Dyslexia and Phonology:

A study of the phonological abilities of Dutch children at-risk of dyslexia

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Dyslexia and Phonology:

A study of the phonological abilities of Dutch children at-risk of dyslexia

Dyslexie en fonologie:
Een onderzoek naar de fonologische vaardigheden van Nederlandse kinderen met een risico voor dyslexie
(met een samenvatting in het Nederlands)

PROEFSCHRIFT
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door

Elise Henriëtte de Bree

geboren op 20 december 1976 te Amersfoort

Promotores: Prof. dr. F.N.K. Wijnen
Prof. dr. W.Z. Zonneveld

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Jpod, Douglas Coupland

After many years of study, it has dawned on me that research is *never* finished and a final version of a paper, let alone a dissertation, does not exist. I am pleased, however, that the results of my work have now been shaped into a coherent narrative.

There are many people who deserve a thank you for helping me get here. First of all, I would like to thank my two promotores, Frank Wijnen and Wim Zonneveld. Wim for introducing me to the Dyslexia and SLI project, for always reading and commenting on every single paragraph I wrote, and for invaluable tip-offs on BBC comedies; Frank for taking on a medieval studies student in his linguistically-based research project, for allowing me to find my own path in research, and for adding ‘hem en eks’, amongst others, to my expressive vocabulary.

Related, I am thankful to the members of the Dyslexia and SLI project, Petra van Alphen, Ellen Gerrits, Jan de Jong, Carien Wilsenach, Marjolein van Woudenberg, and Frank Wijnen. It will just be impossible to forget our teamwork, our ‘extracurricular’ activities, and the laughing fits we shared (‘rrrraaaaarr’). Additionally, thanks are due to the interns of our project, particularly Renate van den Berg, Neely Anne de Ronde-Davidse, and Barbara Richmond-van Olffen.

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General introduction

Acquisition of reading is a complex achievement that is partly determined by spoken language skills. Consequently, the expectation is that if a child shows difficulties in spoken language development, reading difficulties ensue. Indeed, language difficulties have been attested in children with developmental dyslexia. Developmental dyslexia is a specific language-based disorder characterised by difficulties in reading and/or spelling that are unexpected in relation to cognitive abilities and age (Lyon 1995). Recent prevalence of dyslexia in The Netherlands has been estimated at 3.6% of primary school children (Blomert 2003).

Difficulties in language acquisition *preceding* the onset of reading instruction have been found in children with a dyslexic parent or sibling. These so-called at-risk children are at familial risk of developing dyslexia, as dyslexia runs in families. Approximately 30-60% of at-risk children are diagnosed with dyslexia. There is, however, no adequate method yet for early diagnosis of this disorder. A number of language abilities in these at-risk children have been assessed, but many areas of their language acquisition remain unexplored.

The present thesis addresses phonological acquisition of children at-risk of dyslexia as a contribution to the investigation of the linguistic basis of dyslexia. Further evaluation of language development in this population could contribute to the identification of linguistic precursors of dyslexia. Early identification, in its turn, could lead to early intervention. Assessment of phonological skills is further motivated by the phonological deficit hypothesis. This widely acknowledged hypothesis proposes that dyslexia is characterised by poor phonological representations. Studies into the nature of this phonological deficit, however, have often been restricted to higher-level skills such as phonological awareness, and lower-level skills, such as speech perception. Issues of phonology and phonological acquisition, however, have not received much attention. If, as the phonological deficit hypothesis proposes, phonological representations are poor in children with (a risk of) dyslexia, then difficulties can also be expected to arise on other phonological skills. Assessment of phonological acquisition can thus be used to further qualify the phonological deficit hypothesis.

The presumed language difficulties of children with (a risk of) dyslexia raise another question, which is whether dyslexia is similar to specific language

impairment (SLI), resulting from the same underlying deficit. SLI refers to a developmental disorder affecting oral language (grammar) in the absence of non-verbal intellectual disability, distinct neurological or perceptual deficits (Leonard 1998). Children with SLI often demonstrate literacy difficulties at school age. Thus, both in children with (a risk of) dyslexia, and in children with SLI language and reading difficulties occur.

The question arises, therefore, whether, within the language domain, phonological disabilities characterise both dyslexia and SLI. Two models on the relationship between dyslexia and SLI, the single source and qualitative difference hypothesis, assume that phonological difficulties underlie both dyslexia and SLI, whereas a third, the comorbidity hypothesis, argues that phonological difficulties underlie dyslexia, not SLI. Furthermore, whereas the single source hypothesis claims that dyslexia and SLI are caused by the same underlying deficit, the qualitative difference and comorbidity hypotheses argue that the two disorders are distinct. Through qualitative and quantitative comparison of phonological abilities of at-risk and SLI children, this dissertation aims to contribute to the discussion on the adequacy of the models.

Summarising, the aim of this thesis is to assess phonological skills in children at-risk of dyslexia, by studying (previously not assessed) phonological abilities. This study will take an experimental approach. The results of several experimental tasks will contribute to knowledge of linguistic precursors of dyslexia. Furthermore, they will be interpreted within the phonological deficit hypothesis as well as provide insight into the phonological system in dyslexia. Secondly, a comparison between performance of children with a risk of dyslexia and children with SLI is made in most of the tasks to examine whether poor phonology is found in both disorders. It will be assessed whether on the basis of the findings, dyslexia and SLI should be viewed as one or two separate disorders. In other words, it will be investigated which hypothesis on the relationship between dyslexia and SLI can best account for the experimental findings of this study.

The organisation of the dissertation is as follows. In order to answer the question of the role of phonology in dyslexia and SLI, it is necessary to first describe previous linguistic precursor studies of dyslexia, the phonological deficit hypothesis of dyslexia, and the models that discuss the overlap between dyslexia and SLI. This will be done in Chapter 1. This chapter also introduces the main research questions.

In Chapter 2, subject selection and background information of the participating children in this study is described. The design, method and results of the experiments are reported in Chapters 3 to 7. Chapters 3, 4, and 5 discuss findings on tasks tapping phonological acquisition. Chapter 3 presents the results of a task measuring speech production of two-year-old at-risk and control children, and three-

and-four-year-old at-risk, SLI, and control children. Word stress production of three-year-old at-risk and control children is reported in Chapter 4. Chapter 5 discusses the comparison between five-year-old at-risk, SLI, and control children on a task assessing morpho-phonological alternation of voicing in the Dutch plural.

Results on phonological tasks typically associated with literacy skills are reported in Chapters 6 and 7. Findings of a non-word repetition task, tapping phonological processing, are described in Chapter 6. Chapter 7, finally, provides the results of a phonological awareness task, in the form of a rhyme oddity task, presented to five-year-old at-risk, SLI, and control children.

The results are integrated in Chapter 8 in order to arrive at conclusions concerning the role of phonology in children at-risk of dyslexia and children with SLI. The results will also be considered within the phonological deficit hypothesis of dyslexia and the hypotheses on the relationship between dyslexia and SLI.

1

Dyslexia, phonology, and language impairment

1.1 Introduction

This thesis is a result of the project ‘Early language development in specific language impairment and dyslexia: A prospective and comparative study’, conducted at the Utrecht Institute of Linguistics OTS at Utrecht University. The project’s aim was to clarify the nature of the presumed language disorder in children with developmental dyslexia. Four sub-projects tested the hypothesis that language difficulties are attested in children at-risk of dyslexia and that they may be similar to those of children with specific language impairment (SLI). These sub-projects dealt with 1) speech perception and word recognition (van Alphen et al. 2004, van Alphen, Fikkert & Wijnen in preparation, Gerrits 2003, Gerrits & de Bree in preparation), 2) speech production (current thesis), 3) grammatical sensitivity (Wilsenach 2006), and 4) grammatical development (de Jong, Wijnen & de Bree in preparation).

This chapter provides the general background rationale of this project, as well as the specific one of this dissertation, in which phonological acquisition of children with (a risk of) dyslexia is studied. Acquisition is not only compared to that of normally developing children, but also to that of children with SLI in some experiments, as the literature suggests an overlap between the symptoms displayed in dyslexia and SLI.

