ways during these years. There are no words for describing my gratitude. I owe my warmest thanks to my parents Eeva and Osmo Rautanen for their enormous love, care and encouragement. I would also thank my big brother Janne and his family. I am fortunate being raised in such a supportive and academic atmosphere.

Most importantly, with all my heart, I want thank the unbelievable support of my dear husband, Antti. I thank you for your firm support, willingness and tenderness during these years. I feel most privileged to have such an encouraging, challenging, and caring companion in life. Let the journey continue! Finally, I dedicate this thesis to our precious children Aaro and Henrik. I hope this work encourages you in your lives to strive patiently for whatever you feel is worth effort. Whatever I do, you are my greatest source of happiness and inspiration. You remind me every day what really is valuable in life.

Espoossa 16.5.2010

Minna Törmänen

List of Original Publications

I Törmänen, M.R.K. & Takala, M. (2009). Auditory Processing in Developmental Dyslexia: An Exploratory Study of an Auditory and Visual Matching Training Program with Swedish Children with Developmental Dyslexia. *Scandinavian Journal of Psychology*, *50*(3), 277–285.

II Törmänen, M.R.K., Takala, M. & Sajaniemi, N. (2008). Learning Disabilities and the Auditory and Visual Matching Computer Program. *Support for Learning*, *23*(2), 80–88.

III Törmänen, M.R.K. (2009). Auditory-Visual Matching and Language-Based Learning Disorders: Two Studies of Specific Language Impairment and Developmental Dyslexia. *International Journal of Education, 1*(1).

Contents

1 Introduction

> *"We spend far too much of our professional time making predictions about students' lives, and far too little time making a difference in their lives."*
>
> (Ysseldyke, 2005, 125)

In present-day society learning difficulties are especially disabling as our lives have become more dependent on the information obtained from printed and electronic sources, and the rapid mastery of reading skills has come to assume an increasingly important position in education. Currently, more pupils are identified as having *learning disabilities* (LD) than any other type of disability. There are several possible explanations for this growth in the identification of LD. According to Vaughn & Fuchs (2003) these include recognition of the significant academic and social problems realized by individuals with LD, greater social acceptance of LD over other categories of special education, and increasing needs for literacy at home and work (Vaughn & Fuchs 2003). An interesting perspective is that learning disabilities may simply be the manifestations of natural variability in the brain and are, in part, identified because of the cultural demands being placed on the individuals with LD (Gilger & Kaplan, 2001). When identifying LDs the overall aim in the future will be to identify individuals at risk rather than by deficit. Early identification of children at risk for learning difficulties would enable early intervention or planning alternative approaches to learning.

In learning disabilities *comorbidity*, the presence of at least two disorders is usual. Disabilities in literacy and attention may cause emotional problems, and further social problems. One way to prevent this unwanted "snowball-effect" is to use efficient and motivating *interventions*. When using effective methods, the associated brain networks can also be reorganized to alleviate the difficulties that compromise learning. In most cases the "bottlenecks" of learning can be released by additional practice.

The present thesis discusses very relevant areas in the current educational climate: 1) learning disabilities including the role of comorbidity in LDs, and 2) the use of research-based interventions. This thesis consists of four studies of learning disabilities (published in three articles): developmental dyslexia, attention deficit disorder (ADD) and specific language impairment (SLI). These studies have 242 participants, children and adolescents from Finland and Sweden which made an *international* perspective possible.

Despite the many varying theoretical accounts of dyslexia, the strongest empirical evidence suggests that dyslexia is based on an underlying deficit in phonological skills. There is still significant controversy also about the extent to which phonological processing deficits are important in the genesis of learning disabilities. The auditory-visual matching intervention used in this thesis has been studied earlier among children with dyslexia in Finland (Kujala et al., 2001). The results indicated that reading difficulties like dyslexia can be ameliorated by the audio-visual matching training and further, that the training effects can be observed in brain activity.

Dyslexia is considered to have a *universal* basis (Paulesu et al., 2001), depending on the orthography (Seymour et al., 2003). Because of the non-verbal character of the intervention used in this research, it was used both with Swedish and Finnish students with learning disabilities. The results were similar to those from Finland. In addition, this non-verbal training gave an alternative for pupils, also older ones, who have been struggling difficulties with literacy.

The growing recognition of comorbidity between learning disabilities and other disorders is one of the key issues in this thesis. Many educators know that a child whose development is atypical in only a single area is unusual. The scientific research has also demonstrated comorbidity across learning difficulties. The intervention used in this thesis demands concentration on both modalities, auditory and visual, and evidently also attention. The positive intervention effects with individuals with dyslexia encouraged to the use of this intervention with pupils with ADD and SLI.

Learning difficulties might have long-standing effects. For those who struggle to acquire sufficient literacy and other learning skills, schooling becomes frustrating and may form a barrier to later learning. It is important 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.

1.1 Learning Disabilities

Learning disability (Kirk, 1962) is traditionally synonymous with the concept of unexpected underachievement — specifically, concerning students who do not listen, speak, read, write, or develop mathematics skills commensurate with their potential, even though they have had adequate opportunity to learn (Lyon et al., 2001). Learning disabilities (LDs) can also include attention and memory problems and disorders in thinking and using language. The lack of educational achievement is the tip of the iceberg. There are causative extrinsic (such as social) and intrinsic (such as genetic) factors at the base of learning disabilities (Silver & Hagin, 2002). The identification of LDs is frequently based on three components: discrepancy, heterogeneity and exclusion (Fletcher et al., 2004). Discrepancy is indicated by the presence of a difference between IQ and achievement test scores. Heterogeneity represents the multiple domains in which LD occurs. The exclusion component reflects the orientation that the LD should not be identified if the primary cause involves a sensory disorder, mental deficiency, emotional disturbance, economic disadvantage, linguistic diversity, or inadequate instruction (Fletcher et al., 2004).

Recently, increasing concern has been expressed about common definitions and procedures for identifying students with LDs (Fletcher et al., 2004). Current identification methods seem to take too long to identify children in need, and thus, intervention lags behind (Fletcher et al., 2004; Lyon et al., 2001), although the benefits of early intervention, rather before school age, are widely known (e.g., Reynolds & Robertson, 2003). It has been strongly suggested that a Response to Interventions (RTI) criteria should be a part of the identification process of LDs before any special education statements are officially made (Vellutino, 1998).

Due to different classification processes, the prevalence of LDs in the school population varies enormously. Some researchers have argued that the currently recognized 5% prevalence rate is inflated; others argue that LDs are still under-identified (Lyon et al., 2001). Nevertheless, the number of students identified as having LDs has increased more than 200% since the category was established in 1977, with some researchers asserting that many students have been misidentified (Vaughn & Fuchs, 2003).

1.1.1 Developmental Dyslexia

Developmental dyslexia is the most common learning disability in children, affecting 10–15% of school-age children (Vellutino et al., 2004), depending on the orthography (Seymour et al., 2003). A commonly accepted definition of dyslexia, a developmental language disorder, is that it is a specific learning difficulty, primarily affecting the acquisition of reading and spelling, such that these skills are below the level to be expected for a given age and general cognitive ability. Developmental dyslexia affects children irrespective of intelligence, education and social background. The disorder persists throughout life, although the manifestations of dyslexia change with age. This is probably due to neurological maturity, increased practice and experience, and the ways an individual compensates for the condition. Some adults do *com-*

pensate fully for their childhood reading problems (Høien & Lundberg, 1999; Shaywitz, 2003; Ramus, 2004). Current investigations increasingly acknowledge that developmental dyslexia is a *genetic* disorder (Hannula-Jouppi et al., 2005; Grigorenko et al., 2003, Nopola-Hemmi et al., 2002). The likelihood that developmental dyslexia in some children is caused, in part, by genetically based cognitive deficits is supported by several family risk studies (Guttorm et al., 2003; Nopola-Hemmi et al., 2000; Richardson et al., 2003).

The Jyväskylä Longitudinal Study of Dyslexia (JLD) is a large-scale longitudinal developmental study covering the routes to dyslexia, and has followed a group of children with and without a familial risk for dyslexia from birth to the end of the third school year. The study has produced many findings (psychophysiology, developmental, cognitive and social psychology, linguistics, behavioral and molecular genetics, etc.) including causality, diagnosis and intervention. The JLD speech perception studies using neurophysiological 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 six months (Guttorm et al., 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 six months (Richarson et al., 2003). In analyses combining speech perception data and later behavioral 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 et al., 2005). Further analysis showed that the group of children who ultimately manifested reading problems differed in processing basic auditory stimuli in infancy. The analyses using behavioral level measures have reported association between childhood language development and mother-child interaction (Laakso et al., 1999), and symbolic play (Lyytinen et al., 2003). At the age of 2.5 years, children with and without the risk differed in their number of vocalizations (Lyytinen 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 at risk and control groups predict children's later reading related skills (Lyytinen et al., 2001; Lyytinen et al., 2004). Recent studies involve identification of reading trajectories based on the early language and literacy measures (Lyytinen et al., 2006) and identification of developmental paths of reading based on profiles of word recognition and reading comprehension (Torppa 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 et al., 2001), and to detection of sound stimuli which was further connected to phonological and reading skills (Hämäläinen et al., 2005).

1.1.1.1 The Etiology of Developmental Dyslexia

After decades of research, theorists still have fundamental disagreements over the neurological and cognitive basis of the developmental dyslexia. Ramus et al. (2003) have provided an overview of the different theories of dyslexia.

When learning to read, children develop an explicit understanding that words can be broken down into constituent phonemes, which map to visually presented letter strings, known as graphemes. *Phonological-deficit theories* of dyslexia, which have dominated the field for some years, view dyslexia as a cognitive difficulty in processing phonemes (Bradley & Bryant, 1978; Brady & Shankweiler, 1991; Snowling, 1998). According to Snowling (1998) most dyslexics, with and without additional learning difficulties, suffer from poor phonological processing. They have difficulties hearing words that are composed of smaller speech segments and in manipulating speech sounds. These impairments are directly linked to their reading difficulty because decoding of the alphabetical script requires mapping visual symbols to basic speech sounds (Snowling, 2001). However, evidence for poor verbal short-term memory and slow automatic naming in dyslexics also points to a more basic phonological deficit, perhaps having to do with the quality of phonological representations, or their access and retrieval (Snowling, 2001).

While theorists have different views about the nature of the phonological problems, they agree on the central and causal role of phonology in dyslexia. The phonological-deficit theories therefore postulate a straightforward link between a cognitive deficit and the behavioral problem to be explained (Ramus et al., 2003). At the neurological level, it is usually assumed that the origin of the disorder is a congenital dysfunction of left-hemisphere perisylvian brain areas underlying phonological representations, or connecting phonological and orthographic representations (Paulesu et al., 2001; Pugh et al., 2000; Shaywitz et al., 2002).

According to Ramus et al. (2003), the other theories do not dispute the *existence* of a phonological deficit and its contribution to reading retardation; rather the disorder is explained to be more extended, having its roots in general sensory, motor or learning processes, when the phonological deficit is just one aspect or consequence of the more general disorder. The major weakness of the phonological theory is its inability to explain the occurrence of sensory and motor disorders in dyslexia (Ramus et al., 2003).

The way to challenge the specificity of the phonological deficit is to postulate that it is secondary to a more basic auditory deficit (Ramus et al., 2003). *Rapid-auditory-processing hypotheses* propose that dyslexia arises from a basic deficit in processing rapidly successive and transient stimuli that enter the nervous system, affecting all modalities (Hari & Renvall, 2001; Eden et al., 1995; Tallal et al., 1993). In such models, the phonological impairments that are responsible for reading difficulties stem from a lower-level inability to discriminate acoustic cues that are involved in distinguishing phonemes (Temple et al., 2001). Support for rapid-auditory-processing hypotheses arises from evidence that dyslexics show poor performance on a number of auditory tasks, including frequency discrimination (Ahissar et al., 2000) and temporal order judgment (Tallal, 1980; Nagarajan et al., 1999). Abnormal neurophysiological responses to various auditory stimuli have also been demonstrated (Nagarajan et al., 1999; Kujala et al., 2000; Temple et al., 2001). The failure to correctly represent short sounds and fast transitions would cause further difficulties in particular when such acoustic events are the cues to phonemic contrasts, as in /ba/ versus /da/. In this view, the auditory deficit is therefore the *direct cause*, in the course of development, of the phonological deficit, and hence of the difficulty in learning to read. There is also criticism with regards to the rapid-auditory-processing hypotheses. It should be noted that critical discussion surrounding the timing deficit issue relates to a debate about the speech vs. non-speech nature of processing difficulties in dyslexia.

The magnocellular-deficit theory is based on data from anatomical and psychophysical studies, which indicate that many people with dyslexia have mild anomalies in the magnocellular visual subsystem (Eden et al., 1996). Magnocells are neurons concerned with motion perception and temporal resolution, and are important for the control of eye movements. Magnocellular pathways might exist in other sensory modalities, so a multi-modal magnocell deficit might account for the full range of symptoms that are associated with dyslexia, with reading difficulties resulting from a combination of visual and phonological impairment (Stein & Walsh, 1997). Through a single biological cause, the magnocellular deficit theory manages to account for all known manifestations of dyslexia: visual, auditory, tactile, motor and, consequently, phonological. In contrast, a number of researchers fail to find conclusive evidence in favor of the magnocellular deficit theory (Johannes et al., 1996; Skottun, 2000; Lueder et al., 2009). Its opponents point out that findings of magnocellular processing deficits are not uncontested (Walther-Müller, 1995; Skottun, 2000) and, furthermore, that no clear account has yet been proposed to explain how a dysfunctional magnocellular system impedes reading acquisition.

It has been also suggested that dyslexia represents a general impairment in skill automatization that results from *cerebellar dysfunction* (Nicolson et al., 2001). In the cerebellar dysfunction theory of dyslexia the biological claim is that the cerebellum of the individual with dyslexia is mildly dysfunctional and a number of cognitive difficulties ensue (Nicholson et al., 2001). The cerebellum plays a role in motor control and therefore in speech articulation. It is postulated that retarded or dysfunctional articulation would lead to deficient phonological representations. Secondly, the cerebellum plays a role in the automatization of overlearned tasks. A weak capacity to automatize would affect, among other things, the learning of grapheme–phoneme correspondences. The cerebellar theory fails to account for sensory disorders, but its proponents entertain the idea of distinct cerebellar and magnocellular dyslexia subtypes (Fawcett & Nicolson, 2001). It also remains uncertain what proportions of dyslexics are affected by motor problems. A number of studies have failed to find any (van Daal & van der Leij, 1999; Kronbichler et al., 2002); others have found motor problems only in a subgroup of dyslexics (Ramus et al., 2003), and it has been suggested that motor dysfunction is found only in dyslexic children who also have attention-deficit hyperactivity disorder (AD/HD) (Wimmer et al., 1999).

The poor-working-memory hypothesis comes from studies that have found a typical characteristic of dyslexia in short-term and poor verbal working memory (Siegel & Ryan 1989; Swanson 1994; Gathercole & Pickering 2000). Working memory is a system that provides temporary storage that holds and manipulates incoming, task-relevant information and integrates it with other information from the long-term memory in the service of goal-directed behavior (Baddeley 1986, 1992). Basic tasks, like decoding unfamiliar words and simple arithmetic calculations, require holding parts in memory (speech segments or digits) while manipulating other parts of the input stream. The phonological loop component of the working memory model (Baddeley, 1986) consists of two components: a short-term store that maintains phonological representations and is subject to rapid delay, and a subvocal rehearsal process that acts to refresh decaying phonological representations in the store. Spontaneous use of rehearsal does not merge typically until about eight years of age (Gathercole & Hitch, 1993). Any information that can be verbalized (such as spoken words, printed words, nameable objects) can be stored in the phonological loop. Like verbal working memory, the capacity of the phonological loop undergoes steady development from early childhood to early adolescence, leveling off towards 15 years of age.

The third component of the working memory model is the visuo-spatial sketchpad, a system specialized for temporary visuo-spatial storage. The final element of the model, the episodic buffer (Baddeley, 2000), is responsible for the integration of information from different components of both working memory and long-term memory in multi-dimensional representations.

Consequently, poor working memory may impede the performance in a broad range of academic tasks including, but not specific to, reading (Gathercole & Pickering, 2000). According to Banai and Ahissar (2006), the relationships between phonological, psychoacoustic, and working memory deficits in developmental dyslexia are not clear. Because human working memory has mostly been studied with phonological material, it is hard to interpret whether the difficulty in manipulating speech sounds stems from poor processing of sound or from a general difficulty in interstimulus retention and manipulation. Similarly, because adequate performance on any psychoacoustic discrimination task requires both encoding of the specific stimuli to be discriminated and the discrimination process itself, that is, the need to serially retain and compare stimuli, when discrimination is impaired, it is hard to dissociate whether poor performance results from a stimulus-specific deficit (encoding auditory stimuli) or from a deficit related to the discrimination task at hand (retention, comparison, decision making).

