JYVÄSKYLÄ STUDIES IN HUMANITIES
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Riitta Pennala

Perception and Learning of Finnish Quantity

Study in Children with Reading Disabilities and Familial Risk for Dyslexia and Russian Second-Language Learners

JYVÄSKYLÄN YLIOPISTO

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UNIVERSITY OF JYVÄSKYLÄ

JYVÄSKYLÄ 2013

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ABSTRACT

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Previous studies have shown that accurate learning of phonological quantity in Finnish is difficult for Finnish infants who are at risk for dyslexia and for Russian second-language (L2) learners of Finnish. Quantity opposition has different phonological and phonetic constraints in Finnish and Russian. This study investigated the perception and learning of phonemic length by these different learner groups. The study revealed that Finnish children developed in their ability to discriminate phonemic length from grade 1 to grade 3. The children at risk for dyslexia and with reading disabilities differed from the control group in discrimination ability in the 2nd and 3rd grades. Discrimination ability contributed to reading accuracy in the 3rd grade and to spelling accuracy in the 2nd and 3rd grades beyond the traditional markers of dyslexia at school age. The at-risk children with reading disabilities and with phonemic length discrimination ability problems were poorer in reading and in spelling accuracy, especially in the spelling of quantity in the 2nd grade compared to the at-risk children with reading disabilities and without discrimination ability problems, and typical readers. Also, the problems in early risk factors accumulated in the at-risk group. Discrimination ability problems explained spelling accuracy over the accumulation of early risk factors among the at-risk children with reading disabilities. Discrimination ability was not connected to reading fluency. Two- and three-syllable word/pseudo-word final vowel quantity degree training was more difficult for a native 1st grade child with reading disabilities than for the 1st grade Russian L2 learner of Finnish. Quantity degree accuracy scores for two-syllable words were lowest in the L2 learners, and the training effects with words including quantity were generalized to pseudo-words. Training effects generalized to items used in the identification test in two L2 learners. Difficulty in accurate perception of phonemic length is a risk for dyslexia along with other well-known risks, and it may be more difficult to remediate with Finnish school-age children with reading disabilities than L2 learners. Individual differences should be considered when planning training paradigms with phonemic length.

Keywords: quantity, phonemic length, Finnish, Russian, dyslexia, second-language learning, speech perception

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LIST OR ORIGINAL PUBLICATIONS

Study I Pennala, R., Eklund, K., Hämäläinen, J., Richardson, U., Martin, M., Leiwo, M., Leppänen, P. H. T. & Lyytinen, H. 2010. Perception of Phonemic Length and its Relation to Reading and Spelling Skills in Children with Family Risk for Dyslexia in the First Three Grades of School. Journal of Speech, Language, and Hearing Research, 53 (3), 710–724.

Study II Pennala, R., Eklund, K., Hämäläinen, L., Martin, M., Richardson, U., Leppänen, P.H.T. & Lyytinen, H. Precursors and Consequences of Phonemic Length Discrimination Ability Problems in Children with Reading Disabilities and with a Familial Risk for Dyslexia. Journal of Speech, Language, and Hearing Research. (in press).

Study III Pennala, R., Richardson, U., Ylinen, S., Lyytinen, H. & Martin, M. 2011. Tietokoneavusteinen suomen kielen kvantiteetin harjoittelu: venäjänkielisen suomea opettelevan lapsen ja suomenkielisen luku- ja kirjoitushäiriöisen lapsen vertailu. Puhe ja kieli, 31 (1), 3–24.

Study IV Pennala, R., Richardson, U., Ylinen, S., Lyytinen, H. & Martin, M. Computer Game as a Tool for Training the Identification of Phonemic Length. Logopedics Phoniatrics Vocology. (in press).

FIGURES

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1 INTRODUCTION

1.1 The purpose of the study

Finnish is an interesting language, in particular because it includes single and double vowels and consonants. These features together with differences in the duration of speech sounds serve as precursors of a phenomenon termed quantity. This feature is self-evident to most native language users of Finnish. However, it is a well-known fact that the exact length of sounds is difficult to perceive, produce and spell for native children with reading disabilities and with familial risk for dyslexia, and for foreign and second-language (L2) learners of Finnish.

The difficulty of quantity perception has not previously been compared or studied for these two distinct learner groups together. This psycholinguistic dissertation concentrates on the perception and learning of phonemic length by Finnish children with reading disabilities and with familial risk for dyslexia, and by Russian second-language learners of Finnish in grades 1–3. The main focus is on the discrimination and identification of phonemic length in general, but especially in word-final vowels. The study explores whether the reading and spelling problems of dyslexic children vary as a function of perceptual accuracy of sound duration, and discusses the relation of the perception of duration on other cognitive factors underlying dyslexia. It also combines two fields of speech perception research that have only recently started to share their views, namely perception of speech sounds and word (pseudo-word/non-word) recognition. The aim of this study is to bring together two distinct research domains which have an interest in quantity, namely dyslexia research and second-language acquisition, and to test and further develop existing training methods for reading-disabled native speakers and Russian-speaking second-language learners of Finnish.

The dissertation comprises four different studies. The introduction gives the background and wider theoretical contexts for these studies. The introduction begins by defining dyslexia and describing the Jyväskylä Longitudinal

Study (JLD) of Dyslexia, which provides the basis for the dyslexia study presented here. Next, bilingualism, second-language learning and the position of Russian in Finland are introduced, as along with some studies on immigrants learning the Finnish language. These definitions are important starting points, as they help to clarify the peculiarities of the groups of interest in the present study. The term quantity is then defined and discussed in a wider context than in the publications included in this dissertation, and an overview of the studies on Finnish phonological quantity is presented. As the present study concentrates mainly on the perception of spoken words and pseudo-words (also non-words), the theoretical background pertaining to speech perception, phonological awareness, and isolated word recognition is introduced. After this, the theories underpinning dyslexia and second-language speech perception are presented. Finally, the background to intervention studies is introduced. The sub studies and general discussion constitute the concluding parts of the study.

1.2 Biologically based problem in learning to read and spell: dyslexia

1.2.1 Defining dyslexia

Children with reading disabilities and with familial risk for dyslexia are the main focus of this study. Reading proficiency has become increasingly important for people in everyday and professional life. Unfortunately some people never reach a functional level of reading ability and therefore have difficulties accessing written information that for most people is (readily) obtainable. The negative consequences for educational opportunity, using the Internet, reading manuals and instructions in everyday life, and having contact with authorities are of course serious personal problems, but it is also a problem for any democratic society if some citizens cannot share important written information. The problem of achieving reading proficiency has been termed dyslexia. (Gruber 2003: 1.)

Dyslexia is commonly characterized by persistent difficulties with accurate and /or fluent word recognition, decoding, spelling, and problems in reading comprehension, despite normal intellectual functioning, adequate learning opportunities, and no serious emotional or personality disorders. Dyslexics have problems in phonological processing and thus in phonological awareness, grapheme-phoneme correspondences, verbal memory and rapid serial naming. Approximately 6–17 % of the school age population has dyslexia, the estimate depending on the criteria applied for the severity of reading problems. Dyslexia is more common in boys. (Snowling 2001: 14, 138; Vellutino, Fletcher, Snowling & Scanlon 2004: 3–4; Hulme & Snowling 2009: 37–40; Pennington, Peterson & McGarth 2009: 45, 82, 49–57; Ramus, Masrshall, Rosen & van der Lely, in press.) Dyslexia is developmental and heritable, and several candidate genes

linked to dyslexia have been identified. It has been found that a candidate gene for developmental dyslexia is DYX1C1 (Taipale, Kaminen, Nopola-Hemmi, Haltia, Myllyluoma, Lyytinen, Muller, Kaaranen, Lindsberg, Hannula-Jouppi & Kere 2003: 11553). DYX3 has been found to be important for dyslexia susceptibility in many Finnish families (Kaminen, Hannula-Jouppi, Kestilä, Lahermo, Muller, Kaaranen, Myllyluoma, Voutilainen, Lyytinen, Nopola-Hemmi & Kere 2003: 340). In addition, a new candidate gene has been found in chromosome three (Hannula-Jouppi, Kaminen-Ahola, Taipale, Eklund, Nopola-Hemmi, Kääriäinen & Kere 2005: e50). The effects of genes on dyslexia are still under intensive scrutiny.

The terms reading disabilities or poor readers are often used when dealing with dyslexia, and hence the term reading disabilities or reading disabled is used in this study as well.

Seeking to understand the causes behind the reading and spelling problems and how to best remediate them occupies a large number of researchers around the world. The research focus is both in applied areas directed towards classroom teaching and special education, and in more theoretical areas of basic research, where the aim is to understand and describe the causes behind and factors related to dyslexia. (Gruber 2003: 1.) For this dissertation, the theoretical aspect was addressed in studies one and two, and classroom teaching partly in studies three and four.

1.2.2 Jyväskylä Longitudinal Study of Dyslexia (JLD)

The data of the first two studies of this dissertation are from the Jyväskylä Longitudinal Study of Dyslexia (JLD)[1]. The JLD has studied the precursors, predictors, and developmental pathways associated with familial developmental dyslexia in approximately 200 children from birth to the 9th grade, including children with and without a familial risk. From the outset of the JLD, the parents of the children with familial risk for dyslexia (n = 106) were initially selected from 8,427 parents participating in the first stage of a three-stage process (questionnaire, interview, and cognitive assessment). The initial questionnaire explored the incidence of reading and spelling problems among prospective parents (maternity clinic users throughout central Finland) and their relatives. The 190 parents who reported literacy difficulties (personal and/or first-degree relatives) were followed up with an interview and cognitive assessment. Children were included in the at-risk group if their parents (n = 106) had an intelligence quotient (IQ) equivalent to or greater than 80 (Ravens B, C, and D Matrices; Raven, Court & Raven 1992) and obtained z score equivalents of –1.0 or less on tests of reading fluency, reading accuracy, and spelling accuracy, and in at least two of eight computer-aided single-word measures: pseudo-word naming, pseudo-word /word choice, rapid mask word recognition, rapid lexical decision, sylla-

[1] The researcher did not participate in the collection of the JLD data used in this study. Instead, the researcher participated in the data collection of the Tempo project as the main data collector over one year. The project was part of the JLD project (see Oksanen 2012).

ble segmentation, spelling, and oral text reading speed and accuracy. The non-risk children's (n = 93) parents had an IQ within a similar range and gave no report of literacy difficulties in the immediate family (for full details, see Lyytinen, Leinonen, Nikula, Aro & Leiwo 1995; Leinonen, Müller, Leppänen, Aro, Ahonen & Lyytinen 2001). As a result of the test performance and interview, 106 parents were selected to participate in the study, and their children formed the at-risk group. All the children were native speakers of Finnish.

Altogether four previous dissertation studies of Finnish language produced in the Department of Languages, University of Jyväskylä, have utilized JLD data. (Turunen 2003: 3, 9; Nieminen 2007: 3, 26; Richardson 1998: 1, 96–98, 136–137, 149, 163; Torvelainen 2007: 3, 14; Richardson, Leppänen, Leiwo & Lyytinen 2003: 391–395; Richardson, Kulju, Niemi & Torvelainen 2009.) In these studies the speech processing skills were studied in 0.5, 1.5, and 2.5 -year-old children. The findings showed that early signs of dyslexia can be detected in speech processing both phonologically and morphosyntactically. These precursors were evident in the perception and production of duration, in the prosody and phonotactics of word production attempts and word structures, and in the complexity of morphosyntactic features of expressions. The present dissertation study continues this tradition and in part uses JLD data. The project has also published a large number of articles on dyslexia. More details and review studies on the results of the project can be found in the following publications: Lyytinen, Ahonen, Eklund, Guttorm, Laakso, Leinonen, Leppänen, Lyytinen, Poikkeus, Puolakanaho, Richardson & Viholainen 2001; Lyytinen, Aro, Eklund, Erskine, Guttorm, Laakso, Leppänen, Lyytinen, Poikkeus, Richardson & Torppa 2004; Lyytinen, Aro, Holopainen, Leiwo, Lyytinen & Tolvanen 2006; Lyytinen, Erskine, Ahonen, Aro, Eklund, Guttorm, Hintikka, Hämäläinen, Ketonen, Laakso, Leppänen, Lyytinen, Poikkeus, Puolakanaho, Richardson, Salmi, Tolvanen, Torppa & Viholainen 2008.

1.3 Bilingual language acquisition

1.3.1 Second-language learning and bilingualism

In addition to native Finnish children with reading disabilities, Russian-speaking second-language (L2) learners of Finnish are the other main group of interest in this study. When talking about second-language (L2) learning, it is important to set the concept in a wider context. A person's mother tongue (L1) is a language which is usually learned first and the skills of the language spoken at home are the best. It is also a tool of thinking and conceptualizing the surrounding world, and it develops the speaker's identity. It may also be a general language of a family, area or country. Because of the ambiguity and ambivalent nature of the concept, many researchers use the term first language instead of mother tongue. (Lehtinen 2002: 22–23; Toivainen 1994: 55.) A first language is a language which is acquired first in natural contact with the environ-

ment, mostly with one's parents. A child can have several first languages if child's parents speak different languages, and the child acquires the languages simultaneously. (de Houwer 2009: 14, 98, 99; Martin 2003: 76; Sajavaara 1999: 73–75.) As opposed to a first language, L2 is acquired later in life after L1. The term foreign language refers to the learning of novel language in school in formal education (Ellis 1994, 11–12; Martin 2003: 76).

Second-language learning is linked to the concept of bilingualism (or multilingualism). Bilingualism is quite a common phenomenon in the world (Baker 2007: 106; Peltola 2010: 162). There are also long traditions of bilingualism in Finland, Switzerland and Canada (Silvén 2010: 143). The identification of bilingualism is not so clear, however (Peltola 2010: 162). Bilingualism (as well as multilingualism) may be an individual characteristic or that of a social group, community, region or country (Baker 2007: 2). Traditional definitions differentiate between simultaneous and successive or sequential bilingualism. The first means that the two languages are acquired at the same time (exist since birth), and the latter means that they are acquired sequentially in early childhood. Sequential bilingualism is therefore linked to concept of second language acquisition. (Baker 2007: 120; Hassinen 2002: 22.) Baker (2007: 4) states that elective bilinguals are those who choose to learn a language, for example in school, and circumstantial bilinguals learn another language for everyday life.

In addition to these, several other terms are linked to the concept of bilingualism. One definition points out that the skills in two languages must be good enough to be able to describe the language user as bilingual (balanced bilingualism), whereas others think that surviving in daily life with two languages is enough to consider the user as a bilingual. The main difference between these definitions is that the former views bilingualism as an acquired skill, and the latter that the language is mainly learned through teaching. (Peltola, 2010: 162–163.) One definition points out that bilingualism is dependent on language skills, and not the learning environment itself. The implicit idea of balanced bilingualism usually means age- and context-appropriate competence in both languages, but balance may also exist on a low level of competence in the two languages (Baker 2007: 9). A dominant bilingual refers to a speaker whose linguistic manifestation in one language is better than in the other (de Houwer 2009: 47; Peltola 2010: 163). On the other hand, a person may be semilingual, meaning that he/she does not have sufficient competence in either language. Incipient bilinguals have one well developed language, while the other is a developing language. Ascendant bilingualism refers to a developing second language, and recessive bilingualism means that one language is attriting. Thus, language ability and language use should be distinguished from one another. (Baker 2007: 3, 4, 10.) On average, the early language of mono- and bilingual children develops mainly at the same rate (de Houwer 2009: 50).

A second language is usually defined in Finland as a language which is a main language of the society and of the school system and is different from the first language of the learners. It is usually learned in the school context or in everyday life situations in families and society. (Lehtinen 2002: 213; Martin 1999:

1; Martin 2003: 76; Sajavaara 1999: 75.) Children receive teaching in Finnish as a second language if their skill in Finnish (or Swedish) is not good enough to allow them to be taught together with native Finnish speakers. Teaching of the mother tongue or first language of a child is also organized in schools if possible. (Peruskoulun opetussuunnitelman perusteet 2004: 36.)

Languages may differ from each other in, for example, prosody, phonology, morphology, and syntax. Silvén states that mono- and bilingual children receiving teaching in Finnish as a first or second language are at the same stage in their semantic, phonological, and morphological development. Based on her results, she argues that only the more complex inflections are more difficult for bilinguals than for monolinguals. However, the prosody of Finnish is also complex for L2 learners, mainly because of quantity; for example, Russian L2 learners of Finnish differ from native speakers of Finnish in their perception of vowel quantity (Nenonen, Shestakova, Alku & Huotilainen 2003: 531, 534; Ylinen, Shestakova, Alku & Huotilainen 2005: 313).

Assessment of language skills is demanding, and the wide variation in the language skills of L2 learners of Finnish poses challenges to teachers in schools. The length of time the L2 learners have lived in Finland varies: some of them have been born in Finland and some have moved to the country as a child or as a teenager. The children's parents do not necessarily speak Finnish at all, although one parent may be a native speaker of Finnish. In addition, the L2 learners may include children who have dropped out of school, possibly because of war or some other conflict in the home country (refugees), while other children may have not received any formal schooling at all. (Ikonen 1995: 7.)

The Russian-speaking children in this study were elective and circumstantial bilinguals mainly because of the choices of their parents and because of the compulsory elementary school system in Finland. One of the children was simultaneous bilingual with a Finnish-speaking father and a Russian-speaking mother. Three of the children were successive bilinguals because they had not learned Finnish systematically from birth. However, their status as bilinguals, not to mention their precise language skills, was difficult to evaluate accurately, because we did not know the whole language histories of these children. The main criterion is that they were defined as second-language learners in their school environment.

1.3.2 Russian in Finland and studies with immigrants learning Finnish

At the end of 2011, the number of foreign citizens resident in Finland was 183 133 (3.4 per cent) of the Finnish population (5 218 134). Altogether 4 863 351 persons (90.0%) spoke Finnish, 291 219 persons (5.4%) Swedish and 1 870 persons (0.03%) Sami as their native language. Persons with other native language numbered 244 827 (4.5 per cent) of the population. The largest foreign-language groups were Russian (58 331 persons), Estonian (33 076 persons), Somali (14 045 persons), English (13 804 persons) and Arabic (11 252 persons). (see "The Population of Finland grew most in 20 years".) Because of the size of the Russian

population in Finland, it was deemed of interest to study their acquisition of Finnish as a second language.

Several studies exist on the learning of Finnish by immigrant children. Lehtinen (2002: 5) studied the development of Finnish as a L2 among 20 immigrant children during the first year in school. She discovered that all aspects of language developed during their 1st grade, but many of the children continued to have problems in their academic language proficiency at the end of the school year. The mother-tongue lessons seemed to support their acquisition of Finnish language skills: the children whose performance in the Finnish language was weakest were those who did not have the opportunity to receive formal teaching in their L1. The first school year also seemed to socialize the children into greater use of the Finnish language.

One major qualitative study focused on two Vietnamese adults learning Finnish as a second language and on the repetitions and linguistic modifications occurring in negotiations of meaning (Suni 2008). A more recent study of Finnish as a L2 is that by Lehtimaja (2012), who studied how the learning of Finnish as a second language influences students' possibilities of participating in whole-class conversation. (for more detail on studies of Finnish as a second language, see Martin 2007; Suni 2012.) However, studies on the acquisition of Finnish quantity by Russian second-language learners of Finnish are very few. I return to these studies in section 1.4.3.

1.4 Quantity

1.4.1 Defining quantity

The main object of interest of this study, quantity, plays an important role in the analysis of a variety of phonological and morphological phenomena in several languages. These include word stress, tone, compensatory lengthening, shortening processes, minimal word requirements, templatic restrictions, and allomorphic selection. In these phenomena, syllables that are short (or light) are usually distinguished from those that are long (or heavy). In modern studies of phonology, the term quantity refers to either segmental duration or syllable weight. (Davis 2011: 103.) Duration is one of the four[2] features which function as classificatory features of languages. The same term **duration** is used for (both) absolute and perceived duration. (Vainio 2010: 91). Lehtonen (1969: 363) referred to these terms as objective and subjective quantity. In the case of segmental duration, quantity differences among segments are said to be phonemic in languages that contrast a long and short form of a vowel of the same quality and in

[2] Other features are pitch, intensity and complexity. Pitch refers to the perceived highness, intensity refers to perceived loudness, and complexity refers to perceived quality. (Vainio 2010: 91.)

languages that contrast a geminate versus non-geminate consonant (Davis 2011: 103).

Perceptually, the just noticeable differences in duration are said to be between 10 and 40 milliseconds. The listener interprets the duration of a particular sound by relating it to the duration of the word as a whole. The fundamental frequency of the sound has no effect on the perception of duration[3], whereas, up to a certain level, intensity increases the listener's capacity for discrimination. The phonetic formant structure in the case of both long and short quantity degrees seems to be the same (Wiik 1965: 52, 120). The suprasegmental nature of quantity is that the duration of the sound is longer than a single segmental sound, and the time dimension of the acoustic signal functions simultaneously on several levels (syllable, word or sentence). Quantity also functions differently on the sentence (tempo) compared to word (quantity) level (Lehiste 1970: 10, 13, 17, 41, 51, 53; Ladefoged 2006: 22, 24).

In generative phonology, the major issue concerning quantity has been the nature of its phonological representation. Chomsky & Halle (1968) used the feature [±long] to characterize segmental quantity. However, long segments can behave like sequences of two segments in certain contexts. Further inalterability effects were noted whereby long segments seemed to be immune to certain phonological processes. Such observations motivated an autosegmental representation of segmental quantity, in which long vowels and geminates are linked to two slots in the timing of a prosodic tier while a short vowel or singleton consonant is linked to one slot. (Davis, 2011: 104.) Hayes (1989) rejected the segmental nature of the prosodic tier and argued instead for its characterization as moraic, although the current notion of mora goes back to at least to Trubetzkoy (1939/1969). A mora is a unit of timing, and each mora takes about the same time to say (Ladefoged 2006: 245). Hayes stated that compensatory lengthening involves the loss of a moraic segment without the deletion of the mora. (Davis 2011: 105.) In Hayes' theory, a short vowel is underlyingly monomoraic while a long vowel is bimoraic. A geminate is moraic while a short consonant is non-moraic (Davis 2011: 105). Different views have been expressed as to which phonemes in the syllable are counted as mora, and what kinds of syllables are heavy or light in different languages. The interaction between stress and heavy and light syllables is also discussed by Davis. (See Davis 2011: 109–132.)

Pike (1947) introduced the terms stress-timed and syllable-timed as descriptors of the rhythms of languages. He argued that there was a strong tendency in some languages (which he labeled stress-timed languages) for stresses to appear equally spaced in time, while in other languages (syllable-timed languages) the tendency was greater for syllables to be equally timed. According to Lehiste (1970: 40), there are languages where the word as a whole has a certain duration that tends to remain relatively constant. The duration of segments decreases as their number in the word increases.

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[3] See Järvikivi et al., 2010 for the effect of pitch movement.

1.4.2 Finnish phonological quantity

Finnish is a full-fledged, syllable trochee quantity language where feet consist of two syllables and where the first syllable is metrically strong irrespective of its weight (and hence, of the number of mora it contains) (Suomi, Toivanen & Ylitalo 2003: 114, 136). However, in 'pure' syllabic trochee languages there are no distinctions of either syllable quantity (alias syllable weight) or segmental quantity. But if a syllabic trochee language does have a segmental (especially vowel) quantity distinction, it should also exhibit a sensitivity to syllable weight in its assignment of stress (by avoiding stresses on light syllables). Finnish, then, is exceptional among the syllable trochee languages. (Suomi et al. 2003: 114.) Despite this, quantity is one of the most important linguistic features of prosody in Finnish. Other features are tone and intonation. These are structures of discrete categories which are manifested with suprasegmental cues. In other words, they function as phonemes, affecting the semantics of words and expressions. Phonetically, quantity refers to the durations of the sounds, and long sounds are approximately twice as long as short sounds. The durations of the sounds range between 30–300 milliseconds in normal oral reading. (Vainio 2010: 92, 95.)