There are four components to this chapter. Section 1.2 discusses the relationship between dyslexia and language development and looks at results of previous studies of children with a familial risk of dyslexia. On the basis of this overview, general predictions will be formulated about phonological development in Dutch-speaking children at risk of dyslexia. Secondly, this chapter will review the phonological deficit hypothesis of dyslexia and discuss the ensuing expectations about phonological acquisition and production of children with (a risk of) developmental dyslexia (1.3). The third part focuses on the relationship between dyslexia and SLI (1.4). Again, predictions in terms of the different models presented to account for this overlap will be formulated. The general research questions of this thesis, which are based on the conclusions and questions of the first three sections, are presented in the final section (1.5).

1.2 Language development and dyslexia

Dyslexia is generally defined as a reading and spelling difficulty discrepant with intelligence and educational opportunities. It has been characterised as a language-based disorder (e.g. Catts 1989, Kamhi & Catts 1986, Vellutino 1979), where ‘language’ is a term for what theoretical linguists would tend to call ‘grammar’. In addition to their relatively poor written language skills, children with developmental dyslexia have been found to exhibit difficulties on a variety of language tasks, including speech perception and production and syntactic sensitivity (e.g. Byrne 1981, Catts 1986, Joanisse, Manis, Keating & Seidenberg 2000, Lewis & Freebairn 1992, Rispens 2004, Snowling 1981). This raises the question whether these language difficulties are secondary to a reading deficit or whether they (partly) cause dyslexia.

One way to disentangle literacy and language factors is by looking at the language development of children at-risk of dyslexia; children with a dyslexic parent or sibling. As these at-risk children have not yet learned to read and write, language difficulties in this population cannot be the consequence of poor reading skills. Such a starting point allows investigation of linguistic skills to assess the potential of dyslexia as a language-based deficit. Furthermore, this type of investigation might find linguistic precursors and lead to early identification of dyslexia.

1.2.1 Precursor studies

The present study is not the first to address the language skills of children with a familial risk for dyslexia. The view that this might be a fruitful approach of dyslexia is relatively recent, however. Scarborough (1989, 1990, 1991) was the first to study language development of (American English) at-risk children. She followed the development of 32 at-risk children from 2;6 to 5;0 and assessed their reading development at 8;0. Retrospective analysis showed that the children from the at-risk group who became dyslexic produced shorter and less complex utterances when talking to their mother and that they made more mispronunciations of consonants than the non-dyslexic at-risk and control children at 30 months. At 36 and 42 months, syntactic difficulties persisted and vocabulary development was poorer than that of the other children. Finally, at age 5, the dyslexic at-risk children were outperformed by the other children on measures of letter knowledge, phoneme awareness, and expressive naming. Scarborough’s pioneering study thus showed that a broad range of language deficits were present in affected at-risk children from a young age onwards.

The results of subsequent at-risk studies are similar, in that at-risk children have been found to display (subtle) language difficulties before the onset of reading instruction. These findings have been made for a variety of (‘western world’) languages, including British English (Carroll & Snowling 2004, Gallagher, Frith, Snowling 2000, Snowling, Gallagher & Frith 2003), American English (Lefly &

Pennington 1996, Locke et al. 1997, Pennington & Lefly 2001), Australian English (Byrne, Fielding-Barnsley, Ashley & Larsen 1997), Danish (Elbro, Borstrøm & Petersen, 1998), Finnish (Lyytinen et al. 2001, Lyytinen et al. 2004), Flemish Dutch (Boets, Wouters, van Wieringen & Ghesquière 2006) and standard Dutch (van Alphen et al. 2004, Koster et al. 2005, van Leeuwen et al 2006, Rispens 2004) at-risks. Differences between at-risk and control children, subtle or explicit, have been found as young as the age of 15 months (Locke et al. 1997) and 19-23 months (Wilsenach 2006). The range of studies point to difficulties for at-risk children in phonological processing, speech perception and production, grammatical sensitivity and expression, listening comprehension, verbal short-term memory, (rapid serial) naming, and vocabulary.

Some of these precursor studies have been prospective, in that only preschool language measures were reported as the at-risk children had not yet reached reading age. Others have been able to relate preschool language abilities to later reading skills. Between 32 and 66% of the at-risk children developed dyslexia in these studies, as opposed to 2 to 13% of the control children. If poor language development is an indicator of future reading difficulties of at-risk children, the expectation is that the performance in a given at-risk population as a whole will be poorer than that of a group of normally developing children. The question arises whether within the at-risk group, all children show poor language development or only those who actually develop dyslexia. So far, mixed results have been found on this issue (Elbro, Borstrøm & Petersen 1998, Pennington & Lefly 2001, Scarborough 1990, Snowling, Gallagher & Frith 2003).

The precursor studies have established that spoken language development of children at-risk contains indicators of dyslexia in individual children.[1] However, there are still many skills to explore in order to gain better insight into the language profile of children with (a risk of) dyslexia. These findings further invite the consideration that dyslexia is a mild form of language impairment. We will return to this issue later (Section 1.4). The aim of this thesis is to further study language skills in Dutch children at-risk of dyslexia, specifically their phonological skills.

1.2.2 Phonological development in children at-risk of dyslexia

Dyslexia has often been characterised as a disorder with a core cognitive deficit in phonology (Catts 1989, Ramus 2003, Snowling 2001). More specifically, children and adults with dyslexia are assumed to have difficulty encoding, maintaining, and retrieving phonological representations (see Section 1.3 below). This characterisation has predominantly been assessed through measures of phonological

[1] These findings do not rule out the possibility that language difficulties are depressed by literacy abilities, as poor literacy could impact on language development (e.g. Share & Silva 1987). However, the at-risk studies show that a language deficit also precedes dyslexia and cannot only be a consequence of poor reading ability.

processing (tasks demanding encoding, maintaining, and retrieval of phonological representations) and phonological awareness (tasks demanding conscious access to phonological structures). Phonological acquisition in dyslexia has not received much attention, even though the need to do so has been acknowledged (Ramus 2001). The work that has been done, however, has established that acquisition of phonology is poorer in at-risk children (Carroll & Snowling 2004, Locke et al. 1997, Scarborough 1990, Turunen 2003). Nevertheless, research has mainly been restricted to speech sound production, not taking suprasegmental acquisition, for example, into account. Thus, the absence of detailed insights into phonological development clearly motivates further and more elaborate investigation.

The current thesis sets out to study precisely this area. Components of phonological acquisition under scrutiny include speech production (Chapter 3), word stress competence (Chapter 4), and morpho-phonological alternation of the Dutch plural (Chapter 5). These measures span different levels of phonology, which provides a test of the scope of the phonological deficit. Phonological processing and awareness will be measured through non-word repetition (Chapter 6) and rhyme oddity (Chapter 7). In light of previous findings, it is anticipated that difficulties in both phonological acquisition and phonological processing and awareness will surface in the performance of children at-risk of dyslexia.

This thesis aims to characterise the potential difficulties at-risk children display on several phonological tasks. As pointed out, these findings can then be interpreted in the so-called phonological deficit hypothesis of dyslexia. This hypothesis will be discussed next.

1.3 The phonological deficit hypothesis of dyslexia

The previous section established that children at-risk of dyslexia display difficulties in their language development and that poor phonological processing and awareness stand out in children with dyslexia and those at-risk. It was also noted that many areas of phonology have not been assessed in these groups of children. In this section, the phonological deficit hypothesis of dyslexia will briefly be discussed, and expectations for phonological acquisition of at-risk children will be formulated on the basis of this hypothesis.

Although there is no consensus about the cause(s) of dyslexia, a widely accepted explanation is that it stems (partly) from a phonological deficit (e.g. Goswami 2000, Miles & Miles 2001, Ramus 2003, Siegel 1998, Vellutino et al. 2004). Several versions of a phonological deficit hypothesis (PDH) have been proposed, such as the *phonological representations hypothesis* (e.g. Brady 1997, Goswami, 2000, Snowling, Goulandris, Bowlby & Howell, 1986), the *distinctness hypothesis* (e.g. Elbro, Nielsen & Petersen 1994, Elbro 1996), and the *sub-lexical deficit hypothesis* (Ramus 2001, Szenkovits & Ramus 2005). These models each add their own nuance to the deficit. However, the basic assumption of all these models is that poor

phonological representations are a core characteristic of dyslexia. Due to the substantial overlap between the models, they will be collectively referred to as the phonological deficit hypothesis, unless elaboration is required.