There are also studies (de Jong, 1998; McLean & Hitch, 1999) that show that children with deficits in working memory functions have learning difficulties that are often accompanied by behavioral problems. Interestingly, the neural processes serving working memory, and the brain structures underlying this system, continue to develop during childhood untill adolescence and young adulthood. It has been shown that the regions implicated in visuo-spatial working memory in the frontoparietal areas in adults are increasingly engaged in children as they age (Klingberg et al., 2002; Vuontela, 2008).

There is an ongoing debate between proponents of the different theories of developmental dyslexia. According to Ramus et al. (2003), it is possible that most theories are true with different individuals, meaning there could be three partially overlapping subtypes of dyslexia, each being an independent contributor to reading difficulties: phonological, auditory/visual, and cerebellar. Alternatively, it could also be that just one theory accounts for every case of dyslexia, and that the other manifestations observed are markers, i.e., they are associated without causation. When finding the true essence of disorder, the comorbidity (see Chapter 1.4) of learning disabilities also makes the situation difficult. The important concept of this thesis is auditory-visual matching. According to previous results (Karma 1999) and the results of this thesis, it might be suggested that auditory-visual matching is part of the phonological-deficit theories of dyslexia. Despite the role of auditory processing in rapid-auditory-processing hypotheses, the findings concerning auditory-visual matching in dyslexia (Karma 1989; 2002b; Törmänen & Takala, 2009) do not suggest that the speed of processing of serial stimuli distinguishes individuals with dyslexia from control populations. This will be discussed more in Chapter 1.2, Auditory-Visual Matching in Learning Disabilities.

1.1.1.2 Developmental Dyslexia in Different Languages

Developmental dyslexia is increasingly acknowledged to be a disorder of genetic origin with a basis in the brain (Smith et al., 1998, Shaywitz, 2003; Ramus, 2004). However, there continues to be doubt about the universality and specificity of the syndrome because behavioral studies have shown that the nature and prevalence of dyslexia differs across languages (Landerl et al., 1997). The prevalence estimates of dyslexia in different languages seem to be related to the shallowness of the orthography. It is suggested that phonological awareness develops in a similar way, independent of the language environment (Goswami, 1999). Also, independent of language, difficulties in phonological processing seem to be one of the core deficits of developmental dyslexia in languages; they vary greatly in their complexity of grapheme-phoneme correspondence (Paulesu et al., 2001).

The intervention studies of this thesis, which have been conducted in Finland and Sweden, used a nonlinguistic computer program designed in Finland (Karma, 1998) as a training method. While Finnish has a relatively shallow, a two-way shallow orthography, Swedish has a quite deep orthography, deeper in the sense of containing more inconsistent correspondences as well as morphological influence on spelling (Seymour et al., 2003, Laasonen et al., 2001). Further, in the case of the relatively regular languages, the readers with dyslexia are more accurate in grapheme-phoneme conversion and read at faster rate than the readers whose languages have deeper orthographies (Harris & Hatano, 1999; Paulesu et al., 2001).

Is dyslexia a disorder with a universal neuroanatomical basis, or is it a different disorder in shallow and deep orthographies? This was the aim question posed by the research of Paulesu et al. (2001), where Italian dyslexics were compared to French and English dyslexics. According to Paulesu et al. (2001), dyslexia has a universal basis in the brain and can be characterized by the same neurocognitive deficit. The manifestation in reading behavior is less severe in a shallow orthography. Although Italian dyslexics read more accurately than French or English dyslexics, they showed the same degree of impairment on reading latencies and reading-related phonological tasks relative to their controls. In conclusion, a phonological processing deficit is a universal problem in dyslexia and causes literacy problems in both shallow and deep orthographies (Paulesu et al., 2001).

The results of interventions studies of this thesis showed similar results; however, the participant's mother tongue was different. Both Finnish and Swedish participants benefited from the non-verbal intervention. These findings are encouraging from the perspective of treating individuals with dyslexia regardless of their language.

1.1.2 Attention Deficit Disorder, ADD

Different learning situations require that children attend to specific stimuli in the environment that contain complex, competing signals. This process of selecting stimuli from a changing, multisensory environment is determined not only by the physical characteristics of the stimuli itself, but also by the individual interests, motives and cognitive strategies of the person perceiving the stimuli. Attention is needed in the process of selection and it plays a crucial role in learning and development (Fuster, 2003). It could even be suggested that disorders in attention are responsible for cumulative learning difficulties at different ages (Gilger & Kaplan, 2001).

Attention deficits and doubts of Attention Deficit/Hyperactivity Disorder (AD/HD) are the most frequent reasons for a referral to child and adolescent mental health services. AD/HD is an early-onset, highly prevalent neurobehavioral disorder, with genetic, environmental, and biologic etiologies, that persists into adolescence and adulthood in a sizable majority of afflicted children of both sexes. The estimated prevalence rate of AD/HD in school-age children is between 2% and 18% (Skounti et al., 2007). It is characterized by behavioral symptoms of inattention, hyperactivity, and impulsivity across the life cycle and is associated with considerable morbidity and disability. Comorbidity is a distinct clinical feature of both childhood and adult AD/HD. Although its etiology remains unclear, genetic and twin studies provide strong evidence for biological risk and specific genetic underpinnings, and such research continues to increase knowledge in this area.

There are different views on how to classify AD/HD: it is considered a medical diagnosis or a learning disability, or it is said to cause learning problems (Pelham et al., 2005). In this thesis it is considered an LD. Typical children with AD/HD have different kinds of behavioral characteristics such as being inattentive, or alternatively, hyperactive. These children show decreased impulse control, low educational achievement, poor social skills and low self-esteem (Pelham et al., 2005). There are diagnostic criteria for two distinct behavioral dimensions characterized by inattention and hyperactive-impulsive behavior; a combination of these behaviors is classified as an additional subtype of this disorder (Barkley, 2003). Impaired cognitive control has been proposed to represent a core deficit in childhood AD/HD (Barkley, 1997; Durston & Casey, 2006). Consequently, children with AD/HD, especially the hyperactive-impulsive and combined types (Gathercole & Alloway, 2006), perform poorly in tasks requiring inhibitory control (Barkley, 1997). On the other hand, deficits in working memory function may underlie the manifest symptoms of AD/HD. The implication of working memory deficits in the AD/HD type of behavior is supported by the reasoning that inattention stems from an inability to hold mental representations active in order to guide behavior (Barkley, 1997), and distractibility from an inability to maintain the priorization of relevant information, skills that are associated with the executive and storage domains of working memory. Although working memory deficits in particular have often been claimed to be characteristic of at least some children with disorders of attention, there is in fact little evidence that they under-perform on classic measures of working memory such as reading and listening span (Adams & Snowling, 2001). Gathercole et al. (2008) have studied children with inattentive profiles to determine whether the impairment of working memory function results from a primary deficit in working memory or in intermittent failures to attend to working memory tasks. In children with hyperactive profiles of behavior, working memory function is not unexpectedly poor. It does, however, remain possible that children with attentional problems that are of an inattentive nature may have impairments of working memory.

A diagnosis used in the Nordic countries for a combination of AD/HD symptoms and deficiencies in motor control and perception is DAMP (deficits in attention, motor control and perception), which is a subgroup of AD/HD (Landgren et al., 1998). Despite the high diagnostic reliability and the robust evidence of the validity of AD/HD, there are many underlying issues that remain to be resolved. These include establishing developmentally appropriate diagnostic criteria at older ages, further elaborating the impact of gender on symptom expression, and examining risk and protective factors in relationship to prevention or amelioration of AD/HD as well as related functional impairments. This work requires cross-disciplinary research.

1.1.3 Specific Language Impairment, SLI

Specific language impairment, also known as developmental a- or dysphasia, is regarded as a neurobiological disorder, and has a serious impact on a child’s educational and psychosocial outcome. SLI is a relatively common developmental language disorder, with an estimated incidence of around 7%

of the population (Tomblin et al., 1997) and the impairment has a strong genetic basis (Bishop et al., 1996) associated with abnormalities at chromosomes 16 and 19 (SLI Consortium, 2002).

Children with SLI are often late to start spontaneous speech and lag behind normally developing children in acquiring sophisticated language and grammar despite having adequate hearing and at least average nonverbal intelligence, and no known hearing, physical, or emotional problems, and an adequate learning environment (Asikainen, 2005; Bishop, 1992, 2006; Tomblin et al., 1997). Children with SLI have deficits in receptive and expressive language, and often poor phonology, and semantic skills; problems in short-term memory may also occur. Because of this broad span of both language and literacy deficits, some theorists have considered SLI to be a more extreme form of other language disorders, than dyslexia, where oral language abilities are intact (Bishop & Snowling, 2004). It has been proposed that SLI may be due to cognitive and linguistic difficulties (van der Lely & Stollwereck, 1997). However, other theorists have hypothesized that the primary deficit in SLI is in auditory processing (Tallal, 2000; Tallal & Piercy, 1973; Neville et al., 1993; Visto et al., 1996; Wright et al. 1997; Ludlow et al., 1983). According to the *auditory-deficit hypothesis,* SLI is not a hearing loss in the same way as deafness is, but rather an inability to perceive, categorize, and process sounds properly, which may lead to higher-level problems. Such a perceptual processing view emphasizes the importance of the detection and discrimination of low-level, basic acoustic components, suggesting that these bottom-up problems interfere with higher linguistic processing.

Studies (Archibald & Gathercole, 2006; Newbury et al., 2005) of the cognitive processes underlying SLI have implicated deficits in the storage and processing of phonological information. Gathercole & Baddeley (1989, 1990) argued that SLI may involve a *specific deficit of phonological short-term memory*. This component specializes in the temporary storage and processing of verbal material and, importantly, in their model, it is capacity limited. In SLI, it is proposed that this capacity is reduced, thus impeding the efficient processing and storing of phonological information that is crucial to language learning. Gathercole and Baddeley (1990) found that children with SLI performed substantially below not only age controls, but also chronologically younger language controls on a non-word repetition task (a task designed to measure phonological short-term memory), a finding supported by several subsequent studies (Conti-Ramsden & Durkin 2007; Dollaghan & Campbell 1998; Ellis Weismer et al., 2000) and in languages other than English (Reuterskiold-Wagner et al., 2005). That this appears to apply even in cases where the language problems have apparently been resolved (Conti-Ramsden et al., 2001) has provided a basis for suggesting that poor non-word repetition ability is not only a marker, but also a key contributory trait of SLI. In Archibald and Gathercole (2006) study deficits in both verbal short-term and working memory in a sample of children with SLI were established. The data indicate that dual deficits in verbal short-term and working memory were exceed criterial language abilities characteristic of SLI and may plausibly underpin some of the language learning difficulties.

A contrasting account, the '*Extended Optional Infinitive* (EOI)' theory put forward by Rice (2000) and Rice et al. (1995), suggests that SLI results from slow maturation of the linguistic brain system involved in the grammatical marking of finiteness. While the grammatical marking system of a typically developing child matures relatively quickly, with substantial mastery by five years of age, children with SLI continue to treat finite marking as optional for an extended period of development (Rice, 2000).

However, findings in SLI studies are contradictory, and the core problem of the disorder is still under debate. One major difficulty in SLI studies is that it is a heterogeneous disorder with ill-defined boundaries and our understanding of the different phenotypes that are included under the umbrella of SLI needs to be studied. So far differential diagnostics between SLI and other disorders in the spectrum of developmental disorders, social-emotional disorders and learning difficulties are also undetermined (Bishop & Snowling, 2004; Asikainen, 2005).

1.1.4 Language-Based Learning Disorders

An overarching concept for specific language impairment (SLI) and developmental dyslexia is *language-based learning disorders*. This concept summarizes the linguistic components in learning disabilities. Apart from the fact that both of these disorders involve deficits in some part of the language system, they also represent specific deficits occurring in the context of other cognitive abilities that are more or less normal. There is an ongoing debate about whether SLI and developmental dyslexia are two syndromes or one. Although research has traditionally followed separate paths, there has been growing recognition that there are *several commonalities* between these disorders. When formal diagnostic criteria are applied, around 50% of children with SLI meet the criteria for dyslexia, and around 50% of those with dyslexia meet the criteria for SLI (Bishop & Snowling, 2004). Tallal et al. (1996) do not make a specific distinction between developmental dyslexia and SLI, but instead treat language and reading problems as similar and both originating from the same deficit and describe these children using the concept of language-learning impaired. However, evidence from both genetic studies and neurobiological investigations does suggest that, while perhaps moving away from the traditional categories of SLI and dyslexia, caution is needed not to collapse the two disorders together.

In language-based learning disorders at least two overlapping areas can be researched: reading development and properties of spoken language deficits; another approach is to compare the factors underlying the impairment in either of the deficits. In particular, when focusing on the role of auditory perceptual deficits in causing SLI, Tallal et al. (1996) pursue the idea that language and reading difficulties stem from a basic temporal processing deficit. However, the research literature in this area is characterized by inconsistencies in findings from one study to another. McArthur and Bishop (2001) suggested that for the field to progress there is need to establish how far the inconsistencies are consequences of the methods used to assess auditory perception, whether a subgroup of the SLI or reading impaired population can be identified reliably showing such deficits, and whether auditory deficits change with *age*. Many children who have oral language difficulties early in development appear to improve, but then have literacy problems in middle childhood. This has been termed 'illusory recovery' by Scarborough (1990), who suggested that the same underlying deficit manifests *differently* depending on the child's age. This viewpoint is consistent with current mainstream opinion that regards dyslexia as a phonological disorder. The rapid-auditory-processing hypotheses argues that there is a developmental continuum between early language disorders and phonologically-based reading disorders and that it is primarily age that distinguishes developmental language impairment from reading impairment (Tallal et al., 1996). Following this hypothesis, it will be assumed that dyslexia and SLI are distinguished by the *severity* of the disorder. The language problems of children with dyslexia are less severe than those of children with SLI. Thus, in this sense dyslexia is a milder form of SLI (Tallal et al., 1996).

On the other hand, according to Rosen (2003) only a minority of individuals with language-based learning disabilities exhibits any auditory deficits, and further there is little or no relationship between the severity of the auditory and language deficits in language-based learning disabilities (Rosen, 2003). It is not yet clear why some auditory skills but not others differentiate dyslexia and SLI, but the claim, according to Rosen (2003) that the deficit is specific to rapid temporal processing is almost certainly incorrect. Thus, auditory deficits appear not to be causally related to language disorders, but only occur in association with them. According to Rosen (2003), there is a wide variety of theories which attempt to account for dyslexia and SLI and two general approaches have received the most attention. The first posits that both dyslexia and SLI arise from deficits in systems that are specifically linguistic. Dyslexia, in this view, arises from deficits in phonological memory and processing, which is to say, processes specific to speech sounds (Snowling, 1998). Similarly, SLI is claimed to result from deficits in neural systems processing grammar, and more specifically syntax (van der Lely, Rosen et al., 1998).

Snowling et al. (2000) argue against the view of SLI and dyslexia as two manifestations of one underlying disorder. Instead, they propose that the literacy problems often observed in children with SLI differ *qualitatively* from those in children with developmental dyslexia. Phonological processing deficits lie at the heart of the word decoding problems of children with dyslexia, whereas Snowling et al. (2000) suggest that limitations of oral language ability in SLI prevent children from using linguistic context when they are decoding text and prevent these children from comprehending written text. Catts et al. (1999) agree with the idea that oral language development is related to word decoding. A comparison between children with dyslexia and SLI with respect to their developmental track of reading may provide more insight into the question whether the pattern of reading behavior of these two groups of children is qualitatively different.