Four features have an effect on segmental durations in the Finnish language (Lehiste 1970: 42; Suomi & Ylitalo 2003: 37). The most obvious of these is the separate quantity opposition for vowels and consonants (independently of word stress). The second factor affecting segment durations is lengthening of the words's second mora, if this segment is voiced. Thirdly, word stress is associated with the word-initial syllable and with a word-initial two-mora sequence, so that the main stress is always on the first syllable of the word. (Suomi & Ylitalo 2003: 37.) After that stress falls on every other syllable, but never on the last syllable of the word, which is always unstressed. The phonetic nature of stress is not straightforward in Finnish, owing to the interaction between stressed and unstressed syllables. Stress functions as a marker of a word boundary, but this same function is also shared by some other features. (Karlsson 1982: 150, 165). The fourth factor affecting segmental duration is accentuation: a strong, contrastive accent on a word increases segmental durations within the word by 28 % on average in comparison to a weaker, thematic accent or lack of accent (Suomi & Ylitalo 2003: 37). In relation to this, Iivonen (1974: 401; 1974b: 144) has shown that the durations of sounds decrease when the word length increases.

There are no restrictions in the occurrence of vowel quantity degrees. Contrastively short and long vowels can occur before and after both contrastively short and long consonants, and vice versa, and the same contrasts exist in stressed and unstressed syllables. The single–double vowel opposition is valid in any syllable, stressed or unstressed, word initially, internally and finally. While all vowel phonemes participate in the quantity opposition, for consonants the situation is more complicated. Consonants occur as single and as double with the exception that the consonants /*v*/, /*j*/ and /*h*/ only occur as single; /*hihhuli*/ '(religious) fanatic' is the only exception to this rule. In certain

dialects these principles are violated, for example in the form /*vajaa*/ [vajjaa] 'undersized'. Secondly, /*d*/ is doubled in length only in recent loanwords, e.g. /*addikti*/ 'addict'. Thus generally there are minimal pairs like /*rapu–rappu*/ 'a crab–a step' and /*laki–lakki*/ 'a law–a cap'. Thirdly, in contrast to vowels, there is no consonant quantity opposition in word initial and final positions; only single consonants can occur in these positions (if not prohibited by further restrictions). Nor is there quantity opposition in consonant sequences, except that the true obstruents /*p*/, /*t*/, /*k*/ and /s/ can occur as single or double after nasals and the liquids /l/ and /*r*/, e.g. /*sanka–sankka*/, /*hirsi–hirssi*/, /*pelkää–pelkkää*/. Here as elsewhere, the double obstruents always straddle a syllable boundary. (Suomi, Toivanen, Ylitalo 2008: 42).

There are altogether three interpretations of Finnish quantity opposition (Karlsson 1969: 354 – 355; Lehtonen 1970: 30–31). The first is Karlsson's (1969: 354–355) identity group interpretation or diphonemic interpretation, where contrastively long segments are interpreted as sequences of two identical phonemes, i.e. as double vowels and consonants, as against contrastively short or single ones (see also Wiik 1965: 41–42). The recent study by Eerola, Savela, Laaksonen & Aaltonen (2012: 315) demonstrates that phoneme prototypes are not dependent on the phonological quantity opposition, and thus the results support the identity group interpretation of Finnish quantity opposition. However, that study was conducted with synthetic vowels and not with natural speech sounds. In support of the identity group interpretation, in the coding of double-stop consonant letters phonological syllable segmentation does not necessarily help in the identification of quantity. For example, there are a few irregularities in marking phonemic quantity at the morphological level, for example at some word boundaries in sentences, the initial consonant of the suffix or initial position of the word will cause lengthening of the first consonant of the following word in its pronunciation /*Tulet* tänne*/). (Lehtonen 2006: 68; Lyytinen et al. 2006: 60.)

The second of the alternative interpretations of quantity opposition is that long segments are considered paradigmatic phonemes in addition to the short ones, i.e. there would be a phoneme /*A*/ in addition to /*a*/, a phoneme /*K*/ in addition to /*k*/, etc. (here long phonemes are symbolized by capital letters) (Karlsson 1969: 353–354). Recently, Suomi (2008) argued against this paradigmatic interpretation. One of the arguments against the paradigmatic interpretation is that all long consonants would have to be ambisyllabic. For example the word /*takka*/ would be phonemically /*taKa*/, with the syllable boundary somewhere inside the /*K*/, since native speaker intuition cannot accept the syllabifications /*ta.Ka*/ and /*taK.a*/, and the word is undeniably disyllabic. If we argue that the first part of /*K*/ belongs to the first syllable and the second part to the second syllable, then the question inevitably arises as to the exact nature of these subparts of a phoneme, and of the boundary between them. If the first syllable is claimed to be /*taK*/, then it would have to be said that the /*K*/ continues to the next syllable. The third interpretation of the opposition is that long segments are interpreted as short phonemes which are followed by chroneme.

(Karlsson 1969: 354; Karlsson 1982: 70–71; Lehiste 1970: 43; Lehtonen 1970: 30–31; Harrikari 2000; Ylinen, Huotilainen & Näätänen, 2005). This view on quantity opposition approaches duration as similar to pitch or intensity, i.e. a supra-segemental feature, something occurring in parallel with segments.

On the phonological level, Finnish vowels have two lengths, although they can be short, half-long, long, and over-long (Wiik 1965: 134). The double vowels are twice as long as the short ones in the same word position (Lehtonen 1970: 33). Wiik (1965: 116) long ago made the observation that vowels are longer in voiced than in voiceless contexts. Suomi (2006: 494–496) also reported that Finnish vowels and consonants have segmentally different duration stages in different positions within a word and that this depends also on accentuation (sentence stress) (see also Lehtonen 1970: 14). Krull, Traunmüller & van Dommelen (2003: 836) suggest in their study that in Finnish the duration of the vowel in adjacent syllables has a much greater effect on the perception of the quantity of a vowel than does the duration of immediately neighboring consonants.

Word final vowels in Finnish are difficult for L2 learners to perceive as long, as has been shown by (Vihanta 1990: 213). Kirmse, Ylinen, Tervaniemi, Vainio, Schröger & Jacobsen (2008: 131) found that Finns have difficulties in discrimination of word final duration if the duration is shortened. The study by Nenonen (2001b) shows that Russian learners may also have difficulties in the production of Finnish word-final long vowels. An L2 learner-produced vowel in this position is shorter than that produced by a native speaker of Finnish. The study by Myers & Hansen (2005: 317) also shows that increase in the duration of formant pattern transitions of vowels increases the probability of their being perceived as long by Finns. In another study, Myers & Hansen (2007: 157, 184) found that Finnish speakers identify the length category of partially voiceless final vowels on the basis of the duration of its voiced portion, so that partial devoicing of a vowel increases the probability of its being identified as short. The study also revealed that ending formants with a voiceless vowel does not influence Finnish listeners' perception of vowel quantity. This thinking is close to that of Turk & Sawusch (1996: 3782), who have found that extracting length information is easier than extracting loudness information, but lengths and loudness are perceived as a unit.

In this point it is necessary to discuss the terminological choices of this study. Above, I have described the complexity of the quantity phenomenon in Finnish, and the different approaches to its definition. This study concentrates on the perception of the phonemic length of both consonants and vowels in different positions in words, pseudo-words and non-words. Special interest is on word or pseudo-word final position, namely on the /*a*/ vowel quantity opposition. The term (phonological) quantity is used when discussing the phenomenon in a wider context or when it is used to refer to the data at hand. The identity group interpretation is used here, as it is the one most commonly accepted by Finnish phoneticians.[4] The term phonemic length was chosen to describe the

[4] In part, we also use the identity group interpretation because it was required by a reviewer (concerning the third study).

perception tasks used in this study, and the term phonetic duration is used only when discussing the phonetic aspects of the phenomenon. Phonemic length was chosen because it was the simplest way to describe the complexity of the phenomenon of interest, especially on the sub-study level, and it combines the phonetic and phonological level of the phenomenon together. There is, however, the difficulty that the term "phonemic" is usually related to the concept of meaning (semantic). This is not the case with the pseudo-words and non-words. However, we also had material consisting of real words and hence, for this reason, the term phonemic length was the best choice. I use also the terms identification of phonemic length and identification of quantity degree. It is therefore important to remember that the purpose of this study is not to call into question the former research on the definitions of quantity. Instead, the choice of the term was mainly a methodological one.

1.4.3 Duration in Russian and phonetic transfer in learning of Finnish

One focus of this study is on the perception of Finnish phonemic length in general, and especially that of word -final /*a*/ in two- and three-syllable items by Russian L2 learners of Finnish. Therefore, the phonological system of Russian has to be considered and discussed.

The phonological system of Russian differs from Finnish in the role of duration (Nenonen 2001a: 16–17; Nenonen et al. 2003: 492; Ylinen et al., 2005: 313). In Russian there is one vowel in every syllable and it forms the nucleus of the syllable. There is variation in vowel quality, especially the vowel [ɑ]. However, Finnish [ɑ] is qualitatively quite similar to Russian [ɑ]. The Russian vowel system has three duration degrees: stressed vowels are longer than unstressed and unstressed vowels have two duration degrees. Thus, word stress determines the duration of sounds. These differences of duration do not differentiate words from each other. (de Silva 1999: 19, 22, 174; Nenonen, Shestakova, Huotilainen & Näätänen, 2005: 28.) Thus, as de Silva (1999: 69, 71, 176) has stated, a Russian L2 learner of Finnish who does not know the phonological system of Finnish may perceive the syllable with a long vowel as a stressed syllable. Words in Finnish and Russian mostly consist of two or three syllables, but syllabic structures in Finnish are simpler than in Russian (Silvén, 2010: 142).

Earlier experiences of learning and language have an effect on the acquisition of a second language (Cook 2001: 9; Sajavaara 1999: 96). The mother tongue or first language of a child has an impact on what is difficult to learn in the second language (Ringbom 2007). For example, foreign or second-language learners of Finnish do not necessarily differentiate short and long durations in spontaneous speech (Lehtonen, 1970: 14). This is generally termed interference in second language studies. Weinreich (1953: 18–19) argued that there are four different types of phonetic interference: 1) under-differentiation of phonemes, which occurs when two sounds of the L2, whose counterparts are not distinguished in the L1, are confused; 2) over-differentiation of phonemes, which means that contrasting sounds of the L1 are treated as members of one pho-

neme in the L2; 3) reinterpretation of distinctions, which occurs when the bilingual distinguishes phonemes in the L2 by features which in that system are merely concomitant or redundant, but which are relevant in the L1; and, finally, 4) phoneme substitution, which applies to phonemes that are identically defined in the two languages but whose normal pronunciation differs.

Wiik (1965: 15–16) has also divided phonetic interference into types. These are: 1) physical differences between the languages, where one of the two languages has a particular sound which the other one lacks; 2) relational differences, where both languages contain the same sounds, but these sounds are classified differently in the two systems; 3) distributional differences, where both languages have the same sound, but these are restricted to different environments; and 4) segmental differences, where similar combinations of segmental items co-occur in both languages, but the stretch is not divided in the same manner in those languages.

Phonetic interference between Finnish and Russian in phonemic length involves Weinreich's type 1 (under-differentiation) and Wiik's types 2, 3 and 4 (relational, distributional and segmental differences). It also involves Wiik's type 1 (physical differences), if it is a matter of the monophonemic interpretation of long phonemes.

The term interference, used by Weinreich and Wiik, is nowadays considered by many bilinguals to be a negative and pejorative term, as it suggests is the presence of a problem when a bilingual uses language. It is for this reason that the terms transfer and cross-linguistic influence are preferred. (Baker 2007: 110). In light of this thinking, the terms transfer and cross-linguistic influence are mainly used to describe the phenomena involved in the acquisition of phonemic length by Russian L2 learners of Finnish.

1.4.4 General outline of studies of Finnish quantity

Careful research in library web-pages and on the Internet revealed a total of 66 articles and dissertations which address Finnish phonological quantity in one way or another. Table 1 describes these studies in chronological order. Master's theses and conference presentations were excluded from the list.

Various theoretical phonetic and phonological aspects of the phenomenon are the main topics in these studies. The present study differs in this respect from these other studies, as theoretical phonetic or phonological problem setting is not its main focus. Of the 66 studies, 15 studies address the difficulty of Finnish quantity or duration among children with familial risk for dyslexia and/or with reading disabilities, and with dyslexic adults. I return to these studies and describe them in more detail in section 1.6.4, in connection with the JLD project.

In addition to the above-mentioned 15 studies, two quantity studies focus on the spelling development of Finnish children. The first is by Lehtonen (2006), who studied the ways in which 1st grade children use orthographic, phonological, and morphological information in spelling double consonants (geminates). The results showed that school beginners were able to utilize orthographic in-

formation in spelling, whereas the phonological aspects of spelling rules were acquired only later on. The use of morphological information began to emerge as well. As a result, children seem to use multiple kinds of information in spelling from very early on. (Lehtonen 2006: 63.) The other study, by Pekonen (2007), is on the learning of spelling among Finnish children in terms of length marking. The results revealed that the differences between the scores for single and double phonemes were all statistically significant in all the pseudo-word positions, meaning specifically that children made more errors in marking long quantity correctly than in marking single consonants correctly. He also argued from the theoretical point of view that quantity is best described by means of autosegmental phonology. (Pekonen 2007: 6, 145, 149.) These studies show that the spelling of phonemic length is a skill which develops through time and is also challenging for normally developing children. However they learn to mark the correct length through the overall development of spelling skills.

Another 16 studies or articles addressed Finnish quantity and second-language learning or compared of quantity in Finnish with that in some other language structure. Eight of them relate closely to the study at hand. I discuss five in this section and three in section 1.6.6, where I focus on comparisons and studies of quantity between Russian and Finnish.

One of the five above-mentioned studies was authored by Kirmse et al. (2008: 131), who compared the pre-attentive processing of vowel duration in the pseudo-word /*sasa*/ between Finnish and German participants by measuring mismatch negativity (MMN), a brain response reflecting discrimination accuracy. In both language groups, diminished MMN amplitudes for the shortening of vowel duration in the word-final syllable suggested generally more difficulty in the discrimination of vowel duration in word-final position. The results also suggested that the Finnish language group had a generally higher sensitivity to duration contrasts due to the phonological quantity distinction in their native language. However, this study reveals cross-language difficulty in the perception of a word-final vowel.

The study by Ylinen, Uther, Latvala, Vepsäläinen, Iverson, Akahane-Yamada and Näätänen (2010: 1319) also concerns Finnish phonological quantity. They conducted a phonetic intervention study with Finnish learners of English vowels and investigated the impact of quantity on the perception and learning of the English vowels /*i*/ and /*I*/. After training, the Finns were able to use the spectral cues of the vowels more reliably than before the intervention, and correspondingly, relied less on duration and L1 quantity categorization. The MMN brain responses revealed that the training had enhanced the Finns' ability to pre-attentively process the spectral cues of the English vowels.

The studies of most relevance for the purposes of this dissertation are those by Heeren. Interestingly, these three studies bear a close thematic relation to studies three and four of this dissertation. She reports on the possible effects of quantity training with L2 learners of Finnish. In her dissertation (2006) she conducted a training study to find out how perceptual sensitivity develops along a dimension that contrasts two unknown speech sounds, and whether

perceptual development varies with the learner's age. In part, the study concerned training in the Finnish /*t–tt*/ contrast with Dutch adults and 12-year-old children. The increase in perceptual sensitivity near the boundaries of the learned phoneme remained small and did not develop into native-like discrimination peaks. The 12-year-old children and adults learned to perceive non-native phoneme contrasts in similar ways. (Heeren 2006: abstract, 71.)

In another article, Heeren & Schouten (2008: 2291, 2299) reported on a training study with adult Dutch learners of Finnish. They studied the development of perceptual sensitivity along an acoustic continuum between two non-native phoneme categories /*t–tt*/ (*ata–atta*). Phoneme continua from six different speakers were produced in three steps. The stimuli were constructed by shortening the closure of the stop consonant. The Dutch participants were trained using a pre-test-training-posttest design in a laboratory setting. The results showed that the typical discrimination peak in perceptual sensitivity shown by native listeners near a phoneme boundary was not found in the Dutch L2 learners after short-term training. However, small increases in perceptual sensitivity near the category boundary were found, as well as decreases in perception within the category.

Heeren & Schouten (2010) also conducted the same study with 12-year-old Dutch children using same stimuli as in the study with adults. The training was carried out in schools with laptops and headphones. The training was delivered in five sessions, each lasting about 15 minutes. The children were tested individually before and one day after the final training session. The test included identification and discrimination tasks. The short-term training resulted in relatively fast progress on the identification of the trained categories. Changes in perceptual sensitivity remained small and did not show difference between the children and adults, although the latter showed higher discrimination scores than the children. The authors also state that native-like identification as a result of training does not necessarily reflect native-like use of phoneme categories. (Heeren & Schouten 2010: 594, 596, 597, 601, 602.)

TABLE 1 Articles and Dissertations of Finnish Phonological Quantity in Chronological Order

Author(s)	Name of the study	Year	Main focus
Lehiste	The function of quantity in Finnish and Estonian	1965	Comparison of the quantity systems of Finnish and Estonian.
Wiik	Finnish and English vowels. A comparison with special reference to the learning problems met by native speakers of Finnish learning English	1965	Comparison of the Finnish and British English pronunciation. Describes also the identity group interpretation of phonological quantity.
Karlsson	Suomen yleiskielen segmentaalifoneemien paradigma	1969	Describes the paradigm of Finnish segmental phonemes and the three interpretations of phonological quantity.
Lehtonen	Huomioita kvantiteettien foneemirajoista ja subjektiivisista kestohavainnoista	1969	Describes observations of phoneme boundaries and of subjective duration perception of Finnish students. The discrimination of students is more accurate at phoneme boundaries than within quantity classes.
Lehtonen	Aspect of quantity in standard Finnish	1970	Illustrates durational patterns of standard Finnish produced by Finnish students. Results reveal among other things that the length of a word does not have an effect on its sound segments in the context of sentences.
Iivonen	Äännekeston riippuvuus ilmauksen pituudesta	1974	Demonstrates that sentence length has an effect on the duration of sounds in Finnish.
Iivonen	Äännekeston riippuvuus sanan pituudesta irrallaan äännetyissä sanoissa	1974	Describes how durations of sounds decrease as word length increases in Finnish.
Lehtonen	Sanan pituus ja äännekestot	1974	Repeats the results of his dissertation (1970).
Suomi	Voicing in English and Finnish stops	1980	Finns learning English have difficulty not with stops alone,

(continues)

Table 1 (continues)

			but also with other phonetic aspects of the distinction. The difficulty is not predicted by contrastive phonological analysis alone. Complexity of phonetic features and other contextual factors should also be considered.
Hurme & Sonninen	Normaalikuuloisten lasten ja aikuisten sekä kuulovammaisten lasten tuottamien KVKV- ja KVKKV-sanojen kestohahmoista	1982	Only about 30% of the 2- to 4-year-old children and about 80% of the 5- to 6-year-old children produced a statistically significant duration difference in the medial consonants of CVC and CVCV words in a picture-naming task.
Hurme & Sonninen	Development of durational patterns in Finnish CVCV and CVCCV words	1985	About 70-90% of the 3-year-old children and 90-100% of the 6-year-old children were able to make the quantity distinction.
Vihanta	Suomi vieraana kielenä foneettiselta kannalta	1990	Concludes that the pronunciation of Finnish is not easier than the pronunciation of other languages.
Lyytinen, Leinonen, Nikula, Aro & Leiwo	In search of the core features of dyslexia: Observations concerning dyslexia in the highly orthographically regular Finnish language	1995	Discusses three strategies used to search for the core features of dyslexia, and introduces, among other errors, quantity reading and spelling errors made by adults with dyslexia in the JLD data.
Richardson	Kvantiteetin havaitseminen aikuisilla ja kuuden kuukauden ikäisillä lapsilla	1996	Preliminary results of dissertation published in the year 1998.
Lyytinen	In search of precursors of dyslexia	1997	Describes, among other things, how the quantity opposition is difficult for adult dyslexics.
Pihko, Leppäsaari, Leppänen, Richardson & Lyytinen	Auditory event-related potentials (ERP) reflect temporal changes in speech stimuli	1997	Study with adult Finns on perception of stop consonants. The study shows how ERPs reflect changes in speech stimuli.
Harrikari	Length in Finnish - an OT phonology assessment : two studies	1998	Focus on epenthesis as evidence of geminate integrity in Finnish.

(continues)

Table 1 (continues)

Iivonen	Suomen ja saksan vokaalien laadun ja keston vertailua	1998	Comparison between German and Finnish in vowel quality and duration.
Niemi	Modularity of Prosody: Autonomy of Phonological Quantity and Intonation in Aphasia	1998	The Finnish language is used to enrich conception of the dysprosody hypothesis of the output in Broca's agrammatism, i.e., of the claim that agrammatic speech is characterized by aberrant timing and intonation patterns, in a study with aphasics.
Richardson	Familial dyslexia and sound duration in the quantity distinctions of Finnish infants and adults	1998	Studies the role of duration categorization of speech sounds into distinct phonemes by dyslexic adults and their infants with or without familial risk for dyslexia. At-risk infants and dyslexic adults needed significantly longer duration to perceive the length as long compared to controls. They had also difficulties with the secondary cue in a production task using durational cues.
Pihko, Leppänen, Eklund, Cheour, Guttorm & Lyytinen	Cortical responses of infants with and without a genetic risk for dyslexia: I. Age effects	1999	Study with newborns and six-month-old infants with and without familial risk for dyslexia. The groups differed from each other in their responses to the standard /*kaa*/ stimulus compared to deviant /*ka*/ stimulus at the age of six months. The results suggest differences in brain activation patterns between the groups.
Leppänen, Pihko, Eklund & Lyytinen	Cortical responses of infants with and without a genetic risk for dyslexia: II. Group effects	1999	The stimulus presentation rate was slower than in the former study. The ERPs to the deviant /*ka*/ were different from those to the standard /*kaa*/ stimulus already in newborns. In addition, clear group differences in ERPs were found. Infants born with a high familial risk for dyslexia processed speech/auditory stimulus durations differently from control infants at birth.

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Leppänen	Tulella ja tuulella on eroa jo varhain: Vauvoilla, joilla on riski suvussa esiintyvään lukihäiriöön, on eroja aivojen sähköisissä reaktioissa puheärsykkeisiin	1999	Reveals that newborns with familial risk for dyslexia have different responses to quantity opposition.
Richardson	Perinnöllinen dysleksia ja äänteiden kesto kvantiteettieroissa suomalaisilla pikkulapsilla ja aikuisilla	1999	Presentation preceding he dissertation defense (1998).
de Silva	Quantity and Quality as Universal and Specific Features of Sound Systems – Experimental Phonetic Research on Interaction of Russian and Finnish Sound Systems	1999	The study concentrates on pronunciation differences on the word level between Russian and Finnish adults. Interference from Finnish leads to two duration degrees among the Finnish L2 learners of Russian: very long and very short. The study also shows the importance of teaching phonetics to second or foreign language learners.
Harrikari	Segmental length in Finnish – Studies within a constraint-based approach	2000	Theoretical study of Finnish phonological segmental length by using the Optimality Theory developed in the field of generative phonology. Shows evidence for the use of monosegmental interpretation of length in Finnish dialects.
Kunnari	Characteristics of early lexical and phonological development in children acquiring Finnish	2000	Systematic phonological survey of the earliest (already before the age of two years) words of Finnish children. Children produce a wide range of medial consonants throughout the one-word period.
Aoyama	A psycholinguistic perspective on Finnish and Japanese prosody: Perception, production, and child acquisition of consonantal quantity distinctions	2001	A series of psycholinguistic investigations on consonantal distinctions in Finnish and Japanese. Description of differences in adult production, perception, and child acquisition of these distinctions. Finnish children distinguish /*n*/ and /*nn*/ at three years of age, whereas Japanese children do not.