In a nutshell, the phonological deficit hypothesis (henceforth PDH) holds that children and adults with dyslexia have unremitting difficulty in constructing, maintaining, and retrieving phonological representations. Their phonological representations have been variously referred to as 'holistic', 'weak', 'fragile', 'fuzzy', 'indistinct' or 'underspecified'. In other words, the way in which their brain codes phonology is less efficient than that of normally reading children. This problem causes a range of symptoms at the behavioural level, such as difficulties with verbal short-term memory, non-word repetition, phonological awareness, phonological learning of new verbal information, word retrieval, and rapid naming. Phonological representations facilitate reading development; orthographic-phonological associations can take place once phonemic representations emerge. Consequently, poor representations lead to slow literacy development, poor generalisation of word reading skills to non-word reading, and poor spelling development (see Snowling 2001).

The PDH has incorporated issues of individual performance, compensation, and severity. It states, for example, that the impact of the phonological deficit could be moderated by children's resources in other cognitive skills. The severity of the phonological deficit is partly created through the interaction with other cognitive skills, such as semantic, visual, and syntactic skills (see Nation & Snowling 1998, 2004). These factors can moderate or aggravate the deficit. The severity of the ensuing underlying phonological disorder determines the extent of the reading difficulties (Griffiths & Snowling 2002). The phonological deficit seems to be present in 'western world' languages with alphabetic orthography, even though there are differences between the overt reading performance among dyslexics from different languages, depending on the complexity of the orthography of the native language (e.g. Paulesu et al. 2001). Evidence for the phonological deficit has also been found for non-alphabetic languages, such as Chinese (Suk-Han Ho, Law & Ng 2000), but has not been investigated extensively.

The phonological deficit hypothesis is limited in that it does not try to account for poor performance on phonological phenomena, but only for the contribution of phonology to reading. This limitation leads to 'gaps' in the hypothesis. First, the notion of phonological representations is not informed by an advanced theory as to their nature, thus not grounded in (a) linguistic theory. This renders a systematic linguistic investigation challenging. We will here make the minimal assumption that phonological representations are the input required for learning to read and write.

Related to this, ambiguity of terminology arises. For instance, in the *psychological* sense, the term 'underspecified' refers to incomplete, deficient, phonological representations. The *phonological linguistic* interpretation of

'underspecification', however, is that redundant information does not need to be specified at a given level of representation. The former interpretation thus signals a deficit, whereas the latter is related to economy, beneficial to the grammar underlying behaviour. It is important to point out that the former sense will feature in this dissertation.

This latter distinction becomes especially urgent when it is concluded that studies into poor representations have led to mixed findings. On the one hand, it has been argued that the representations lack detail and segmental organisation on tasks tapping phonological processing and awareness (e.g. Swan & Goswami 1997a), i.e. there is *too little* detail in their (lexical) representations. On the other hand, findings have shown that dyslexics are better than controls at discriminating acoustic differences between stimuli from within the same phonological category (e.g. Serniclaes et al. 2004), which would suggest *too much* detail in their (phoneme) representations. Well-informed assessment of phonological abilities in children with (a risk of) dyslexia should lead to more insight into the nature of the representation difficulties.

Studies into the phonological deficit have typically focused on high-level phonological processes, such as phonological awareness, or lower-level perceptual tasks involving the discrimination and categorisation of speech sounds. There is, however, much more to phonology than awareness and categorical perception. Acquisition and production of speech sounds and sound patterns, as well as on-line operations on phonological representations also belong to the phonological domain. These aspects have generally not received attention, despite indications that phonological acquisition does not function properly in children with (a risk of) dyslexia. If dyslexia is characterised by poor phonological representations, then phonological development should also be more difficult for children with (a risk of) dyslexia than for normally developing children.

The current thesis aims to further qualify the phonological deficit hypothesis of dyslexia through assessment of the acquisition of a variety of phonological patterns in children at-risk of dyslexia. It will be investigated whether the PDH should create room for expectations of poor phonological acquisition. Such a study has the additional benefit of gaining more knowledge of linguistic characterisation of dyslexia.

Despite these limitations of the PDH, most versions of this hypothesis, if only through extension of reasoning, could allow for poor phonological acquisition. For example, some models link dyslexia to a connectionist (e.g. Snowling, Gallagher & Frith 2003) or an analogical *reading* model (e.g. Goswami & East 2000). These models could be joined to connectionist and analogy-based models of *language* learning. It should be stressed, however, that most PDH studies neither explicitly refer to phonological acquisition, nor to intricately developed linguistic theories.

Only one phonological deficit hypothesis explicitly argues for analysis of phonological acquisition, the *sub-lexical deficit hypothesis* (Ramus 2001, Szenkovits & Ramus 2005). This hypothesis proposes that, if phonological representations of children with dyslexia are poor, this should be traceable in their phonological acquisition, as phonological representations also include acquired phonological patterns of the native language. In this model acquisition of the language-specific phonological structures, patterns, and rules takes place through the sub-lexical level that contains 'whatever information that can be represented in a phonological format, that is, words, whole utterances and nonsense sequences of phonemes' (Ramus 2001, p.201). A deficit in sub-lexical representations will cascade into difficulties in the phonological lexicon, the orthographic-phonological route, and the orthographic lexicon. Furthermore, the sub-lexical deficit hypothesis is the only model to explicitly take into account some form of 'grammar', i.e., the language-specific regularities and patterns, and to imply the need to systematically assess the acquisition of this grammar in children with (a risk of) dyslexia.

The present study assesses the performance of at-risk children on a number of tasks tapping speech production, acquisition of the Dutch word stress system, and morpho-phonological alternation of the Dutch plural. Poorer performance of at-risk compared to control children is anticipated by the sub-lexical deficit hypothesis for all tasks, because this model assumes poorer acquisition. Such expectations can only be surmised for the other phonological deficit hypotheses of dyslexia.

In contrast, expectations of both the sub-lexical deficit hypothesis and the phonological deficit hypothesis are clear for typical phonological processing and awareness tasks, non-word repetition and rhyme oddity. Both hypotheses anticipate difficulties on these tasks for the at-risk children.

Section 1.2 on precursor studies discussed findings of language acquisition difficulties of at-risk children. This section (1.3) has referred to (potential) difficulties, specifically of phonological acquisition, of at-risk children. These findings and assumptions raise the question whether dyslexia can be subsumed under the heading of language impairment. Additionally, this leads to the question if and how dyslexia and specific language impairment are related and what the role of phonology is within both impairments. This will be discussed in the next section.

1.4 Dyslexia and specific language impairment

A relationship between language skills and dyslexia, in both children at-risk of and children with dyslexia, was established in 1.2 as it was shown that children with (a risk of) dyslexia display language difficulties. The reverse is also true: an overwhelming and increasing number of studies have reported literacy problems in children with (preceding) speech and language difficulties (e.g. Aram, Ekelman & Nation 1984, Bird, Bishop & Freeman 1995, Bishop & Edmundson 1987, Boudreau & Hedberg 1999, Briscoe, Bishop & Norbury 2001, Catts 1993, Catts, Adlof, Hogan

& Ellis Weismer 2005, Catts, Fey, Tomblin & Zhang 2002, Larrivee & Catts 1999, Leitão & Fletcher 2004, Menyuk et al. 1991, Nathan, Stackhouse, Goulandris & Snowling 2004, Nauclér & Magnusson 2002, Stothard et al. 1998). The incidence of reading difficulties in children with (a history of) specific language impairment (SLI) is high, between 40-60% (Catts, Hu, Larrivee & Swank 1994, but see Catts et al. (2005) for a percentage between 17-29%). The general consensus is that children with persistent and severe language difficulties run the greatest risk of developing reading difficulties (Bishop & Edmundson 1987, Bishop & Adams 1990, Catts 1993, Catts, Fey, Zhang & Tomblin 1999, Catts et al. 2002, Nathan et al. 2004, Raitano et al. 2004, Stackhouse 2000).

These findings suggest that dyslexia and SLI might be related disorders. This is also endorsed by genetic studies reporting that SLI and reading impairment in families co-occur (Van der Lely & Stollwerck 1996, Flax et al. 2003). Furthermore, the diagnosis of dyslexia and SLI can often occur in the same child. McArthur, Hogben, Edwards, Heath, and Mengler (2000) assessed reading and language skills of both dyslexic and SLI groups. Performance on norm-referenced reading and language tests revealed that about 50% of both dyslexic children and children with SLI fulfilled the criteria of the alternative diagnostic category. Similarly, Eisenmajer, Ross, and Pratt (2005) found that 55% of a group of children with learning disabilities displayed concomitant language and reading difficulties.