Some researchers claim that problems with oral and written language stem from the same source (Tallal et al., 1996) and that SLI and dyslexia are at both ends of a continuum of language problems, with the SLI children being the most severely affected, whereas other researchers claim that the nature of the reading problems in the two groups is different (Snowling et al., 2000). A possible explanation of the opposing views on the relationship between literacy and language problems is the *heterogeneity* of both disorders. McArthur & Bishop (2001) provide an overview of the literature on auditory processing deficits in subjects with SLI and dyslexia and draw the conclusion that there may be a subgroup of subjects who demonstrate poor auditory processing skills and who in turn have co-occurring language and literacy problems that are interrelated. However, development of literacy skills in children of the SLI population without a basic temporal processing deficit, may either follow the normal track, or may be hampered by weak general language skills (Catts et al., 1999; Snowling et al., 2000). This idea of a *subgroup* within the SLI and dyslexic population, which suffers from concomitant reading and language problems due to a temporal processing deficit, fits in with the observation that in general children with SLI are at higher risk for dyslexia than normally developing children, but that not all SLI children are dyslexics. Thus, it may be that there is a group of children who can be described as dyslexic and SLI, but that there are also children who only display either SLI or dyslexia, or whose development of literacy skills is hampered by their language problems. In the latter scenario, the language and reading problems do not stem from a single deficit, but are symptoms of two different mechanisms. McArthur and Bishop (2001) plead for a better and more complete description of both reading and language abilities in children who are impaired in at least one domain, to determine whether a temporal processing deficit is actually related to both language and reading impairment. This recommendation would indeed lead to more insight into the relationship between development of language and reading skills and the origin of deficits of those skills. According to the results of binary Study III of this thesis, there seems to be a *relationship* between developmental dyslexia and SLI, at least in auditory-visual matching.

1.2 Auditory-Visual Matching in Learning Disabilities

Auditory structuring ability (Karma, 1989, 2002b) is defined as a sub-skill of auditory processing. It is a general ability to relate tones with each other. This ability, which can be seen as a general human capacity, can find expression in many areas, such as music and language. Karma (1984) has defined musical aptitude as an auditory structuring ability. This ability is seen as clearly different from sensory acuity, i.e., the ability to hear small differences in the different parameters of sounds. Auditory structuring ability is seen as being similar to spatial ability in that both require elements to be identified which form patterned (structured) relationships to each other. While auditory structures are realized primarily through temporal, heard patterns, spatial relationships are predominantly visual. Spatial ability may form the basis for more experience-related abilities, such as mechanical-technical ability (Karma 2002b). Similarly, auditory structuring is required in the segmentation and synthesis of the heard word, so that the constituent elements (phonemes) are represented in the right temporal order. Auditory structuring is represented in the segmentation and synthesis of the heard word; for example *CAR* consists of letters /k/, /a:/, /r/, but not in a random order; without auditory structuring it could be *ACR* or *CRA*. While reading is also a visual process, it might be that the concept of auditory structuring is not sufficient. A more useful concept might be *auditory-visual matching*.

Phonological awareness is the ability to segment heard speech—for example, to indicate whether a pair of words might rhyme, or to count the number of words in a sentence. This can be considered a form of auditory structuring when applied to speech. *Phonemic* awareness is more specific, reflecting the ability to identify each individual component of a spoken word in order to map it to the correct written letter(s). While phonological awareness is a predisposing property of the child's developing cognitive-perceptual skill which can predict early reading and writing mastery, phonemic awareness is largely a consequence of learning to read and write (Goswami & Bryant, 1990), and may be considered to be a specific form of phonological awareness.

There is no consensus at the moment about the role of different dysfunctions in the etiology of dyslexia. According to some studies (Kujala & Näätänen, 2000; Lachmann et al., 2005) it can be presumed that there are different forms of dyslexia. One important prerequisite both of understanding better these subtypes and of designing effective remediation programmes are to be able to precisely define the dysfunctions. This would help to specifically target the training to those aspects in phonological perception that are affected. The mismatch negativity (MMN; Näätänen et al., 1978) is a component of the event-related potential (ERP) to an odd stimulus in a sequence of stimuli. It arises from electrical activity in the brain (Näätänen et al., 1978). With the MMN, it might be possible to determine the sound features that are the most problematic for dyslexic individuals (Kujala et al., 2000). Evidently, the MMN can be used to probe questions such as whether dyslexia is a dysfunction specific to the phonological system or a more general auditory deficit. MMN studies have so far shown that the cortical discrimination of not only speech but also non-speech sounds is affected in dyslexia (Leppänen et al., 2001; Schulte-Körne et al., 1998).

According to several authors (Mody et al., 1998; Studdert-Kennedy & Mody, 1995) problems in phonological processing are the major factor underlying reading difficulties in most individuals with dyslexia. Phoneme segmentation and awareness tasks as well as rhyming skills differentiate good and poor readers, and serve as valid predictors of the future reading ability (Snowling, 2000). Specifically, it has been proposed that for the individuals with reading impairment, phonemes involving rapid temporal transitions are especially difficult to discriminate from one another (Mody et al., 1998, Schulte-Körne et al., 1998), whereas according to the competing theory, individuals with dyslexia might actually have a more general auditory dysfunction underlying their phonological difficulties than one confined to the processing of merely linguistic stimuli (Hari & Kiesilä, 1996; Kujala et al., 2000; Wright et al., 1997). According to the latter theory, individuals with dyslexia have problems in discriminating rapid temporal changes typically present in speech, which would disturb the development of the phonological code and, thus, affect correct speech perception and language development.

Lachmann et al. (2005) studied auditory processing in 8–11-year-old children with developmental dyslexia by means of event-related brain potentials (ERP). It was found that both cortical sound reception and sound discrimination were impaired in children with dyslexia. The analysis of the data obtained from two dyslexic subgroups, Dyslexics-1 being impaired in non-word reading (or both non-word and frequent word reading) and Dyslexics-2 in frequent word reading but not in non-word reading, revealed that the MMN was specifically diminished in the latter group whereas it was normal-like in Dyslexics-1 (Lachmann et al., 2005). However, no differences were found between these subgroups in sound reception as indicated by the responses elicited by the standard stimuli. These results show that different diagnostic subgroups of dyslexics have different patterns of auditory processing deficits as suggested by similarly impaired sound reception in both dyslexic groups and the sound-discrimination impairment specific to one of the groups (Lachmann et al., 2005).

Another important aspect in defining dyslexia with an electrophysiological measure is to be able to do it as early as possible in the individual's life. In this respect, too, the MMN holds promise, as it can be recorded in infants (Alho et al., 1990; Leppänen et al., 2001) and even in premature newborn infants (Cheour-Luhtanen et al., 1996). If the auditory dysfunctions could be determined in early infancy, as suggested by MMN findings indicating altered auditory processing in 6-month old infants at risk for dyslexia (Leppänen et al., 2001), a remediation program targeted on the specific central auditory processing problems of the child could be started at an early developmental stage with a high degree of central nervous system plasticity.

In the research by Kraus et al. (1996) on children without learning problems and children with learning problems, impaired discrimination of a rapid speech change was correlated with the diminished magnitude of an electrophysiological measure that is not dependent on attention or a voluntary response. The ability of children with learning problems to discriminate another rapid speech change was reflected in the neurophysiology. These results indicated that some children's discrimination deficits originate in the auditory pathway before conscious perception. This has implications for differential diagnosis and interventions for children with LDs including attention disorders.

However, in the understanding of the role of auditory processing in the genesis of language difficulties have been hampered theoretically by a lack of agreement about the relationship between basic auditory skills, speech perception and phonological processing abilities, and also methodologically by frequent uncontrolled group differences in experimental studies. According to

Bailey and Snowling (2002), not all children with language–based learning disabilities demonstrate non-verbal auditory processing problems. It has been suggested that, where present, auditory processing deficits may be a 'synergistic risk factor' for language impairment (Bishop et al., 1999), that exerts a moderating influence when children are already at genetic risk of language disorder, but they are neither necessary nor sufficient to explain language difficulties.

Apart from phonological-deficit theories of dyslexia, another theory, which obviously links auditory processing with reading development, is rapid-auditory-processing hypothesis. This specifies that the deficit in dyslexia lies in the perception of short or rapidly varying sounds (Hari & Kiesilä, 1996; Merzenich et al., 1996; Tallal et al., 1996). However, Karma's (1989; 2002b) findings concerning auditory-visual matching in dyslexia do not suggest that *speed* of processing of serial stimuli distinguishes individuals with dyslexia from control populations. This may reflect differences in stimuli and in participants in the different studies. In Karma's (1989; 2002b) research as well as in this thesis, the stimulus was a repetition of 3–5 tone sound *patterns*, while in Tallal's (1980) and Hari and Kiesilä's (1996) studies, tone pairs were used. In research by Tallal et al. (1996), the stimuli were spoken words stretched by using a computer algorithm stressing short phonemes, while the stimuli used in this study were sounds from different *instruments*. In Hari and Kiesilä's (1996) study the participants were adults, while in the other studies they were children. More generally, a number of researchers fail to find conclusive evidence in favor of the rapid-auditory-processing theory in developmental dyslexia (Blomert & Mitterer, 2004; MacArthur & Bishop, 2001).

Learning to read involves the *visual processing* of written language. However, the ease of reading acquisition is related to the development of phonological awareness. Those children who develop the ability to hear the individual sound categories within a word are able to associate these phonemes with their written letter representations (Lyytinen et al., 2005). When auditory and visual dependent reading strategies were studied, it was noticed that auditory dependent strategies have a greater impact on reading comprehension skills than visual ones (Sencibaugh, 2007). Some problems in dyslexia may be the result of problems in encoding both visual and auditory information. To synchronize the information may be challenging (Pammer & Vidyasagar, 2005). It is noteworthy that in this thesis as well as in Karma's studies (1999, 2002b; e.g., Kujala et al. 2001) the used stimulus was both auditory and visual demanding a lot of *concentration*.

The magnocellular theory of dyslexia tries to integrate the deficits in all modalities. In Amitay et al. (2002), the study showed perceptual deficits in both visual and auditory tasks in individuals with dyslexia. However, their pattern of impairments was inconsistent with a magnocellular deficit or a specific deficit in processing brief stimuli (Amitay et al., 2002). Evidence that individuals with dyslexia also have dysfunctions in nonlinguistic auditory and visual perception supports the view that a general sensory-processing disorder may be involved (Ramus, 2003; Stein & Walsh, 1997; Farmer & Klein, 1995). A further possibility is that combining auditory and visual information may be difficult for people with dyslexia even when unimodal processing appears intact (Pammer & Vidyasagar, 2005; Breznitz & Meyler, 2003; Breznitz, 2002).

1.3 Complex Comorbidity

Comorbidity is an important issue in this thesis. The results of Study III of language-based learning disabilities showed that comorbidity was evident, according to formal diagnoses of children with SLI; 63% of children (N=84) had additional diagnoses. Comorbid is a term that was originally borrowed from physical medicine. Its meaning indicated the presence of at least two diseases. When the term comorbidity was transferred into the developmental disabilities field, one element was missing that prevented its accurate application: the precise distinction between symptom and disorder (Gilger, Pennington, & DeFries, 1992). According to Gilger et al. (1992), a child having difficulties with learning, behavior, mood and writing, displays symptoms that could be indicative of a learning disability, AD/HD and/or developmental coordination disorder. Whether that child is displaying comorbid disorders or variable manifestations of one underlying impairment is an open question (Gilger et al., 1992). The co-occurrence of apparently disparate symptoms causes problems in both diagnosis and treatment, while it raises questions about the etiology and mutual interdependence of various disorders.

The comorbidity of developmental problems is quite extensive. The rates of overlap between *reading* and *attention problems* that have been reported have varied from 10–90%, but most typically are said to be in the range of 35–50% (Dykman & Ackerman, 1991; Willcutt & Pennington, 2000). Several studies have demonstrated that children with an attention deficit display a high prevalence of language problems (Sharstry, 2007). Tirosh and Cohen (1998) investigated a community sample of more than 3000 children: they found the expected rate of AD/HD (approximately 5%), about 45% of whom suffered from some type of language impairment. Carte et al. (1996) also reported a very similar prevalence rate. Gillberg and colleagues have probably done the most research examining the overlap of *attention* and *motor problems*, and have proposed their own phrase to differentiate this subgroup: children with deficits in attention, motor control, and perception (DAMP) (Gillberg & Rasmussen, 1982; Hellgren, Gillberg, & Gillberg, 1994).

Considerable data demonstrates that children with developmental *dyslexia* have a high incidence of *motor difficulties* (Dewey et al., 2000; Fawcett & Nicolson, 1995). The fact that children with learning or attention problems, or both are at risk for *social skills deficits* is well known (Kavale & Forness, 1996). Many studies now document the overlap of AD/HD with anxiety or depression, or both in children and adolescents (Biederman et al., 1996), as well as adults (Rucklidge & Kaplan, 1997). Although much of this work has focused on AD/HD, Cohen et al. (2000) have shown an association between receptive language disorders and psychiatric referral.

Deficits of working memory are found in children with learning difficulties in *literacy* and *mathematics* (Gathercole & Pickering, 2001; Swanson, 1993) that are extremely rare in samples of children without learning difficulties. The studies of Gathercole et al. (2004a) and Pickering and Gathercole (2004) also indicate that impairments of working memory are more characteristic of children whose learning difficulties extend across the domains of literacy and mathematics than of those with difficulties restricted to literacy alone (Gathercole et al., 2004a; Pickering & Gathercole, 2004). Working memory is proposed to constitute a capacity-limited bottleneck for learning different academic subjects (Gathercole et al., 2006). The association of reading difficulties and poor mathematics abilities with scores obtained in complex memory tasks (Gathercole et al., 2006), and the finding of a general lack of capacity for the processing and storage of verbal information in reading disabled children (de Jong, 1998) support this idea. There are findings of children with both attentional disorders and reading difficulties, who do show some evidence of working memory deficits (Roodenrys, Koloski, & Grainger, 2001). These deficits appear to relate to the comorbid reading difficulties rather than only the attentional problems.

Besides learning difficulties, common comorbid problems in *specific language impairments* (SLI), are clumsiness, visuomotor dysfunction and emotional disorders (Bauermeister et al., 2007; Bruce, 2006). SLI is also characterized by a broad spectrum of developmental impairments (Webster, 2006). Because children with SLI can be slow to develop in a range of domains (Haynes & Naidoo, 1991) and have problems with auditory, visual, tactile, and phonetic perception, as well as motor tasks (Bishop, 1992; Powell &

Bishop, 1992), it is theorized that they have a generalized neuromaturational delay (Locke, 1994, 1997).

Language is an eminently integrative function and none of its components operate in isolation from the other. In addition, language development is functionally dependent on *emotional* regulation (Fujiki et al., 2002). Taking that into account it is not surprising that children with SLI commonly exhibit comorbidity in other developmental areas, such as *psychiatric* and *behavioral* disorders (Glokowska et al., 2006; McCabe, 2005; Westby & Blalock, 2005; Toppelberg & Shapiro, 2000; Redmond & Rice, 1998; Beitchman, 1996). A connection between problem behavior and language development was confirmed in the study of Estrem (2005) documenting that observed *aggression* increased as expressive and receptive language scores decreased in 100 preschoolers. A significant interrelationship between language disorders, attention deficit disorders and autism spectrum disorders has also been revealed (Bruce, 2006; Beitchman, 2001; Cohen et al., 2000).

The development of language is also intertwined with the development of *motor skills* (Bishop, 2002). According to Webster et al. (2005), children identified on the basis of language impairment show significant motor comorbidity. The common association between language and phonologic impairment seen in children with SLI (Leonard, 1998) raises the possibility that factors that contribute to motor planning and sequencing may also be important for other phases of language processing. Motor deficits seen in SLI are usually described similarly to those seen in other neurodevelopment disorders such as developmental coordination disorder (Hill, 2001). The fact that various disorders overlap in SLI can be seen as an indication of a shared underlying etiology and that behavioral expressions of disorders are different due to various factors such as the timing and severity of disruption to brain development (Gilger & Kaplan, 2001).

The term SLI has been used to identify children with language impairment in the context of normal nonverbal cognitive function; however, evidence is increasing that SLI is associated with a range of impairments in other developmental domains (Tannock & Brown, 2000; Webster et al., 2005). Previous studies that examined the clinical phenotypes of children with SLI have identified a range of impairments in domains other than language. Webster et al. (2006) prefers to use the term developmental language impairment (DLI) to describe children who would otherwise meet the criteria for SLI. Despite the range of impairments seen in children with SLI, it is unclear whether these deficits are secondary to the effects over time of the underlying communication disorder or whether they are a separate but intrinsic part of the underlying disorder that leads to language impairment.

In conclusion, pure forms of any developmental learning or behavior disorder are difficult to find. Whilst most children's difficulties resolve, children whose difficulties persist into elementary school may have long-term problems concerning literacy, socialization, behavior, and school attainment. Students with learning disabilities have been shown to differ from their normally achieving peers not only in the development of linguistic skills, but also in the motivational and emotional profiles they display already in the first grade (Poskiparta et al., 2003). In particular, the child's ability to maintain focused attention on both the learning task and instructional discourse is beneficial for reading acquisition (Lepola et al., 2005; Onatsu-Arvilommi & Nurmi, 2000; Rowe & Rowe, 1999). One motivational component, associated with teacher–student and parent–child interaction, is the child's social dependence, that is, a lack of the responsibility the child is expected to assume over his or her own learning activity. The kind of other-focusing motivational tendency is especially found to be associated with surface-level cognitive processing (Graham & Golan, 1991), as well as learning difficulties in reading and mathematics (Vauras et al., 1999).