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Kunnari, Nakai & Vihman	Cross-linguistic evidence for the acquisition of geminates	2001	Preliminary results seem to suggest that Finnish children begin to distinguish singleton vs. geminate stops in production by the end of the one-word period, possibly even early in this period, whereas Japanese children do not reliably distinguish them even at the end of the one-word period.
Nenonen	Venäläiset suomenoppijat suomen kielen pitkien painottomien vokaalien havaitsijoina	2001a	Studies the perception of vowel length by Russian school-aged children learning Finnish. The native language, word structure, and task type have effects on their perception of vowel length. A long stressed vowel disturbs the perception of length, and a geminate has an effect on the perception of a long vowel following the consonant. This is because the geminate violates the L1 word structure of learners.
Richardson, Haukkamäki, & Leiwo	Lukivaikeudet ja suomen pituuden hahmottaminen ja merkitseminen	2001	Describes the difficulties of Finnish language (also quantity) for dyslexic and infants with familial risk for dyslexia.
Leppänen, Richardson, Pihko, Eklund, Guttorm, Aro & Lyytinen	Brain responses to changes in speech sound durations differ between infants with and without familial risk for dyslexia	2002	Report on differences between 6-month-old infants with and without a high risk for familial dyslexia in brain electrical activation generated by changes in the temporal structure of speech sounds (consonant duration changes).
Lyytinen, Leppänen, Richardson & Guttorm	Brain functions and speech perception in infants at risk for dyslexia	2003	Summary of the results of previous behavioral and ERP studies in the JLD assessing speech sound responses.
O'Dell	Intrinsic timing and quantity in Finnish	2003	The study concentrates on the contradiction between in-

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			trinsic timing and quantity.
Richardson, Leppänen, Leiwo & Lyytinen	Speech perception of infants with high family risk for dyslexia differ at the age of six months	2003	Article on speech perception results of dissertation (1998).
Suomi & Ylitalo	Durational and tonal correlates of accent in Finnish	2003	Study that explicitly distinguishes the phonetic correlates of sentence accent from those of word stress in Finnish. The timing of f0 movements is dependent on the moraic structure of the target words. The finding seems to be connected with the typologically rare combination of stress (or rhythmic) and quantity systems in Finnish.
Isei-Jaakkola	Lexical quantity in Japanese and Finnish	2004	Study of the similarities and differences in lexical quantity in Japanese and Finnish.
Suomi & Ylitalo	On durational correlates of word stress in Finnish	2004	Segments and syllables have a reliably longer duration when they occur within the word's first two morae than when they occur outside this domain. If the second-syllable single vowel constitutes the word's second mora, its duration is very much longer than otherwise. Secondary stress is shown to involve a similar although attenuated durational variation in the second-syllable vowel of the word's second foot. A voiced consonant is lengthened when it constitutes the word's second mora. The motivation for this second-mora lengthening is to provide room for the phonetic realization of accentuation.
Suomi	Moraic Patterns in Finnish prosody and lexicon	2004	Description of moraic patterns in Finnish.
Karvonen	Word prosody in Finnish	2005	Studies the interplay of rhythmic, weight-based, and morphological factors on surface stress in Finnish. Quantity

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			sensitivity is part of the research.
Myers & Hansen	The origin of vowel-length neutralization in vocoid sequences: evidence from Finnish speakers	2005	Studies vowel-length neutralization in which a vowel after a vocoid must be long. This arises from the inherent acoustic ambiguity of such sequences, which are realized with a diphthongal transition from one formant pattern to the next, with no clear boundary between the two. Neutralization in vocoid sequences originates from listeners' difficulties in determining the duration of vowels in this context. Lengthening of the second vocoid arises when listeners attribute some of the transition duration to that segment. A production study with Finns shows that speakers treat the transition as belonging in part to the realization of the postvocoid vowel. Two perception studies show that increasing the duration of the transition increases the probability of such a vowel being identified as long.
Suomi	Temporal conspiracies for a tonal end: segmental durations and accentual f0 movement in a quantity language	2005	Study of interaction between segment durations and the tonal manifestation of accent in Finnish. Accentual lengthening affected all segments in the target words reliably, but the lengthening was highly nonlinear. The word's first two morae were extensively lengthened, other segments less. In some positions, the extent of lengthening seemed to be constrained by a need to maintain the quantity opposition.
Suomi	Suomen kielen prominenssien foneettisesta toteutumisesta	2005	Research on Finnish prominence from the phonetic point of view. Quantity opposition is a part of this description.
Heeren	Perceptual development of phoneme contrasts in adults and children	2006	A training study on how perceptual sensitivity develops along a dimension that contrasts two unknown speech

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			sounds, and whether perceptual development varies with the learner's age. Part of the study concerned the training of the Finnish /*t*–*tt*/ contrast. The increases in perceptual sensitivity near the learned phoneme boundaries remained small and did not develop into native-like discrimination peaks. It was shown that 12-year-old children and adults learn to perceive non-native phoneme contrasts in similar ways.
Lehtonen	Sources of information children use in learning to spell: The case of Finnish Geminates	2006	Investigation of the ways in which children use orthographic, phonological and morphological information in spelling double consonants (geminates) in Finnish. Children just starting school are able to use orthographic information in spelling. Phonological aspects of spelling rules are acquired later on. During the first school year the use of morphological information began to emerge.
Suomi	Suomen segmenttikestojen määräytymisestä	2006	Concentrates on changes in segmental duration during the production of Finnish.
Ylinen	Cortical representations for phonological quantity	2006	Study of cortical representations of phonological quantity in native speakers and Russian L2 users of Finnish using behavioral and electrophysiological methods. The Finns MMN response was enhanced by native-language prototypes. The duration of the MMN response of L2 learners was native-like only for a L2 vowel dissimilar to L1. Establishment of representations of L2 quantity may require several years of language exposure.
Myers & Hansen	The origin of vowel length neutralization in final position: Evidence from Finnish speakers	2007	Studies the phonological pattern of final vowel shortening at the end of an utterance. Partial devoicing of the final vowel makes it difficult to hear the end of the vowel and thus favors identification of final vowels as short. When

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			language learners generalize such an identification pattern, they have adopted a final shortening pattern. The experiments with Finns establish that there is both final lengthening and final devoicing in the language. Finnish speakers identify the length category of partially voiceless final vowels on the basis of the duration of the voiced portion, so that partial devoicing of a vowel increases the probability of its being identified as short.
Pekonen	Suomen kvantiteetti ja kirjoitusprosessi: Mallinnusta ja empiriaa	2007	Studies learning of the spelling of length among Finnish children with 28 pseudo-words. The differences between single and double phonemes were all statistically significant in all the pseudo-word positions. Quantity is best described by reference to autosegmental phonology.
Suomi	On the tonal and temporal domains of accent in Finnish	2007	The study focused the temporal and tonal domains of accent in Finnish. The results show that in Finnish segment durations are adjusted to achieve a temporally and tonally uniform realization of accent.
Heeren & Schouten	Perceptual development of phoneme contrasts: How sensitivity changes along acoustic dimensions that contrast phoneme categories	2008	Focuses on the typical peak in perceptual sensitivity near a phoneme boundary in an acoustic dimension that contrasts two non-native speech sounds. The study shows that the typical peak in perceptual sensitivity near a phoneme boundary that native listeners show is not found in relatively inexperienced language learners, despite their ability to classify a continuum in a native-like way after short-term laboratory training. A discrimination peak may be achieved by language learners, but only after much more language experience than short-term laboratory training can offer.

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Kirmse, Ylinen, Tervaniemi, Vainio, Schröger & Jacobsen	Modulation of the mismatch negativity (MMN) to vowel duration changes in native speakers of Finnish and German as a result of language experience	2008	Investigates the pre-attentive processing of vowel duration in a pseudo-word, /*sasa*/, in Finns and Germans with MMN. In both language groups, diminished MMN amplitudes for the shortening of vowel duration in the word-final syllable suggested a generally more difficult discrimination of vowel duration in the word-final position. Results suggest a generally higher sensitivity to duration contrasts in the Finnish language group.
Suomi	Suomen kvantiteettiopposition fonologisesta tulkinnasta	2008	Discusses the paradigmatic and identity group interpretation of quantity, and defends the identity group interpretation.
Suomi, Toivanen & Ylitalo	On the phonological interpretation of the quantity opposition	2008	Discusses the paradigmatic and identity group interpretation of quantity, and defends the identity group interpretation.
Takegata, Tervaniemi, Alku, Ylinen & Näätänen	Parameter-specific modulation of the mismatch negativity to duration decrement and increment: Evidence for asymmetric processes	2008	The study investigates whether stimulus parameters (sound type and vowel duration) exert a differential influence on the MMN for a duration decrement and increment of an equal magnitude among Finnish adults. ERPs were recorded in16 healthy adults presented with repetitive standard sounds interspersed with duration changes (deviants). The interactions demonstrated asymmetries in the MMN for duration increment and decrement.
Hämäläinen, Leppänen, Eklund, Thomson, Richardson, Guttorm, Witton, Poikkeus,	Common variance in amplitude envelope perception tasks and their impact on phoneme duration perception and reading and spelling in Finnish children with reading disabilities	2009	The study of auditory and speech perception abilities of 9-year-old Finnish children with and without reading disabilities, and association between auditory, speech perception, reading, and spelling skills. The results showed, among other things, group differences in phoneme duration discrimination (phonemic length).

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Goswami& Lyytinen			
Nakai, Kunnari, Turk, Suomi & Ylitalo	Utterance-final lengthening and quantity in Northern Finnish	2009	Studies utterance-final lengthening in Northern Finnish with particular focus on its interaction with the language's single vs. double vowel distinction. It seems that Finnish regulates utterance-final lengthening to preserve its quantity system. Specifically, the voiced portion (the portion that is relevant to the perception of vowel quantity) of the longest single vowel (the half-long vowel) was restricted. Double vowels were lengthened less when the vowel in an adjacent syllable was double. Utterance-final lengthening is a universal tendency but must be learned in each language.
Suomi	Durational elasticity for accentual purposes in Northern Finnish	2009	The study examines the elastic behavior of segment durations in Northern Finnish. The locus of duration-to-tone adjustment tends to have constant duration across different word structures, and it ensures the tonally and temporally uniform realization of accent. This characteristic seems to distinguish Northern Finnish from many other languages.
Heeren & Schouten	Perceptual development of the Finnish /t-t:/ distinction in Dutch 12-year-old children: A training study	2010	Studies the development of perceptual sensitivity in child L2 learners along an acoustic dimension that contrasts two non-native speech sounds, and compares their language learning to that of adult learners. Both adult and 12-year-old Dutch learners of Finnish increased their sensitivity in the newly trained category boundary region, but the changes remained small. Although the manner and speed of learning were comparable between age groups, adults

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			showed higher discrimination scores than children.
Leppänen, Hämäläinen, Salminen, Eklund, Guttorm, Lohvansuu, Puolakanaho & Lyytinen	Newborn brain event-related potentials revealing atypical processing of sound frequency and the subsequent association with later literacy skills in children with familial dyslexia	2010	Use of ERPs to investigate the pitch processing of dyslexic children with familial risk background as newborns and relates the ERPs later to these same children's pre-reading cognitive skills and literacy outcomes. Newborn ERPs reflecting passive change detection were associated with phonological skills and letter knowledge prior to school age, and with phoneme duration perception, reading fluency and spelling accuracy in the 2nd grade. Results suggest that a proportion of dyslexic readers with familial risk background are affected by atypical auditory processing.
Järvikivi, Vainio & Aalto	Real-Time Correlates of Phonological Quantity Reveal Unity of Tonal and Non-Tonal Languages	2010	The study suggests that there is no unidirectional causal link from perceptual sensitivity towards pitch information to the appearance of a tone language. The contrastive categories of tone and quantity may be based on simultaneously co-varying properties of the speech signal and the processing system, even though the conscious experience of the speakers may highlight only one discrete variable at a time.
Vainio, Järvikivi, Aalto & Suni	Phonetic tone signals quantity and word structure	2010	The structure of disyllabic word stems in Finnish are signaled tonally and the phonological length of the stressed syllable is further tonally distinguished within the disyllabic sequence. The results indicate that the observed association of tone and duration in perception is systematically exploited in speech production in Finnish.
Ylinen, Uther, Latvala, Vepsäläinen,	Training the brain to weight speech cues differently: A study of Finnish second-language users of English	2010	Studies whether the non-native-like cue weighting could be changed by using phonetic training with Finnish learners of English. The Finns relied more on duration in vowel

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Iverson, Akahane-Yamada & Näätänen			recognition than the native English speakers before the training. After the training the Finns were able to use the spectral cues of the vowels more reliably than before. The MMN brain responses revealed that the training had enhanced the Finns' ability to pre-attentively process the spectral cues of the English vowels.
Eerola, Savela, Laaksonen & Aaltonen	The effect of duration on vowel categorization and perceptual prototypes in a quantity language	2012	Studies the identity group interpretation of the quantity opposition in Finnish with categorization task with synthesized stimuli. Large individual variation was found in the categorization. The results suggest that quantity does not affect the category formation between /*y*/ and /*i*/. The results suggest that phoneme prototypes are not demonstrably dependent on the phonological quantity opposition, and are in accordance with the identity group interpretation of Finnish quantity opposition.
Leppänen, Hämäläinen, Guttorm, Eklund, Salminen, Tanskanen, Torppa, Puolakanaho, Richardson, Pennala, Lyytinen	Infant brain responses associated with reading-related skills before school and at school age	2012	The study investigates neurocognitive processes related to phonology and other risk factors for later reading problems. The findings suggest persisting developmental differences in the organization of the neural networks subserving auditory and speech perception, with cascading effects on later reading-related skills in children with familial background for dyslexia. Atypical auditory/speech processing is not likely to be a sufficient reason for dyslexia but rather one endophenotype or risk factor.
Nakai, Turk, Suomi, Granlund, Ylitalo	Quantity and constraints on the temporal implementation of phrasal prosody in Northern Finnish	2012	The study investigated interactions between vowel quantity and two types of prosodic lengthening (accentual lengthening and the combined effect of accentual and ut-

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& Kunnari	terance-final lengthening) in disyllabic words in Northern Finnish. In both types of prosodic lengthening, vowels were lengthened less when they were next to a syllable containing a double vowel than when they were next to a syllable containing a single vowel. A durational ceiling effect was observed for the phonologically single, half-long vowel under the combined effect of accentual and utterance-final lengthening. The findings support the view that quantity languages regulate the non-phonemic use of duration because of the high functional load of duration at the phonemic level. The combined effect of accentual and utterance-final lengthening appeared to have its own lengthening profile.

1.5 Phonological processing and awareness

Quantity is a phonological phenomenon, and therefore the phonological aspects of the perception and learning of quantity and phonemic length should be considered in this study. Phonological processing and awareness are also common processes for native Finnish children with reading disabilities and for L2 learners, like for all language learners, so the mechanisms behind them and the effects of the language structures are linked to the phonological aspects of perception and learning quantity and phonemic length.

The main concept behind phonological processing and awareness is metalinguistic awareness. Metalinguistic awareness means the ability to think about language as an object, and it includes the abilities to identify, analyze, and manipulate language forms. Metalinguistic awareness develops gradually during childhood (Menn & Stoel-Gammon 1995: 349). It is crucial in learning to read because reading is fundamentally a metalinguistic activity. (Koda, 2007: 220.) Metalinguistic awareness is also crucial for L2 learners, because they do not have to relearn the fundamentals of language structure. They have this knowledge from the acquisition of their first language. On the other hand, there are views according to which reading in a second language depends on L2 and not L1 proficiency. In addition, children can also learn to read first in their second language. (Baker 2007: 156, 331, 332.)

Phonological processing is considered to refer collectively to all psycholinguistic aspects of the processing of speech-based information, including perception, phonological awareness, short-term and long-term memory, and naming speed. The phonological system of the language learner develops in interaction with perception and production. (Richardson 1993: 42.) Phonological awareness is a by-product of a child's growing understanding of the structure of spoken sounds and this awareness precedes and supports the task of linking speech and graphic symbols in the initial development of literacy (Koda 2007: 219, 231). Phonemic awareness is a fine-grained version of phonological awareness, with the insight that each spoken word is made up of phonemes (Rice & Brooks 2004: 46.) Visually presented information must be converted into its phonological form in order to be stored and processed efficiently in working memory, and this is a part of reading. (Koda 2007: 224). Problems in phonological awareness are thus crucial risk factor for developmental dyslexia, as was described above in section 1.2.1 (see for example, Vellutino et al. 2004: 3–4; Pennington et al. 2009: 45, 82, 49–57).

Considerable variation exists in the way phonology is represented graphically in typologically diverse languages (Koda 2007: 230–231). Finnish is a shallow, phonemic orthography, and is many ways optimal from the perspective of literacy acquisition (Aro 2004: 14–15). It has been argued that typically developing Finnish children have acquired the phonological system in the age of 5–7 years (Kunnari & Savinainen-Makkonen 2010: 201), maybe partly because of this transparency. Phonemic length is a crucial part of phonological processing

and awareness, but constitutes an exception to this grapheme-phoneme correspondence in pronunciation[5] (Lehtonen 2006: 65) because of its surpasegmental nature. L2 input and processing experience also seem to have a primary impact on learners' developing phonological awareness and decoding competence, but L1 influence has continuing importance as well. (Koda 2007: 235.)

There is a developing cross-language consensus that before literacy phonological forms are constructed in the mind as larger unit representations, not just as single phonemes. For example, the psycholinguistic grain-size theory (PGST) assumes that there is a general developmental progression in phonological representation and in all languages pressure for segmental specificity as more vocabulary items are acquired. The sequence of phonological development seems to depend largely on speech perceptual and language acquisition factors, which seem to be similar across orthographies. There are at least three sources of evidence that the sequence of phonological development is language-universal before literacy. In studies with identical tasks and children at the same developmental stage, evidence has been found in a) cross-language studies, b) studies in single languages, and c) studies looking for cross-language differences in phonological development on the basis of contrasting phonological structure. (Goswami 2006: 464.)

The PGST argues that before literacy, phonological restructuring occurs largely at the word, syllable, and onset-rime level. (Goswami 2006: 464.) The PGST predicts that the beginning reading system will experience dual pressure: functional pressure towards smaller units (graphemes), and linguistic pressure towards bigger units that are phonologically more accessible. However, developing high-quality phonological representations at small grain sizes (phonemes) will be the key factor in successful reading acquisition in all alphabetic languages, because the small grain sizes map onto graphemes. The PGST predicts that the ease with which reading acquisition and phonemic restructuring are accomplished varies with a) the phonological structure of the spoken language, and b) the consistency with which the orthography of that language represents phoneme-level information. Phonemic awareness skills seem to develop more rapidly in children learning consistent orthographies. (Goswami 2006: 470, 471, 478.) (See also Ziegler & Goswami 2005: 19–20.) (On phonological problems in dyslexics, see Metsala, Brown & Stanovich 1998.)

Close to this thinking is the "radical" templatic theory of phonology. It proposes that a limited number of specific, actual word shapes are the first steps in phonological learning. After acquiring one or a small number of phonological templates, the child develops a wider variety of these. They are based on input experience with adults and with babbling patterns. At the same time, children induce a range of other phonological categories and structures from the known word shapes in phonology. As a result an adult template-based model of phonological representations is developed (Vihman & Croft 2007: 683,

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Ikola (2000: 19–20) has introduced six other less common cases in Finnish where orthography differs from pronunciation.

686.) Menn & Stoel-Gammon (1995: 345) have also argued that children's earliest phonological units appear to be whole words.

These theories may be more appropriate in languages where the grapheme-phoneme correspondence is not as straightforward as it is in Finnish, for example in English. However, as quantity is a suprasegmental feature involving syllables or whole words or even sentences, these theories may be appropriate for probing the complexity of the phenomenon.

1.6 Speech perception

1.6.1 Theories of perception of speech sounds

Speech perception and theories related to this phenomenon form the main larger theoretical background of this study. In this section, some of the main views are briefly introduced.

The fundamentals of speech perception lie in psychoacoustics (sensory resolution and auditory categorization) (Pardo & Remez 2006: 201). Speech perception is also a highly context-dependent phenomenon, and linguistic experience affects perception processes (Pisoni, Lively & Logan 1994: 156–157). For more than half a century scholars have studied the comprehension of spoken language. There have been two research domains of interest: speech perception and spoken word recognition. The former has focused on processes that operate to decode speech sounds regardless of whether the sounds comprise words, and the latter has concentrated on spoken word recognition. (For a review, see Samuel 2011: 49, 62, 68.)

In the beginning of speech perception studies, the focus was on two observed phenomena: categorical perception and right ear advantage. (For a review, see Samuel 2011: 50.) Categorical perception of speech is based on the findings of Liberman, Harris, Hoffman & Griffith (1957: 367), who suggested that consonants in vowel contexts were perceived categorically, but not when they were presented in isolation. This led to the suggestion that – since vowel-consonant combinations are considered to be speech and isolated consonants as noise – the perception of speech is different from the perception of sounds in general, i.e. the speech-is-special hypothesis.

Categorical perception formulations can be divided into two schools of thinking. First, some results pointed strongly towards considering categorical perception as an innate property in humans (Eimas, Siqueland, Jusczyk & Vigorito 1971: 306; Kuhl & Miller 1975: 71–72). According to Kuhl (1979: 1668), infants are born with certain categorization abilities (e.g. the acoustic vowel space), which carry the characteristics of potentially all the vowel systems of all languages. However, Kuhl and colleagues (1992) have also demonstrated how the perceptual system is altered by learning, i.e. how mother tongue input affects categorical perception. Logan, Lively and Pisoni (1991: 881–882), in turn, proposed that the effect of categorical perception is a result of learning.

In the categorical perception and right-ear advantage studies, syllables were used in which a particular acoustic variable was varied so that the syllable at one end of the continuum was heard in one way, and at the other end in a different way (/*ba*/ and /*pa*/, Liberman, Cooper, Shankweiler & Studdert-Kennedy 1967: 431– 433; Samuel, 2011: 50). The categorical tendency was strongest for stop consonants, weaker for other consonants, and weak for vowels. Based on the finding that listening showed a reporting advantage for speech played to the right ear, Liberman et al. (1967: 431, 454–455) proposed the existence of a special processor of speech sounds, different from the neural mechanisms which were related in perceiving other sounds. This processor was designed to extract the speaker's intended gestures that were used to produce speech. This approach was called *the Motor Theory* of speech perception (Liberman et al. 1967; Liberman and Mattingly 1985; for a review, see Samuel 2011: 51).

Trading relations was one phenomenon which supported the Motor Theory. Many studies reported these relations among multiple acoustic cues that could be accounted for as deriving from the same motor commands. Former studies had shown that place information can be provided by both the special distribution of the burst at the onset of a consonant and by the patterns of formant transitions of the consonant into the following vowel. (for a review, see Samuel 2011: 51.) The concept of *coarticulation* was also closely linked to the Motor Theory, and Mann & Repp (1981: 548) studied this phenomenon in their laboratory. Early speech perception research had revealed that vowels and consonants were not produced independently of the sounds around them, but that these segments were co-articulated, and this was a major source of acoustic-phonetic variation. Another theoretical phenomenon supporting the Motor Theory was *duplex perception* (Rand 1974). This occurred when a synthetic syllable was broken into two pieces and each piece was presented to one ear. The transitions were simultaneously producing a non-speech and a speech percept, consistent with the notion that two different processors were using this input – one for speech and one for other sounds. (For a review, see Samuel 2011: 51.)