The findings of reading difficulties in children with language impairment yield the question whether these poor reading skills are characterised by a phonological deficit, similar to that attested in dyslexia (see 1.3). Indeed, direct comparisons between language and literacy profiles of dyslexic and SLI children are slowly accumulating and suggest at least a partial overlap between the two groups on language skills, especially on phonological processing skills, such as non-word repetition (Catts et al. 2005, Fraser & Conti-Ramsden 2005, Kamhi & Catts 1986, Rispens 2004, Scheltinga, van der Leij & van Beinum 2003). Comparisons between children *at-risk* of dyslexia and children with SLI, however, are still scarce. Carroll and Snowling (2004) compared phonological processing, phonological learning, phonological awareness, and emergent literacy of four-and six-year-old at-risk children and children with speech impairment (not SLI). They found that the groups showed similar difficulties, but performance of the at-risk group was in-between that of the control and the speech-impaired group. A first report of a comparison between Dutch at-risk and SLI children between three and five-years of age is found in van Alphen et al. (2004). Delays were found in both groups in speech perception, phonological processing (see Chapter 6) and word recognition. Again, the at-risk group performed in-between the control and SLI group.

Studies into dyslexia and SLI show that there are similarities between the two disorders in terms of symptoms. They raise the question whether dyslexia and SLI are distinct or whether they are (partially) different manifestations of one underlying

disorder. Phrased differently, the question is whether there is a common core cognitive deficit that can account for both language and literacy difficulties. Furthermore, the role of phonological abilities in both populations demands further attention. These issues are discussed next.

1.4.1 Dyslexia and SLI: Same or different?

Broadly speaking, there are two main views on the relationship between dyslexia and SLI. The first is that they are qualitatively similar disorders, with language disorders manifest at an early age and reading disorders attested at school-going age (Catts 1989, Kamhi & Catts 1986, Tallal, Allard, Miller & Curtiss 1997a, Tallal, Miller, Jenkins & Merzenich 1997b). In contrast, the second interpretation is that there may be behavioural similarities between dyslexia and SLI, but that the two are nonetheless distinct disorders (Bishop & Snowling 2004, Catts et al. 2005, Goulandris, Snowling & Walker 2000, Nathan et al. 2004, Snowling, Bishop & Stothard 2000). As will be seen, the role of phonology is crucial for all hypotheses. The models are presented in Figure 1 and will be discussed below.

The first interpretation argues that the source for the difficulties the dyslexic and SLI children encounter is similar. For example, Tallal and colleagues (Tallal 1980, Tallal et al. 1997ab) pursue the idea that language and reading difficulties stem from a basic temporal processing deficit. This deficit interferes with the auditory processing of rapidly changing acoustic features of speech, which will impact on the acquisition of speech, and in turn, on the learning of language, including linguistic representations. Tallal et al. propose that there is a developmental continuum between early language disorders and phonologically based reading disorders and that it is primarily the factor age that distinguishes developmental language impairment from reading impairment. Thus, difficulties with rapid auditory perception underlie poor phonological processing, language impairment, and dyslexia. In this view, there is no distinction between the two disorders. Tallal et al. merge the categories of dyslexic and SLI into one category, 'language learning impairment' (Tallal et al. 1997a). These investigators' model for the relationship is thus a *single source hypothesis*. [2]

A second interpretation within the single source model stems from Kamhi and Catts (1986) and Catts (1989), who argue that dyslexia is a developmental language disorder, rather than a disorder stemming from auditory difficulties. The disorder is mainly caused by a phonological processing deficit and manifests itself in different

[2] The literature often refers to the single source hypothesis as the severity hypothesis. The model refers to the disorder(s), which is the same but manifests itself in different degrees of severity (severe language and/or literacy problems). The term severity is potentially ambiguous, however, as differences in severity between the two groups can also occur in the qualitative difference hypothesis. Differences in severity on different behavioural (language) tasks do not necessarily imply that difficulties are caused by one single underlying source. In order to prevent confusion, the term single source hypothesis will be used here.

ways during development, with speech-language difficulties at younger ages and reading difficulties at school age. In this view, the division between dyslexia and SLI also fades.

Both single source models assume that literacy difficulties for both the dyslexic and SLI groups are caused by the same underlying deficit (auditory perception and/or phonological processing). Age determines whether language or literacy difficulties are more prominent.

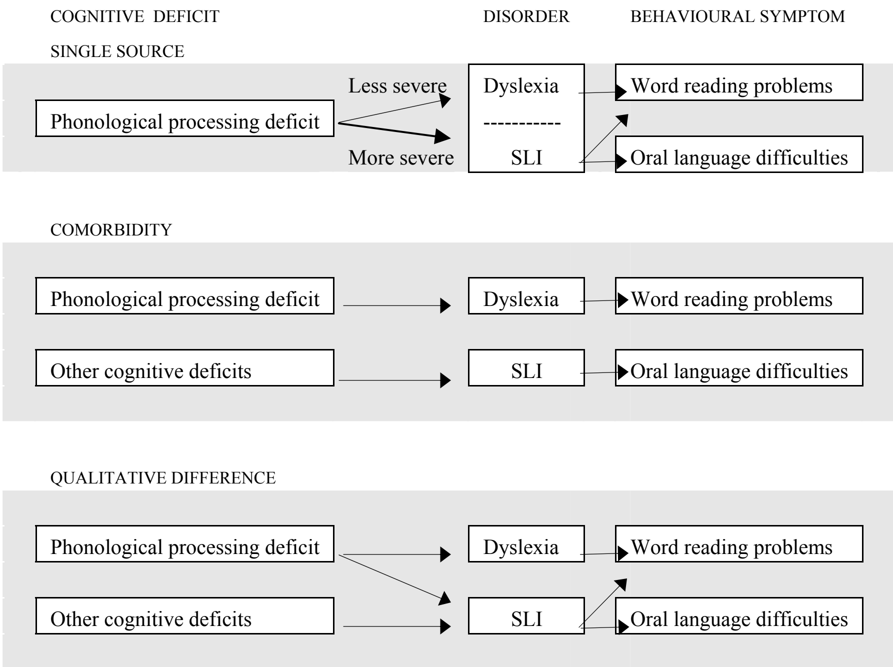

Figure 1. Models of the relationship between dyslexia and SLI. Based on Catts et al. (2005).

In contrast, there are those who advocate that SLI and dyslexia are distinct disorders. Two hypotheses adhere to this point of view. The first is a recently proposed hypothesis from Catts et al. (2005), the *comorbidity hypothesis*. This model asserts that SLI and dyslexia are distinct, but comorbid disorders. Children with only SLI show oral language deficits (i.e. difficulties with syntax, semantics, and discourse) and children with only dyslexia show poor phonological processing. Phonological processing difficulties thus underlie SLI *only* for those SLI subjects who have both

dyslexia and SLI, not in populations with only language impairment.[3] This comorbidity hypothesis argues that dyslexia and SLI are distinct developmental disorders with different cognitive deficits and different behavioural manifestations.

The second model that purports that dyslexia and SLI are different disorders is the *qualitative difference hypothesis*. This model claims that poor phonological processing is characteristic of dyslexic and SLI children. Phonological processing difficulties thus constitute a risk of both disorders. However, the profiles of the disorders differ qualitatively on other (language) skills (e.g. Bishop & Snowling 2004, Catts et al. 1999, Kamhi et al. 1988, Snowling 2000, Snowling, Bishop & Stothard 2000). Phonological processing deficits lie at the heart of the word reading problems of children with dyslexia. For children with SLI, phonological processing difficulties, but also limited oral language abilities, interfere with the acquisition of literacy skills and prevent them from using linguistic context when they are decoding text, rendering additional reading comprehension difficulties. This qualitative difference hypothesis thus accommodates findings that the literacy difficulties of SLI children change over time, encompassing both word reading and reading comprehension difficulties (Stothard et al. 1998). Whereas the dyslexic children could possess the ability to compensate for their poor reading through linguistic knowledge for contextual facilitation, such an option is absent for children with SLI.

Recently, the qualitative difference hypothesis has been cast into a *quadrant model* (Bishop & Snowling 2004), which, language-wise, plots phonological and non-phonological (semantics, syntax) skills, see Figure 2.