Gilger and Kaplan (2001) use an interesting concept of *atypical brain development*, *ABD*. Learning disabilities may simply be the manifestations of natural variability in the brain and are, in part, identified because of the cultural demands being placed on the LD individual. ABD is meant to serve as an integrative concept of etiology, the expression of which is variable within and across individuals. ABD does not itself represent a specific disorder or disease. It is a term that can be used to address the full range of developmental disorders that are often found to overlap in any sample of children. It is also a term that appropriately links neurology to learning and behavior (Gilger & Kaplan, 2001). ABD might be a practical concept that correctly highlights the variable etiology of developmental learning difficulties, and the variable neuroanatomical basis of LD. ABD is also a concept that highlights the fact that comorbidity is the *rule* and not the exception when looking at the whole range of developmental disabilities (Kaplan et al., 2006).

1.4 Environmental Factors in Learning Disabilities

Understanding learning disabilities requires a developmental perspective, because these disorders have their origins in genetic and environmental factors that generally act early in development and change the development trajectory in particular domains of functioning. Etiology is concerned with distal causes of disorders, the particular genetic and environmental risk and protective factors that cause one child to have a disorder and another not to have the disorder. These distal causes act on brain development changing the wiring and/or the neurotransmitter systems of the brain (Pennington, 2008). These structural and neurological changes in the brain affect behavior observable by teachers, parents and peers, but because brain development is an open process that continues throughout the lifespan, the environment, including the social environment also affects brain development. So a child without genetic risk factors for dyslexia may end up with a reading disorder because the environment does not provide adequate spoken language and pre-literacy input. On the other hand a child with genetic risk factors for a particular learning disorder may benefit from compensating environmental protective factors and end up only with a sub-clinical form of the disorder. This also means that to achieve a fully scientific understanding of why one child has a disorder and another does not is a very ambitious goal, since it requires disentangling complex developmental pathways (Pennington 2008).

There are numerous research results on *learning disabilities* and environmental *factors* and according to Samuelsson & Lundberg (2003, 214) there is a substantial social-cultural bias in the delineation of literacy skills and in the definitions of reading disabilities. Various studies in Sweden have researched dyslexic problems and environmental factors, like home and school conditions, and the literacy environment among adult and adolescent prison inmates (Samuelsson et al., 2000; Svensson et al., 2003; Samuelsson et al., 2003; Samuelsson & Lundberg, 2003). One common problem in the research addressing the prevalence of dyslexic problems among prison inmates has been to ignore the impact of socio-cultural and educational factors that might influence reading and writing skills. There is considerable support for the position that constitutional factors related to deficits in phonological processing skills are a strong predictor of dyslexic problems. The results also suggest that phonological ability constitutes the only measure relatively unaffected by environmental influences; it is unlikely that dyslexia is a determining factor of delinquent behavior. A long period of school failure due to other aspects than phonological deficits, such as social, motivational and/or emotional problems interfering with a positive experience of literacy and the literate culture are adversely related to print exposure, and thus, experientially caused reading problems.

Svetaz, Ireland & Blum (2000) studied risk and protective factors in learning disabilities associated with emotional well-being. Emotional distress, suicidal behaviors, and violence involvement were compared among adolescents with and without learning disabilities. Adolescents with LDs had twice the risk of emotional distress, and females were at twice the risk of attempting suicide and exhibiting violent behavior than their peers. While educational achievement was below that of peers, connectedness to school and to parents was comparable; it was identified as most strongly associated with diminished emotional distress, suicide attempts, and violence involvement among adolescents with LDs. Svetaz et al. (2000) suggest that, given the increased importance of emotional well-being, clinicians need to assess social and emotional as well as educational and physical functioning. It is important to be aware of the role *protective factors*, like family, school-connectedness, and religious identity in learning disabilities. Together these variables suggest that a sense of belonging is central in diminishing risk and promoting emotional well-being.

It is evident that families, teachers, and schools must ensure that the individual with problems in school receives a comprehensive and systemic evaluation to rule out the presence of LD and possible comorbidity. Given this information, counseling and, offering families educational interventions is crucial. Future behavioral and genetic research related to the development of learning disabilities should support a better understanding of biological and environmental influences on learning disabilities; in practice it is important to apply early intensified support when any problems occur and to use research-based interventions.

1.5 Interventions

> *"The results of the Kujala et al. (2001) study indicates that reading difficulties can be ameliorated by special training programs and, further, that the training effects can be observed in brain activity."*
>
> (Kujala et al., 2001)

Any child with learning disabilities will need an intervention program specifically aimed at addressing typical problems. To avoid the negative effect in educational performance of LD effective interventions are needed (Committee of Learning Disabilities, 2007). In Finland early intervention and early support are considered important if children have learning problems (Finnish National Board of Education, 2004; Strategy for Special Education, 2007), and intervention and support are offered immediately when difficulties are noticed.

Selected meta-analyses in special education have been reviewed to capture the relative effectiveness of various interventions (Forness, 2001). According to 24 meta-analyses, if special educators used modality-based interventions and social-skills training in special classes, fewer and less substantial benefits for students were expected. If behavior modification and direct instruction with mnemonic strategies for remembering content were used, greater benefits could be expected. Thus, the best practice appears to also include monitoring students' progress and providing positive assistance for improvement; teaching cognitive–behavioral self-management, and, at least in the case of children with AD/HD, considering a systematic course of stimulant medication. Children whose teachers use interventions based on these recommendations generally can expect to have much better outcomes (cognitive and/or academic) than children whose teachers depend on perceptual training, modality-adapted instruction, social-skills training, or diet restrictions. It must be stressed, however, that some particular versions of interventions may produce much greater effects than the general type of intervention with which they are classified, whereas other versions may produce much weaker effects. Some subgroups of students may benefit greatly, even when the average effect size (ES) for an intervention is modest, whereas other interventions may produce modest benefits for certain subgroups of students even when the mean ES is compelling (Forness, 2001). It is difficult to pinpoint whether an intervention is more effective for certain types of problems, is better for certain types of children, or has greater efficacy than other interventions. In addition, the comorbidity of learning disabilities makes the situation even more challenging. In this thesis auditory-visual matching intervention was used to rehabilitate children with various learning disabilities.

According to Gathercole et al. (2006) impairments of working memory and of verbal short-term memory are associated with a variety of neurodevelopmental disorders. In order to minimize the adverse consequences for learning and educational progress that result from these impairments, early diagnosis followed by remedial support that targets relevant domains of learning is strongly recommended. Educational support strategies that reduce the working memory demands of learning activities may be an effective intervention for children with SLI (Archibald & Gathercole, 2006).

Given the evidence favoring the phonological deficit explanation of reading deficit, it is not surprising that expectations have been positive about training programs designed to increase phonological or phonemic awareness. Several studies show that reading development profits from such training (Uusitalo-Malmivaara 2009), especially before children receive formal teaching of reading (Lundberg, Frost, & Petersen, 1988). According to Snowling (2000), children with oral language impairments beyond the pre-school years require intensive programs of speech and language therapy and there is some sufficient evidence of the benefits of phonological awareness training for dyslexia (Snowling, 2000).

However, analyses of individual differences in the growth of phonological awareness indicate that some children do not benefit from such an intervention. There are studies (Andreassen et al., 2006; Gustafson et al., 2000) reporting that a subgroup of poor readers seems to be *treatment resistant*. In a longitudinal Swedish intervention study (Gustafson et al., 2000) poor readers received phonological awareness intervention over one year. It was shown that there was progress in phonological awareness, but the intervention did not improve reading skills. However, a re-analysis of the results revealed important individual differences, for the improved readers, both orthographic and phonological word decoding predicted text reading performance. For the resistant readers, only orthographic decoding skills predicted text reading before, during and after the intervention, in spite of a steady increase in phonological awareness (Gustafson et al., 2000).

The results of the Gustafson et al. (2000) study indicate that a training program focusing on phonological awareness is only moderately successful for children who have received formal reading instruction in school for several years and still have not achieved satisfactory reading skills. These results might support the expressed view of Stanovich (1986) that lower level deficits in poor readers are difficult to treat at a relatively *late age*.

Computer-assisted instruction can also be used to improve the learning experience and the performance of children with learning difficulties. Nowadays, computers are an integral part of the daily life of many children, and it is likely that the use of computer-assisted learning in the classroom will prove to be an asset for every pupil. Children with learning difficulties are motivated by certain uses of computer technology, and this fact must be exploited to ensure the greatest benefit to struggling learners. Technology provides students with a new way to learn. Current multimedia applications encourage children’s active participation, increase motivation, and involve a variety of modalities (e.g., visual, auditory, and/or tactile). They also provide greater levels of student interactivity and independence through high-interest and self-paced activities (Lee & Vail, 2005). Different studies have shown that students with disabilities can learn through a variety of multimedia computer programs using various multimedia formats for instruction. These included simulation (Mechling & Gast, 2003), games (Dattilo et al., 2001), and drill and practice (Boone et al., 1996). The content areas of the programs were mathematics, leisure-related skills or literacy skills (Lee & Vail, 2005).

Computer-based programs have often been successful with auditory and/or visual training (e.g., Ecalle et al., 2008; Magnan & Ecalle, 2006). According to Elbro & Petersen's (2004) study in a 17-week phonological awareness intervention program where several cues were given to each speech sound, the trained at-risk children outperformed the untrained at-risk children. The training effects could be still found seven years after the intervention. The used program was tailored to meet the needs of children involved (Elbro & Petersen 2004). Good results were also found with children with dyslexia through a reading program called Phono-Graphix (Wright & Mullan, 2006). Computer-based audio-visual training of small children with reading disabilities was also successful. Both discrimination of phonetic features of voicing and recognition of written words were used in three different studies with kindergarten children. The audio-visual training focused on voicing contrasts; the children had to process the phonetic features in both hearing and in reading. All three interventions lasted from five to ten weeks, no longer than 15–20 min/day (Magnan & Ecalle, 2006). When the intervention is intensive, tailored for the individuals and long enough, results seem to be good. In the Klingberg et al. study (2005), the working memory of 53 AD/HD children aged 7 to 12 years was improved with computerized, systematic practice. The study showed that working memory could be improved; the training also improved response inhibition and reasoning and resulted in a reduction of inattentive symptoms of AD/HD (Klingberg et al., 2005). The computer game Literate (*Ekapeli*) has been developed based on research results of "The Jyväskylä Longitudinal Study of Dyslexia in Finland" (see page 5). "Literate" is based on Finnish methods of literacy teaching and the knowledge that difficulty with learning letter-sound relations has a negative impact on learning, irrespective of any heterogeneous influences that may have been exerted during the course of the child's preceding development (Lyytinen et. al., 2006). The computer game is based on a simple concept of a 'catching game' that drills children in the translating of sounds to letters in both directions, to aid both spelling and reading. In relating phonemes to graphemes, the child is presented via headphones with a sound (a phoneme or larger unit of sound such as a syllable or word) and asked to catch with the mouse the corresponding falling ball target. According to Hintikka et al., (2005) and Lyytinen et al., (2007), letter knowledge has increased in children with initially poor pre-reading skills. More remarkably, these results were achieved after only a short period of playing the game, such that risk children playing the game advanced from behind to eventually match the performance of non-game-playing, non-risk peers. In the Uusitalo-Malmivaara study

(2009), there was a difference between attentive and inattentive students after Literate intervention.

The training effects of an auditory-visual matching computer program, called *Audilex*, have been explored in several studies with children with dyslexia (Karma, 1989, 1999; Kujala et al., 2001) and demands attention and concentration of both modalities, auditory and visual. This thesis has studied auditory-visual matching with children with different learning disabilities such as developmental dyslexia, ADD or SLI. A study by Kujala et al. (2001) aimed to determine whether audiovisual training without linguistic material has a remedial effect on reading skills and central auditory processing in children with dyslexia. The study found that this training resulted in plastic changes in the auditory cortex, indexed by enhanced electrophysiological mismatch negativity and faster reaction times to sound changes (Kujala et al., 2001). Importantly, these changes were accompanied by improvements in reading skills. The results indicate not only that a special training program can mitigate reading difficulties, but also further, that brain activity can reflect the effects of training. Moreover, the fact that the effects of training were obtained by using a program that did not include linguistic material indicates that dyslexia is at least partly based on a *general* auditory perceptual deficit (Kujala et al., 2001; see also Lyytinen et al., 2005).

Corroborating results to the MMN studies were obtained by Heim et al. (2000) with children who had language-based learning disabilities. The children were given training in syllabic speaking, writing, and reading, which resulted in improved reading, spelling, and phonological awareness. Furthermore, the MMN responses to a syllable change (/ba/–/da/) resembled more the responses of control children more after than before the training. This was also reflected at the behavioral level in that the children with language-based learning disabilities became better at discriminating syllables along the /ba/–/da/ continuum. These results suggest that the MMN response can be used in evaluating the training effects in dyslexia and other language impairments (Heim et al., 2000).

One characteristic of the used training procedure of the *Audilex* program is the brief period of training. Some studies also suggest that long and elaborate training may not be necessary to bring about improvements in reading skills (Ecalle et al., 2008; Lyytinen et al., 2007; Hintikka et al., 2005; Agnew et al., 2004; Kujala et al., 2001). From an applied perspective, this aspect of the training is very important. It is clear that the aim of any treatment that is administered is to bring about a lasting improvement. The possibility that such a computer-based training program as *Audilex* could be used either as part of or in addition to the school curriculum has implications for educational resourcing and teaching methods.

The auditory-visual matching training also seemed to be an efficient and simple vehicle in training and *motivating* the students with various learning disabilities (Studies I–III). Those findings were further supported in Study II by the teacher reports showing that the school behavior, with respect to task orientation, the maintenance of mental effort, and motivation, seemed to improve in the trained students. The dilemma of positive intervention effects is not unambiguous; it is a larger concept than just good results in different tests. It is conceivable that training raises concentration by giving a student even a slight feeling of success and confidence in his or her own performance. Increasing confidence can motivate the student to practice, focus and concentrate on reading, which, in turn, could prevent the otherwise cumulative disadvantages of learning disabilities.

In the Andreassen et al. (2006) study, students with severe dyslexia were evaluated for the effects of counseling 8 months after an assessment of each student's strengths and problems. They reported clear progress in the students' reading abilities, which could not be related to age, cognitive level, place of residence, or previous special education received, but instead to improved motivation. Lepola et al. (2000) investigated the effects of motivation and metacognition on the development of phonological awareness and reading development. The results showed that initially good reading development is associated with an increase in task orientation and a decrease in both social dependency and ego-defensiveness in the following years. Poor reading development was associated with the opposite tendencies (Niemi & Poskiparta, 2002; Poskiparta et al., 2003).

Self-Determination Theory, SDT (Deci & Ryan, 1985) is one option that can be used to explain the positive intervention effects from a wider perspective. SDT is a macro-theory of human motivation concerned with the development and functioning of personality within social contexts. It focuses on the degree to which human behaviors are volitional or self-determined, that is the degree to which people endorse their actions at the highest level of reflection and engage in actions with a full sense of choice. The SDT claims that there are three basic psychological needs: autonomy, competence and relatedness. Psychological well-being, autonomous self-regulation and corresponding motivation lead to overall self-determination. In Self-Determination Theory different types of motivation are distinguished based on the different reasons or goals that give rise to an action. The most basic distinction is between *intrinsic motivation*, which refers to doing something because it is inherently interesting or enjoyable, and *extrinsic motivation*, which refers to doing something because it leads to a separable outcome. According to Ryan and Deci (2000), the quality of experience and performance can be very different when one acts for intrinsic versus extrinsic reasons.

Intrinsic motivation has emerged as an important phenomenon for educators, a natural wellspring of learning and achievement that can be systematically catalyzed or undermined by parent and teacher practices (Ryan & Stiller, 1991). Because intrinsic motivation results in high-quality learning and creativity, it is especially important to detail the factors and forces that engender versus undermine it. Students can perform extrinsically motivated actions with resentment, resistance, and disinterest or, alternatively, with an attitude of willingness that reflects an inner acceptance of the value or utility of a task. In the former case, the classic case of extrinsic motivation, one feels externally propelled into action; in the later case, the extrinsic goal is self-endorsed and thus adopted with a sense of volition. Understanding these different types of extrinsic motivation, and what fosters each of them, is an important issue for educators who cannot always rely on intrinsic motivation to foster learning. According to Ryan and Deci (2000), in schools the facilitation of more self-determined learning requires classroom conditions that allow satisfaction of three basic human needs: to feel connected, effective, and agentic as one is exposed to new ideas and exercises new skills (Ryan & Deci, 2000).