An alternative view of the Motor Theory was created by Fowler and Rosenblum (1990: 742). They developed a non-speech version of the duplex theory. The theoretical perspective of Fowler was *the Direct Realist* view, which was closely associated with the thinking of Gibson (1966). Direct Realism argued for a more straightforward object of perception, namely that the perceptual primitives are the articulatory gestures and not merely the intentions (or motor patterns) governing the movements. In contrast to the Motor theory, the Direct Realist view regarded speech as less special, since the mechanisms of perception are thought of as being common to both all modalities and all species. Direct Realism argues that speech acquisition does not involve linguistic information, but instead, the input that a mother tongue acquirer receives is gestural and nonlinguistic (Hawkins 1998).

The next step in the research of speech perception theories was auditory theories. The background for this came from Fowler & Rosenblum (1990). *The*

General Auditory approach proposes that speech sounds are perceived with the same mechanisms that are used in the perception of sounds more generally. In this view, there is no role for gestures in speech perception—speech is just another (important) environmental sound that maps onto whatever the representations are for sounds in general. (Diehl, Lotto & Holt 2004: 154–155.) The perceptual magnet effect (PME) developed by Kuhl (1979: 1668; Kuhl et al. 1992) and first applied to speech sound stimuli (voice onset time, VOT) in syllable initial plosives by Samuel (1982) is based on the principle that the most often occurring category members eventually form centers which are considered to be the most prototypical representatives of the category. The most important aspect of these centers or prototypes is that they function as magnets pulling the other members of the category towards the center and thus inhibiting the discrimination between sounds near the prototype. This distortion of acoustic linearity is referred to as the perceptual magnet effect, which is part of Kuhl's *Native language magnet theory* (NLM). The further a category member is from the prototype, the easier it is to discriminate from the other category members. Consequently, as the category members become more distant from the center, the magnets lose their grip and eventually another magnet for another category takes hold of the speech sound, thus resulting in a category boundary. Therefore, the boundary effect is merely a consequence of the effect of the central magnet. (Iverson & Kuhl 1995: 561; 1996: 1130; for a review, see Samuel 2011: 53.) There are different views as to what the prototypes actually are. To mention just two Jusczyk (1994: 246) has proposed that the initial prototypes are syllables, and these representations could support phoneme prototype representations. A second way a prototype may be established is that the listener updates the presentation with each input (Goodman, Lee & DeGroot 1994: 24). In conclusion, the perceptual magnet effect model offers an explanation for the human ability to distinguish between good and poor category members and also for the categorical perception effect (Iverson & Kuhl 1995: 561; 1996: 1130; for a review, see Samuel 2011: 53).

The debate on the Motor Theory, Direct Realism and the General Auditory theory in relation to speech perception continues. Galantucci, Fowler & Turvey (2006) includes a discussion of the competing views. The advocates of a motor component in speech perception have in recent years drawn heavily on the discovery of mirror neurons. (For a review, see Samuel 2011: 53–54.)

Finally, I touch on the issue of normalization in speech perception studies. Questions on normalization and invariance have been often addressed in studies concerning speech. Normalization refers to the problems involved when listeners perceive the speech of another speaker. The problems may relate either to the perception of the varying acoustic properties (the fundamental frequency, formant transition, etc.) of the speech within one individual (Verbugge & Rakerd 1986 54–55; Nearey 1989: 2088), or to the acoustic differences between the speech of different speakers (Syrdal & Gopal 1986: 1099). To perceive speech sounds, it is necessary for the listener to normalize the signal, i.e. try to find the invariants. During language acquisition, speakers develop a speaker-

independent model with prototypical hierarchies and a separate speaker-dependent system for special cases demanding extra effort (Rosner & Pickering 1994: 258–259).

1.6.2 Theories of isolated spoken and visual word recognition

This study concerns partly isolated spoken and visual word recognition. Word recognition research has been central in cognitive psychology and psycholinguistics, because words are relatively well-defined minimal units that involve several interesting codes of analysis and processing distinctions. The lexicon is built upon early acquired words from the initial orthographic, phonological, and/or semantic representations. (Balota, Yap & Cortese 2006: 287, 316.) Evidence has demonstrated that bilingual word recognition involves the parallel activation of both languages. This is also true in situations where the observed words are not identical. Both languages appear to be active during speech processing, even in highly proficient bilinguals. (Schwartz & Kroll 2006: 975, 976, 990.)

Three different effects or models in word recognition studies have been very influential. In the *phonemic restoration effect,* a small piece of speech, typically a phoneme and its transitions to adjacent phonemes is cut out of a word, and, for example, white noise replaces the missing speech. Experimental participants failed to notice the missing speech in these studies. (Warren 1970: 392; for a review, see Samuel 2011: 54, 55.) Ganong (1980) demonstrated a similar tendency for word recognition processes (*Ganong effect*). McGurk & MacDonald (1976) reported that listeners' compromise between the visual and auditory input streams (visual stimulus /*ga*/ and audio stimulus /*ba*/ was perceived as /*da*/) (*McGurk effect*). (For a review, see Samuel 2011: 54.) The most influential early approach was Marslen-Wilson's (1975, 1987; Marslen-Wilson & Welsh 1978) *Cohort model*. Marslen-Wilson & Welsh (1975) presented listeners with recorded passages and told them to repeat the input as close in time as they could. Marlson-Wilson suggested that the first 150–200 milliseconds of a word could be used to access lexical representations that were consistent with the input. (For a review, see Samuel 2011: 55, 57.) Allopenna and colleagues (1998) further developed an eye-tracking methodology that provided evidence for the activation of multiple lexical candidates in speech perception (for a review, see Samuel 2011: 56).

Since Marlsen-Wilson's Cohort model, other models have been proposed in research on spoken word recognition. These have had much in common with the Cohort model. Most of these models share the view that speech is encoded at multiple levels of analysis, and in most cases these levels include phonetic features of some kind, sublexical units of some kind (most often phonemes), and some form of lexical representations. A major division among the competing models has been whether the processing flow is seen as entirely bottom-up (features → phonemes → words) or is instead viewed as a more interactive, top-down (lexical → phonemic) process (Dahan & Magnuson 2006: 249–252, 257; for a review, see Samuel 2011: 57.) Cutler & Norris (1979) developed a number of

models (including *Race, Shortlist,* and *Merge*) that were designed to account for spoken word recognition with bottom-up principle. The opposing view has been presented in two models, the *TRACE model* (McClelland & Elman 1986) and Grossberg's *Adaptive Resonance Theory* (Grossberg 1980; for a review, see Samuel 2011: 57.) In addition to these, nonsegmental features, i. e. features which do not apply directly to a given segment, have also been a topic of research. These include coarticulation, phonotactic probabilities, and prosodic influences (such as lexical stress, lexical tone, and indexical factors, i. e. subjective ways of pronouncing a word). (For a review, see Samuel 2011: 59.)

There are also features which have an effect on visual word recognition. The effect of word length in lexical decision performance appears to depend on both the frequency and particular length of the word. Low-frequency words are more similar to non-words than to high-frequency words, and this also affects visual word recognition. Emotionally meaningful stimuli tend to be rated as more familiar. Orthographic and phonological neighbors also play a role in visual word recognition. Semantic variables associated with lexical representations can also modulate the ease of word recognition (Goswami 2006: 467, 478; Balota et al. 2006: 312, 314–316, 319). For example, Davies, Cuetos & Glez-Seijas (2007: 179, 192) found that Spanish-speaking dyslexic children's reading was significantly affected by word frequency, orthographic neighborhood size and word length. Longer words were more difficult than shorter ones.

Beginning readers of Finnish have problems with word length. The memory demands of recoding are high because a large number of phonemes require to be assembled before pronunciation is accessed. (Lyytinen et al. 2006: 60.) Moreover, length seems to affect dyslexics more than chronological age controls in lexical decisions, because dyslexics predominantly rely on a sublexical reading strategy (Martens & de Jong 2006: 148). Recently, Hautala (2012: 3) found new evidence for this, showing that dysfluent readers were still using a serial reading strategy in the 5th grade whereas typically reading adults used a whole word procedure.

Non-native word recognition may also be compromised when fine phonetic discrimination at the segmental level is required. (Bradlow & Pisoni 1999: 2074.) In the study by Bradlow and Pisoni (1999: 2074, 2083–2084), non-native listeners of English had reduced sensitivity to crucial acoustic-phonetic cues due to their lack of experience with speech in the target language. Thus, word recognition accuracy was reduced accordingly. Lehtonen and Laine (2003: 213) have found that native speakers of Finnish had whole word-level representations for frequent, inflected words whereas bilingual subjects did not. However, this was not the case with medium or low-frequency words in either group. The native speakers used morpheme-based recognition with these nouns. The authors argued that this was because it saves processing time and is based on high exposure to frequent, inflected words. However, the word stems and inflections are also represented separately in the lexicon of Finnish readers, and the context also affects the activation of the lexicon (Niemi & Laine 1994: 67).

This study concentrates on the discrimination and /or recognition of isolated spoken pseudo-words and/or non-words in each of the four studies, and on visual and spoken word and pseudo-word recognition in the two latter studies, where the results of children training phonemic length identification with a computer game are reported. Words / pseudo-words were chosen as units because phonemic length is determined by a larger context than a single syllable – as described above in section 1.4 – and sentence-level discrimination or identification would have been too difficult to control for because of all the sentence-related phonetic variables. Only pseudo-words and/or non-words were used in the same-different judgment task and identification tests, whereas in the intervention game in studies three- and four- word and pseudo-word minimal pairs were used. Consequently, because they occurred in pairs, these were not in the true sense isolated items in the discrimination and identification test paradigms in which they were presented. However, the items were isolated in terms of an absence of sentence context and, mainly, an absence of meanings. The items in studies three and four were also orthographic and phonological neighbors, and the length of the items was also taken into account.

Overall, the spoken and visual word recognition in this study is closely linked to the top-down ideas of PGST and "radical" templatic phonology. It seems also that Finnish dysfluent readers or children with reading disabilities have problems in forming representations of whole word units. The same effect is found with L2 learners of Finnish. Phonemic length and quantity is difficult to learn without whole word or maybe even sentence level processing skills. O'Dell (2003: 111) has suggested that a Finnish listener seems to hear speech comprehensively (several phonetic features at the same time) and not just single features of it. This aspect may be one reason for the difficulty of poor readers and L2 learners of Finnish in learning phonemic length.

1.6.3 Theories on dyslexia

General speech perception and spoken and visual word recognition theories are linked to theories on the causes underlying developmental dyslexia. The precursors and backgrounds of dyslexia have been widely studied over the past several decades. First of all, it has been found that dyslexia has biological origins. Several candidate genes have been identified as linked to dyslexia (Taipale et al., 2003: 11553; Kaminen et al., 2003: 340; Hannula-Jouppi et al., 2005: e50). The ventral and dorsal streams in the brain are also crucial in conceptualizing dyslexia. The ventral stream is involved in the processing of speech signals for comprehension, whereas the dorsal stream is involved in translating acoustic speech signals into articulatory representations that occur in the frontal lobe, which is essential for speech development and normal speech production (Hickok & Poeppel, 2007: 394). Poussu-Olli investigated the consequences of biological, prenatal and early childhood illnesses. She studied 745 school beginners, of whom 94 were diagnosed as dyslexics, while another 96 of the children were chosen as controls with no reading or spelling problems. The pregnancies of the mothers of the dyslexic children were more complex, there were nutrition

problems, and labor was prolonged. These problems were associated with the reading and spelling problems of the children in the first school year. The children in the dyslexia group were more often ill before school age compared to the control group, and illnesses were reflected in their behavior. Illnesses included otitides, headaches, and allergies. (Poussu-Olli 1993; Poussu-Olli 1994: 108.)

It is commonly agreed that difficulties in phonological awareness is the main factor behind dyslexia. These problems can result from speech perception difficulties and poor speech sound representations and production, and the problems are reflected in poor performance in tasks requiring participants to blend, isolate, or manipulate speech sounds as well as in reading non-words (i.e., phonological awareness). Psycholinguistic research indicates that an unstable or underspecified phonological representation in the mental lexicon is a core deficit in dyslexia. (Brady, Shankweiler & Mann 1983: 345, 346, 360, 364, 365; Mody, Studdert-Kennedy & Brady 1997: 227; Snowling, Nation, Moxham, Gallagher, & Frith 1997: 31; Elbro, Borstrom & Petersen 1998; 36; Goswami 2000: 134, 142–144, 146; Ramus et al., in press.) The recent study reveals that the 9-year-old children with developmental dyslexia do not show enhanced MNN amplitude to the native-vowel prototype, unlike the control group, suggesting their impaired tuning to native-like speech representations (Bruder, Leppänen, Bartling, Csepe, Demonet & Schulte-Körne 2011: 1107). Dyslexics also have limitations in performance of working memory, and problems with rapid retrieval of phonological information from long-term memory. (Brady, Shankweiler & Mann 1983: 345, 346, 360, 364, 365; Mody, Studdert-Kennedy & Brady 1997: 227; Snowling et al. 1997: 31; Goswami 2000: 134, 142–144, 146; Goswami, Ziegler, Dalton & Schneider 2003: 235.) In addition, researchers have argued that the phonetic and acoustic similarities may cause accuracy problems in speech perception (Adlard & Hazan 1998: 171; Snellings, van der Leij, Blok & de Jong 2010: 151; Studdert-Kennedy 2002: 11).

In principle, it is also possible that higher-level speech and phonological processing problems stem from a more basic auditory impairment that is not restricted to the processing of speech sounds. It has been proposed that children with language learning impairments and children with dyslexia have difficulty in processing brief and/or rapidly changing acoustic events in speech and non-speech (e.g. Tallal 1980: 182,189, 194; Booth, Perfetti, MacWhinney & Hunt; 2000: 101; Reed 1989: 270; Witton, Stein, Stoodley, Rosner, & Talcott 2002: 866; Richardson, Thomson, Scott & Goswami 2004: 215), in other words, in the processing of the dynamic envelope of speech (Goswami 2011: 3; Lehongre et al. 2011: 1080). Thomson, Fryer, Maltby & Goswami (2006: 334, 344) found that duration discrimination predicted variance in reading and spelling in adults with dyslexia. There were also group differences in intensity and rise time sensitivity, contrary to the results of Richardson and colleagues (2004: 225–226). In the Finnish context, Hari and Kiesilä (1996: 138) found that adult dyslexics have difficulties in the processing of rapid sound sequences. On the other hand, in view of the fact that speech consists of other acoustic variations as well as brief

transitions, the interactions of a variety of factors—such as intensity, fundamental frequency, and duration—may play a significant role in speech perception (Serniclaes, Sprenger-Charolles, Carré & Demonet 2001: 396). Recently, Hämäläinen, Salminen and Leppänen (2012: 1) published a meta-analysis on auditory processing deficits in individuals with dyslexia. The data analysis showed that frequency, rise time, duration discrimination, amplitude and frequency modulation were most often impaired in this group. This suggests that auditory processing aspect accounts for problems in phonemic length discrimination and identification.

Three other theories also seek to explain the reasons behind dyslexia. The visual theory or syndrome of dyslexia is characterized by a preponderance of real-word paralexic errors which are visually (orthographically) but not semantically related to the target word. Such an association problem could be the consequence of a slow and inefficient phonological lexicon (Vellutino et al. 2004: 11) or of a more general neurological timing problem preventing visual and auditory-phonological areas from being activated at the same time (Breznitz 2002: 15; Breznitz & Berman 2003: 247; Paulesu, Frith, Snowling, Gallagher, Morton, Frackowiak & Frith 1996: 143). According to this hypothesis, dysfluent readers have a deficit in storing words or parts of words in the orthographic lexicon as a consequence of a lack of multiple, redundant associations between the single graphemes and grapheme clusters of word spelling and the single phonemes or larger morphophonological segments (e.g., syllables, morphemes, onsets, rimes) of word phonology. Recent evidence in support of the theory is presented in the studies by Facoetti, Ruffino, Peru, Paganoni & Chelazzi (2008), Facoetti, Corradi, Ruffino, Gorgi & Zorzi (2010), and Hautala (2012).

According to the cerebellar theory, the dyslexic's cerebellum is mildly dysfunctional, causing dysfunctional articulation via weak motor control, which leads in turn to deficient phonological representations. The cerebellum plays a role in the automatization of overlearned tasks, which, among other things, would affect the learning of grapheme-phoneme correspondences. Finally, the magnocellular theory of dysfunction attempts to integrate all the findings related to the theories mentioned above. The magnocellular theory is not restricted to the visual pathways alone but is generalized to all modalities, in other words to the visual, auditory and tactile pathways. (Ramus, Rosen, Dakin, Day, Castellote, & White 2003: 842–843.) The theory is nowadays closely linked to rapid auditory processing and rise time that is, to issues addressed in the auditory theory of dyslexia.

The causal paths leading to specific developmental disorders have come under scrutiny in recent years. Pennington (2006: 404–406) introduced a multiple cognitive deficit model of developmental disorders, suggesting that reading and spelling problems can stem from cumulative risk rather than a single factor. The role of a phonological deficit can, nevertheless, be regarded as central in dyslexia. A child with this deficit is more likely to pass the diagnostic threshold for dyslexia than children with intact phonological skills. (see also Snowling 2008: 142). Aro, Poikkeus, Eklund, Tolvanen, Laakso, Viholainen, Lyytinen,

Nurmi & Ahonen (2009: 883) also found evidence of the accumulation of risk factors in the group with familial risk for dyslexia studied in the Jyväskylä Longitudinal Study of Dyslexia project. The risk factors were related to language, phonological awareness, memory, rapid serial naming, visuomotor skills, and parenting. Pennington, Santerre–Lemmon, Rosenberg, MacDonald, Boada, Friend, Leopold, Samuelsson, Byrne, Willcut and Olson (2012: 212, 222) showed evidence that a hybrid model is the best fitting model in explaining dyslexia. It means that there are multiple possible pathways to dyslexia, some involving single deficit and some involving multiple deficits.

In this study, the main idea is that there are different pathways to dyslexia, while the results are consistent with the proposition of multiple deficits model, and speech perception problems form background for it.

1.6.4 Phonemic length as a problem for children with familial risk for dyslexia

Difficulty with learning and perception of quantity and duration among children with familial risk for dyslexia and/or with reading disabilities, and among dyslexic adults was treated in altogether 15 studies or articles. All these studies were published in connection with the JLD project (Lyytinen et al. 1995; Leinonen et al., 2001). The first of these studies, by Lyytinen et al. (1995: 188, 190, 191; see also Lyytinen 1997), found that adults with dyslexia and with a familial background for dyslexia made significantly more quantity errors in reading pseudo-words and non-words than typically reading adults. The shortening of vowels correlated significantly with pseudo-word reading, spelling, phonological lexical decision time, and with rhyming errors.

The studies with the most relevance for the present research are those by Richardson. She studied the perception and production of duration (phonemic length) with newborns and six-month-old infants with familial risk for dyslexia and their dyslexic parents. She showed that six-month-old infants at risk for dyslexia required a period of silence of 40 milliseconds or more to perceive the /*t*/ phoneme as crossing the categorical boundaries between short and long duration (Richardson 1998: 1, 96–98, 136–137; Richardson et al., 2003: 391–395). The duration of word medial consonants and word final vowels was longer in dyslexic adults than controls in a production experiment. The same was observed in 18-month-old at-risk infants (Richardson 1998: 1, 149, 163; Lyytinen, Leppänen, Richardson & Guttorm 2003: 116–123; see also Richardson 1996; 1999; Richardson, Haukkamäki & Leiwo, 2001, Richardson et al. 2009).

These behavioral findings were further supported in the JLD by brain response measurements using event-related potential (ERP) techniques. Pihko, Leppänen, Eklund, Cheour, Guttorm and Lyytinen (1999: 1, 4) studied the cortical responses of newborns and six-month-old infants with and without a familial risk for dyslexia. They differed from controls in their responses to the standard /*kaa*/ stimulus compared to deviant /*ka*/ stimulus at the age of six months. The results suggest differences in brain activation patterns between the groups. In the study by Leppänen, Pihko, Eklund & Lyytinen (1999: 1), the rate of

stimulus presentation was slower than in the former study. The ERPs to the deviant /*ka*/ were found to be different from those to the standard /*kaa*/ stimulus already in newborns. In addition, clear group differences in ERPs were found. The results suggest that infants born with high familial risk for dyslexia process speech and auditory stimulus durations differently from control infants already at birth. (See also Leppänen 1999; Lyytinen et al. 2003: 124–135.)

Leppänen, Richardson, Pihko, Eklund, Guttorm, Aro and Lyytinen (2002: 407–408) studied the differences between 6-month-old infants with and without a high risk for familial dyslexia by measuring brain electrical activation generated by changes in the temporal structure of speech sounds (consonant duration changes). They found that the brain activation of the at-risk infants was atypical for the same consonant duration changes observed as atypical in the behavioral studies by Richardson (1998; Richardson et al. 2003; see also Lyytinen et al. 2008: 127). Leppänen, Hämäläinen, Salminen, Eklund, Guttorm, Lohvansuu, Puolakanaho & Lyytinen (2010: 1362) also investigated pitch processing in newborns with a familial risk background using ERPs and how these ERPs later related to the same children's pre-reading cognitive skills and literacy outcomes. Newborn ERPs reflecting passive change detection were associated with phonological skills and letter knowledge prior to school age and with phoneme duration perception (phonemic length), reading fluency and spelling accuracy in the 2nd grade. Results suggest that a proportion of dyslexic readers with a familial risk background are affected by atypical auditory processing.

The study by Hämäläinen, Leppänen, Eklund, Thomson, Richardson Guttorm, Witton, Poikkeus, Goswami& Lyytinen (2009: 511–512) focused on auditory and speech perception abilities among 9-year-old Finnish children with and without reading disabilities, and the associations between auditory, speech perception, reading, and spelling skills. The results showed significant group differences in phoneme duration discrimination (phonemic length) but not in perception of amplitude modulation and rise time. Children with problems in rise time processing also had problems in phoneme duration discrimination and spelling. They suggest that difficulties in auditory processing could affect speech perception skills, leading in turn to phonological processing problems and dyslexia, at least in some children with reading disabilities. In the most recent study, Leppänen, Hämäläinen, Guttorm, Eklund, Salminen, Tanskanen, Torppa, Puolakanaho, Richardson, Pennala, Lyytinen (2012: 35) conclude that atypical auditory and speech processing is not likely to be a sufficient reason by itself for dyslexia but rather one endophenotype or risk factor.

These results yield information about the difficulties children with reading disabilities, and with a familial risk background, have in the processing of phonemic length and duration. Dyslexics have problems in discriminating the quantity degree and they also produce durations that are longer than those produced by control subjects, at least in certain positions in a word/pseudoword. These results have been reported for infants and children as well as for adults with dyslexia. Dyslexic adults also seem to have problems in accurately reading quantity. However, this phenomenon is not strictly language-specific:

Gibbon (2007: 255) states that in general, children with phonological disorders vary in their ability to discriminate between phonological contrasts that they do not produce in expressive phonology.

This study continues the tradition of these studies by investigating problems in phonemic length discrimination and identification and their connections with reading and spelling skills in children with poor reading skills and with familial risk for dyslexia, and with Russian L2-learners of Finnish.

1.6.5 Theories on second-language learning

As with dyslexia, there are also several theories behind second-language learning. In this section, I first describe them briefly and then assess their relative importance for the theories of studies comprising this dissertation.