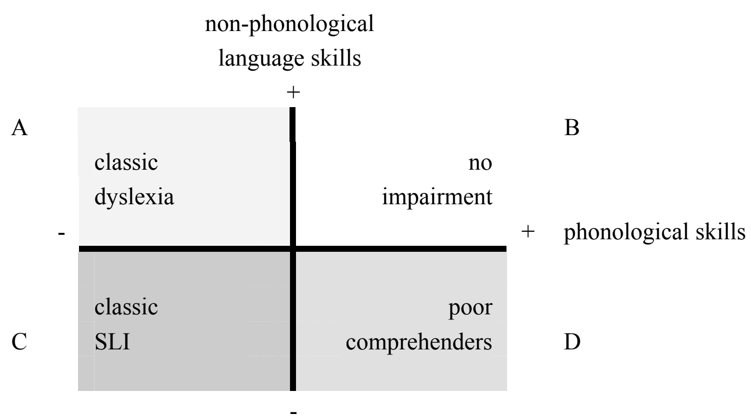

Figure 2. The quadrant model proposed by Bishop and Snowling (2004).

[3] It should be noted, however, that Catts et al. (2005: p.1391) admit that poor non-word repetition in children with SLI cannot always be ascribed to comorbidity with dyslexia. Thus, the phonological processing deficits in children with SLI are not always related to dyslexia.

The quadrant model shows how both phonological and non-phonological skills do or do not contribute to the profile of dyslexia (A), SLI (C), poorly comprehending children (D),[4] and non-impaired children. With respect to classic SLI, both phonological and non-phonological skills contribute independently to the disorder, whereas classic dyslexia is characterised through impaired phonology, but relatively intact non-phonological language skills. Poor comprehenders share the continuum of non-phonological difficulties with SLI, but do not display phonological difficulties. For the non-impaired children, finally, both phonological and non-phonological difficulties are absent. The model thus accounts for poor phonological skills in dyslexia and SLI. Furthermore, variation within both these populations is also incorporated; the quadrant shows that the disorders can spread their effects to the borderline of each disorder.

In contrast to the comorbidity hypothesis, both the single source and qualitative difference hypothesis underscore the importance of phonological processing deficits of children with language impairments and reading difficulties. A large body of research testifies to such a phonological processing deficit, which has been found for children at familial risk of dyslexia (Gallagher, Frith & Snowling 2000, Carroll & Snowling, 2004), children and adolescents with dyslexia (Bruck, 1990, Pennington & Lefly, 2001, Snowling et al. 1997, Ramus et al. 2003, White et al. 2006), and children and adolescents with SLI (Bishop, North & Donlan 1996, Botting & Conti-Ramsden 2001, Nathan, Stackhouse & Goulandris 1998, Stothard et al. 1998). The difference between the single source and qualitative difference hypotheses resides in the fact that the qualitative difference hypothesis incorporates both phonological and non-phonological components. Additionally, genetic, biological, and other cognitive influences are part of this hypothesis, whereas the single source model is limited to phonological processing.

1.4.2 Comparing the single source, comorbidity, and qualitative difference models

The present thesis evaluates the single source, comorbidity, and qualitative difference hypotheses, and thus the relationship between dyslexia and SLI by focusing on the phonological skills of children at-risk of dyslexia and children with SLI. It should be emphasised here that this is a prospective comparison. It is not known yet which of these at-risk (and SLI) children will actually be diagnosed as dyslexic when reading instruction commences. However, the hypotheses generally focus on populations diagnosed with dyslexia. Thus, expectations can only be

[4] Children who display semantic and morphosyntactic deficits in the absense of phonological difficulties are referred to as poor comprehenders (see Nation, Clarke, Marshall, and Durand 2004). In terms of reading, they demonstrate a deficit in reading comprehension despite (near) normal word recognition ability.

extrapolated for the at-risk population, of whom between 32-66% is expected to be dyslexic (recall Section 1.2.1).

The comorbidity hypothesis claims that phonological processing is only poor in those SLI children who will develop dyslexia. If this is the case, then tasks traditionally used in dyslexia research, such as non-word repetition (Chapter 6) and rhyme oddity (Chapter 7) are not expected to be poor in the majority of SLI children, as 40-60% of these children, or less on the basis of the findings of Catts et al. (2005), are expected to develop reading difficulties. Expectations are less explicit for other phonological measures. Nevertheless, it could be argued that the comorbidity hypothesis suggests that phonological abilities (in general) are not impaired in children with SLI, except when these children are dyslexic. Thus, performance on tasks tapping phonological skills, such as speech production (Chapter 3) and the phonological component of morpho-phonological alternation (Chapter 5) should not prove excessively difficult for the SLI children.

Phonological difficulties are argued to be the core deficit of SLI and dyslexia in the single source and qualitative difference models. This would mean that the present study cannot decide between these two models. However, by studying different phonological skills it can be determined whether difficulties arise for both groups. Severity differences alone cannot decide between the models. Poorer performance of the SLI than the at-risk group, a difference in severity of the deficit, could be rallied as support for a single source interpretation, but could also be interpreted within a qualitative difference model. Assessment of error patterns, on the other hand, could shed more light on the different hypotheses. Qualitatively different error patterns on the phonological tasks would favour the qualitative difference hypothesis. Furthermore, within-group analysis will yield more information on the phonological profiles of children within the at-risk and SLI group.

The expectation on the basis of the single source and qualitative difference hypothesis is that phonological processing (non-word repetition, Chapter 6) and phonological awareness (rhyme oddity, Chapter 7) will be poor in both children with (a risk of) dyslexia and children with SLI. Next to poor performance on these phonological skills typical of literacy research, both the single source and qualitative difference hypothesis anticipate difficulties for the groups on speech production (Chapter 3) and morpho-phonological alternation (Chapter 5). Error analyses are required to decide between these two models.

Now that an outline has been made of the three premises for this thesis, it is time to turn to the general research questions that will be addressed.

1.5 General research questions

The overview of background information leads to two general research questions for this thesis. They will be presented here and expectations will briefly be formulated.

1) Do children at-risk of dyslexia experience difficulties in their phonological acquisition?

The expectation on the basis of previous findings of at-risk children (Section 1.2) is that difficulties will be present across the different phonological levels assessed. These differences can be mild or more pronounced.

The phonological deficit hypothesis (1.3) explicitly anticipates difficulties with phonological processing, such as non-word repetition (Chapter 6) and phonological awareness tasks, such as rhyme oddity (Chapter 7), but is not specific about other phonological abilities. One phonological deficit hypothesis, the sub-lexical deficit hypothesis, in contrast, assumes that difficulties on all levels of phonology should occur, including speech production (Chapter 3), word stress competence (Chapter 4), and morpho-phonological alternation (Chapter 5). The results obtained here will shed light on the phonological deficit and contribute to the analysis of the phonological deficit model.

2) Do the children at-risk of dyslexia and children with SLI show similar areas of weakness and similar performance in phonological acquisition?

This question involves a comparison of performance of at-risk and SLI children, which will be targeted in Chapter 3 (speech production), 5 (morpho-phonological alternation), 6 (non-word repetition), and 7 (rhyme oddity). On the basis of findings of comparisons between children with dyslexia and SLI, and the models of dyslexia and SLI (1.4), it is anticipated that the children at-risk of dyslexia will show difficulties on the same tasks as children with SLI.

The findings will be interpreted within the single source, the comorbidity, and the qualitative difference hypotheses. If the majority of children with SLI do not show difficulties on phonological (processing) tasks, the comorbidity model is supported. However, findings of poor performance on the phonological tasks in the at-risk and SLI groups would favour the single source and qualitative difference hypotheses. Possibly, error patterns can decide between these two hypotheses. If both groups of children display difficulties with phonological acquisition, but dissimilar difficulties, this could point towards the qualitative difference model.

These are the questions that will be investigated in this thesis. The experimental design is presented in Chapter 2, followed by the different phonological experiments conducted with the at-risk, dyslexic, and SLI populations in chapters 3 to 7. Finally, Chapter 8 consists of a summary of the findings and answers to the questions presented here.

2

Method

2.1 Introduction

The project 'Early language development in specific language impairment and dyslexia: A prospective and comparative study' aimed to clarify the nature of the presumed language disorder in children with a risk of developmental dyslexia. This was conducted through a dual comparison, with chronological age peers as well as with children with specific language impairment (SLI). The present chapter discusses subject selection of these three populations (2.2), including background information, the general test procedures (2.3), and presents an overview of the data points per measure (2.4).