One essential element of understanding this process involves recognition how easily internal changes to external; giving even the smallest rewards, symbolic praise or pressure, can harm the intrinsic motivation, and change the joy of doing to focus on performance and create possible anxiety. Supportive feedback concentrates on the process and shared joy of having had the courage to try. The nutriments of creativity are innovation, creativity, autonomy and play, while the killers, are in turn, control, competition, error focus and pressure (Thuneberg, 2007).

Psychological well-being and its relation to academic and prosocial motivation, self-regulation and achievement at school have been studied by Thuneberg (2007). A major goal of the study was to stress the importance of personal relationships in learning. A mechanism in those interactions was a developmentally adequate balance of relatedness and autonomy, and the quality of feedback relate to trust as prerequisite of being able to face challenges, trying without fear of mistakes (Thuneberg, 2007). As a result of the study, considerations of an intervention model were suggested. (Fig. 1)

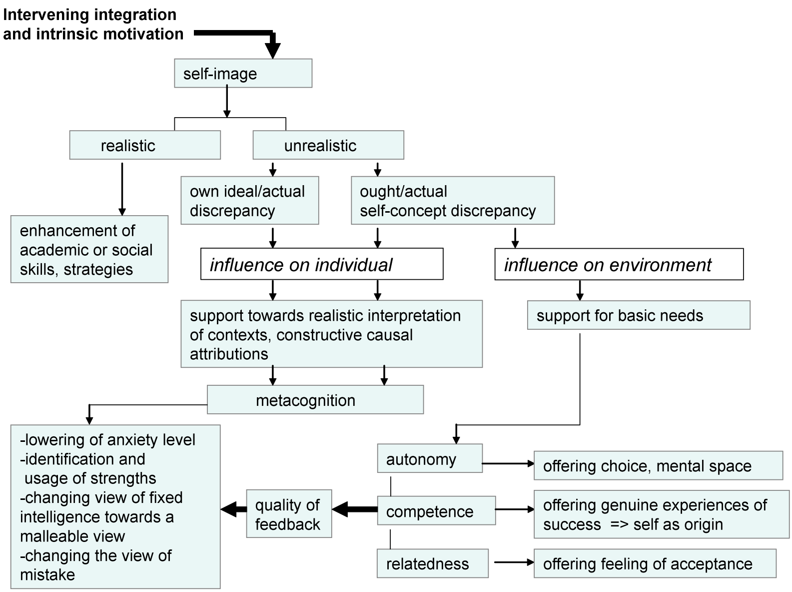

Figure 1. Suggestion of Considerations for Intervention Planning (Thuneberg 2007)

The aim of the model was to shift external motivation in a more intrinsic direction. According to Thuneberg (2007), this can be achieved by first studying a student's self-concept, and then trying to affect both inner and environmental factors—including a consideration of the basic psychological needs, such as autonomy, competence and relatedness.

vDnDv [illegible]

> *"We have an obligation to think of students who are struggling to learn as difficult to teach before we label them as unable to learn."*
>
> (Fletcher et al., 2004)

The model of Response-To-Interventions (RTI, e.g., also called problem-solving model, intervention support team, intervention based assessment) is integrally linked to the concept of providing intensive early intervention to prevent later failure and possible learning disabilities. According to Vaughn and Fuchs (2003), RTI can both promote effective practices and help to close the gap between identification and intervention. An RTI model could yield several promising benefits: identification of students using a risk rather than a deficit model, early identification and instruction of students with LD, reduction of identification bias, and a strong focus on student outcomes (Vaughn & Fuchs, 2003). In addition, identification models that incorporate RTI represent an opportunity to provide early interventions to reduce inappropriate referral and identification, also establish a prevention model for students to eliminate the "wait to fail" model. It is also an opportunity to move more quickly into intervention for older students who have not had the opportunity or simply not profited from early intervention.

To accomplish this goal, identification models for LDs should require educators to intervene as early as possible and then, if appropriate, refer students for more formal evaluations or other services. The model of intervention followed by necessary evaluation appropriately modifies the more common practice of testing to diagnosis that has been the basis for LD identification over the past 30 years; this change, a movement away from "test and treat" models to "treat and test" models, is the essence of proposals for alternative identification models for LD (Gersten & Dimino, 2006).

Response to interventions allows teachers to judge which students need special education in reading or other areas based on whether or not the student can respond to either typical classroom instruction, or the type of support that is possible in a typical classroom (e.g., brief but intensive small-group intervention on key skills). Another appealing feature is the fact that it is a form of dynamic assessment (Gersten & Dimino, 2006).

The roots of a response to interventions to the identification of LD proposed that the validity of a special education classification be judged according to three criteria (Vaughn & Fuchs, 2003). The first criterion is whether the quality of the general education program is such that adequate learning might be expected. The second consideration is whether the special education program is of sufficient value to improve student outcomes and thereby justify the classification. The third criterion is whether the assessment process used for identification is accurate and meaningful. When all three criteria are met, a special education classification is deemed valid. The first two criteria emphasize instructional quality: first in the setting where the problem develops and second under the auspices of the special services the classification affords. By implication, the assessment process, referred to in the third criterion requires judgments about the quality of instructional environments and the student's response to those environments (Vaughn & Fuchs, 2003).

1.5.2 Intensified Support and Special Needs Education

"Special Education is a service not a place."

Response to interventions model has theoretical similarities when applying the Finnish Strategy for Special Education (2007) by *intensified support* and *special needs education*. This strategy proposes that the current practice in Finland be changed to focus on clearly earlier support and prevention and that this intensified support be adopted as the primary form of support before a decision on special education is made. The intensified support would be used to bolster learning and growth and prevent the aggravation and escalation of problems relating to learning, social interaction or development (Strategy for Special education in Finland, 2007).

Implementation of an intensified support and special needs education model may provide an opportunity to move from a deficit model to *a risk model* for both identifying and intervening with students with learning disabilities. This offers a potential benefit to a large number of students—including those with learning problems without LD as well as students with LD. Ideally, all students would be screened early for potential problems in academic, behavioral and social domains. Those students who are identified as "at risk" would be provided highly effective instruction to reduce their risk in the identified area (e.g., language, reading, numeracy/math, behavior). Students whose intensified support moved them out of risk status would receive no further supplemental intervention. Students whose response to well-documented, effective, and well-implemented intervention was weak or who remained at risk would be considered for extra support in special needs education. Thus, potentially, many students could benefit from this type of an identification procedure. When well implemented, intensified support and possible special needs education could also serve to better integrate services between general and special education. According to Vaughn and Fuchs (2003), in a well functioning system, resources from general education could be used to: 1) bolster core academic and behavioral programs within general education so that fewer students were at risk for learning and behavior problems and 2) assist in screening and instruction for students to assure that those who did not respond to instruction were in need of special education.

2 Overall Aims of the Present Thesis

The present thesis focused on two main issues: 1) learning disabilities and the role of comorbidity, and 2) using research-based interventions. A goal is to describe learning disabilities, like developmental dyslexia, attention deficit disorder (ADD) and specific language impairment (SLI), and possible comorbidity. Learning disabilities were rehabilitated by auditory-visual matching computer program. Because of the non-verbal character of the intervention, it was used both with Swedish and Finnish students with learning disabilities.

3 Overview of the Original Studies

The present thesis consist series of four studies published in three articles. There are 242 participants in these studies which were conducted in both Finland and Sweden.

3.1 Overview of the Main Method and Intervention

3.1.1 The Auditory-Visual Matching Test

Each child in this thesis participated in the Auditory-Visual Matching Test (Karma 1998). Test version 2 of the computer program devised by Karma (1998) was used (Fig. 2), which consisted of abstract, nonverbal tasks requiring auditory-visual matching. The auditory-visual matching test included a set of 30 tasks. In the test, a pattern was displayed on a computer screen, after which a sound pattern was played; the pattern remained on the screen throughout the entire task. Various sound patterns featuring 3 to 15 elements were graphically represented on the screen as horizontal sequences of rectangles.

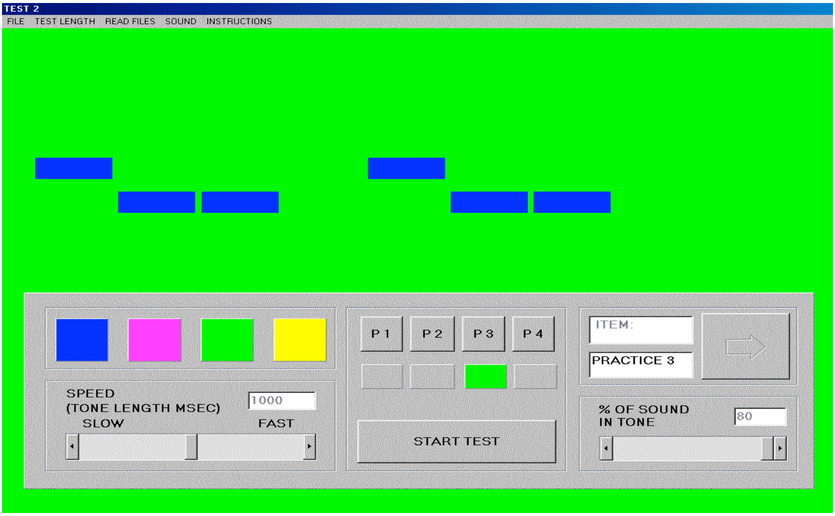

Figure 2. Screen Grab Showing Material from the Auditory and Visual Matching Test. Note. The black patterns are followed by sounds; P3 = practice session 3. In the computer screen the four squares below; the repeating patterns are colored blue, cerise, green and yellow.

The sound elements varied in pitch, duration, and intensity (see Figure 3), and were visually represented on the screen by the respective vertical position, length, and thickness of the rectangles. Participants pressed the space bar on a computer keyboard when the sound pattern matched the rectangle on the screen. The time window for doing this was when the last sound of the pattern was being played. When a participant responded correctly, the computer registered a hit. Stimulus elements were presented with a 1,000-ms stimulus (element)-onset asynchrony (SOA) and a 550-ms sound duration throughout the test, following the same regulation as those used in the studies of Karma (1999) and Kujala et al. (2001). A computer screen presented four different choices of colors: blue, purple, green, and yellow.

3.1.2 Audilex Intervention

A computer program called *Audilex*, has been used as an intervention method in this thesis. It is based on the concepts of auditory structuring ability and auditory-visual matching (see Chapter 1.2). The *Audilex* computer program consists of tests and games, the aim of which is to train the participants' perception of sound structures, and to learn to attend to both visual and auditory patterns, in order to analyze and match their similar element structure in time and space. Matched series are always ‘read’ from left to right, which corresponds to moving ahead in time. The games are aimed to promote preliminary skills for reading and writing. This computer-training program, which has been developed in Finland (Karma 1998), can be used with children from the age of five years.

The Training Procedure

In *Audilex* intervention 16 sessions with the computer game were played over a period of eight weeks. Each training session lasted for 15 minutes and occurred twice a week in a resource room. The training was carried out during school days during regular classes or in the breaks, but not when a pupil was having special education.

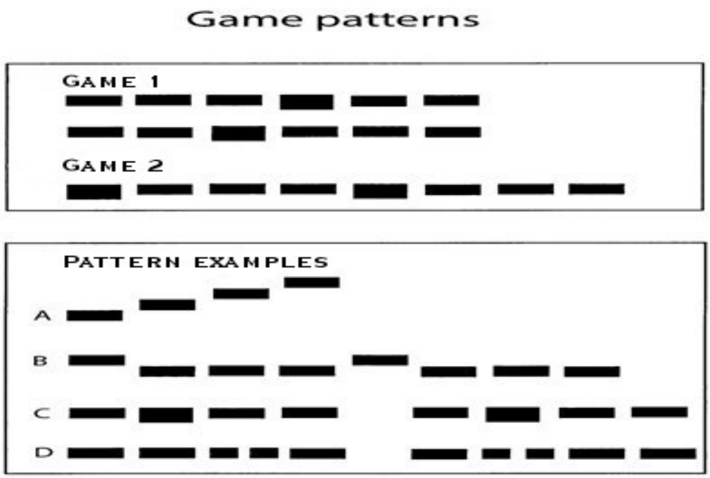

Figure 3. Task Examples of the Patterns Used in Computer Game Version 1 and 2.

Two versions of the *Audilex* game (Karma 1998) were used during the training period (Figure 3). In game 1, two patterns appeared on the screen. After two seconds, a sound sequence was played that corresponded to one of the patterns. Participants were instructed first to look at the pattern on the computer screen and then listen to it. The player’s task was to indicate which one of the patterns was played. In game 2, only one pattern was drawn on the screen after which a corresponding sound sequence was played. The player’s task was to follow the pattern (from left to right) as it was being played. The player had to press the space bar when the sound corresponding to the last element of the visual pattern was being played. After a correct response, the child was rewarded with a smiling face on the screen, whereas after an incorrect response, the same pattern was repeated, but the color of the rectangle changed at the moment when the sound corresponding to it was played. Both easy and difficult patterns were randomly presented throughout the training period. Each training session began with a stimulus block with a 1,000-ms stimulus (element)-onset asynchrony (SOA) and a 550-ms sound duration. During the sessions, players could change the SOA within a window of 200–1800 ms and the sound duration within a window of 30–80% of the SOA (60–1440 ms). After one or two training sessions, players changed the duration.

Both versions of the game (1 & 2) were used. Players chose which version to play. Version 1 was preferred during the first four training sessions and version 2 during the remaining sessions. Training began with game version 1.

3.1.3 Research Design

Intervention studies in this thesis used a pre-tests-intervention-post-tests research design. Auditory-visual matching test was the main method; in addition reading-skill tests and assessments were used.

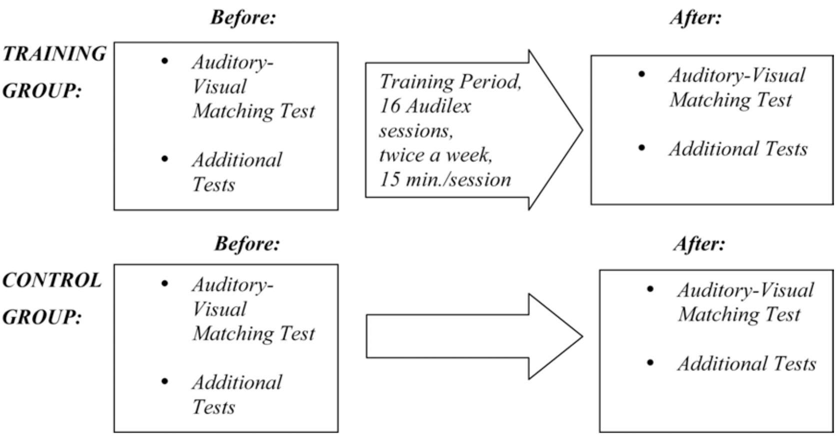

Figure 4. Research Design

3.2 Study I: *Auditory Processing in Developmental Dyslexia: An Exploratory Study of an Auditory and Visual Matching Training Program with Swedish Children with Developmental Dyslexia*

3.2.1 Aims

The aim of this study was to investigate the role of auditory structuring in developmental dyslexia, using the Audilex program which requires children to match auditory and visual nonverbal events, and to establish whether such perceptual training could have a beneficial effect on reading and reading-related task performance.

3.2.2 Participants

Forty-one Swedish pupils aged between 88 months (7 yrs 4 m) and 149 months (12 yrs 5 m) (*M*=117.1, *SD*=15.8) participated in Study I. They all had received a formal diagnosis of *developmental dyslexia* from a qualified educational psychologist or special teacher. All were in mainstream education following age-appropriate curricula. The participants came from three different elementary schools in the same Swedish town.

The participants were placed in age groups and then divided into a training group and a control group in a random manner. The training group received training (Audilex), while the control group received no specific activity training. Both groups received special education in a resource room throughout intervention. The training group consisted of 21 pupils (5 girls, 16 boys), with an average age of 117 months (9 yrs 9 m; M=116.8, SD=16.4) and the control group of 20 pupils (6 girls, 14 boys), with an average age of 117 months (9 yrs 9 m; M=117.4, SD=15.5).

3.2.3 Measures and Procedure

The pre-test/post-test design was used. The tests administered were the auditory-visual matching test (see Chapter 3.1.1) and two reading-skill test batteries. Training comprised twice-weekly sessions of 15 minutes, over eight weeks using Audilex intervention (see Chapter 3.1.2).