The critical period for learning a first language is the period during which individuals must be exposed to language interaction if they are to acquire linguistic competence. The language systems acquired are, in chronological order, prosody, phonology, morphology, and syntax (including syntactic features of the lexicon). (Paradis 2004: 59.) The language-specific representations for the phonemes of the mother-tongue are developed during early infancy. (Cheour, Ceponiene, Lehtokoski, Luuk, Allik, Alho & Näätänen 1998: 351). Research evidence suggests that infants who are exposed simultaneously to two languages develop phonotactic sensitivities at the same rate as monolinguals (Schwartz & Kroll, 2006: 973). The optimal period for becoming bilingual is thus during the first year of life, because by the end of it the native speech perception skills have begun to show improvement, and non-native speech perception has begun to decline (Cheour-Luhtanen, Alho, Kujala, Sainio, Reinikainen, Renlund, Aaltonen, Eerola & Näätänen 1995: 55, 56; Cheour et al. 1998: 353; Kuhl et al. 2008: 979). At approximately the age of 6 months infants are able to discriminate non-native speech contrasts without relevant experience to them (Werker & Tees 1984: 49, 61; Jusczyk, Friederici, Wessels, Cvenkerud & Jusczyk 1993: 418). It has also been suggested that learning a new language is more difficult after the age of 12 years (Abrahamsson & Hyltenstam 2009: 249). To mention one study, Flege, Schmidt & Wharton (1996: 143) found that early Spanish L2 learners of English are more likely to establish new phonetic categories for stops compared to late bilinguals.

In the field of L2 research, there are two distinct views related to the representation of two languages in one mind. One is the suggestion that the two languages are combined together in the learner's brain, while the other proposes that the speaker has two separate systems, one of which is be activated according to the situation. The research traditions of L2 speech perception can be subsumed under one or other of these two theoretical viewpoints. (Peltola 2010: 163, 164, 166.) The single storage system hypothesis states that there is one system but two input and two output channels, one for each language. The separate storage hypothesis states that bilinguals have two independent language storage and retrieval systems, the only communication channel being a translation process between the two separate systems. (Baker 2007: 150.) In accordance

with these to hypotheses, there exist at least six different models which purport to explain L2 sound perception. These are all conceived in relation to first language acquisition; however, because LI acquisition is not the focus of this study, the models are introduced mainly in terms of L2 speech perception.

The first (1) model is Major's Ontogeny Phylogeny Model (OPM). He proposes that L1 and L2 acquisition are aided by a set of innate linguistic universals which provide the L1 learner with a head start. These are universal grammar, learnability principles, markedness, underlying representations, rules processes, constraints and stylistic universals. L2 learners are faced with three learning scenarios, "normal", "similar" or "marked", depending on the linguistic phenomena to be learned. "Normal" means that the L2 phenomena are dissimilar from those of the L1 and not typologically rare, in which case learning is easier than in the other two scenarios. "Normal" refers to a decrease in the influence of the L1, an increase and then a decrease in the influence of the universal component, and an increase in the influence of L2. Whereas "normal" means that the L2 is acquired, "similar" and "marked" mean that the learner's system is still developing under the three states mentioned in the theory. (Major 2002: 76.)

The second (2) model is Brown's Phonological Interference Model (PIM). It assumes that phonemes have an internal structure composed of a hierarchy of phonological features which are contained in the phonological component of Universal Grammar. She states that general auditory discrimination mapping can be broken down into universal phonetic categories. These phonetic stimuli are then processed at the second level, comprising the speaker's feature geometry, or phonological structure (phonemic categories). According to Brown, the L1 phonological grammar mainly maps the L2 input onto existing phonological categories. (Brown 1998: 148.)

The third (3) model is Best's Perceptual Assimilation Model (PAM). It was developed by Best & Strange (1992) and focuses on phonemic contrasts in the second language system. It argues that an adult listener has no mental representations for perceiving speech; rather, he/she directly seeks and extracts from the speech signal patterns of articulatory gestures and gestural constellations that are similar to those in the L1. If a listener perceives discrepancies between native and non-native phones, he/she cannot perceive a direct correspondence between the articulatory-gestural properties of the native and non-native phones. Listeners tend to assimilate non-native sounds to L1 categories as a function of their similarity with L1 sounds. There are four patterns by which the L2 categories can relate to the L1 phonemes: 1) two L2 categories are assimilated to two native categories; 2) both the non-native phonemes may be assimilated equally well or poorly to a single native category; 3) the non-native sounds may be too discrepant from the gestural properties of any native categories to be assimilated into categories of the native phonology and should therefore be perceived as non-speech sounds; and 4) the non-native pair may both be assimilated to a single native category, yet one may be more similar than the other to

the native phoneme (Best & Strange 1992: 28–29; Best 1994: 190, 191; Best 1995: 193–195.)

The fourth (4) model is Kuhl's Native Language Magnet theory (NLM), introduced above in chapter 1.6.1. In the NLM theory, the similarities and differences between the L1 and L2 are seen from the point of view of prototype compatibility: if the prototypes are identical, learning is expected to be relatively easy, but if they are acoustically different, learning may be difficult. In other words, the native language prototypes attract the wrong sounds to the group and the learner fails to distinguish the sounds of the new L2 system from each other, because they are members of the same category in the first language (Kuhl 1991; 1992, 2008: 979).

The fifth (5) model is the Speech Learning Model (SLM) developed by Flege. It primarily concerns L2 pronunciation, and hence focuses on bilinguals who have spoken their L2 for many years. A basic assumption of the model is that many L2 production errors have a perceptual basis. The SLM states, first, that the L2 sounds in the target language may be dissimilar from the native phonemes. In this case the target language sound is classified as new. The greater the perceived distance is of an L2 sound from the closest L1 sound, the more likely it is that a separate category will be established for the L2 sound. Also the earlier L2 learning commences, the smaller will be the perceived phonetic distance needed to trigger the process of category formation. Second, the two languages have either identical or highly similar categories, and consequently the target category is said to be identical. Learning is not a major obstacle in this case. Third, the L2 sound may not be identical to any L1 sound, but the relation can be characterized by the term similar and this difference causes severe problems. An assumption that SLM makes is that the phonetic systems used in the production and perception of vowels and consonants remain adaptive over the life span, and that phonetic systems reorganize in response to sounds encountered in an L2 through the addition of new phonetic categories, or through the modification of old ones. (Flege 1988; Flege 1995: 237–238, 233, 263, 264; Flege 2003b: 12; Flege & MacKay 2004: 5–6.)

The final, sixth (6) model is the Linguistic Perception Model (LP). It is embedded in the framework of functional phonology (Boersma 1998). It claims that cognitive linguistic knowledge underlies speech perception. The L2 version of the model states that the L2 perception is handled from the beginning by a separate perceptual system which began as a copy of the L1 system but evolves along with experience of the L2 (Escudero & Boersma 2004: 582; Escudero 2007: 124–128).

Strange (2011: 456, 465) has recently introduced a working model (7) of first and second language speech perception, titled the Automatic Selective Perception (ASP) model. Strange describes speech perception as purposeful, information-seeking activity whereby adult listeners detect the most reliable acoustic parameters that specify phonetic segments of their L1 using selective perception routines. In contrast, late L2 learners have to employ greater attentional resources in order to extract sufficient information to differentiate pho-

netic contrasts that do not occur in their L1. He describes two modes of perception — a phonetic mode, in which the details of the articulatory realization of phonological segments are consciously available to the perceiver, and a phonological mode, by which word forms are recognized rapidly with little cognitive effort.

The L2 learners of the present study were approximately seven years old, and were thus still at the biological stage where learning a second language is relatively easy. The most well-known L2 speech perception models may be the ones of Best, Kuhl and Flege. In the present research context, the thinking of Patricia Kuhl may be the most appropriate as the interest is on categorical perception, discrimination of phonemic length, identification of quantity degree, and on training with prototypical word and pseudo-word forms. However, in relation to the L2 learners of Finnish, the thinking of Best and Flege also contribute to the theoretical background of this study.

1.6.6 Phonemic length as a problem for Russian second-language learners of Finnish

Studies on the acquisition of Finnish quantity by L1 Russians provide the major reference point and background for the studies reported in this dissertation. The first is a study by Vihanta (1990: 204, 206, 212–214), who, although not specifically concerned with L1 Russians, introduces the importance of teaching Finnish phonetics to foreign and second language learners of Finnish. He argues that prosodic features have an effect on the foreign accent of L2 learners, and in general they are the most difficult aspects of a language to learn. He also describes the difficulty of learning the Finnish quantity opposition if there is no such feature in the L2 learner's native language, which is the case, for example, in Russian.

The study by de Silva (1999: 1, 82–84, 88, 91, 168, 174) focuses on pronunciation differences on the word level between Russian and Finnish adults. According to her results, interference from Finnish leads to two degrees of length in Finnish L2 learners of Russian: very long and very short. Vowel duration together with durational differences in consonants, whose durational distribution is greater in the pronunciation of Finnish, interfere with the rhythmic structure of single words in Russian. The study also shows the importance of the teaching of phonetics to foreign or second-language learners of Finnish. A case study with Russian L2-learner of Finnish by Nenonen (2001b: 30) also shows that the long sounds of Finnish are mostly produced as too short, and that short vowels are lengthened by word stress. There are also cases where short vowels occur as overlong.

Nenonen (2001a) studied the perception of vowel length by Russian school-aged children learning Finnish. She found that long stressed vowels disturb the perception, and a geminate has an effect on the perception of a long vowel following the consonants. This is because the geminate violates the learners' L1 word structure. Native language, word structure, and task type also had effects on the learners' perception of vowel length. Ylinen (2006) stud-

ied the cortical representations of Finnish phonological quantity in native speakers and Russian L2 users of Finnish by using behavioral and electrophysiological methods. Mismatch negativity (MMN) was used to compare the neural representation for quantity between Finns and L2 users of Finnish. The results showed that Finnish speakers' MMN response to quantity was determined by the activation of native-language phonetic prototypes rather than by phoneme boundaries. (Ylinen, Shestakova, Huotilainen, Alku & Näätänen 2006: 175.) Finns seemed to process phoneme quality and quantity independently in separate brain representations (Ylinen, Huotilainen & Näätänen 2005: 1857). The MMN response to duration or quantity-degree changes was enhanced in a speech sound but this was not found with Russians (Nenonen et al. 2003: 492). The duration of the MMN response was, however, native-like for an L2 vowel different from any in their mother-tongue (Nenonen, Shestakova, Huotilainen & Näätänen 2004: 26). She concludes that it may take a long time for Russian L2 learners of Finnish to develop the representations for quantity and duration category boundaries in the brain (Ylinen et al. 2005: 313). (Flege 1998: 24; for a review see Ylinen 2006.)

1.7 Computer-based phonological intervention

Studies III and IV concentrate on learning and training of Finnish phonemic length with computer-based software. Therefore the background to the phonological intervention is discussed in this section.

During the last two decades, the incorporation of speech technology into linguistic and applied linguistic inquiry has begun to yield major results in research and practice. Technology has been used for many decades in phonological research as well as in teaching phonetics, phonology, and pronunciation. (Chun, 2006: 274.) Learning games have been used in preventing reading disabilities in preschool education, and games have been demonstrated to be effective in training phonological skills, for example discrimination of sounds and recognition of pseudo-words/non-words (Lyytinen 2004: 169; Torgesen & Barker 1995: 76;). Phonologically based interventions seem to be at their most promising in preventing reading and spelling problems among dyslexics. An increasing number of evaluation studies report beneficial effects of phonological training on reading performance (Snowling & Nation 1997; Swanson 1999; Wise, Ring, & Olson 1999; 2000; Hatcher 2000; Lovett, Lacerenza, Borden, Frijters, Steinbach & De Palma 2000; Torgesen, Alexander, Wagner, Rashotte, Voeller & Conway 2001; Pogorzelski & Wheldall 2002; Tijms, Hoeks, Paulussen-Hoogeboom & Smolenaars 2003). Computer games have also been used in the special education and training of immigrants in Finland. This environment has enhanced learners' motivation to train the contents at hand. (Rantanen, Kankainen, Latvala & Lyytinen 2008.) Examples of the training of Finnish quantity in Dutch children and adults were earlier in section 1.4.4 (Heeren 2006; Heeren & Schouten 2008; 2010).

”Edutainment” games (education + entertainment) began to emerge about two decades ago. Their aim was to combine the entertainment of games with the educational purposes of school. (Jalonen 2003: 8.) The intervention game used in this study - Graphogame - is one example of an edutainment game. The original version of the game was designed in 2002 at the University of Jyväskylä, and has since been further developed in collaboration with the Niilo Mäki Foundation (Lyytinen, Erskine, Kujala, Ojanen & Richardson 2009: 671). The idea for the game came from research on reading development, and specifically from finding the bottlenecks for those who have specific problems in learning to read. The basic Graphogame provides training opportunities for associating speech sounds with letters or larger units. The findings of efficacy studies show that by training with Graphogame alone, even children who found learning difficult can acquire letter-sound correspondences after only a few hours of independent playing (Lyytinen, Ronimus, Alanko, Poikkeus & Taanila 2007: 119, 123; Lyytinen et al. 2008: 135–137; Saine, Lerkkanen, Ahonen, Tolvanen & Lyytinen 2011: 1017–1020, see also Richardson, Aro & Lyytinen 2011). The game is now widely used in schools, but can also be used at home (see “Lukimat”). It is also in use on mobile phones by African children.

Four dissertation studies have used Graphogame as a methodological tool in an intervention. The study by Huemer (2009: 3) concentrated on training grapheme-phoneme conversion in 1st grade Finnish-speaking poor readers, and on training reading speed in Finnish and German poor readers. The Finnish children improved their letter-sound knowledge, and the computer game enhanced global reading speed, as also did general assisted reading practice. It was also found that using sub-lexical units, such as consonant clusters and syllables enhance reading speed, and enable generalization effects. It has been argued that training with larger stimulus sets may better generalize to new stimuli, as this renders participants less likely to form erroneous category representations based on perceptually salient cues. Training with larger stimulus sets could teach listeners to more efficiently focus attention on the critical acoustic cues instead of irrelevant variation. (Iverson, Kuhl, Akahane-Yamada, Diesch, Tohkura, Kettermann & Siebert, 2003: B54.)

Ketonen (2010: 97) conducted a game-based intervention study comprising six children with familial risk for dyslexia and with phonological problems. The children were drawn from the JLD project. The training was carried out during preschool or 1st grade. The results showed that the six-month phonological and letter-sound knowledge intervention trained the letter-sound knowledge of the children. The training did not have an effect on the later reading and spelling skills of the children.

Saine (2010: 3) studied the reading development of children at-risk for dyslexia among Finnish school beginners. The group that received the computer-based intervention with Graphogame reached mainstream level in letter knowledge, reading fluency, accuracy, and spelling accuracy, and their achievement continued to be visible the 3rd grade in letter knowledge, phonological awareness and naming speed. However, in her study, the at-risk group

comprised the lowest achieving 30 % of children in the age group, and thus it is plausible that these children were not all at true risk for reading disabilities, as the prevalence of the reading disability in the general population is much lower (see for example Hulme & Snowling 2009: 37–40).

Ronimus (2012: 3) focused on the motivational side of the game in her dissertation. Her results revealed that the game's reward system increased the time spent playing the game. Moreover, the school environment was more motivating than the home environment. Interest in reading and lack of previous experience with Graphogame also had a positive influence on the children's enjoyment of the game. In connection with this result, Peltola, Kujala, Tuomainen, Ek, Aaltonen & Näätänen (2003: 25) concluded in their L2 study that learning in a classroom environment may not lead to the formation of new long-term native-like memory traces.

There are several other factors that may be problematic in intervention studies. For example, children with a family history of reading difficulties are less responsive to interventions designed to provide the skills required for reading development than children not at similar family risk (Ketonen 2010). The tests may also be problematic: the effects of using the same test in pre- and post-assessments, or environmental distractors, for example noise in the school environment, should be considered. Also, when evaluating the post-assessment results, it should be noted that the effects may be stronger immediately following the intervention than, for example, one year afterwards. In fact, such results are typical of intervention research in which powerful interventions are followed by a period of time in which the intervention is no longer available (Scammaca, Vaughn, Roberts, Wanzek & Torgesen 2007: 31; Shanahan & Barr 1995: 978–979.)

In the JLD, one intervention study used Graphogame as a part of language-oriented training with 3rd grade reading-disabled children with familial risk for dyslexia. The other training paradigm of the study was conducted purely with auditory stimuli. One component of the language-oriented training was computer-based training in the duration of speech-sounds. This training paradigm was auditory sound-based throughout, but without speech sounds. The results showed that the language-oriented training had an effect on the reading accuracy of the children, but not on their reading fluency. In the follow-up assessment the effects were the same, diminishing only in the reading of the pseudo-word text in the language-oriented training group. (Oksanen 2012: 4.)

In the present study, we used minimal pairs in the phonemic length identification training. This was justified by the fact that the minimal pair contrast is probably the best known and most widely studied phonological training technique, partly because it typically involves a game format presenting pairs of words that the child basically produces as identical (i.e., homophonous). The minimal pair method was first introduced in speech therapy by Weiner (1981: 97). Through contexts that focus on minimal pair distinctions, children learn the communicative importance of producing contrasts that are sufficiently distinct for listeners to detect. (Gibbon 2007: 264.) Minimal pairs have been widely used in auditory and phonetic L2 training (for example: Jamieson & Morosan 1989:

88, 90; Kawai & Hirose, 1997: 657; 2000: 131; Hardison 2005: 579, 585; Iverson et al., 2005: 3268–3269; Iverson & Evans, 2009: 868–870).

1.8 Aims of the study

This study sought to answer the following questions: a) What are the consequences of phonemic length discrimination ability problems and their connection with reading and spelling skills in Finnish children with familial risk for dyslexia (Studies I and II)? b) Is the multiple deficit model the best model to describe development leading to dyslexia (Study II)? c) Is the perception and learning of phonemic length in the Finnish language more difficult for children with a familial risk for dyslexia or for Russian L2 learners of Finnish (Study III), and do these processes have the same backgrounds and roots? d) What is the best prototype of phonemic length in Finnish (Study IV)? A further aim was to conduct a pilot study of quantity training using Graphogame (Studies III and IV). The four studies are briefly described in next section. These questions are also discussed in the general discussion section.

2 SUMMARY OF THE STUDIES

2.1 Study I

The main aim of the first study was to examine the ability of Finnish children with familial risk for dyslexia and with and without reading disabilities, and controls without familial risk to discriminate phonemic length. The focus was on the developmental span of discrimination ability and its associations with reading accuracy, reading speed, and spelling accuracy in grades 1, 2, and 3 after taking into account the variance explained by more traditional markers of dyslexia, i.e. verbal short-term memory, phonological memory, naming speed, and verbal IQ.

2.1.1 Methods

All the participants were drawn from the Jyväskylä Longitudinal Study of Dyslexia (JLD) sample (Lyytinen et al., 2001; Lyytinen et al., 2004; Lyytinen et al., 2008). From this sample (N = 199), 184 were included in this study. The children were allocated to one of three groups according to their reading skills, i.e., children with Reading Disabilities (RD) or Typical Readers (TR) at the end of the 2nd grade, and according to their family risk status, i.e., Family Risk (FR) or no family risk, i.e. the Control group (C). There were 35 children in the RDFR group, 69 children in the TRFR group, and 80 children in the TRC group.

The ability to discriminate phonemic length was assessed at the end of grades 1, 2 and 3. The task consisted of 3 pseudo-word and 19 non-word[6] pairs with an inter-stimulus interval ISI of 1000ms. The stimuli for the task were nat-

[6] The difference between pseudo-words and non-words was that pseudo-words share the phonology and follow the phonotactic rules of Finnish, but have not been encountered previously as words. Non-words do not share the phonology of Finnish and are devoid of meaning. In addition, the criterion of a non-word is that if one phoneme of the item is changed to other phoneme with the same place of articulation as the original one, the item cannot be encountered as a Finnish word. For example, /*raameli*/ → /*laameri*/ or /*laameli*/.

ural speech sounds. Twelve of the pseudo- and non-word pairs differed from each other in phonemic length. The remaining 10 pairs were identical. The task required the participant to decide whether the two stimuli were identical or not, and included three practice pairs. D prime (d') values were used to eliminate the occurrence of possible response biases by taking into account both hits and false alarms instead of the sum of correct responses.

Verbal short-term memory, naming speed, and IQ were tested in the 2nd grade. Phonological memory was tested at the end of the 3rd grade. Multivariate analysis of variance (MANOVA) for repeated measures was used for the group comparisons through grades 1, 2 or 3. Group differences at each grade level were further tested with a one-way analysis of variance (ANOVA). A chi-square test was used to examine whether there were group differences (between the RDFR, TRFR and TRC groups) in the number of children who had problems in zero, one, two, or three of the following skills: verbal IQ, verbal short-term memory and rapid serial naming in the 2nd grade. Pearson correlation coefficients were used to examine the connections between discrimination ability and reading accuracy and speed, as well as spelling accuracy. Hierarchical stepwise regression analyses were used to examine the variance explained by the ability to discriminate phonemic length in reading and spelling skills after controlling for verbal short-term memory, phonological memory, and rapid serial naming.

2.1.2 Results

All three groups developed in their discrimination ability from grade 1 to grade 3. RDFR made more errors in phonemic length discrimination than TRC in grades 2 and 3. TRFR differed from TRC only in the 3rd grade. Discrimination ability in the 1st grade explained reading accuracy in grade 3 in RDFR group, and 2nd grade discrimination ability explained unique variance of spelling accuracy in grades 2 and 3 in RDFR group. The association was particularly strong in spelling accuracy in the 2nd grade ($\Delta R2 = 0.21$). At the individual level in the 2nd grade, 31.4 % of RDFR, 14.7 % of TRFR, and 8.8 % of TRC performed below -1.25 standard deviations in the discrimination task.

2.1.3 Discussion

Phonemic length discrimination was the most challenging for dyslexic readers with familial risk for dyslexia and it was related to reading and spelling accuracy skills. Problems in discrimination ability indicate of compromised speech perception, and the results indicated that problems in this ability could be one of the accumulating risk factors affecting development leading to dyslexia among Finnish children.

2.2 Study II

In the second study, we continued the research on phonemic length discrimination problems among children with reading disabilities and with a familial risk for dyslexia, and among control children with typical reading skills and with or without familial risk in the 2nd Grade. We wanted to determine whether the ability to discriminate phonemic length has an effect on reading accuracy and fluency, spelling accuracy and quantity, and on other than quantity errors in reading and spelling among these three groups of children. We also studied differences in the accumulation of problems in pre-reading skill areas between the children with familial risk for dyslexia, with reading disabilities and with or without problems in discrimination ability. Third, we studied whether discrimination ability explained reading accuracy and fluency, and spelling accuracy after taking into account the effect of the accumulation of problems in the pre-reading skill areas among the children with familial risk for dyslexia and with reading disabilities.

2.2.1 Methods

All the participants (n = 180) were members of the Jyväskylä Longitudinal Study of Dyslexia (JLD) (Lyytinen et al., 2001; Lyytinen et al., 2004; Lyytinen et al., 2008). The dyslexia criterion was applied in both the 2nd and 3rd grade, with the result that there were five children more in dyslexia group than in the first study. The children were allocated into three groups: children with Reading Disabilities and with Discrimination Problems (RDDP, n = 13), children with Reading Disabilities and with Typical Discrimination abilities (RDTD, n = 27), and children with Typical Reading skills (TR, n = 140). They were assessed at ages 1.0–6.5 for language, phonological awareness, verbal memory, and rapid automatized naming, for IQ at age 5.0, and for IQ, discrimination ability, reading and spelling skills in the 2nd grade. Statistical differences and relationships of measures were examined on a group level with one-way analysis of variance (ANOVA) with post-hoc pairwise comparisons, and with Pearson's Chi-Square test. Regression analyses were carried out among the reading-disabled children (RDDP and RDTD groups) to determine the effect of discrimination ability problems on reading accuracy and fluency and spelling accuracy after controlling for the accumulation of problems in pre-reading risk areas. The accumulation of risk areas was included in the model in the first step and phonemic length discrimination in the second step.