2.2 Subject selection

Two age groups took part in the project. The first was the 'baby' group (1;6-3;0), consisting of normally developing children and children with a familial risk of dyslexia. These children were tested four times over a period of 1,5 years. They were 1;6 at the first time of testing and approximately 3;0 at the fourth session.

The second group of children was the 'toddler' group (3;0-5;0), which included at-risk, SLI, and normally developing children. SLI can be diagnosed from the age of 3;0 onwards, which is why SLI children were only included in the toddler group. These children were seen four times between the ages of 3;0 and 5;0, of which three sessions included phonological tasks.

Due to time constraints, this thesis does not report data from sessions at all ages. Rather, a selection was made. Data from the baby group are presented of the two-year-olds (speech production, Chapter 3) and the three-year-olds (word stress competence, Chapter 4). Results discussed from the toddler group were obtained from three-and-four-year-olds (speech production, Chapter 3), four-year-olds (phonological processing, Chapter 6), and five-year-olds (morpho-phonological alternation, Chapter 5, and phonological awareness, Chapter 7).

Children of the at-risk and control groups were recruited through calls in local newspapers, parental magazines, and a call on the project's website. The main selection criterion for the at-risk children was a history of reading difficulties of at least one of the parents or an older sibling. The majority of at-risk children had a parent with dyslexia and only three at-risk children were included on the basis of

such a sibling. These siblings had been diagnosed as dyslexic by educational psychologists. The dyslexic parents were presented with five standardised reading-related measures to confirm their literacy problems, 1) a non-word repetition dictation task (3 practice items and 26 test items), 2) two measurements of technical reading skills, 3) a verbal memory test (non-word repetition: 3 practice items and 48 test items), 4) rapid naming (numbers, letters, capital letters, images, colours, and saccaded numbers), and 5) verbal competence. The technical reading tasks are a) the *Een-Minuut-Test* (EMT; Brus & Voeten 1972), a task in which as many existing words have to be read correctly in the time span of one minute, and b) *De Klepel* (Van den Bos, Lutje Spelberg, Scheepstra & de Vries 1994), a non-word reading test, where the time frame is two minutes. The verbal competence task (Analogies) was taken from the Dutch version of the *Wechsler Adult Intelligence Scale* (WAIS, Uterwijk 2000). In order for the child to be included in the at-risk group, the parent had to show poor performance on all the tasks, except the verbal competence task, as this is often a relative strength for (higher educated) dyslexics, in contrast with their reading and spelling abilities. Additionally, more strict terms were applied in that performance on the EMT or Klepel had to be $<10^{th}$ percentile, or $<25^{th}$ percentile on both the EMT and Klepel, and a discrepancy of at least 60% between verbal competence and performance on the EMT and Klepel (based on Kuijpers et al. 2003).

Children with SLI were recruited through speech therapists and ESM schools (Ernstige Spraak en taal Moeilijkheden, schools for children with severe speech and language difficulties) across the Netherlands. Prior to the start of the project, they had been classified as SLI after extensive assessment of speech and language abilities by certified speech pathologists. This means that these children performed more than 1,5 standard deviation below the mean on all language tasks. Furthermore, the usual exclusionary criteria were applied (see Leonard 1998) in that the children possessed no primary perceptual disorder or neurological deficit, no hearing problems, and reached IQ scores within the normal range.

The control children, finally, came from families without dyslexia or language impairment, and showed no language difficulties themselves. The total number of children is presented in Table 1.

All participating children had to have normal hearing,[1] absence of neurological difficulties, and normal non-verbal IQ. The latter was measured through the SON-R (*Snijders-Oomen niet-verbale intelligentietest*; Snijders, Tellegen & Laros 1988), a standardised Dutch non-verbal intelligence test which can be used with children between 2;6 and 7;0. It consists of six separate tasks, tapping different skills (mosaics, categories, puzzles, analogies, situations, and patterns).

[1] Nevertheless, in all three groups, some children were implanted with pressure-equalising tubes over the years. These numbers are low (control baby 2, at-risk baby 8, control toddler 3, at-risk toddler 8, SLI 7).

Table 1. Number of children in each group participating in the project.[2]

	Baby			Toddler				All
	Control	At-risk	Total baby	Control	At-risk	SLI	Total toddler	Total
All	44	85	129	43	74	37	154	283
Drop-out	8	16	24	11	9	9	29	53
Completed	36	69	105	32	65	28	125	230

The children were presented with the SON-R during their fourth test session, which was at the age of three for the baby group and five for the toddler group. Due to time constraints, the children were presented with four subtests. The tasks selected were different for the two age groups, as validity changed over time for the combination of tasks. For the baby group, mosaics, categories, puzzles, and situations were selected. For the toddler group, the selected subtests were mosaics, categories, analogies, and patterns. Results are presented in Table 2.

Table 2. Performance on the SON-R per group.[3]

	Baby		Toddler		
	Control	At-risk	Control	At-risk	SLI
	n=31	n=66	n=30	n=62	n=26
Mean IQ	110.7	108.8	115.2	111.0	101.0
SD	17.3	15.2	15.6	14.4	11.4

An independent samples t-test was used to assess whether differences occurred on IQ between the baby groups. This was not the case ($t(95)=0.537$, $p=0.59$). In contrast, differences were found for the toddler group on a one-way Anova ($F(2, 115)=7.448$, $p=0.001$). A Tukey HSD posthoc showed that the SLI group reached significantly poorer scores on the SON-R than the toddler control and at-risk groups ($p<0.01$).

This difference in nonverbal IQ performance is potentially problematic, as language tasks could also tap cognitive skills. Furthermore, it is not clear whether poorer IQ impacts on language (and reading) development, or whether the effect is the other way around. However, the children's IQ was always above 75 and mean

[2] These numbers reflect the total number of children participating in the project. However, this does not necessarily mean that data of all these children were available on all tasks at all times of measurement, as data recording could have failed, children could have refused to take part in a task, or the session had to be cancelled for some other reason.

[3] Not all children completed the SON-R, as some of the children did not participate in or complete the last test session.

IQ of the groups was above 100.[4] Nevertheless, non-verbal IQ will be incorporated in statistical analyses as a covariate for the toddler data of this thesis to ensure it did not have a confounding effect on the outcome of the data.

2.2.1 Issues surrounding subject selection

2.2.1.1 Language impairment

Subject selection inevitably leads to some difficulties. First of all, the selection criteria differed between the at-risk and SLI group. Whereas the former group was selected on the basis of *family history* (dyslexia ascertained in one of the parents or siblings), the SLI group was selected on *clinical diagnosis* (speech-language development evidently poorer than normal development). However, in order to explore the phonological deficit in children at risk of dyslexia and compare it with SLI children, this is the only viable approach.

Previous research has indicated that at-risk children show a delay in language development (see Chapter 1). A first indication of language difficulties can be expressed through the number of children of our project from each group receiving speech and language therapy. Table 3 presents these (incomplete) data, obtained through questionnaires (see 2.2.3). The at-risk group contained children receiving therapy for (mild) stuttering or lisping, as well as those with a more pronounced speech deficit, whereas only the former category was found in the control group. However, generally, no central language deficit was attested in the at-risk sample. As expected, all SLI children received speech therapy.

Furthermore, we sought to exclude a familial history of language impairment in our control and at-risk groups. Thus, the parents of these children should be free of language impairment. Such exclusion, however, is problematic, as no standardised test in Dutch is available to ascertain whether adults are to some degree language-impaired. To circumvent this issue, parents were asked whether they had received speech therapy at younger ages and, if so, for which reason(s). The percentages of parents with speech therapy did not differ across groups and was always less than 30%. Additionally, none of the at-risk and control parents had been diagnosed with severe language impairment at pre-or school-going age. In this way, we tried to take precautionary measures against ambiguous subject selection, despite appreciating that this was not completely feasible within our design.

Related, inclusion of control and at-risk children with a history of speech-language delays had to be minimised. Due to taxing test sessions and limited

[4] Furthermore, even though dyslexia and SLI are often characterised on the basis of a discrepancy between the specific deficit (reading or language impairment) and unimpaired general cognitive ability, this reliance on IQ and the discrepancy is questioned in an increasing amount of literature, including Bishop (1994), Bishop & Snowling (2004), Catts (1989), Dethorne & Watkins (2006), Eisenmajer, Ross & Pratt (2005), Kamhi (1998), Shaywitz, Fletcher, Holahan & Shaywitz (1992), Stanovich (1994), Tager-Flusberg & Cooper (1999), Tomblin & Zhang (1999), and Toth & Siegel (1994).

manpower, the children were not screened on standardised language tests. Therefore, we applied the selection criterion that the children should not have a background of speech-language therapy, excepting cases of non-linguistic therapy such as lisping.