Reading-Skill Tests

Two sets of tests from a Swedish battery devised to measure reading skills at different school ages were used. These were standardized, pencil-and-paper tests of reading. The first test battery (Jacobson, 1993) consisted of *word* and *letter segmentation* tests. Word segmentation test measured word recognition (phonetic reading in the lower grades and more of orthographic ability for older pupils). The letter segmentation tests serves as a control test measuring manual speed and visual-motor ability (Jacobson, 2009). The second test battery (Johansson, 1992; Järpsten et al., 1983) measured phonological awareness, decoding, fluency and phonological processing. It consisted of tests of *reading* short, isolated *words*, *reading speed*, *nonsense words*, and *spelling*.

In the first test battery, in the word segmentation test (Jacobson, 1993), speed was assessed with a list of 120 items consisting of strings of three conjoined words, e.g., "snöbåtko" = snowboatcow. The length of the words varied between two and seven letters. The participants marked word boundaries as quickly as possible in three minutes and the number of correct answers was recorded. The *letter-segmentation test* (Jacobson, 1993) required respondents to identify as many double letters as possible during 90 seconds. The test contained 80 segmentations and they were for example: "KSBBSOOFE" or "GRCVVJMUULUA." This test was used to gain an interpretation of speeded letter identity processing.

The second test battery (Johansson, 1992; Järpsten et al., 1983) consisted of four different tests. The test of *reading* 50 short, isolated *words* included Swedish words of all grammatical classes, and included number words. The test became progressively more difficult in word length and content. *Reading speed* measured how long the respondent took to name a list of 50 unconnected written words. The test of *reading nonsense words* used three- and four- letter pseudo words, which resembled Swedish ones. *Spelling* was assessed by a graded test requiring the child to spell 36 two- to four-syllable Swedish words to dictation. All tests in the first and second test battery were made age-appropriate by using different versions for younger (aged 7–9) and older (aged 10–12) pupils.

3.2.4 Results

After *Audilex* intervention, the trained group outperformed [$F(1,39)=6.06$; $p<.018$; $d=.8$] the control group on the auditory-visual matching test. In addition, some, but not all reading-skill test results were improved after training. *Reading nonsense words* was significantly improved after the training period [$F(1,39)=5.37$; $p=.026$; $d=.8$]. *Reading speed* also showed some improvement after training, although the effect was of marginal significance [$F(1,38)=4.74$; $p<.036$; $d=.5$]. The gender of the participants did not affect outcomes.

While some reading-related tasks showed score change following training, others did not. Was this because the tasks that failed to show change were simply not sufficiently sensitive to show any effects? In further analyses exploratory factor analysis was used to examine correlations between tasks, when age and training group were statistically excluded from analysis (i.e., by covariation). This suggested two factors: (1) a *phonological* factor, comprising nonsense word reading, reading speed, reading words, and spelling and (2) a *segmentation factor*—reflecting tests of word- and letter-segmentation. These factors were poorly correlated with each other.

Multilevel analysis was then carried out using factor scores to analyze the training effect in more detail. The variables in this analysis were the used tests (reading-skill and auditory-visual matching tests) training and control groups, and age in months. The four reading-skill tests: nonsense word reading, reading speed, reading words, and spelling comprised the phonological factor. The alfa-coefficient of the set was .83. The other factor (word segmentation test, letter segmentation test) failed to contribute to the model. Similar results obtained when outliers were dropped from the analyses. There was a significant difference between pre- and post-tests [$F(1,38)=24.01$; $p<.001$]. The four reading-skill tests (comprising a phonological factor), showed a significant gain in the training group compared to the control group [$F(1,38)=11.81$; $p<.001$]. According to multilevel analyses, age also had a significant effect on training. Younger participants' scores increased more than those of the older ones [$F(1,38)=14.28$; $p<.001$].

3.2.5 Discussion

In children with developmental dyslexia, a set of reading skills related to phonological processing improved following training on a nonverbal auditory-visual matching game. The improvements were most marked in the younger children and in nonword reading accuracy. While some aspects of the data, such as the greater heterogeneity of the pre-test scores in the training group (the pre-test of reading speed in the training group showed greater variation (SD=127.98) compared to the control group (SD=49.20), it is unlikely that such ad-hoc accounts can explain the increase in post-test scores in the trained group.

Research by Kujala et al. (2001) suggests that the effectiveness of auditory and visual matching training is, perhaps, related to the youth of the children involved. It is possible to draw the same conclusion from this study, where participants' ages varied between 7 and 12. There were significant age-based differences in the effectiveness of the training program in the reading of nonsense words, reading speed and in spelling short words. There was also a significant age-based difference in the auditory-visual matching test.

The present study, conducted in Sweden, used a nonlinguistic computer program designed in Finland (Karma, 1998) as a training method. The prevalence estimates of dyslexia in different languages seem to be related to the shallowness of the orthography. Difficulties in phonological processing seem to be one of the core deficits of developmental dyslexia in many languages, which can vary greatly in their complexity of grapheme-phoneme correspondence (Paulesu et al., 2001). Whereas Finnish has a relatively shallow writing system, Swedish has a deeper orthography. That is, Swedish contains more inconsistent letter-sound correspondences, and more orthographic patterns that reflect morphological forms (Seymour et al., 2003, Laasonen et al., 2001). Readers with dyslexia tend to be more accurate in grapheme-phoneme conversion and read at a faster rate where the language is represented by a shallow orthography than by a deeper one (Harris & Hatano, 1999; Paulesu et al., 2001). The results of this study were similar to Kujala et al. (2001) despite the differences in the mother tongue and orthographic mappings of the two populations tested. These findings are encouraging with respect to the possibility of treating individuals with dyslexia whatever their language and orthography.

Several studies have shown a correlation between nonlinguistic processing and reading skills (Kujala et al., 2001; Talcott et al., 2000), and also between acoustic temporal processing problems and language related impairments, including dyslexia (Temple, 2001; Kujala et al., 2000; Snowling, 2000; Nagarajan et al., 1999; Hari & Kiesilä, 1996). In addition, the study by Kujala et al. (2001) has shown that training to discriminate non-speech stimuli can improve language related abilities. For example, Tallal et al. (1996) and Merzenich et al. (1996) used both non-speech sounds and speech stimuli in training language learning impaired children. However, that study did not allow one to identify the role of non-speech stimuli in improving children's ability to discriminate different sounds in speech. The current results suggest that the developing language processing system which is used to support reading, may build on principles that are also engaged in processing acoustic non-speech representations and matching them to a visual feature.

In summary, the results of Study I are encouraging with respect to both understanding and treating dyslexia. One explanation of the effectiveness of audiovisual training might be that the training program was nonlinguistic. Pupils with developmental dyslexia have tried to learn to read and write effectively for some time by struggling with words and letters; a training program containing no linguistic material is therefore highly motivating. In conclusion, the relationship demonstrated here between performance on a non-verbal task requiring auditory-visual matching, and reading tasks clustered around a phonological factor, suggests that developmental dyslexia may be associated with, and affected by, some amodal or cross-modal mapping skills.

3.3 Study II: *Learning Disabilities and the Auditory and Visual Matching Computer Program*

3.3.1 Aims

The main aim in Study II was to explore the development of auditory processing in children with different learning disabilities, like dyslexia and Attention Deficit Disorder (ADD). The development was promoted with an auditory-visual matching computer program; thus, the other aim was to test the development of the auditory structuring ability in children with dyslexia and ADD. The hypothesis was that the youngest children with dyslexia benefit from the program most.

3.3.2 Participants

The participants were 62 Swedish pupils with learning disabilities (15 girls, 47 boys) aged between 7 years and 19 years (91–238 months) (*M*=152.2, *SD*=48.6). It was possible to divide the participants into two groups based on different learning disabilities; one group consisted of students with a diagnosis of *dyslexia* (n=32) aged between 7 years and 19 years (91–228 months) (*M*=149.7, *SD*=48.3). The other group consisted of students with *Attention Deficit Disorder*, ADD (n=30). Their ages varied between 7 and 19 years (96–238 months) (*M*=154.8, *SD*=49.6).

The formal diagnoses had been received from a qualified educational psychologist or special education teacher; the participants followed the general curriculum. According to the special education teachers, the participants of *Study II* had sub average performance in school subjects, such as mathematics and foreign languages. The group with Attention Deficit Disorder also had attentional problems in school settings and the home environment. Due to their learning disabilities, the children had had special education from the first grade. This occurred once or twice a week with a special education teacher in a resource room. The participants came from three different elementary schools and two senior high schools in the same Swedish town.

3.3.3 Measure and Procedure

This study applied a pre-test–intervention–post-test design. An auditory-visual matching test was the primary measure; in addition teacher's reports were used. The computer training with Audilex lasted eight weeks and occurred twice a week for 15 minutes per session.

Teacher's Reports

The special education teachers were requested to write a report of the students' school behavior before and after the training period. This information was collected to determine the intervention's effects on the students' school behavior. School behavior was described as task orientation, motivation and the maintenance of mental effort. The special education teachers wrote the reports before and after the intervention as a part of an annual evaluation. The goals for school behavior were operationalized according to local school plans about the student's personal development, including learning and social development (Skolverket, 2007). However, as an optional method when studying school behavior might have been for example standardized descriptor scales.

3.3.4 Results

After the training period, an improvement in the auditory-visual matching tests and in the teacher reports was found. The comparison between pre- and post-test of the auditory-visual matching test revealed that the subjects in both intervention groups were significantly better on the auditory-visual matching test [$F(1,61)=82,82$; $p<.001$]. The group with the diagnosis of dyslexia (n=32) performed significantly better on the auditory-visual matching post-test [$F(1,31)=33.97$; $p<.001$] after the training period. The other group, who had a ADD (n=30), performed significantly better on the auditory-visual matching post-test [$F(1,29)=53.20$; $p<.002$].

According to the hypothesis of this study, the *youngest* children with dyslexia would benefit most from the intervention. In the analysis the participants were divided into three age groups. In the first age group, the subjects' ages were between 7 and 9 years. The results representing the difference after the audiovisual training in age groups were significant among the youngest subjects aged between 7 and 9 years; in the group with *dyslexia* [$F(1,11)=14.54$; $p<.003$], and among participants with ADD [$F(1,10)=33.97$; $p<.001$]. However, the training also had a positive effect on auditory-visual matching with *older* students with dyslexia. In the second group, the subjects' ages were between 10 and 12 years. The participants in the second age group with *dyslexia* performed significantly better on the auditory-visual matching post-test [$F(1,8)=12.43$; $p<.009$] as well as the second age group with ADD [$F(1,6)=14.66$; $p<.009$]. The oldest participants were in the third group, and their ages varied between 16 and 19 years. It was possible to find significantly better results in the oldest age group with *dyslexia* [$F(1,10)=14.36$; $p<.004$] and the oldest age group with *ADD* [$F(1,11)=11.42$; $p<.006$]. In the tests the effect sizes (by using Cohen's *d*) were large (see Cohen 1988).

According to the teachers, this intervention also had a positive effect on the students' *school behavior*. Teacher reports on 55 students (89%) were returned; 29 reports from the group with dyslexia and 26 reports from the group with ADD. The results of the teachers' reports could be summarized in three different groups. According to these reports and the observations made by the researcher, for the majority (84%) of the students who were involved, the intervention used had a positive effect on their school behavior.

In both groups 55% (n=30) of the students had a major change in school behavior. According to the teacher reports, minor changes in school behavior were reported in only 29% (n=16). Interestingly, the intervention used had an extremely positive effect on 84% (N=46) of those students who had a major change in their school behavior.

3.3.5 Discussion

It was shown in Study II that the auditory-visual training improved auditory structuring significantly more ($p<.001$) in children with dyslexia, which was expected based on earlier studies (Karma, 1989, 2002b; Kujala et al., 2001). However, the children with other learning disabilities such as ADD also showed improvement after the intervention, which contradicted the hypothesis. In addition, auditory structuring improved significantly in the trained adolescents with a diagnosis of dyslexia. The auditory-visual matching training seemed to be an efficient and simple vehicle in training and motivating the students with various learning disabilities. Those findings were further supported by the teacher reports showing that the students' behavior, with respect to task orientation, the maintenance of mental effort, and motivation, seemed to improve in the trained students. The results of this study, especially those concerning dyslexia, support the idea that the causes of reading impairments are mostly perceptual in nature, which is confirmed by several studies (e.g., Ramus et al., 2003; Shaywitz, 2003). It can be thought, that if there are problems in pre-reading processes such as the sense of direction or the perceiving and processing of auditory and/or visual patterns and their combinations, the demand to understand text may place too great a burden on the child. It has also been hypothesized, that pre-reading processes should be automatized to a satisfactory degree before actual reading can efficiently take place (Karma, 2002b). Previous studies have demonstrated that auditory temporal processing can be trained at the sound and/or phoneme level (Agnew et al., 2004; Strehlow et al., 2006). When the training has been focused not only to auditory processing but also to a combination of auditory and visual processing, significant positive transfer effects on reading skills and comprehension has been revealed (Kujala et al., 2001).

One reason for the effects of the intervention shown in Study II might be that the training improved the functions of orienting, alerting and executive attention control. Examples of brain plasticity as shown by training-induced increases of performance can be found in both children and adults. Training-oriented programs with computers, such as Attention Process Training (APT) have led to specific improvements in executive attention in tasks quite remote from those that have undergone training (Sohlberg et al., 2000). The ATP activities address difficulties with sustained attention, slowed speed of information processing, distractibility, shifting attention between multiple tasks, and attending to more than one source of information at a time. The APT has some similarities with the auditory-visual training used in this study. The APT has also proven successful in training attentional abilities in children with AD/HD (Kerns et al., 1999). Recent studies have revealed that even very brief attention training in five 45 min sessions on the computer did reduce difficulties in executive attention in children (Rueda et al., 2005). In addition, training had significant positive effects on overall IQ, mostly due to increasing scores in visual tasks. Other kinds of attention training for children with AD/HD have improved performance on non-verbal abstract reasoning (Klingberg et al., 2002), suggesting that training of attention may benefit cognitive functioning extending over a range of tasks. The auditory-visual training used in this study did foster brain processes related to attentional control.

Participants in auditory-visual matching training can be an opportunity for some children who have a growing risk of learning disabilities, as well as for older students. It is conceivable that training increases concentration by giving a student even a slight feeling of success and confidence in his or her own performance. Growing confidence can motivate the student to practice, focus and concentrate on reading, which, in turn, could prevent the otherwise cumulative disadvantages of learning disabilities. This assumption was slightly supported in the present study by the teacher reports revealing improved school behavior.

3.4 Study III: *Auditory-Visual Matching and Language-Based Learning Disorders: Two Studies of Specific Language Impairment and Developmental Dyslexia*

3.4.1 Aims

The purpose of this binary study was to investigate the role of auditory-visual matching and overall cognitive performances of children with language-based learning disorders, like specific language impairment (SLI) and developmental dyslexia.

3.4.2 Participants

The study design consists of two different studies (N=212). The **first study** was exploratory between children with *SLI*, *developmental dyslexia* and *typical language development* (TLD). The participants came from six different elementary schools in Finland and Sweden. One of the schools was a special elementary school; others were mainstream schools. In Study 1, 164 children ranging in age from 6 years (78 months) to 13 years (158 months) (M=110, SD=20) served as participants. The participants included 112 Finnish pupils (43 girls, 69 boys) and 52 Swedish pupils (11 girls, 41 boys).

The participants with a diagnosis of *SLI* (n=84) came from the same special elementary school in Finland. A certified speech-language clinician had previously diagnosed these children with SLI [(F 80 Specific developmental disorders of speech and language) ICD-10**].** Children with SLI had an Individualized Education Plan (IEP) and they received speech therapy in their schools. In the SLI group 63% of the children had additional diagnoses according to the International Statistical Classification of Diseases and Related Health Problems.

A qualified educational psychologist or special education teacher had formally diagnosed the children with *developmental dyslexia* (n=52); they served as controls. Due to their developmental dyslexia, they had received remediation from special education teachers since the first grade (age seven) and they followed the general curriculum. The participants came from three different mainstream elementary schools in the same Swedish town. Based on school records and background information supplied by teachers, the children who served as *typical language development* controls (n=28) had no history of speech, language, or hearing problems or of any other exceptional educational needs, and came from the same elementary school in Finland.

Encouraged by interesting results, a **second study**, an intervention was executed. Forty-eight children, pre-schoolers (N=23) and first-graders

(N=25) with language-based learning disorders, like specific language impairment and developmental dyslexia participated in the study. They came from the same mainstream elementary school in Finland.