2.2.2 Results

The typically reading children (TR) were significantly better than the other two groups in all the reading measures except quantity errors in text reading. The at-risk children with reading disabilities and with discrimination ability problems (RDDP) were poorer than the at-risk children with reading disabilities and

without the discrimination problems (RDTD) only in quantity errors in pseudo-word text reading. Interestingly, RDTD, but not RDDP group, was poorer than TR group in reading fluency of the pseudo-word text. TR group performed better than the other groups in all the spelling accuracy measures except in other than quantity errors in the spelling of words, where it differed only from RDDP group. The RDDP group was poorer than RDTD group in all the spelling accuracy measures, with large effect sizes, except in other than quantity errors in the spelling of non-words, where the groups did not differ from each other. Pre-reading skills (early language, phonological awareness, verbal memory and rapid automatized naming) were poorer in RDDP than RDTD group. Discrimination ability explained spelling accuracy after the accumulation of risk areas had been taken into account, and the accumulation of risk areas explained reading fluency of pseudo-word text reading when it was entered in the model in first step. In the regression analysis, none of the measures explained reading accuracy in the 2nd grade.

2.2.3 Discussion

Commonly known pre-reading skills were connected to poor reading skills but having problems in phonemic length discrimination ability enhanced the effect of other risk areas, making spelling problems more severe among the Finnish children with reading disabilities and with familial risk for dyslexia in the 2nd grade. Discrimination problems are related to different reading and spelling profiles of dyslexia. In this sense, problems in phonemic length discrimination are also a clear risk factor for dyslexia.

2.3 Study III

The third, longitudinal study[7], was conducted with two 1st graders, a normally developing Russian-speaking L2 learner of Finnish and a native speaker with reading disabilities. Both children had difficulties in identification of Finnish vowel quantity degrees. Previous studies have shown that quantity is difficult for Russian L2 learners of Finnish because it functions differently in the two languages. There was also evidence that perception of quantity distinctions can be problematic for native Finnish children with reading disabilities. We focused on the identification of /*a*/vowel phonemic length in a pseudo-word context. All the quantity distinctions occurred at the end of the pseudo-words, and the geminate /*kk*/ preceded them (for example *kekka* – *kekkaa*[8]). We were interested

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7 The home university of Sari Ylinen is university of Helsinki. (See the cover page of article).

8 The item /*kekkaa*/ is actually a spoken form of the Finnish verb /*keksiä*/ (invent). None of the children recognized /*kekkaa*/ as an actual word. The use of the spoken form of the word is not in the list of 9996 most frequent words used in newspapers,

in whether computer-assisted training improves the perception of vowel quantity, general phonemic length discrimination ability and vowel length discrimination ability. We also studied whether the training has effects on reading and spelling accuracy and on the reading speed of vowel quantity. We further studied whether the training has effects on the accuracy of grapheme-phoneme correspondences, writing of letters, phonological awareness, reading speed and accuracy, and spelling accuracy.

2.3.1 Methods

Children's cognitive abilities and language competence were assessed in pre- and end-measurement point and in follow-up measurement point. The children were tested for letter naming, sound naming, letter spelling, phonological awareness, discrimination of /*a*/ vowel quantity, discrimination of general phonemic length, naming speed, reading fluency and accuracy, spelling, IQ, expressive vocabulary, receptive vocabulary in Russian (with the Russian-speaking child), spelling and reading of pseudo-words with /*a*/ vowel quantity, and reading speed of non-words (together with pseudo-words with /*a*/ vowel quantity).

Vowel phonemic length identification ability was assessed seven times during the period, four times before the intervention, and three times after the intervention with pseudo-words /*kekka–kekkaa*/ and /*parsikka–pariskkaa*/(see Figures 1–2). The children received computer-assisted identification training (Ekapeli (Graphogame), see Hintikka, Aro & Lyytinen, 2005: 158–159, 163; Lyytinen et al., 2009: 671) on Finnish phonological quantity with words and pseudo-words ending with the syllables /*-ka*/ and /*-kaa*/. Vowel duration was modified with Praat-software (Boermsa & Weenink 2005). The /*a*/ vowel durations were prototypical for their quantity category in the game (see examples of the spectrograms and oscillograms of prototypical sounds in Figures 3–6). The cut-off criterion for poor identification ability, as indicated by the quantity category boundary, was a *d'* z-score of -1.0, which was set by the performance of the age standard group (*N* = 37). The children also received training by means of letters, syllables and word forms.

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and is thus relatively infrequent. The word /*keksiä*/ is ranked 1653 on the list (Suomen sanomalehtikielen taajuussanasto.)

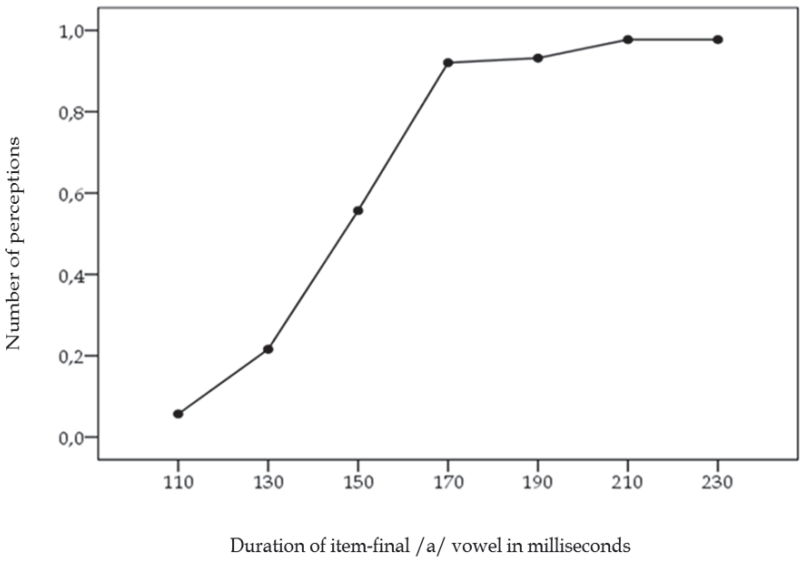

FIGURE 1 Perception of duration of item-final vowel /a/in items /*kekkaa–kekkaa*/ in the norm value test with 37 children from Jyväskylä, Finland.

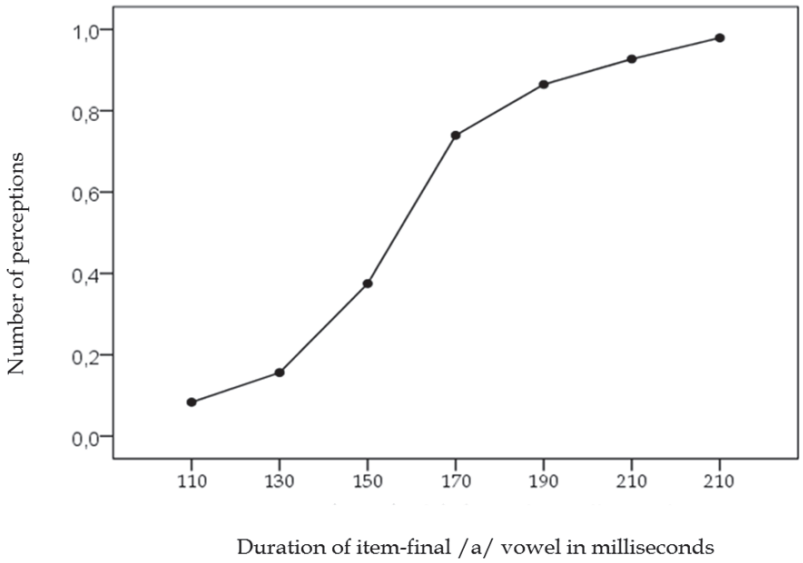

FIGURE 2 Perception of duration of item-final vowel /a/ in items /*parsikka–parsikkaa*/ in the norm value test with 37 children from Jyväskylä, Finland.

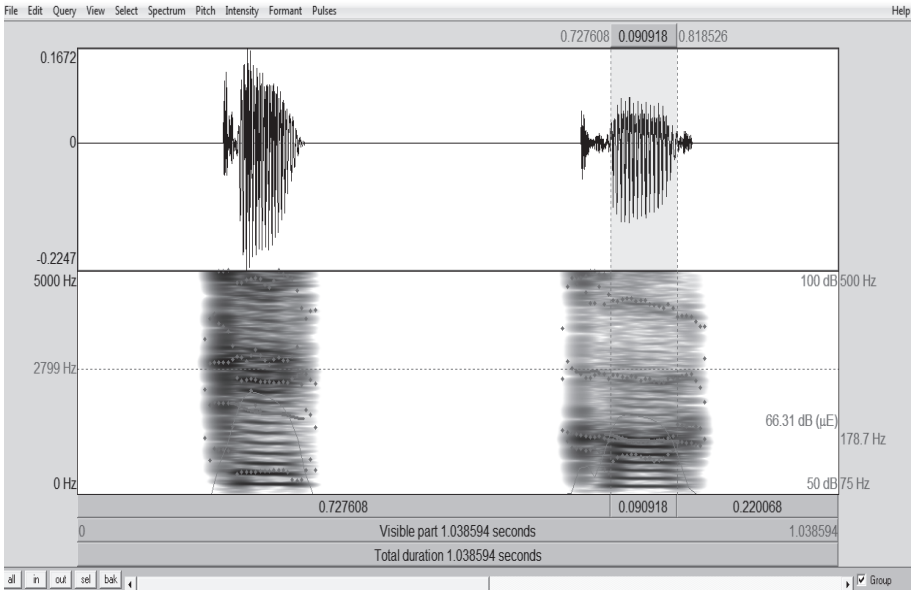

FIGURE 3 Oscillogram and spectrogram of the item/*kekka*/. The duration of the final vowel /a/ is 90 msec.

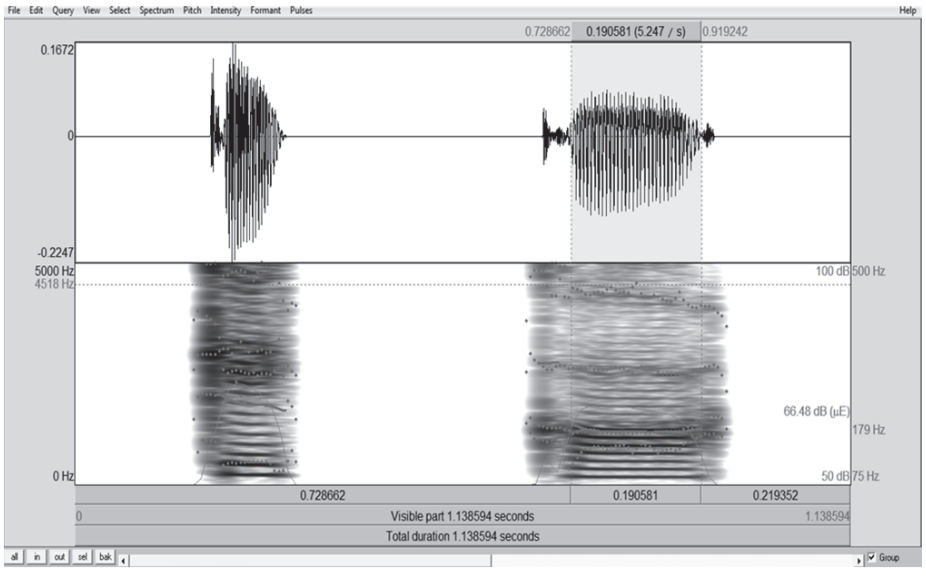

FIGURE 4 Oscillogram and spectrogram of the item /*kekkaa*/. The duration of the final vowels /aa/ is 190 msec.

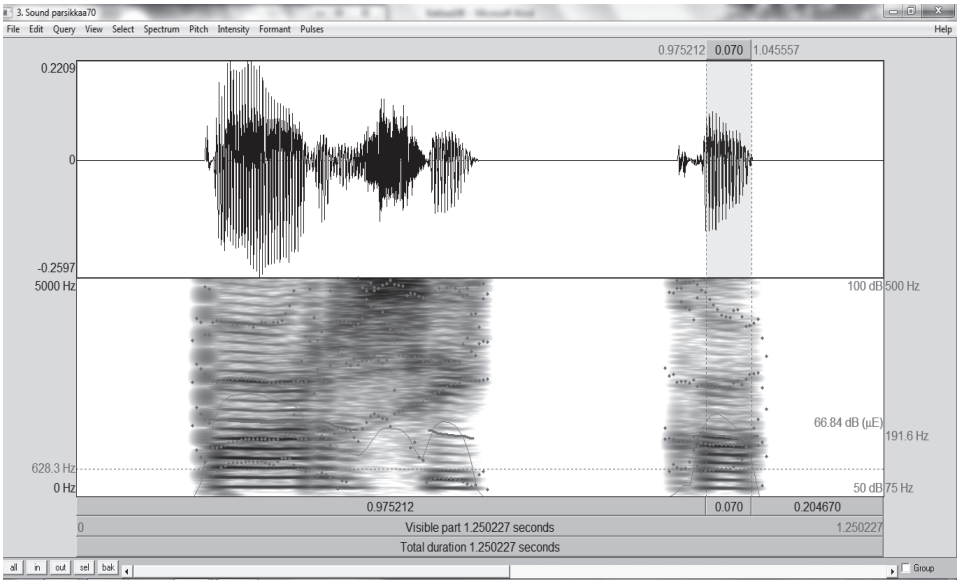

FIGURE 5 Oscillogram and spectrogram of the pseudo-word /*parsikka*/. The duration of final vowel /a/ is 70 msec.

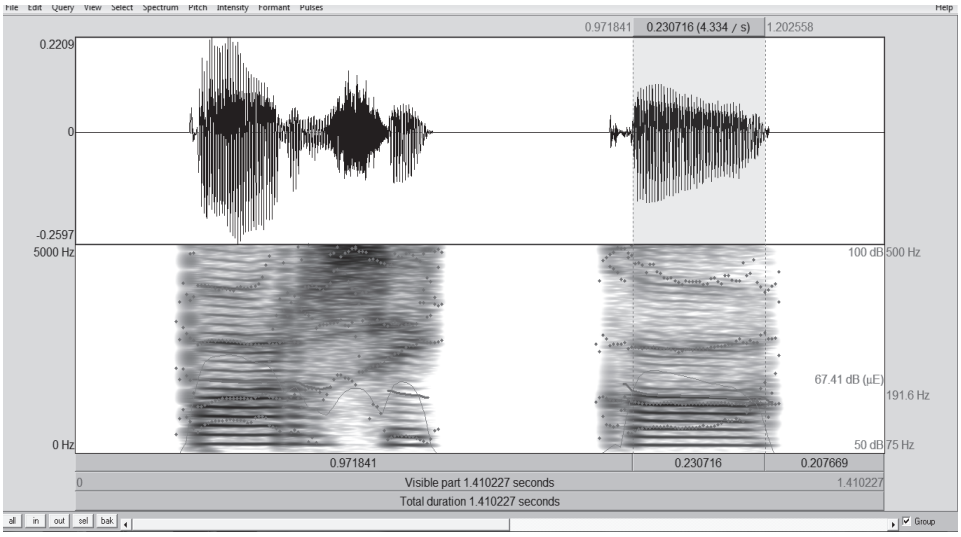

FIGURE 6 Oscillogram and spectrogram of the pseudo-word /*parsikkaa*/. The duration of final vowels /aa/is 230 msec.

2.3.2 Results

After the training sessions, the Russian-speaking L2 learner performance resembled the age standard group in the phonemic length identification task whereas the reading-disabled L1 speaker reached this level only at the follow-up measurement point. The L2 learner improved his overall performance in the general phonemic length discrimination task after the training whereas the L1 speaker's performance in discrimination of /*a*/ vowel phonemic length only showed improvement at the follow-up measurement point. The L1 learner performed poorly in the general phonemic length discrimination task after the intervention. The L2 learner also improved accuracy in reading and spelling accuracy of quantity, grapheme-phoneme correspondence, spelling of graphemes, and phonological awareness. The L1 speaker improved overall accuracy in reading fluency and spelling of quantity.

2.3.3 Discussion

The results reveal that perception of phonemic length may be more difficult to remediate in reading-disabled L1 learners (i.e., from biologically compromised background) than in Russian speaking L2 learners of Finnish, whose performance reflects insensitivity to the specific feature to be learned due to the difference of the phonological systems between L1 and L2. However, the results of this case study cannot be generalized to the population level. The main purpose of the study was to provide a new perspective for quantity research and for future studies involving quantity training both in native children with reading disabilities and in L2 learners of Finnish.

2.4 Study IV

In the fourth study, we focused on computer-assisted training of vowel quantity in four 1st grade Russian-speaking L2 learners of Finnish who had problems in vowel quantity identification before training. The quantity degree varied in the end of the stimuli. The training included two- and three-syllable word and pseudo-word minimal pairs. Each of these game streams included two levels of minimal pairs with larger and smaller differences in the duration of the vowel /*a*/. We studied whether there were statistically significant differences between the streams and between words and pseudo-words. We then studied whether there were differences between minimal pairs with larger and smaller duration differences, and studied whether the identification of short vowels was easier to learn than that of long vowels. Finally, we studied whether the training had effects on the identification of /*a*/ vowel quantity degree in final position in two- and three-syllable pseudo-words.

2.4.1 Methods

N was constructed from the answers of the children in the game. The identification of quantity degree was assessed in pre-, end-, and follow-up measurement points. Pre-measurement took place before the training, end-measurement after the training, and the follow-up measurement six months after the training when the children were in the 2nd grade. The phonemic length training was carried out in four game streams with two- and three-syllable word and pseudo-word minimal pairs by beginning with two-syllable words and continuing with pseudo-words of the same syllable length (for example */kukka–kukkaa/ 'a flower'* and a partitive case form of the word). Each stream included two levels of minimal pairs with larger and smaller differences in the duration of item-final */a/*. Thus the game comprised a total of 16 minimal pair levels. The game started with testing letter names and sounds and then continued with the training of letter-sound correspondences, a simple word-forming task and an auditory detection task. The game also included a word-forming task, syllable identification task and auditory detection between the game streams.

Wilcoxon Signed-Rank Tests were used to determine whether there were differences in the correctness of streams, words and pseudo-words, minimal pairs with larger and smaller duration differences in /a/ vowels, and long and short */a/* vowel durations in different items. Levels 1 and 2, and 3 and 4, were analysed together. *z d'* values were used to determine whether the children had improved their performance in the identification of pseudo-word-final */a/* vowel quantity degree identification after the game. Input values were partly used because one child had missing data due to the difficulty of some quantity streams. The items would seem too difficult without including input values. The mean of the variable was used as an input value in SPSS.

2.4.2 Results

Accuracy in identification of quantity degree was lowest in the two-syllable words and highest in the three-syllable pseudo-words. The accuracy of identification of quantity degree was higher in the minimal pairs with larger than smaller differences in duration. Accuracy scores were lower for long duration than for short duration. When short and long vowels were studied separately, they were both significantly more difficult to identify among words compared to pseudo-words. Overall, words were more difficult than pseudo-words, indicating development of identification of quantity degree during the playing. The ability to identify quantity degree was generalized to stimuli used in the identification test in two of the children.

2.4.3 Discussion

When examined as a group, the results suggest that the children developed in their identification of quantity degree during playing. In addition, the representations of word forms including quantity degree generalized to pseudo-words.

The inclusion of other than quantity items in the beginning of the game did not help in the perception of quantity differences in the minimal pairs of the first quantity stream, as this stream was the most difficult of all the streams for the children. The ability to identify quantity degree developed during the training in two of the children. This indicates that the quantity game form used in this study may not be effective for all L2 learners of Finnish. The content, stimuli, and the starting point of the game should be considered in future studies, as well as individual perception abilities.

3 GENERAL DISCUSSION

3.1 The different language learners of the study

This study focused on the perception and learning of Finnish phonemic length by Finnish children with reading disabilities (dyslexia) and with familial risk for dyslexia, and by controls without the risk. The precursors and risk factors behind dyslexia are important to study, because reading proficiency is important in everyday and professional life.

Correct perception of duration (signaling quantity degree) has been found to be difficult for infants with a familial risk for dyslexia (Richardson 1998: 1, 96–98, 136–137; Richardson et al., 2003: 391–395) as well as for the at-risk children with reading disabilities (Hämäläinen et al. 2009: 511–512; Leppänen et al. 2010: 1362). The main purpose of this dissertation was to study in more detail the role of perception abilities of phonemic length in the development of reading disabilities and dyslexia at school age. Based on previous results, we expected that children with reading disabilities would show problems in perception of phonemic length, and in the reading and in spelling of quantity. We also wanted to study the role of familial risk for dyslexia together with the perception of phonemic length in reading and spelling skills.

The other learners of interest in this study were Russian children learning Finnish as a second language (L2) in Finnish schools because Russian-speaking people comprise the largest group speaking a foreign language in Finland (see "The Population of Finland grew most in 20 years").

The phonological system of Russian language differs from Finnish in the use of duration (Nenonen 2001a: 16–17; Nenonen et al. 2003: 492; Ylinen et al., 2005: 313). In Russian there is one vowel in every syllable and it forms the nucleus of syllable. Word stress determines the durations of sounds, but the duration differences per se do not differentiate words from each other. (de Silva 1999: 19, 22, 174; Nenonen et al. 2005: 28.) Thus, as de Silva (1999: 69, 71, 176) has stated, Russian L2 learners of Finnish who do not know the phonological system of Finnish perceive syllables including a long vowel as stressed. The difficulty of

Finnish quantity for Russians has been shown on the perceptual level in the dissertation by Ylinen (2006: 4). Therefore, Russian L2 learners of Finnish were expected to show problems in the perception of phonemic length. At the same time, because they did not have learning problems, they were expected to show faster development in perception ability compared to Finnish children with reading disabilities and with familial risk for dyslexia.

3.2 Outline of the results

Studies I and II concerning children with reading disabilities and with familial risk for dyslexia, and typically reading children with or without familial risk in the Jyväskylä Longitudinal Study of Dyslexia (JLD) showed that Finnish children develop in the ability to discriminate phonemic length from grade 1 to grade 3. Goodman and colleagues (1994: 4) have already suggested that speech perception abilities develop from childhood to adulthood. The children with familial risk for dyslexia and with reading disabilities differed from the control group in discrimination ability in the 2nd and 3rd grades. The study also showed a stronger contribution of discrimination ability over school-age traditional markers of dyslexia to reading accuracy in the 3rd grade and to spelling accuracy in the 2nd and 3rd grades in the children with familial risk and with reading disabilities.

The children with familial risk for dyslexia, with reading disabilities and with phonemic length discrimination ability problems were poorer in reading and spelling accuracy and made more quantity errors in the 2nd grade compared to the children with familial risk for dyslexia, with reading disabilities and without discrimination ability problems, and to typical readers with or without the risk. The results are similar to those of the study of Thomson, Fryer, Maltby and Goswami (2006: 334, 344) where they found that duration discrimination predicted variance in reading and spelling with dyslexic adults. The problems in well-known risk factors for dyslexia (early language skills, phonological awareness, verbal memory and naming speed) accumulated in the group of children with reading disabilities, with familial risk for dyslexia and with phonemic length discrimination ability problems in the 2nd grade. Discrimination ability explained spelling accuracy among the at-risk children with reading disabilities after the accumulation of pre-reading risk areas for dyslexia was taken into account. Discrimination ability did not have any connections to reading fluency.