Table 3. Number of children receiving speech therapy per group. [5]

	Baby		Toddler		
Speech therapy	Control	At-risk	Control	At-risk	SLI
No	27	38	24	28	-
	100%	77%	77%	61%	0%
Yes	-	10	6	17	16
	0%	21%	19%	37%	100%
No answer	-	1	1	1	-
	0%	2%	3%	2%	0%

Fourth, as the children at this stage were still too young to possess reading skills, we cannot yet establish which at-risk children and which SLI children will develop reading difficulties and dyslexia, frustrating claims about the relationship between language development and reading. However, our primary aim was to establish what happens in the language acquisition phase *preceding* reading instruction. Absence of reading skill information does not damage the research questions targeted here. Our claim is not that a strict dichotomy is present between the groups on a behavioural and/or cognitive level. Rather, we want to assess the language profiles before reading instruction begins and establish whether the developmental paths are the same for the at-risk and SLI groups.

2.2.1.2 Age matching

This study only included age-matched control groups, rather than MLU-matched or age *and* language-matched comparison, for example. It is appreciated that only age-matching is not ideal, but it does help us in answering the questions addressed in the project. Group matching is a debated topic, especially in SLI research (see Leonard 1998, p.27-31 for an overview of the difficulties associated with group matching). The aim of the present project was to find out whether a delay or differences could be traced between children at-risk of dyslexia and normally developing children in the baby group, and SLI and at-risk and control children in the toddler group. A delay can only be traced if children are compared within the same age group.

[5] It should be noted here that during our project, speech and language pathologists who collaborated in the project referred ten at-risk children (10/134=7%) whose problems were deemed severe to a speech therapist (see Gallagher, Frith & Snowling (2000) who found that 9/63 (14%) of at-risk children displayed severe language difficulties).

Furthermore, matching based on measures other than age would depend on the outcome of each session. Different types of matching would thus be unpredictable, impractical, and time-consuming. Thirdly, as the project encompassed a wide range of linguistic areas, it would be very hard to find one overlapping measure allowing adequate matching for all fields of study. Finally, comparison with younger children could be confusing, as the comparison then also measures cognitive differences.

2.2.1.3 Gender

A final issue concerning subject selection is the gender asymmetry attested in our groups of children. As Table 4 shows, the number of boys in the SLI group by far exceeded the number of boys in the control group. The fact that more boys than girls with language impairment were recruited (approximately an 8:1 ratio) is in line with findings that more boys than girls are diagnosed with language impairment (see Bishop 1997a and Leonard 1998 for an overview).

The boy:girl ratio in the control group, however, was equal (approximately 1:1) and different to that of the SLI group. Research on gender differences in early language learning has shown that female babies and toddlers are advanced in early language production compared with males. Nevertheless, the children with SLI were selected on the basis of their delayed language development. In other words, their language development is always poorer than that of normally developing children.

The situation is more challenging for the different gender ratios in the toddler at-risk (approximately 2:1) and control groups (1:1). However, this thesis has only included data of the toddler group from age 3;10 and up, which is beyond the earliest stages of language development. This sampling error is not likely to interfere with data interpretation.

Table 4. Number of girls and boys per group.

	Baby		Toddler		
	Control	At-risk	Control	At-risk	SLI
Male	16	35	22	25	33
	36%	41%	51%	34%	89%
Female	28	50	21	49	4
	64%	59%	49%	66%	11%

2.2.2 Additional background information

General subject selection criteria were discussed in Section 2.2.1 and 2.2.2. Additional background information of the families was obtained through a questionnaire sent out to the parents. The families predominantly came from urban and suburban areas with a middle-class background. In total, 169 out of 230 (73%) of the questionnaires were returned, see Table 5.

Table 5. Numbers of sent and received parental questionnaires per group.

	Baby Control	At-risk	Toddler Control	At-risk	SLI
Sent to	36	69	32	65	28
Responses	27	49	31	46	16
%	75%	71%	97%	71%	57%

The low number of responses of the SLI parents/caregivers stands out. This group was the smallest, and with only 16/28 (57%) of questionnaires returned, renders analysis difficult. The low percentage was due to the fact that we contacted SLI children and their parents through their schools, whereas we had a direct link to the parents and children of the at-risk and control groups.

The questions relevant for this thesis, concerning birth date, birth order, and maternal and paternal education will be discussed here. The findings are descriptive and are only presented to provide background information on the subject samples. First, birth date was looked into (Table 6), as premature birth could lead to poorer language development and learning abilities (e.g. Briscoe, Gathercole & Marlow 1998, Sansavini et al. in press, and see Kessenich 2003 for an overview). Only one child, from the SLI group, was premature in having been born before the 32nd week of gestation. All other premature children were born between 34 and 39 weeks of gestation.

Table 6. Subjects' birth date per group.

		Baby Control	At-risk	Toddler Control	At-risk	SLI
Birth date	On time	19	37	26	38	11
		70%	79%	84%	83%	69%
	Too early	6	7	1	5	4
		22%	15%	3%	11%	25%
	Late	2	3	4	3	1
		7%	6%	13%	6%	6%

Birth order has also been found to affect to some extent children's language and general development (e.g. Bishop 1997b, Tomblin, Hardy & Hein 1991), even though the finding has been challenged (Bornstein, Leach & Hayes 2004, Tomblin 1989). In our sample, the number of children in a family ranged from one to five, with most families comprising two or three children. The birth order of the participating children is shown in Table 7. Excepting the SLI children, the majority in the groups were firstborn.

Table 7. Subjects' birth order per group.

		Baby		Toddler		
		Control	At-risk	Control	At-risk	SLI
Position of child	1	17	25	16	34	3
		61%	51%	52%	74%	19%
	2	8	18	7	9	8
		29%	37%	23%	20%	50%
	3	3	4	6	1	4
		11%	8%	19%	2%	25%
	4	-	2	1	2	-
			4%	3%	4%	
	5	-	-	1	-	1
				3%		6%

With respect to maternal education (Table 8), studies have shown that language and vocabulary input and children's development differ according to mother's education (e.g. Dollaghan et al. 1999, Hart & Risley 1995, Hoff-Ginsberg 1991) and that maternal education can be a predictor of reading outcome (Catts, Fey, Zhang & Tomblin 2001, but see Boada & Pennington 2006, who did not).

Table 8. Maternal education per group. Secondary and tertiary refers to secondary and tertiary education, the number next to it refers to the number of educational years this encompasses starting from the first grade of secondary school onwards.

Education level; years	Baby		Toddler		
	Control	At-risk	Control	At-risk	SLI
secondary 4/5	1	4	3	7	6
	4%	8%	10%	15%	38%
secondary 6	1	-	-	-	1
	4%				6%
tertiary 7/8	6	22	2	15	3
	22%	45%	6%	33%	19%
tertiary 9	13	16	12	21	4
	48%	33%	39%	46%	25%
University or higher >9	6	5	13	2	2
	22%	10%	42%	4%	13%
No answer	-	2	1	1	-
		4%	3%	2%	

As Table 8 shows, the mothers of the control group enjoyed the highest level of education, followed by those of the at-risk children (cf. Snowling, Gallagher & Frith 2003). The pattern for the SLI group was different, with maternal education levels varying widely.

The picture was similar for paternal education (Table 9). However, the level of paternal education of the fathers of the SLI children did not show the great variation it did for the mothers' education level.

Table 9. Paternal education per group. Primary, secondary, and tertiary refers to primary, secondary, and tertiary education. For secondary and tertiary education, the number next to it refers to the number of educational years this encompasses starting from the first grade of secondary school onwards.

Education level; years	Baby		Toddler		
	Control	At-risk	Control	At-risk	SLI
primary	-	-	-	1 2%	-
secondary 4/5	-	8 16%	3 10%	4 9%	3 19%
secondary 6	-	-	-	-	1 6%
tertiary 7/8	9 33%	13 26%	4 13%	17 37%	7 44%
tertiary 9	10 37%	15 31%	8 26%	13 28%	4 25%
University or higher >9	8 30%	10 20%	15 48%	9 20%	1 6%
No answer	-	3 6%	1 3%	2 4%	-

The background measures do suggest some differences for the groups, especially between the at-risk and control groups on the one hand, and the SLI group on the other. These differences were inherent in our method of subject selection. As only IQ will be taken into account in statistical analyses, it is useful to be informed of the other differences.