3.4.3 Measures and Procedure

In this binary study the auditory-visual matching test (see Chapter 3.1.1) and assessment inventory were the primary measures; in addition different reading-skill tests were used in both studies. The pre-test/post-test design was used in the second intervention study. The training comprised twice-weekly sessions of 15 minutes, over eight weeks using Audilex intervention (see Chapter 3.1.2).

Assessment Inventory

To explore different skills and possible deficits in the overall cognitive development of children with language-based learning disorders (like SLI and developmental dyslexia) the researcher conducted an assessment inventory in both studies. The inventory consisted of four different categories of children's development: sensory, cognitive, social-emotional, and physical/motor. Attention has been paid to the maturational aspects: 1) auditory, visual and tactile discrimination were evaluated in sensory abilities; 2) children's use of cognitive skills and strategies, like linguistic skills, memory, and logical-thinking were evaluated, and 3) social-emotional skills were evaluated by motivation, task orientation, social dependence, and ego-defensive orientation. Interaction skills and ability to concentrate were also evaluated, and 4) in motor development students' somatic knowledge, fine, gross motor and sensor-motor functions were evaluated. In the first study the pupils' special education teachers or speech therapists evaluated them, whereas in the second study the special education teachers evaluated the pupils.

Reading-skill Tests

In both studies decoding and reading comprehension was assessed by two sub-tests of the *Standardized Elementary School Reading Test Battery* called *ALLU* (Lindemann, 2000) that has been constructed to evaluate the reading status of 7–13-year-old Finnish-speaking children. This test battery has age-matched tasks.

The decoding test (max. 9) consists of word and sentence recognition, which included letter cluster identification, picture-word matching, and picture-sentence matching, a silent word decoding test and word recognition.

Every task has four alternative answers. The reading comprehension test (max. 9) included a narrative story and an expository text together with questions with four alternative answers for each. The questions assess literal (e.g., fact-finding, ordering information) and inferential text comprehension skills (e.g., deriving word meaning and making inferences beyond sentence level). One point was given for each correct answer. Testing was carried out individually in two 30–45 min sessions by the children's speech therapists or special education teachers. The child could refer to the text for the entire duration of the test.

In the **second intervention study,** two reading-skill tests were used as criteria to participate in the intervention. *The Standardized Elementary School Reading Test Battery* (Lindemann, 2000) was used with first-graders and *the School-Readiness Assessment* (Vauras et al., 1994) was used with pre-schoolers (n=23). This assessment is commonly used in Finnish schools. In this test knowledge of the alphabet was measured with the 19 most frequently appearing letters in the Finnish language, presented visually one at a time by the special education teacher. The children were asked to name the presented letter. Spelling of the alphabet was measured with 19 letters in the Finnish language, presented orally one at a time by the experimenter. The children were asked to write the requested letter. In addition, a pre-school word recognition measure was administered to assess the "pre-reading" skill level. It consisted of 18 mainly two-syllable familiar words to which 4 alternative pictures were given. The maximum score was 39.

In the **second study** scores from the two reading skill tests served as criteria for participation in the intervention. The *Standardized Elementary School Reading Test Battery* (first-graders) showed that the overall reading level was below the age-normal range: in reading comprehension (M=4.46, SD=2.06) and in decoding (M=2.77, SD=1.88). The *School-Readiness Assessment* was used with pre-schoolers showed that pre-reading skill levels were below the age-normal range (M=27.10; SD=9.58).

3.4.4 Results

The **first study** was exploratory between children, ages varying from 6 to 13 with children with SLI (N=84), developmental dyslexia (N=52) and typical language development (N=28). It was shown that children with SLI have very *similar* difficulties to children with dyslexia in auditory-visual matching. The results of the auditory-visual matching test of children diagnosed with SLI were below average (*M*=23.42, *SD*=4.94) as were those of the children diagnosed with dyslexia (*M*=21.56, *SD*=6.34). Children with typical language development showed no difficulties (*M*=28.86, *SD*=1.65) in the Auditory-

Visual Matching Test. Cronbach´s Alpha coefficients were over .85. The results for the children diagnosed with SLI support the view of auditory deficits (Tallal, 2000; Kraus et al., 1996). The Standardized Elementary School Reading Test Battery showed that the overall reading level was below the age-normal range with children with SLI (Reading Comprehension, *M*=3.04, *SD*=1.70 and Decoding, *M*=2.79, *SD*=1.76). As a shortcoming it can be pointed out that there was no control group in the first study. For example multiple baseline single-subject design would be a relevant methodological option. Single-subject experimental research design can personalize the data collection process because data is collected on each participant, and is individually analyzed.

It was evident that there was *comorbidity*: 63% of children with SLI had additional diagnoses. This was supported by the results of the Assessment Inventory, which evaluated the development of overall cognitive performances, like sensory (*M*=1.87, *SD*=0.41), cognitive (*M*=1.79, *SD*=0.36), social-emotional (*M*=2.05, *SD*=0.48), and motor development (*M*=2.08, *SD*=0.49). For further analysis, the participants were divided into three *age* groups, some had difficulties (scored below 1.6 of a possible 3.0) with auditory discrimination (*M*=1.38, *SD*=0.44) in the category of sensory development and in auditory memory (*M*=1.44, *SD*=0.53) from the category of cognitive development. Difficulties also occurred with linguistic skills such as semantics (*M*=1.59, *SD*=0.53) and with dysnomia (*M*=1.43, *SD*=0.51) in the category of cognitive development. The Assessment Inventory showed no significant differences between the four categories, which supports the view of previous studies (Bishop & Adams, 1990; Johnson, 1992) that children with SLI have problems with auditory, visual, tactile, and phonetic perception, as well as with motor tasks. Difficulties in *auditory discrimination* in the category of sensory development, as well as difficulties in *auditory memory* and in linguistic skills such as semantics and dysnomia in the category of cognitive development, were expected based on some theories about deficits in SLI (Tallal, 2000; Archibald & Gathercole, 2006). Surprisingly, the oldest participants performed worse overall in all cognitive development categories, which supports the view of *comorbidity* in developmental disorders (e.g., Botting & Conti-Ramsden, 2000)

Encouraged by the interesting results of the **first study**, a **second intervention study** was executed. Forty-eight children, pre-schoolers (N=23) and first-graders (N=25) participated in the Audilex training period. Following the audio-visual training period, differences between pre- and post-tests were found in the Auditory-Visual Matching Tests. Children diagnosed with language-based learning disorders performed significantly better [*F*(1,47)= 33.1;

p<.001; *d*=.98] in the auditory and visual matching test after the training period. Dividing the participants into age groups yielded no differences in the training effect: pre-schoolers performed significantly better [*F*(1,22)= 19.5; *p*<.001; *d*=.95] and as well as first-graders [*F*(1,24)= 14.2; *p*<.001; *d*=1.0] after the training period. Cronbach´s Alpha coefficients were over .68.

The training effect was also shown according to the Assessment Inventory. After the Audilex training, special education teachers evaluated children's sensory (*M*=2.55, *SD*=0.51), cognitive (*M*=2.46, *SD*=0.50), socio-emotional (*M*=2.43, *SD*=0.50), and motor development (*M*=2.67, *SD*=0.37). According to the Assessment Inventory children with language-based learning disorders performed well in all four categories of children's development. Thus, the intervention appears to have slightly improved the children's sensory development as well as their overall cognitive performance.

oDpDm [illegible]

The purpose of this *binary study* was to investigate auditory-visual matching with children who have language-based learning disorders, like SLI or developmental dyslexia. The **first study**, which was an exploratory study, showed that children with diagnoses of SLI have difficulties in auditory-visual matching *similar* to those of children with dyslexia.

Although there are a wide variety of theories, which attempt to account for SLI, two general approaches have received the most attention. The first posits that SLI arise from deficits in systems that are specifically linguistic. However, the linguistic and sensory deficits are not necessarily exclusive. Also auditory and visual processing deficits may be linked, as expressed most elegantly in the form of the magnocellular hypothesis (Stein, 2001). However, some researchers have failed to find conclusive evidence of the magnocellular deficit theory (Johannes et al., 1996; Skottun, 2000). More importantly, the rapid-auditory-processing hypothesis makes explicit claims that phonological deficits arise from the auditory deficits, which in turn lead to the language disorder. Insofar as literacy requires explicit meta-phonological awareness related to the auditory structure of speech, it is easy to see how an impaired phonological system could lead to dyslexia. However, it is notable when using the concept of auditory-visual matching, that there was no time pressure in the auditory-visual matching computer program. It can be suggested that there are deficits even when no time pressure is used. For SLI, grammatical difficulties have frequently been tied to imperfect perception of the relevant morphological inflections (Rosen, 2003). It has also been hypothesized that limitations in working memory, arising from a phonological coding deficit, can impede the learning of various grammatical structures

(Joanisse & Seidenberg, 1998). According to the Assessment Inventory, participants from the **first study** also had difficulties in *auditory memory*. There are studies (Conti-Ramsden & Durkin, 2007; Archibald & Gathercole, 2006; Gathercole & Baddeley, 1989, 1990) that argue that that SLI may involve a specific deficit of phonological short-term memory and interestingly also in languages other than English (Reuterskiold-Wagner et al., 2005). It has been hypothesized that poor non-word repetition ability might be a key contributory trait of SLI.

Some investigators (Bailey & Snowling, 2002) have assumed a common substrate for dyslexia and SLI (in effect that dyslexia is a mild form of SLI), but this assumption is likely only to be justified for children whose SLI is characterized by expressive language difficulties and phonological processing problems, rather than for those who exhibit pragmatic language abnormalities, involving difficulties with the use of language in interaction. The distinctions between different forms of language difficulty have sometimes been obscured by the use of the term 'language learning impaired', but it is important to note that SLI children have more extensive language problems than dyslexic children, encompassing poor vocabulary, grammatical deficits and faulty comprehension and production of sentence structure.

An important result of the **first study** was the *comorbidity* in SLI; according to the formal diagnoses, fifty-three percent of the participants also had an additional diagnosis. It was possible to find similar results from the Assessment Inventory, which explored different skills and possible deficits in the children's development of overall cognitive performance. It can be supposed that language-based learning disorders are characterized by a broad spectrum of developmental impairments. Comorbidity in SLI has also been reported in many studies. According to Tomblin et al. (2000), children with language impairments are at a significantly greater risk for both reading disability and behavioral disorder. Children with SLI have been reported to experience concurrent difficulties in the area of social and behavioral development (Botting & Conti-Ramsden, 2000; Redmond & Rice, 1998). This has often been thought to arise from such factors as frustration, peer rejection, and lack of confidence due to poor linguistic skills. However, there is now increasing concern that problems with social relationships and other behavioral difficulties may be characteristic of children with SLI well after language difficulties are supposed to have been resolved (Clegg, Hollis, & Rutter, 1999). This supports the results from this study when older participants (11–13 yrs) did not succeed as well as younger ones in the assessment of overall performance. In order to offer individual and qualified education to children with specific language impairments, a comprehensive assessment of their cognitive strengths and difficulties to specify more accurately the nature of their difficulties must be undertaken. Assessment should form part of the evaluation and follow-up of children with language-based learning disorders. The Assessment Inventory used in this binary study can be a practical tool to investigate and evaluate children with language-based learning disorders.

In the **second study** it was shown that nonverbal computer training *improved* auditory-visual matching significantly in children with language-based learning disorders. This result might support the view that phonological deficits arise from general auditory deficits, which in turn might lead to a language-based learning disorder. When the training has been focused not only on auditory processing, but also on a combination of auditory and visual processing, significant positive transfer effects on reading skills and comprehension have been revealed (Kujala et al., 2001). Because the auditory-visual matching training is nonverbal, the explanations can be directed towards perception and processing. It is notable that also attention and concentration is needed. It is also possible that the effects of this intervention were connected to motivational factors; the engagement between the pupil and the researcher elicited a positive interaction and further change in overall cognitive performance in general.

The auditory-visual matching training can be an opportunity for some children who have a risk of language-based learning disabilities, as well as for older students. Success in training increases confidence. That can motivate the student to practice, focus and concentrate on reading, which, in turn, could prevent the otherwise cumulative disadvantages of learning disabilities. In spite of various intervention programs, studies show accelerating numbers of learning disabilities (Vaughn and Fuchs, 2003). It is evident that there is a growing need for practical methods for children at risk. It can be strongly supposed that the intervention used in this study is easy to apply in preschool or school settings and the teachers or school-assistants could carry it out. This would also be cost-effective.

In addition, the auditory-visual matching training could also be a learning opportunity for older students who have the risk of comorbidity. It seems that the learning-friendly nature of the auditory-visual matching computer program motivates the students, thus encouraging them to practice otherwise difficult tasks. Further, the auditory-visual matching training might have international implications because of the promising results in this study as well as earlier studies (Kujala et al., 2001; Törmänen & Takala, 2009) and can be considered a universal instrument because of its nonverbal character.

In conclusion, language development is a dynamic process involving various aspects of social, cognitive and emotional behaviors. To acquire a sound base for linguistic development, a child has to become aware of how to use language as a means of communication, learning and transmission of emotions. Children with language-based learning disorders cannot use language and related skills optimally and they meet many obstacles in tapping everyday learning opportunities. Thus, it is of great importance to prevent cumulative disadvantages and to provide interventions that take into account the multidimensional nature of language development.

4 General Discussion

The present thesis discusses important areas in education: 1) learning disabilities including the role of comorbidity in LDs, and 2) the use of research-based interventions. The series of four studies researched different learning disabilities by rehabilitating them with auditory-visual matching intervention in Finland and Sweden. The results of these intervention studies confirmed, that the auditory-visual matching computer program, called *Audilex* had positive effects.

Positive Intervention Effects

This thesis presents many interesting and useful results and perspectives on learning disabilities. The positive effects of *Audilex* intervention are encouraging with respect to understanding, treating, and identifying different learning disabilities. Much controversy ensues about the extent to which auditory or phonological processing deficits are important in the genesis of language-based learning disorders, particularly in developmental dyslexia and specific language impairment. The improvements in reading-skill tests, which are thought to rely on phonological processing, suggest that such reading difficulties in language-based learning difficulties may stem in part from more basic perceptual difficulties, including those required to manage the visual and auditory components of the decoding task. In addition, deficits in phonological processing can be associated with deficits in both short-term and working memory. There is a consensus that phonological processing deficits are the problems in language-based learning disabilities. However, the research on the role of auditory processing in this area is characterized by inconsistencies in findings from one study to another. The studies using neuropsychological methods (i.e., ERP studies) and further mismatch negativity are promising to solve the etiology of auditory processing in learning disabilities. It might be possible to research the neural basis of audiovisual processing underlying reading and language-based learning disabilities, and to further study the impaired neural processing stages of speech and auditory information in dyslexia and other language and learning deficits.

The positive results of using audiovisual intervention in various learning disabilities are encouraging, not only because of its usefulness in practice; the auditory-visual matching training could have international implications because of the promising results in this thesis and can be considered a *universal* instrument because of its nonverbal character. Difficulties in phonological processing seem to be one of the core deficits of language-based learning disorders in many languages; the findings from this thesis are encouraging with respect to the possibility of treating individuals with language-based learning disorders and with other learning disabilities whatever their language and orthography.

This research emphasized the importance of looking at *comorbidity* in learning disabilities, which was evident based on Studies II and III. There is increasing concern that problems with social relationships and other behavioral difficulties may be characteristic of children with language-based learning disorders well after language difficulties have supposedly been resolved (Clegg, Hollis & Rutter, 1999). This was supported in the results of Study III in which younger participants performed better than did older ones in the assessment of overall performance. Considering children as language-impaired, for instance, is a good starting point, but it often does not do justice to the person's condition nor will it fully describe all of the atypical symptoms seen in a large proportion of children with the same diagnosis.

Inter-Modal Transpose

> *The question of what develops in cognitive development, the nature of individual differences and most importantly that related to the influence of the environment on intellectual development.*
>
> (Adey et al., 2007, 76)

An overview of the data of this thesis raises very interesting and new perspectives about auditory-visual matching intervention. Training program Audilex has been studied earlier among children with dyslexia in Finland (Kujala et al., 2001). The aim of this thesis was to use auditory-visual matching intervention with pupils with different learning disabilities despite languages. The Finnish or Swedish participants came either from pre-school, elementary schools or senior high schools and they had dyslexia, attention deficit disorder (ADD) or specific language impairment (SLI). Interestingly, positive effects of auditory-visual matching training were possible to find in all intervention studies despite learning disability, language, gender or age. An overview of the data arises interesting and epochal questions: What really happens during auditory-visual matching training? Why this intervention is effective in different learning disabilities despite languages? A compression and new perspectives of the data are needed.