The results suggest that the perception problems of phonemic length are severe for at-risk children with reading disabilities still at school age, and that these problems are evident in reading and in spelling skills, especially in accuracy of the spelling of quantity. It also shows that difficulty in the perception of phonemic length is an accumulating risk factor for dyslexia together with other well-known risks. This is important finding because it shows that the processing and perception of phonemic length forms an exception to the skill of

learning grapheme-phoneme correspondence in Finnish (see Ikola 2000: 19–20). However the children did have problems in grapheme-phoneme correspondences, as was shown by the reading and spelling errors the children made in studies II and III. This has been shown to be a strong predictor of reading disabilities in Finnish children with familial risk for dyslexia (Lyytinen et al., 2007: 110). It also shows that the ability to perceive phonemic length has its own impact on dyslexia independently of phonological awareness. In general, the results support the multiple cognitive deficit model of dyslexia (Pennington 2006: 404–406; Snowling 2008: 142; Aro et al. 2009: 883).

The results of studies I and II are in accordance with those of Richardson and colleagues. Richardson showed that six-month-old infants at risk for dyslexia required 40 milliseconds or longer silence to perceive the /*t*/ in pseudoword /*at:a*/ as long as compared with controls (Richardson 1998: 1, 96–98, 136–137; Richardson et al., 2003: 391–395). These behavioral findings were further supported in the JLD by brain response measurements using event-related potential (ERP) techniques (Pihko et al. 1999: 1, 4; Leppänen et al. 1999: 1). (See also Lyytinen et al. 2003: 124–135; Leppänen et al. 2002: 407–408; Hämäläinen et al. 2009: 511–512; Leppänen et al. 2010: 1362).

The study by Lehtonen (2006: 71, 75, 76, 77) concludes that 1st grade children do not pay attention to the length of speech sounds they hear in spelling Finnish geminates whereas 2nd graders are able to pay attention to the length of the sound they hear. However, in the second half of the first school year children begin to use the phonological aspect of the geminate spelling rule. Lehtonen shows that geminate spelling requires different processing than other consonant clusters. For Finnish children it takes longer to learn the phonological than the orthographic aspect of the geminate spelling rule. Lehtonen's results show that phonemic length should be quite easy for typically developing Finnish children to spell in the 2nd grade.

The identification training of two- and three-syllable word and pseudoword final vowel quantity degree used in studies III and IV was designed on the basis of the NLM, and prototype theory of Flege (1988) and Kuhl (1992, 2008: 979). Problems in the perception of quantity were more difficult to remediate and perception ability developed more slowly in a native 1st grade child with reading disability than in same-age Russian L2 learner of Finnish. Two-syllable words, including quantity, presented the most difficulty for Russian L2 learners of Finnish in the identification training of quantity degree, and the representations of words including quantity were generalized to the representation of pseudo-words among the game stimuli. The training effects with prototypical items were generalized to stimuli (phonemic length near the category boundary) in the identification test at the post-assessment time point in two children. The results were in accordance with previous studies showing that phonemic length (phonological quantity) is challenging for Russian L2 learners of Finnish (Vihanta 1990: 213; de Silva 1999: 69, 71; Nenonen 2001a: 11; Ylinen 2006: 4). It may also be that the Russian children had problems in learning Finnish grapheme-

phoneme correspondences resembling those in the native reading-disabled children with familial risk for dyslexia.

Based on the results, we can construct the hypothesis that dyslexics who have problems in phonemic length discrimination or identification abilities may have problem in the dorsal stream in the brain. (Hickok & Poeppel, 2007: 394). This same area is activated in L2 speech sound discrimination. However, this study was conducted with behavioral methods. It should be considered what further contribution brain imaging studies could make to the conceptualization of the perception and learning of phonemic length and quantity in children at different ages and in different stages of language learning. In other words, further studies with these two learner groups are needed to see the processes in the brain. It can be concluded that the perception and learning of phonemic length seems to be more difficult for Finnish children with a familial risk for dyslexia than for Russian L2 learners of Finnish.

Intervention studies on Finnish children with familial risk for dyslexia and reading disabilities have shown that remediation of their reading, and spelling skills or reading-related skills can be challenging (Salmi 2008; Huemer 2009; Ketonen 2010; Oksanen 2012), although a number of studies have reported beneficial effects of training phonology on reading performance (Snowling & Nation 1997; Swanson 1999; Wise et al. 1999; 2000; Hatcher 2000; Lovett et al. 2000; Torgesen et al. 2001; Pogorzelski & Wheldall 2002; Tijms et al. 2003). There are also several reports on the positive impact of Graphogame on skills of children at risk for reading difficulties at the beginning of schooling (Lyytinen et al. 2007; Lyytinen et al., 2008; Lyytinen et al. 2009; Saine et al. 2011; Richardson et al. 2011). Some studies have shown that vowel perception difficulties may persist for a long time in students of a new language (Flege 1998: 24; Pallier, Bosch & Sébastian-Galles 1997: B9; Ylinen et al. 2005: 313; Heeren 2006: abstract) or that remediation may take a long time, while other experiments have shown otherwise (for example Best, Faber & Levitt 1996: 2602). The studies on pre-attentive perception of non-native vowels have shown that new representations can be formed at least in the context where authentic input is provided for several years (Winkler et al. 1999: 641). For example, Ylinen and colleagues (2010: 1319) showed, using MMN brain responses, that phonetic training enhances Finns' ability to pre-attentively process the spectral cues of English vowels. Heeren and Schouten (2010: 594) have also shown that prototypical representation of Finnish phonological quantity can be enhanced with short training, although changing the accuracy of perception near the category boundary is more difficult.

Taken together, previous studies of phonological training conducted with children with reading disabilities and L2 learners have shown mixed results. However, it is possible that the biological and neurological nature of dyslexia and speech and/or auditory perception problems render their remediation more difficult than in the case of typically developing L2 learners. (Brady et al. 1983: 345, 346, 360, 364, 365; Mody et al. 1997: 227; Elbro et al. 1998: 36; Goswami 2000: 134, 142–144, 146; Tallal 1980: 182,189, 194; Booth et al. 2000: 101;

Reed 1989: 270; Witton et al. 2002: 866; Goswami et al. 2003: 235; Richardson et al. 2004: 215; Goswami 2011: 3; Lehongre et al. 2011: 1080; Bruder et al. 2011: 1107).

It should be noted that the comparisons of the intervention results between the child with reading disabilities and the Russian L2 learner of Finnish in the third study cannot be generalized to larger populations because it was a case study with only two children. Individual features may also more easily have effects on the results than would be a study with a large number of participants. Studies with larger groups would give more reliable information about the effects of training of phonemic length. However, the present findings of the study suggest that the perception of phonemic length should be intensively trained both in Finnish children with reading disabilities and in L2 learners of Finnish, using Graphogame or other learning tools, and it should be accorded extra input in schools. The development of the training of phonemic length perception also needs further study.

3.3 Aspects in testing

Bilinguals themselves, and others, compare their language skills to those of the monolinguals around them. Generally bilinguals are thought to be equally proficient in both of their languages, and this is expected from children too. Language abilities and skills vary individually, but the variation is generally within the same range as it is among monolinguals. Comparison of the development of mono- and bilinguals is not optimal; however, this is only one way to approach the issue. We might ask instead: what circumstances would be ideal to develop balance and harmony between skills in two languages? Thus, monolingualism should not be taken as a norm for bilingualism. (Baker 363; de Houwer, 2009: 308–309, 328.) Alternatively, a bilingual child should be compared to a child who has faced the same kind of requirements in the learning process (Korpilahti 2010: 149).

When testing bilingual children, the deficiencies observed are often a result of narrow academic tests. They fail to measure the discourse patterns that children from different cultures are able to use with considerable competence. The translations of norm tests may also render such tests invalid and unreliable. (Baker 2007: 11, 144–147, 322, 361.) Language skills should also be assessed in both languages (Korpilahti 2010: 149). The absence of appropriate tests of the mother-tongue skills of L2 learners or their availability in Finland (or in other countries) is a problem. This is an area which needs developmental work on test materials and international collaboration between specialists in speech, language, and psychology from different countries. For this reason we did not translate the Finnish test into Russian, and instead asked the native Russian teacher of the children to evaluate their language proficiency in studies III and IV. The perception of speech also encompasses a variety of different processes and structures. Therefore it is not enough to determine whether a group of L2

learners do or do not differ significantly from a group of native speakers (Flege 2003a: 20).

In this study, we compared Russian L2 learners' results to those of a monolingual Finnish-speaking group. This concerned in particular the identification and discrimination of phonemic length. The training stimuli were based on the quantity degree identification norm values of Finnish-speaking children, which is in discordance with the view that bilinguals should not be compared with monolinguals. However, this kind of study could not have been conducted without the norm group values, because without those we would not otherwise have had any material to compare the development of Russian-speaking children. The problems in learning of phonetic aspects of the target language may also be very disturbing for a learner itself. Therefore the comparisons of L2 learner's skills to Finnish children were justified in this case.

In addition to the complex nature of vowel quantity, the testing of the perception of duration is, for other reasons, also difficult. Traditional studies on vowels have addressed the effect that distortions of the test setting have on perception (Iverson & Kuhl 2000: 883) and how various co-articulatory contexts affect the perception of vowels (e.g. Macchi, 1980: 1636; Parker & Diehl 1984: 369). The fact that several acoustic variables are in process in the sound at the same time may make the perception of duration more difficult.

This dissertation concentrates on the discrimination and identification of phonemic length. Flege (2003a: 23) has argued that the most direct behavioral method for evaluating the perception of L2 vowels is to ask L2 learners to identify those vowels. Two-alternative forced-choice (2AFC) experiments, however, may be problematic. Still, identification is a better method for training than discrimination, because listeners need to be exposed to different exemplars of the same category during training in order to decrease their sensitivity to discriminate stimuli in the same category (Guenther, Husain, Cohen & Shinn-Cunningham 1999: 22). A problem for discrimination tests is that the results of the test typically reflect an auditory component instead of, or in addition to, information stored in long-term memory representations (Flege 2003a: 25). Based on this, discrimination testing does not necessarily show problems in perception of phonemic length alone, but also problems in general auditory ability. Testing and training the perception of phonemic length with identification tasks seem to be a better approach than using discrimination tasks. This is important when we think of training and teaching methods in the long run. We performed the testing partly with items written on paper as two-alternative forced-choice tasks. If the testing had been implemented with a simple auditory button-pressing task, this too would have been problematic, as the pressing of the button cannot be controlled accurately.

To consider the problems in the testing performed here, the phonemic length discrimination task had quite a small number of items (same-different judgment task, 22 pairs in the current study). Usually discrimination of speech sounds is studied with a greater number of stimuli to achieve reliability. However, we studied the perception in children, and their concentration on a task

which requires careful listening for phonetic details in speech may be poorer in a long lasting task. Therefore, we could not conduct a long experiment with a large number of stimuli. However, we included more items in the identification and discrimination tests of the intervention study.

One problem is that the identification ability of the Finnish norm group was not tested at either the end or follow-up assessment in the intervention study. The norm value test was conducted in the beginning of February, and the pre-assessments were conducted about the same time. The end assessment was conducted in March, and the follow-up assessment in September in the same year. If the norm value test had been conducted at these points as well, comparison of the results would have given more reliable information on the development of the perception skills of the Russian-speaking children and of the Finnish child with reading disabilities after the intervention. This is because children's language skills develop rapidly during the first school years. However, the study was carried out over a period of eight months and the summer holiday between grades inevitably impairs the target language skills of L2 learners because they do not have Finnish language teaching during that time and may also spend much time with Russian-speaking relatives. Therefore the ability to perceive phonemic length may not have developed as fast during this period.

3.4 Developing the training of phonemic length and other future implications

With respect to the future of quantity training with Graphogame, there are various factors that need to be considered. First, what is the most appropriate age for training, especially with L2 learners. The children in the training study were seven years old. The results of previous studies show that the sensitivity to discriminate non-native speech sounds decreases after the first year of life (Werker & Tees 1984: 49: Cheour-Luhtanen et al. 1995: 55, 56; Cheour et al. 1998: 353; Kuhl et al. 2008: 979; 61; Jusczyk et al. 1993: 418). Hence, the training of phonemic length in L2 learners, and perhaps also in children with reading disabilities, should be conducted earlier, perhaps as early as during the first year of life. However, this would be difficult because parents rarely know in what circumstances the children will live their lives, and what languages they would need or want to learn. One appropriate phase could be the time when the learning of L2 or preschool is about to begin. However, early exposure to an L2 has been reported to be insufficient in itself to guarantee native-like discrimination of L2 vowels (Flege & MacKay 2004: 1–2, 27–28; Højen & Flege 2006: 3072, 3075, 3078, 3083). It has also been claimed that adults can acquire, with varying success, even the most difficult non-native phonemes during extensive exposure to a new language (Pisoni et al. 1994: 146; Rvachew & Jamieson 1995: 411; Winkler et al. 1999: 641). Giannakopoulou, Uther & Ylinen (in press) showed that training

in phoneme identification and discrimination of vowel duration can also be effective with adult L2 learners. In conclusion, while an intervention may be possible at any age, training in an earlier phase of life seems to be more effective than an intervention conducted in adulthood. The training should be conducted as early as possible, in light of the view that the learning of a new language becomes more difficult with increasing age (Abrahamsson & Hyltenstam 2009: 249).

Training in phonemic length could also be done with consonants as well as vowels. An effective way to teach pronunciation (phonemic length) is via listening. Listeners use stress and prosody as a way of learning more about the structure of speech (Goodman et al. 1994: 12). For this reason, it should be considered in education. Motivation is also important when learning a second language (Baker 2007: 132) and for children with reading disabilities (Ronimus 2012: 3), and repeating aloud the stimuli during playing should be taken into account.

The game would also benefit from having more different speakers pronouncing speech sounds. This would increase the variability of the items, which would also more closely resemble natural speech. Samuel (2011: 64) concludes that stimuli produced by several different speakers are more efficient for training non-native contrasts, as well as for the perceptual learning of accented speech (see also Pisoni et al., 1994: 146; Giannakopoulou et al., in press). However, Perrachione and colleagues (2011: 461) claim that high-variability training does not affect the perceptual abilities of all learners.

Another aspect what should be considered is the duration of the training. Lyytinen et al. (2008) have suggested that Graphogame is effective as a short-term intervention. Ketonen (2010: 97, 101), Hatcher, Hulme & Snowling (2004) and Scanlon, Vellutino, Small, Fanuele & Sweene (2005) all suggest that an intervention lasting six months is not enough for children who have familial risk for dyslexia, poor letter knowledge and difficulties in phonological skills. The length of training should probably be considered individually for each child.

Overall, the spoken word and visual word /pseudo-word / non-word recognition regarding surpasegmental phonemic length in this study is closely linked to the top-down ideas of the PGST (Goswami 2006) and "radical" templatic phonology (Vihman & Croft 2007), according to which the items to be learned should be larger units than single phonemes. We can thus ask: should the items in the testing and training be syllables or words? In other words, what is the prototype of the phonemic length of short and long vowels and consonants in Finnish? Huemer (2009: 3), in her dissertation, found that sub-lexical units, such as consonant clusters and syllables offer a way of achieving generalization effects. It has been argued that training with larger stimulus sets may generalize better, and they could teach listeners to more efficiently focus their attention on critical acoustic cues instead of irrelevant variation. (Iverson et al. 2003: B54.) The perception of duration differences is also claimed to be easier when they are presented together in speech and in writing (Geber 1996: 166). Training with larger items is also possible because recognition of all the letters

at the same time is possible when a word is formed of less than ten letters (Hyönä, 2010: 102). In relation to this, semantics could be added to the training, because word recognition is better when the word is presented in a predictable sentential context than when it does not have such support (for a review, see Samuel 2011: 59). Semantic variables associated with lexical representations can modulate the ease of word recognition (Balota et al. 2006: 319).

These implications present us with a dilemma. First, word/pseudo-word-level discrimination and identification is problematic for beginning readers of Finnish because they have problems with the processing of word length. The memory demands of decoding and recoding are high because a large number of phonemes require to be assembled before pronunciation is possible. (Lyytinen et al. 2006: 60.) More importantly, the length of items seems to affect dyslexics more than chronological age controls in lexical decision-making, because dyslexics predominantly rely on a sub-lexical reading strategy (Martens & de Jong 2006: 148; Hautala 2012: 3). It has been argued that non-native word recognition may also be difficult when fine phonetic discrimination at the segmental level is required. (Bradlow & Pisoni 1999: 2074.) Second, Lehtonen and Laine (2003: 213) found that bilingual subjects do not have whole word-level representations of frequent, inflected words, and Nenonen (2001a: 26) showed that Russian L2 child-learners of Finnish have problems in the accurate spelling of quantity (Nenonen 2001a: 26). In conclusion, phonemic length is determined by a larger context than a phoneme or syllable, and hence training with larger units is needed to develop correct representations for phonemic length. It also requires different kinds of stimulus types, as it seems that there is not necessarily an ideal prototype for phonemic length in the short and long duration categories. These facts should be carefully considered in future studies concerning phonemic length, as well as individual language and learning skills of children.

Overall, this psycholinguistic study sought to combine the fields of speech sound perception, isolated word recognition, and an intervention for children with reading disabilities and another for L2 learners. In conclusion, problems in perception of phonemic length seem to be a risk factor for dyslexia, together with other well-known risks, and more difficult to remediate in children with reading disabilities and with familial risk for dyslexia compared to Russian L2 learners of Finnish. However, it seems that the problem can be trained with appropriate learning tools, for example with Graphogame. Individual differences also need to be considered when planning training paradigms for phonemic length.

TIIVISTELMÄ

Tämä tutkimus pyrkii antamaan tietoa suomenkielisten luku- ja kirjoitushäiriöisten lasten ja venäjänkielisten suomea toisena kielenä opiskelevien lasten suomen kielen kvantiteetin havaitsemisesta. Osa tutkimuksesta keskittyy myös kvantiteetin oppimiseen tietokonepohjaisella Graphogame-pelillä. Tarkastelun kohteina ovat 1–3 luokan suomenkieliset lapset, venäjänkielisistä pelkästään ensimmäisen luokan oppilaat. Kyseisten ryhmien kvantiteetin oppimista ei ole aiemmin vertailtu samassa tutkimuksessa, joten tarkastelu on asetelmaltaan uusi ja ajankohtainen.

Suomen kielen kvantiteetti koostuu äänteiden fysikaalisesta kestosta sekä havaitusta lingvistisestä pituudesta. Kvantiteetti havaitaan kategorisesti lyhyeksi tai pitkäksi, vaikka todellisuudessa äänteiden kestoja on loputon määrä ja niiden havaitseminen ja luokittelu on subjektiivista ja kontekstistaan riippuvaista. Kvantiteetin identiteettiryhmätulkinnan mukaan kontrastiivisesti pitkät vokaalit ja konsonantit tulkitaan kahden identtisen foneemin jonoiksi. Kirjoitetussa yleiskielessä lyhyttä äänteen kestoa ilmaistaan yhdellä grafeemilla, ja vastaavasti pitkää äänteen kestoa ilmaistaan kahdella grafeemilla.

Kvantiteetin tarkka oppiminen voi olla vaikeaa niin syntyperäiselle luku- ja kirjoitushäiriöiselle lapselle, jolla on suvussa esiintyvä geneettinen riski dysleksiaan, kuin toisen kielen oppijalle, jonka kielessä ei esiinny vastaavaa kvantiteettioppositiota. Dysleksian taustalla ajatellaan olevan fonologisen prosessoinnin ongelmat, jotka johtuvat joidenkin näkemysten mukaan puheäänteiden representaatioiden heikkoudesta. Joidenkin näkemysten mukaan näiden taustalla ovat yleiset, auditiivisen havaitsemisen ongelmat. Nykyisten dysleksiaa koskevien teoreettisten näkemysten mukaan useat eri vaihtoehtoiset polut kognitiivisissa ja kielellisissä taidoissa tai varhaisten kognitiivisten ja kielellisten taitojen kasautuvat riskitekijät ovat todennäköisimmin dysleksian taustalla.

Tutkimuksessa tarkasteltiin rinnakkain kahta ryhmää, joista yhdelle kvantiteetin oppimisen vaikeus on biologispohjaista ja toiselle kielten välisistä eroista johtuvaa. Viitteitä dysleksia-riskilasten vaikeudesta prosessoida kvantiteettia ovat antaneet etenkin Ulla Richardsonin tutkimukset, joiden mukaan puolivuotiaat riskivauvat tarvitsivat kontrollejaan pitemmän äänen keston havaitakseen sen pitkäksi. Myös pituuden tuottamisessa oli vastaavia eroja näiden ryhmien välillä 1;6 vuoden iässä, kuten myös heidän vanhemmillaan. Myös ERP-tutkimukset ovat viitanneet siihen, että riskivauvoilla on poikkeavuutta kestojen synnyttämissä aivovasteissa. Viola de Silvan ja Sari Ylisen tutkimukset ovat puolestaan paljastaneet suomen kielen kvantiteetin haasteellisuuden venäjänkielisille suomen kielen oppijoille, niin lapsille kuin aikuisillekin. Ylisen tutkimukset ovat osoittaneet, että suomenkieliset aikuiset prosessoivat foneemin kvantiteetin ja kvaliteetin erillisinä, ja havaitseminen näyttäisi olevan yhteyksissä foneemien prototyyppeihin. Venäjänkielisillä suomen oppijoilla ei myöskään ole havaittu foneemiraja-efektiä kvantiteettikategorioiden välillä. Suomenkielisten kaltaiset ERP-vasteet syntyivät vain äänteille, joita oppijat eivät pystyneet prosessoimaan oman äidinkielensä kategorioiden kautta. Toisin kuin suomen-

kieliset, venäjänkieliset suomen kielen oppijat näyttävät myös ylittävän epäsananloppuisen vokaalikeston havaitsemisessa kategoriarajan lyhyemmällä kestolla kuin suomenkieliset, ja syntyperäisten puhujien foneemisen pituuden kategorisointi on nopeampaa kuin venäjänkielisillä toisen kielen oppijoilla.

Tämä viitekehys antoi mielenkiintoisen lähtökohdan kvantiteetin representaatioiden havaitsemisen ja oppimisen tutkimiselle. Väitöstarkastelu antaa tietoa siitä, onko foneemisen pituuden erottelutaidolla yhteyttä dysleksiariskiryhmän luku- ja kirjoitushäiriöisten lasten luku- ja oikeinkirjoitustaitoihin kouluiässä, miten foneemisen pituuden prosessointi on heillä yhteydessä muiden kognitiivisten ja kielellisten ongelmien kasautumiseen, ja mitä ongelmia erottelupulmat voivat aiheuttaa luku- ja kirjoitustaidossa. Lisäksi tutkimuksessa tarkastellaan tapaustutkimuksen keinoin, aiheuttavatko foneemisen pituuden tunnistaminen, erottelu sekä kvantiteetin lukeminen ja kirjoittaminen samalla tavoin pulmia suomenkielisille luku- ja kirjoitushäiriöiselle lapselle kuin venäjänkieliselle lapselle ja voidaanko piirteen oppimiseen vaikuttaa tietokonepohjaisen harjoittelun avulla. Tutkimuksessa tarkastellaan myös kvantiteettiärsykkeiden oikeellisuusasteita venäjänkielisille lapsille tehdyssä interventiossa ja pyritään antamaan parannusehdotuksia kvantiteetti-intervention kehittämiseen tietokonepohjaisella menetelmällä. Tutkimuksen taustalla olevaa Graphogame-peliä on sovellettu jo laajasti suomenkielisten luku- ja kirjoitushäiriöisten lasten tutkimiseen ja kouluopetukseen. Maahanmuuttajien ja venäjänkielisten osalta tutkimustieto on vielä vähäistä.