A meta-analysis has been used to find out underlying factors. The design of the experiments of this thesis first describes the analyzed situation (Table 1.).

Table 1. The Design of the Experiments in Studies I–III

	Dyslexia			**ADD**			**SLI**
	AG1	*AG2*	*AG3*	*AG1*	*AG2*	*AG3*	*AG1*
Swedish	X	X	X	X	X	X	
Finnish	X						X
Girl	X	X	X	X	X	X	X
Boy	X	X	X	X	X	X	X

Note. X = Positive Intervention Effect
Note. Age Groups, AG; 1 = 6–9 yrs, 2 = 10–12 yrs, 3 = 16–19 yrs

Different variables have been described in tables 2 and 3 showing the effects of auditory-visual training. In the meta-analyses all variables shown in Table 1 are analyzed. Dependent and independent variables are compared as *contrast pairs*. The *Audilex* intervention effects in language, gender, different learning disabilities and in age has been researched using effect sizes. Tables 2 and 3 present interesting findings of the effects of language and different learning disabilities (LD).

Table 2. The Effect of the Language Analyzed by Contrast Pairs

Language	***Age Group***	***Gender***	***LD***	***Effect Size***
Swedish (Study I)	1	Boys	Dyslexia	0.80
Finnish (Study III)	1	Boys	Dyslexia	1.00

Table 2 shows that there are no differences in the dependent variables, only independent variable, *language* differs. According to large effect sizes (by using Cohen’s *d*) intervention was effective in both languages with boys with diagnosis of dyslexia. Using a contrast-pair analysis it can be concluded that despite the language, intervention had positive effects. This is an interesting and a remarkable finding.

In table 3 contrast-pairs analyses shows that independent variables are different in *learning disabilities*. It can be hypothesized that auditory-visual matching training is not specific to dyslexia because it has an effect also on other learning disabilities. When using these analyses it can be concluded that there is positive intervention effect despite language, learning disability, *gender* or *age*. It is noteworthy that the effect of intervention varies in different *age groups*. This is a complex situation; additional data and analyses are required. However, these issues of the meta-analyses are core findings of this thesis and self-evidently need further studies.

Table 3. The Effect of Learning Disability Analyzed by Contrast Pairs

Learning Disability	***Age Group***	***Effect Size***
Dyslexia (Study II)	1	1.25
ADD (Study II)	1	1.71
Dyslexia (Study II)	1	1.25
SLI (Study III)	1	1.00
ADD (Study II)	1	1.71
SLI (Study III)	1	1.00

Different explanations can be summarized describing these results: 1) auditory-visual matching, matching two modalities might have represented an inter-modal transpose; 2) well-designed computer program offered an immediate feedback; 3) during 15 minutes session pupils could maintain their attention throughout every session.

It is possible to conclude that matching two modalities might induce a third, cognitive factor or ability. Earlier I have hypothesized that this might be because of increased attention and concentration. For example this cognitive factor might have an effect on working memory, but this needs naturally further studies. According to collected data, training auditory-visual matching might increase *general cognitive ability*. Audilex training was effective for all different groups. According to Adey et al (2007) general cognitive ability (or 'intelligence') is a general component which operates across all contexts and domains being general and also modifiable. The plasticity of the brain can be considered to be a general intellectual processor in the mind that can be improved. In response to appropriate environmental influences, the plasticity goes 'as far as the brain itself' (Adey et al, 2007, 92).

The concept of *inter-modal transpose* describes matching modalities and transposing action to practice, perhaps having an effect on general cognitive ability. Transposing can also describe the situation when a pupil after experiencing positive Audilex training can benefit more from learning situations in school. This might be the consequence of increased attention, motivation or interventions different nature compare to usual tasks at school.

There were 16 sessions in intervention and Audilex was played twice a week. Each training session, held in quiet resource room, lasted for 15 minutes. According to research notes all participants *concentrated* very carefully in every session. All age groups experienced Audilex games motivating although its layout and rewarding system, a smiling face, are quite simple. An emotionally important factor is that computer program offers a quick, *imme-*

diate feedback. Participants enjoyed success and some of them stated that, finally they succeeded when playing a computer game. Also the non-verbal characters of the games were motivating. Because of the pleasant and supportive learning environment students were motivated and concentrated on otherwise challenging tasks.

During these sessions the researcher sat beside the student. The computer program was guiding the situation and the researcher concentrated mainly on maintaining the action. This situation offered a possibility for supportive and quick feedback. This situation can be also called *scaffolding*, which represents the kind and quality of cognitive support which an adult can provide for a child's learning which anticipates the child's own internalization of mental functions. Importantly, during the intervention a human relationship was created. According to research notes after success in training, students started to realize their strengths, their self-confidence was growing and positive transfer to school behavior was a reality; importantly they were committed to learning.

Identification and Interventions

The positive intervention effects in different learning disabilities are of course important and also useful, but they show quite realistically the problems in the identification of learning disabilities. One possible implication for the use of the auditory-visual matching test is that it can be used to rehabilitate as well as *identify* certain learning disabilities. In some studies (Karma, 2002b; Kujala et al., 2001) an auditory-visual matching computer program has been used to diagnose and train individuals with dyslexia. Because auditory-visual matching demands both attention and concentration it might be considered as a relevant concept in the view of comorbidity in learning disabilities. Movement from a deficit model to a risk model for identification and interventions in LDs is inconsistent with the history of special education and of LD. Interventions with students with LD has been marked by the persistent attempt to identify underlying processing deficits associated with students' LD and then the subsequent design and implementation of interventions to remediate those deficits. Although there is little doubt that many individuals with LD have underlying neurological deficits, the field simply has been unsuccessful at reliably identifying those deficits and, more importantly, in linking the assessment of processing deficits to effective interventions (Kavale & Forness, 2000).

Offering individual and qualified education to children with special needs requires comprehensive *assessment* of their cognitive strengths and difficulties in order to specify more accurately the nature of their difficulties. Assessment should form part of the evaluation and follow-up of children with special needs. Assessment of the cognitive development of the child often forms the basis of the individual educational plan (IEP) targets, but in a changing and fast developing world the social and emotional needs of a child also need to be addressed. The Assessment Inventory of overall performance used in Study III can serve as a practical tool for both investigating and evaluating children with learning disabilities.

The Response to Interventions may represent a promising alternative to the traditional testing method of identifying students with LD. Traditional practices rely on waiting for the student to have extreme difficulty learning and for teachers to recognize this and refer the student for special education. This less-than-reliable practice leaves the burden for screening on the teacher. Often referred to as a "wait to fail" model, it has several disadvantages which include relatively late identification for students who have special needs: imprecise screening through teacher observation; false negatives which are not provided necessary services or provided services too late; treatment-resistant characterization, and use of identification measures that are not linked to interventions.

Response to Intervention is one classification method that can be used to forecast, and therefore allow intervention to minimize those persistent difficulties. Intensified support can be used similarly. Based on the results of this thesis, it can be strongly supposed that the *Audilex* intervention is a useful tool in *early* and *primary* intervention. In addition, the auditory-visual matching training could also be an opportunity for older students who have not received proper instruction or beneficial early intervention, as was shown in Study II. It seems that the child-friendly nature of the auditory-visual matching computer program motivates the students, thus encouraging them to practice otherwise difficult tasks. Success in training increases confidence. That can *motivate* the student to practice, focus and concentrate on reading, which, in turn, could prevent the otherwise cumulative disadvantages of learning disabilities. The Self-Determination Theory and the role of different types of motivation (Deci & Ryan, 1985, 2000) also explain these positive intervention effects as well as inter-modal transpose. These broad and possibly long-term effects are the real reason for using interventions.

The number of special education pupils has been growing for ten years in Finland. The growth in special education is attributable to factors relating to statistics compilation and rehabilitation, advances in diagnostics, new knowledge produced by research into special education and changes in educational legislation. Another explanation is the divergent administrative procedures in municipalities, which is seen in significant differences between local authorities in transferring pupils to special education. It is also problematic that current special education research and statistics describe the supply of special education rather than need for it (Strategy for Special Education, 2007). It is evident that there is a growing need for *practical methods* and *various intervention* programs for children at risk. It can be strongly supposed that the intervention used in this thesis is easy to apply in pre-school or school settings and the teachers or school-assistants could carry it out. This would also be cost-effective. To implement interventions in intensified support and if needed in special needs education, validated adaptations or prevention approaches are needed. In addition, measures are required to index responsiveness or learning over time. These tools are available for some, but not all, academic areas, and they are better developed at some grade levels. For example, a fair amount of work has been accomplished in reading to provide the groundwork for both intervention and measurement procedures. In contrast, in mathematics, spelling, and written expression, although measurement procedures for tracking growth are well established, validated intervention methods for testing responsiveness to interventions require further attention (Vaughn & Fuchs, 2003).

Fundamentally, underlying deficits have not been reliably identified, and corresponding instructions have not adequately addressed the learning problems of students with LD. Thus, although the assessment of processing abilities and the provision of process-oriented interventions may have a fruitful future, the most effective current model for addressing students' LD is one that relies on progress-monitoring approaches directly linked to explicit and systematic intervention. Some recommendations are needed about how to organize instructional levels; many core features of the RTI model have not been delineated. These include the need for universal screening procedures, the use of intervention-focused classroom instruction, ongoing progress monitoring, and development of research-based interventions related to learning. A central concern might be the lack of defined measures and criteria used in the implementation process. In fact, Semrud-Clikeman (2005) pointed out that the assessment measures to be used for academic screening have not been defined or discussed. Kavale (2005) raised concerns about the vague definition of a successful RTI model and about who decides when formal referral for special education is warranted.

“From Teaching to Learning”

In 2006 nearly half of Finnish special education pupils were integrated either totally or partially into mainstream education and the others were taught in special groups in ordinary schools or in special schools (Strategy for Special

Education, 2007). In the Nordic countries a growing number of special-needs pupils are studying in their neighborhood schools and in ordinary teaching groups. Inclusion, recommended in the educational programs of many countries, means educating students with disabilities alongside their same-age peers in the general education settings. In Finland inclusion is also the official educational policy. One central way to support inclusion in Finland has been a system called part-time special education or *inclusive special education.* Participating in inclusive special education demands neither an individual educational plan (IEP) nor any official decisions because it is temporary for the pupils and takes only part of their school day; the pupils remain in mainstream education. According to Itkonen and Jahnukainen (2007), pupils receiving inclusive special education exit special education status; they are not considered disabled, but they are in need of short-term special education.

Inclusive special education has been considered one of the possible reasons for the success of Finnish pupils in PISA *(*Programme for International Student Assessment) (Kivirauma & Ruoho 2007).[1] In 2003 Finland ranked first in reading, and in 2006 Finland ranked first in science and second in mathematics and in reading. These good results have been achieved with moderate costs in comparison with other countries, as well as with less time at school, in hours and in years. Finnish children did perform well in PISA tests, at least partly because continuous support has been offered whenever needed, mainly by a special education teacher (PISA, 2006; Arinen & Karjalainen, 2007).

An exploratory study (Takala, Pirttimaa & Törmänen, 2009) of inclusive special education in mainstream education in Finland concentrated on the work profile, used pedagogical settings and methods of a special education teacher. It was possible to find three issues from the work profile: teaching (mainly in small groups, in co-operational settings, and individually), consulting, and background work. The work of special education teachers was partly inclusive, but included also segregative elements (Takala, Pirttimaa & Törmänen, 2009). In response to recent trends future challenges seem to be an increasing amount of co-teaching and consultation.

Implemented to provide support for increasing the inclusion of students with disabilities, *co-teaching* usually consists of one general education teacher paired with one special education teacher in an inclusive classroom of general education and special education students. The advantages to the idea of fully using the talents and abilities of both the general education teacher and the special education teacher in tandem for the inclusive classroom set-

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1 PISA is an assessment of the skills of 15-year-old in reading, mathematics and science, done every third year of in more than 30 OECD countries.

ting are threefold. Obviously it would benefit not only students with learning disabilities, but also the students without learning disabilities. Professional collaboration likewise benefits the teachers. There are research results of co-teaching when a special education teacher is present in the classroom and can target specific problems with immediate intervention strategies; all students, from the high-achievers (Stevens & Slavin, 1995) to those students who are at risk (Walther-Thomas, 1997), can benefit from the situation. In addition to learning and study strategies brought to the classroom by the special education teacher, a social aspect is brought into play as students interact with others who are different than them. These interactions can include tutoring, when higher achieving students solidify their knowledge by presenting it to a peer. These social skills include not only communicating, problem-solving and relating, but also developing a deeper social aspect. A deeper understanding of differences in humans occurs through empathy, in recognition not only of these people's weaknesses, but also their strengths. The result is a more balanced social climate in the school that reflects the real world.

As schooling has become more complex and students more diverse, and the need for systemic improvement more pressing, the pressure for teachers to emerge from their classrooms and begin to work together has grown significantly. It is important to introduce new approaches towards children's' learning process and thereby to support teachers on their way to changing their practice. The overall aim will be to develop, implement and disseminate materials for teacher training and for all educational staff, to change attitudes and beliefs about the learning of all children and to recognize that the learning potential of any child is the result of many factors. There is a need to use an assessment tool to identify the multiple skills of children within a spectrum of potential, and a training package to improve the teacher's capacities for research, evaluation and assessment. In addition to sufficient preparation, teachers need consistent support to implement interventions.

As communication and interaction develops, interdisciplinary work will grow and children will achieve more and have greater benefits from professionals working together. The ideal of co-teaching, collaboration between two equal partners will focus on curriculum needs, innovative practice, and appropriate individualization. Hargreaves (2003) suggested that teacher collaboration can lead to increased confidence, which can lead in turn to more experimentation and risk-taking, and ultimately continuous improvement. However, genuine collaboration must be spontaneous, voluntary, unpredictable, and development oriented.

When using research-based interventions and a range of strategies, curriculum in schools become more engaging and meaningful, personalizing learning for the individual pupil, and creating communities of learners who support and share in each other's learning. Strategies like *universal design of curriculum* (Rose, Meyer & Hitchcock, 2005) or designing a student-centered curriculum, focus on making curriculum accessible to a wide diversity of learners by virtue of the variety that has been designed into what students will learn. According to Ferguson (2008), strategies such as project- and problem-based curriculum design and integrating various subjects into study of a broader problem, theme or project are ways to ensure that the resulting curriculum is interesting, engaging and meaningful to pupils. When these curriculum design strategies are combined with differentiated instruction (Tomlinson, 2003), individual students' learning can be personalized to their current abilities as well as their interests. Planning for differentiation involves thinking about different ways that any lesson or learning project might be changed to better meet students' needs. A teacher can differentiate content (what specifically each student learns), processes (how each student learns) and products (what the student produces as evidence of learning). In addition, teachers can take into account and differentiate according to students' current abilities, their interests and learning strategies or intelligences (Gardner, 1998). When principles of differentiation are combined with meaningful curriculum design, classrooms become busy, productive work environments where learning is the focus as well as the result (Tomlinson & McTighe, 2006).

Individualized Education

Evidence for genetic influences on learning disabilities should not discourage educators' best efforts toward intervention and remediation. Many examples of genetically influenced problems exist; fortunately, research-based interventions are usually effective. Much evidence shows that the increased use of *interventions in a supportive environment* can be helpful for the remediation of children with special needs. Evidence also exists that intervention directed toward highly heritable learning disabilities could have significant benefits in children with special needs. The knowledge of comorbidity in learning disabilities supports the idea that interventions should be individually designed, ultimately to select the most effective and research-based interventions to help children with special needs. Every child has skills and strengths that enable a powerful way of learning. It is important to find a motivating factor by making the school experience more appealing. Maximizing this motivating factor by enhancing their self-esteem allows them to have fun in school. Individualizing provides opportunities for social, physical, emotional and cultural development and encourages all students to think positively about themselves and others. Self-esteem levels are an important factor in a student's educational experience. Many at-risk students fail because of the lack of desire to learn rather than the inability to learn; the use of research-based interventions and intensified support maybe helpful. Raising self-esteem and motivation through quality education is one way of stimulating this desire to learn, which may encourage a student to learn and try harder, and ultimately rescue students with or without learning disabilities before they fail.

One major goal of this thesis is to widen the perception of every child as a special person who has individual, educational needs. It is important to remember that greater diversity creates a culture, in which the picture of what is considered to be normal is expanding. Such an inclusive educational setting places many demands and challenges on teachers, use of various pedagogical settings, methods and interventions, co-operation and finally, for school organization; the knowledge of leadership skills and cross-disciplinary research are also needed.

> *"It has been well said that if your pupil does not learn the way you teach, you must teach in the way they learn."*

(Miles, et al. 2008)

Notes

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Original Publications