Tutkimuksen aineistona on Jyväskylän yliopiston Lapsen kielen kehitys -projektin (LKK) kansainvälisesti merkittävä pitkittäistutkimuksen aineisto, jossa on seurattu 199 lasta heidän syntymästään lähtien peruskoulun päättymiseen saakka. Puolella projektin lapsista on geneettinen riski luku- ja kirjoitushäiriöön, ja toisella puolella lapsista ei ole tätä riskiä. Tässä tutkimuksessa on käytetty koko projektin aineistoa, eli saatavilla olevia tietoja riskiryhmän luku- ja kirjoitushäiriöisiltä lapsilta, riskiryhmän normaalilukijoilta ja kontrolliryhmältä. Mukana on myös yksi LKK-projektin ulkopuolinen ensimmäistä kouluvuottaan käynyt suomenkielinen lapsi, jolla oli havaittu luku- ja kirjoitushäiriöitä.

Toisen kielen oppijoista tarkastelun kohteina ovat venäjänkieliset lapset, sillä venäjänkieliset ovat Suomen suurin maahanmuuttajaryhmä. Tutkimuksessa on mukana tietoa yhteensä neljältä oppimispulmattomalta venäjänkieliseltä lapselta, joista yksi on mukana kahdessa osatutkimuksessa (3 ja 4). Kaikki lapset olivat 1. luokan oppilaita ja iältään noin seitsemänvuotiaita. Kaikki venäjänkieliset lapset, samoin kuin LKK-projektin ulkopuolinen luku- ja kirjoitushäiriöinen lapsi, on valittu tutkimukseen samasta koulusta Helsingin alueelta. Tutkimuksessa on käytetty myös haastattelulomaketietoja, joita on saatu lasten vanhemmilta, luokanopettajilta, erityisopettajilta, venäjän opettajilta, S2-opettajalta sekä koulun terveydenhoitajalta. Lisäksi tutkimuksessa on kerätty pilottiaineistoa jyväkyläläisiltä suomenkielisiltä ensiluokan oppilailta (N = 37). Menetelminä tutkimuksessa on käytetty tilastotieteellistä, kvantitatiivista tarkastelua sekä osittain myös kvalitatiivisia menetelmiä.

Tutkimus koostuu kaiken kaikkiaan neljästä artikkelimuotoisesta osatutkimuksesta. Näistä kaksi ensimmäistä käsittelee puhtaasti foneemisen pituuden erottelutaidon tutkimista LKK-projektin lapsilla. Tutkimusten keskiössä on 22 ärsykeparista muodostunut foneemisen pituuden sama-eri-erottelutehtävä, joka on teetetty lapsille 1., 2. ja 3. luokan lopussa. Foneemisen pituuden erottelupulman tulosten tarkastelussa käytettiin *d'*-arvoa, ja havaitsemisen ongelmarajana on pidetty -1.25 keskihajonnan suuruista eroa verrattuna kontrolliryhmän suoriutumiseen. Testillä on mitattu foneemisen pituuden erottelutaitoa epäsanoilla, jotka ovat lähinnä suomen kielen rakenteen vastaisia. Kaikki tutkimuksen ärsykkeet ovat puheääniä.

Ensimmäinen osatutkimus

Ensimmäisessä tutkimuksessa tarkasteltiin foneemisen pituuden erottelutaidon kehitystä ensimmäiseltä kolmannelle luokalle, sekä taidon yhteyttä luku- ja oikeinkirjoitustaitoihin riskiryhmän luku- ja kirjoitushäiriöisillä lapsilla ja normaalilukijoilla sekä kontrolliryhmällä. Tutkimuksessa havaittiin, että kaikki LKK-projektin lapset kehittyivät erottelutaidossa ensimmäiseltä kolmannelle luokalle siirryttäessä. Riskiryhmän luku- ja kirjoitushäiriöisten lasten (n = 35, dysleksia-kriteeri 2. luokan mukaan) erottelutaidot olivat kontrolliryhmää heikommat (n = 80) toisella ja kolmannella luokalla, ja riskiryhmän normaalilukijoiden erottelutaidot (n = 68) olivat kontrolliryhmää heikommat kolmannella luokalla. Riskiryhmän lapset eivät eronneet kuitenkaan toisistaan erottelutaidossa. Yksilötarkastelussa havaittiin, että riskiryhmän luku- ja kirjoitushäiriöisistä lapsista 31.4 prosentilla, riskiryhmän normaalilukijoista 14.7 prosentilla ja kontrolliryhmästä 8.8 prosentilla oli ongelmia foneemisen pituuden erottelutaidossa toisella luokalla, jolloin ryhmäerot olivat suurimmat.

Erottelutaito ei korreloinut merkitsevästi riskiryhmän normaalilukijoiden ja kontrolliryhmän keskuudessa lukutarkkuuden ja -sujuvuuden eli nopeuden sekä oikeinkirjoitustarkkuuden kanssa, mutta riskiryhmän luku- ja kirjoitushäiriöisillä lapsilla ensimmäisen ja kolmannen luokan erottelutaidosta havaittiin korrelaatio toisen luokan lukutarkkuuteen. Ensimmäisen ja toisen luokan erottelutaidosta oli yhteys toisen luokan oikeinkirjoitustarkkuuteen, ja yhteys oli erityisen vahva toisen luokan erottelutaidosta. Korrelaatiot erottelutaidon ja lukemisen sujuvuuden välillä eivät olleet merkitseviä.

Korrelaatiotarkastelun perusteella tehtiin regressioanalyysitarkastelu, jonka tuloksena havaittiin, että riskiryhmän luku- ja kirjoitushäiriöisillä lapsilla ensimmäisen luokan erottelutaidolla oli merkitsevä yhteys kolmannen luokan lukutarkkuuteen jopa sen jälkeen, kun varianssit kouluiän lyhytkestoisessa muistissa, fonologisessa muistissa ja nopeassa nimeämisessä oli kontrolloitu. Älykkyyden lisääminen malliin ei muuttanut juurikaan tuloksia. Samalla asetelmalla toisen luokan foneemisen pituuden erottelutaito selitti merkitsevästi toisen ja kolmannen luokan oikeinkirjoitustarkkuutta, vaikka edellä mainittujen muuttujien varianssit oli kontrolloitu. Älykkyyden lisääminen malliin pudotti selitysasteita jonkin verran, mutta ne säilyivät kuitenkin selvästi merkitsevinä.

Toinen osatutkimus

Toisessa pitkittäistutkimusaineiston tutkimuksessa keskityttiin edellisen tarkastelun perusteella riskiryhmän luku- ja kirjoitushäiriöisiin lapsiin (n = 40, dysleksia-kriteeri 2. ja 3. luokan mukaan) sekä tyypillisesti lukeviin kontrollilapsiin (n = 140). Tutkimuksessa haluttiin selvittää toisen luokan foneemisen pituuden erottelutaidon yhteyttä luku- ja oikeinkirjoitustaitoihin toisella luokalla sekä vertailla varhaisten, lukutaitoa edeltävien taitojen eroja riskiryhmän sisällä. Näitä olivat varhaiset kielitaidon mitat, fonologinen tietoisuus, verbaalinen muisti sekä nopea sarjallinen nimeäminen, joita mitattiin ikävuosina 1.0–6.5. Varhaisissa taidoissa määriteltiin olevan ongelmaa, jos lapsen suoritus oli alle -1.25 keskihajontaa verrattuna kontrolliryhmän suoritukseen vähintään kahdessa mittauspisteessä kolmesta kullakin osa-alueella. Vertailut tehtiin kolmen ryhmän kesken, joita olivat riskiryhmän luku- ja kirjoitushäiriöiset lapset, joilla havaittiin foneemisen pituuden erottelupulmaa (n = 13), riskiryhmän luku- ja kirjoitushäiriöiset lapset, joilla ei ollut foneemisen pituuden erottelupulmaa (n = 27), sekä riski- ja kontrolliryhmän tyypillisesti lukevat lapset (n = 140). Ongelmakriteeri erottelutaidossa oli sama kuin edellisessäkin osatutkimuksessa.

Tyypillisesti lukevien lasten ryhmä oli muita kahta ryhmää parempi kaikissa muissa lukemisen tarkkuuden mitoissa, paitsi ei kvantiteettivirheissä tekstin lukemisessa. Luku- ja kirjoitushäiriöisten lasten ryhmä, jolla oli foneemisen pituuden erottelupulmaa, oli toista luku- ja kirjoitushäiriöisten lasten ryhmää heikompi ainoastaan epäsanatekstin lukemisessa kvantiteettivirheissä. Luku- ja kirjoitushäiriöisten lasten ryhmä, jolla ei ollut foneemisen pituuden erottelupulmaa, oli kontrolliryhmää heikompi epäsanatekstin lukemisen sujuvuudessa. Oikeinkirjoittamisessa luku- ja kirjoitushäiriöisten lasten ryhmä, jolla oli foneemisen pituuden erottelupulmaa, oli toista luku- ja kirjoitushäiriöisten lasten ryhmää heikompi kaikissa mitoissa paitsi muissa kuin kvantiteettivirheissä epäsanojen kirjoittamisessa. Tyypillisten lukijoiden ryhmä oli muita kahta ryhmää parempi kaikissa oikeinkirjoittamisen mitoissa paitsi sanojen kirjoittamisessa muissa kuin kvantiteettivirheissä: Ryhmä erosi kyseisessä mitassa ainoastaan luku- ja kirjoitushäiriöisten lasten ryhmästä, jolla oli foneemisen pituuden erottelupulmaa.

Tulosten mukaan luku- ja kirjoitushäiriöisillä lapsilla, joilla oli foneemisen pituuden erottelupulmaa, oli merkitsevästi enemmän heikkoutta varhaisissa taidoissa (varhainen kieli, fonologinen tietoisuus, verbaalinen muisti ja nopea sarjallinen nimeäminen) verrattuna riskiryhmän luku- ja kirjoitushäiriöisiin lapsiin, joilla ei ollut foneemisen pituuden erottelupulmaa.

Regressioanalyysit näyttivät, että foneemisen pituuden erottelutaito selitti oikeinkirjoittamisen tarkkuutta jopa sen jälkeen, kun varhaisten taitojen kasautuvien riskitekijöiden muuttujan varianssi oli kontrolloitu luku- ja kirjoitushäiriöisten lasten riskiryhmässä. Kasautuvat riskitekijät selittivät lukemisen sujuvuutta ollessaan mallissa ensimmäisenä, ja kumpikaan muuttujista ei selittänyt lukemisen tarkkuutta.

Kolmas osatutkimus

Väitöskirjan kolmas osatutkimus käsitteli ensimmäistä luokkaa käyvän suomenkielisen luku- ja kirjoitushäiriöisen lapsen sekä samanikäisen venäjänkielisen oppimispulmattoman suomen oppijan sanan- ja epäsananloppuisen /*a*/ vokaalin kvantiteetin havaitsemista sekä kvantiteetin kategorioiden edustajien havaitsemista tietokonepohjaisen Graphogame-intervention avulla. Lisäksi tutkimuksessa tarkasteltiin sitä, oliko harjoittelulla vaikutusta vokaalikvantiteetin lukutarkkuuteen, lukusujuvuuteen tai oikeinkirjoitustarkkuuteen. Tutkimuksessa tarkasteltiin myös sitä, oliko peliharjoittelulla yhteyttä grafeemi-foneemivastaavuuden, grafeemien kirjoittamisen, fonologisen tietoisuuden tai yleisempään lukusujuvuuden ja oikeinkirjoitustaidon parantumiseen suhteutettuna suomenkielisten lasten ikätasoon.

Tutkimuksen epäsanat erosivat sanoista vain yhden foneemin perusteella. Lasten kategoriarajan havaitsemista testattiin ja verrattiin samanikäisten suomenkielisten lasten epäsanaloppuisen kvantiteetin identifioimiseen *d'*-arvojen kautta. Lapsen tunnistustaidon ajateltiin olevan heikko, jos se oli heikompi kuin -1 keskihajontaa verrattuna kontrolliryhmän suoritukseen. Identifikaatiotaitoa testattiin neljä kertaa ennen interventiota, kerran sen aikana, kerran intervention päättymisen jälkeen ja puoli vuotta intervention päättymisen jälkeen seurantamittauksessa lasten ollessa toisella luokalla. Lisäksi lasten foneemisen pituuden erottelutaitoa testattiin LKK-projektin tehtävällä, ja sama–eri-erottelutehtävänä kaksitavuisella epäsanalla, joka päättyi /*a*/-vokaalin kvantiteettiin. Kirjainten, äänteiden ja kirjainten nimien tuntemusta, kirjainten kirjoittamista, fonologista tietoisuutta, verbaalista lyhytkestoista muistia, nopeaa sarjallista nimeämistaitoa, sanavarastoa suomeksi ja venäjäksi (venäjänkielisellä), luku- ja oikeinkirjoitustaitoja sekä kvantiteetin lukemis- ja kirjoitustaitoja sekä yleistä älykkyyttä testattiin ennen interventiota. Samat testaukset teetettiin intervention jälkeen sekä seurantamittauksessa, paitsi että älykkyyden ja sanavaraton testaukset jätettiin pois, koska interventiolla ei ajateltu olevan niihin vaikutusta. Lasten syntyperäiseltä venäjän kielen opettajalta pyydettiin lisäksi arviota lasten venäjän kielen puhumisesta ymmärtämisestä, lukemisesta ja kirjoittamisesta jokaisen kolmen mittauksen yhteydessä. Näin siksi, että sopivia venäjänkielisiä standardoituja testejä ei ollut saatavilla. Lapset pelasivat kvantiteetin identifikaatiopeliä prototyyppisillä minimipareilla yhteensä kolme viikkoa viitenä päivänä viikossa koulupäivän aikana, noin 20 minuuttia kerrallaan tutkijan ollessa pelaamistilanteessa läsnä.

Tulosten mukaan venäjänkielinen lapsi näytti saavuttavan suomenkielisen ikätasonsa vokaalikvantiteetin identifikaatiossa jo loppumittauksessa, ja taito säilyi venäjänkielisellä lapsella seurantamittauksessa. Suomenkielisellä lapsella oli vaikeuksia identifikaatiotaidossa, ja hän saavutti vertailukohtana olevan ryhmän taitotason vasta seurantamittauksessa. Venäjänkielinen lapsi paransi yleisen foneemisen pituuden erottelutaitoa yli 1.5 keskihajontaa alkumittauksesta loppumittaukseen, ja yli hajonnan ero säilyi seurantamittauksessa, kun taas suomenkielisellä lapsella tämä taito ei juuri muuttunut. Vokaalin kvantitee-

tin erottelutaidossa suomenkielinen lapsi paransi suoritustaan seurantamittauksessa 1.68 keskihajontaa verrattuna alkumittaukseen, kun taas venäjänkielisellä tässä ei tapahtunut muutosta, osittain johtuen keskittymiseen liittyvistä tekijöistä. Kumpikaan lapsista ei kuitenkaan ollut kummassakaan erottelutehtävässä alkumittauksessa ratkaisevasti yli -1 keskihajonnan vertailuryhmää heikompi, ja he olivat tehtävässä keskenään samalla tasolla alkumittauksessa. Venäjänkielinen lapsi paransi jonkin verran kirjain-äännevastaavuuden hallintaa, kirjainten kirjoittamista, fonologista tietoisuutta ja kvantiteetin luku- ja oikeinkirjoitustarkkuutta. Suomenkielinen lapsi paransi selvästi yleistä lukusujuvuutta sekä oikeinkirjoitustarkkuutta. Toinen oikeinkirjoitustesteistä teetettiin täsmälleen samoilla ärsykkeillä kuin interventio.

Neljäs osatutkimus

Tutkimuksen viimeisessä osatarkastelussa keskityttiin Graphogame-peli-intervention tarkasteluun neljällä venäjänkielisellä lapsella. Artikkelin tarkoitus oli antaa tietoa kaksi- ja kolmitavuisten yksöis- ja kaksoisvokaaliin päättyvien sanojen ja epäsanojen kestojen havaitsemisen tarkkuudesta sekä siitä, miten kvantiteetti-interventiota pelikontekstissa voitaisiin edelleen kehittää. Tilastollisten vertailujen kohteina olivat lasten vastaukset pelikontekstissa. Kvantiteetin identifikaatiota testattiin alku-, loppu- ja seurantamittauksessa samanlaisella testillä kuin kolmannessa osatutkimuksessa, ja vertailukohtana oli myös sama pilottiaineisto.

Pelijakso alkoi kirjainten nimien ja äänteiden tunnistuksen testauksella, kirjain-äännevastaavuuden harjoittelulla sekä yksikertaisella sananmuodostustehtävällä. Tämän jälkeen kvantiteettiminimiparit esitettiin siten, että ensimmäisenä kenttänä olivat kaksitavuiset sanat, sen jälkeen kaksitavuiset epäsanat, sitten kolmitavuiset sanat ja lopuksi olivat kolmitavuiset epäsanat. Jokaisessa kentässä oli neljä tasoa, josta kaksi ensimmäistä oli helpompaa, koska /*a*/ vokaalien kestot olivat minimipareissa millisekunneissa mitattuna toisistaan kauempana (lyhyt ja pitkä kesto) verrattuna kahteen jälkimmäiseen tasoon. Eri tasojen äänteiden kestot olivat identtisiä kaksitavuisissa ärsykkeissä ja vastaavasti kolmitavuisissa ärsykkeissä. Kenttien välissä oli väliharjoitustehtäviä.

Tutkimuksen perusteella tarkkuus pelin ensimmäisen kvantiteettikentän ärsykkeissä, toisin sanoen kaksitavuisissa sanoissa, oli heikompi kuin muissa ärsykkeissä. Lisäksi tulosten mukaan tasojen 1 ja 2 parit olivat helpompia kuin tasojen 3 ja 4 parit, paitsi sanojen yhteenlasketussa tarkkuudessa ja kolmitavuisissa ärsykkeissä. Tuloksissa oli myös hieman viitteitä siitä, että pitemmät kestot saattoivat olla venäjänkielisille lapsille vaikeampia kuin lyhyet kestot. Pelilokitulokset osoittavat, että lasten kvantiteetin identifikaatio kehittyi pelaamisen aikana, ja sanojen opitut representaatiot laajenivat koskemaan epäsanoja. Kvantiteetin identifikaatiotehtävässä neljästä lapsesta kaksi paransi selvästi kvantiteettiasteen tunnistustaitoa pelaamisen seurauksena.

Yhteenveto

Tulosten mukaan suomenkieliset lapset kehittyvät foneemisen pituuden erottelutaidossa koulutaipaleen kolmella ensimmäisellä luokalla. Taito on selvästi yhteydessä luku- ja kirjoitushäiriöisten dysleksia-riskilasten lukemisen tarkkuuteen kolmannella luokalla, ja oikeinkirjoitustarkkuuteen toisella ja kolmannella luokalla, kun perinteisemmät dysleksian ennustajat on kontrolloitu. Riskiryhmän luku- ja kirjoitushäiriöiset lapset, joilla on foneemisen pituuden erottelupulmaa, tekevät enemmän luku- mutta erityisesti oikeinkirjoitusvirheitä (kvantiteettivirheitä) verrattuna niihin riskiryhmän luku- ja kirjoitushäiriöisiin lapsiin, joilla ei ole foneemisen pituuden erotteluongelmaa, sekä enemmän kuin tyypillisesti lukevien lasten kontrolliryhmä toisella luokalla. Lisäksi ongelmat varhaisissa kognitiivisissa, ennen kouluikää mitatuissa taidoissa näyttävät kasautuvan foneemisen pituuden erottelupulman omaaville riskiryhmän luku- ja kirjoitushäiriöisille lapsille vakavampiasteisina verrattuna niihin riskiryhmän luku- ja kirjoitushäiriöisiin lapsiin, joilla erotteluongelmaa ei niin selkeästi ole. Myös varhaisten taitojen kontrolloimisen jälkeen taidolla on merkittävä yhteys toisen luokan oikeinkirjoittamistarkkuuteen tässä samassa ryhmässä. Kvantiteetin hallitseminen ei kuitenkaan näytä olevan yhteydessä lukemisen sujuvuuteen.

Tulokset antavan viitteitä siitä, että riskiryhmän luku- ja kirjoitushäiriöiset lapset, joilla on havaitsemisen ongelmaa foneemisessa pituudessa, kärsivät vakavampiasteisista kognitiivisista ja/tai kielellisistä ongelmista kautta linjan verrattuna riskiryhmän luku- ja kirjoitushäiriöisiin lapsiin, joilla ei ole foneemisen pituuden erotteluongelmaa. Näin ollen tämän taidon kartoittaminen ja vaikutukset kuntoutus- ja harjoitusmenetelmiä suunniteltaessa olisi otettava huomioon jo varhain uudella tavalla. Ongelman konkreettisuudesta antavat viitteitä kolmannen osatutkimuksen tulokset, jossa vertailtiin suomenkielisen luku- ja kirjoitushäiriöisen lapsen ja venäjänkielisen lapsen kvantiteetin identifikaatioharjoittelun tuloksia. Näyttäisi kaiken kaikkiaan siltä, että venäjänkielinen lapsi pystyy nopeammin omaksumaan kvantiteettiasteen tunnistamisen lyhyenkin harjoittelun myötä, ja mahdollisesti yleistämään oppimansa representaatiot muihin kuin harjoiteltuihin ärsykkeisiin. Suomenkielisellä luku- ja kirjoitushäiriöisellä lapsella oppiminen on hitaampaa ja viivästynyttä, ja yleistymisefektit ovat epävarmoja. Tutkimus on kuitenkin tapaustutkimus, joten sen tuloksia ei voida yleistää koskemaan koko populaatioita. Tutkimus jättää kaiken kaikkiaan useita kysymyksiä ratkaistavaksi tulevaisuutta ajatellen.

Tulosten mukaan venäjänkielisellä suomen oppijalla, jolla ei ole oppimisvaikeutta, kvantiteetin identifikaation harjoitteleminen saattaa vaikuttaa positiivisesti nopeallakin aikavälillä havaitsemistaitoihin. Tämä johtuu siitä, että heidän oppimisongelmansa johtuvat kielten erilaisista fonologisista järjestelmistä kvantiteetin suhteen, eikä neurologisesta ongelmasta, kuten luku- ja kirjoitushäiriöisillä lapsilla, joilla on mahdollisesti suvussa esiintyvä riski dysleksiaan. Kvantiteettipeli-interventiossa olisi kuitenkin hyvä kiinnittää huomiota harjoittelussa käytettäviin ärsykkeisiin ja niiden kompleksisuuteen sekä siihen, miten selvät representaatiot oppijoilla on. Mahdollisesti myös ärsykkeiden ääneen

toistaminen harjoittelun aikana voi parantaa oppimistuloksia. Myös kognitiivisten ja kielellisten taitojen kartoittaminen tutkimusten yhteydessä niin omalla äidinkielellä kuin suomen kielelläkin on tarpeen.

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APPENDIX 1

Minimal pairs in the Graphogame

Two syllable words	Two syllable pseudo-words	Three syllable words	Three syllable pseudo-words
hukka – hukkaa	hekka – hekkaa	kirsikka – kirsikkaa	kursikka – kursikkaa
kukka – kukkaa	kekka – kekkaa	mansikka – mansikkaa	mensikka – mensikkaa
lakka – lakkaa	lekka – lekkaa	mustikka – mustikkaa	mestikka – mestikkaa
nokka – nokkaa	nikka – nikkaa	neilikka – neilikkaa	noilikka – noilikkaa
pakka – pakkaa	pikka – pikkaa	persikka – persikkaa	parsikka – parsikkaa
rikka – rikkaa	rakka – rakkaa	puolukka – puolukkaa	pielukka – pielukkaa
sukka – sukkaa	sikka – sikkaa	rentukka – rentukkaa	rantukka – rantukkaa
takka – takkaa	tekka – tekkaa	silmukka – silmukkaa	salmukka – salmukkaa
tikka – tikkaa	vikka – vikkaa	simpukka – simpukkaa	sampukka – sampukkaa
vakka – vakkaa	vukka – vukkaa	valtikka – valtikkaa	veltikka – veltikkaa