2.3 General test procedure

Children from both age groups were seen four times. The children of the baby group were always tested in the child language laboratory at the Utrecht Institute of Linguistics OTS. The situation varied for children from the toddler group; the at-risk children were tested in the language laboratory, but children from the control group

were tested at their day care centre, kindergarten, or in our child language laboratory, and the children with SLI were tested at their schools or in the language lab. When children were tested at the university, a parent or caregiver was present. When children were tested at their school, kindergarten or daycare centre, they were tested individually, or a teacher or speech therapist was present.

Test sessions were always demanding, as at least four tasks (of the four projects) were presented to the children. The speech and language tests generally took at least one hour to complete. Furthermore, in the final sessions of the baby and toddler groups, four subtests of the SON-R IQ test were presented to the children, adding another hour to the session. There were six different experimenters, including the postdoc and PhD researchers of the project and a research assistant. They adhered to a testing protocol with a fixed order of experiments for every session.

2.4 Data points per measure

As indicated before, data obtained in two baby sessions and three toddler sessions are discussed in this thesis. Table 10 presents the number of children tested, the number of data points available for the phonological task, and the number of data points used for the analysis of each task.

Table 10. Number of data points available and used for the different phonological tasks.

Age	Cohort	Measure	Chapter	Children tested	Data points available	Data points analysed
2;6	Baby	Speech production	3	97	89	31
3;0	Baby	Word stress competence	4	97	77	77
3;10	Toddler	Speech production	3	130	125	49
4;6	Toddler	Non-word repetition	6	118	110	110
5;0	Toddler	Voicing alternation of the plural	5	114	107	107
5;0	Toddler	Rhyme oddity	7	114	100	100

As can be seen, the tasks tapping speech production show a large discrepancy between the number of data points available and used. This is due to the time-consuming nature of the transcription and analyses. For all other tasks, all available data were taken into account. The results are reported in Chapters 3 to 7.

3

Speech production

3.1 Introduction

Poor phonological skills have been argued to underlie dyslexia. However, within the phonological domain, the role of speech production of children with a risk of dyslexia is not clear. This chapter examines speech production skills of two-and three-year-old at-risk children. The assumption is that, if phonological representations are affected in dyslexia, then acquisition of phonology would be difficult for children with (a risk of) dyslexia.

Secondly, as it has been proposed that the overlap between dyslexia and specific language impairment (SLI) lies in the realm of phonology, the question arises whether performance of children at-risk of dyslexia and children with SLI is similar on a task tapping speech production. Therefore, data of the three-year-old at-risk group are compared to that of children with SLI.

The design of the chapter is as follows. First, a review of studies into speech production of children at-risk of dyslexia will be presented (3.2), followed by a section on speech production of children with SLI (3.3). The expectations of performance of at-risk and SLI children based on the relevant hypotheses are formulated in the subsequent section (3.4). After these preliminaries, Study 1 and 2 are presented. The first compares speech production of two-year-old children at-risk of dyslexia and normally developing children (3.5), the second data of at-risk, SLI, and control children (3.6). The General discussion (3.7) interprets the results of Study 1 and 2. Finally, the conclusion (3.8) summarises the main findings of this chapter.

3.2 Speech production of children with (a risk of) dyslexia

Speech production skills include articulation difficulties as well as more systematic difficulties with the acquisition of the phonological system. Studies conducted both into the speech production of dyslexic children and those at-risk of dyslexia are relatively rare. Infrequent studies with the former group could be attributed to the fact that problems with speech production are difficult to discern in children with dyslexia. At the age at which children can be diagnosed as dyslexic, the acquisition of their phonological system has generally been completed. However, several studies have looked into speech production and found that children with dyslexia

exhibited residual speech difficulties. They have been found to display word-specific rather than phoneme-specific production errors, especially with multi-syllabic words (Catts 1986, Kamhi et al. 1988, Nation, Marshall & Snowling 2001, Snowling 1981, Swan & Goswami 1997ab, Thomson 2004). It has been argued that these word-specific production difficulties are markers of other phonological difficulties, i.e. they reflect the children's poor phonological representations and processing (Catts 1986, Stanovich, Nathan & Zolman 1988).

The number of studies into speech production of children with a familial risk of dyslexia is also limited. Phonological acquisition in general has not received much attention in this population. The aim of this thesis is to (partly) fill the void of data on phonological acquisition of at-risk children. Studies into speech production of at-risk children so far have found mixed results. There have been studies that found significantly poorer performance of at-risk children compared to their controls. Scarborough (1990, 1991), for example, found that the 22 at-risk children in her sample who turned out to be dyslexic exhibited a significantly poorer percentage consonants correct score (PCC) in a mother-child play session at 2;6 than the 44 control children and the 12 at-risk children without dyslexia. Furthermore, Carroll & Snowling (2004) assessed speech production in 17 at-risk children aged between 3;11 and 6;6. Results on a picture naming task showed clear PCC differences between the control (92%) and at-risk groups (81%). Additionally, the number of children with speech production difficulties was higher in the at-risk than the control group. Similarly, a Danish study found that pronunciation accuracy at 6 years of age differentiated the dyslexic at-risk children from the non-dyslexic at-risk and control children (Elbro, Borstrøm & Petersen 1998).

Differences between at-risk and control children were less pronounced in a Finnish study with 2;6 year-old children (Turunen 2003). Naming task data of 19 pictures (produced twice) were used to compare the phonological skills of 105 at-risk children and 91 control children. Analysis per word suggested that the at-risk group exhibited more difficulty with acquisition of two-, three-and four-syllable targets. They showed a smaller number of target-like productions in several word-specific analyses. However, the at-risk group was only significantly poorer in correct realisation of the /r/, not on number of namings and correct production of three-and four-syllable words, consonant clusters, diphthongs, and production of /s/.

The tendency of only a mild delay in the at-risk group at younger ages was also found in an American study that assessed phonological production of 15-month-old infants (Locke et al. 1997). This study found that there was an inclination towards less complex and varied babbling patterns of a 15-month-old at-risk group (13 children) compared to a control group (12 children). A mild delay was also found by Gallagher, Frith and Snowling (2000). They presented 63 at-risk and 37 control children at 45 months with the *Edinburgh Articulation Test* (Anthony, Bogle, Ingram & McIsaac 1971). When dividing the at-risk group into literacy delayed

(LD) and literacy normal (LN) on the basis of the literacy skills at age six, the differences on the articulation test did not yield significant differences between the literacy delayed, literacy normally, and control groups, although the literacy delayed group's performance was slightly poorer than the other two groups (see also Snowling, Galllagher & Frith 2003).

A similar picture emerges for Dutch studies into speech production of at-risk children. In a study specifically focused on weak syllable truncation (e.g. *ballón* 'balloon' realised as [bɔn]) and consonant cluster avoidance (e.g. *bloem* 'flower' realised as [bum]), at-risk children in two age groups (1;11-2;6 and 2;7-4;0) were found to apply more truncation and cluster avoidance than their controls (de Bree & van der Pas 2003). However, differences were not significant, except for consonant cluster avoidance for the older age-group. In contrast to these findings of either significant or subtle differences of speech production between at-risk and control children are the findings by Gulpen (2004). She did not find differences between the two groups in terms of speech production measured through a picture naming task with three-year-old Dutch at-risk (9) and control (10) children.

The causes for these different findings are not clear. Even though it is tempting to refer to small sample size as a limiting factor, this does not seem likely, as the study by Carroll & Snowling (2004) and de Bree & van der Pas (2003) included only 17 and 31 at-risk children, but still obtained significant differences. Similarly, differences cannot be the result of the division in only at-risk and control groups compared with at-risk dyslexic, at-risk not dyslexic, and control groups, as both types of divisions have rendered mixed results. Age does not seem to be an explanation either. Despite findings suggesting that at younger ages a mild delay is present and at later ages a more pronounced delay surfaces, this does not completely hold true. Scarborough, for example, found differences at 2;6, i.e., a young age, whereas Gallagher, Frith and Snowling (2000) and Gulpen (2004) did not for three-year-olds. Nevertheless, this chapter will look at speech production in two-and three-year-olds to assess whether findings are different for the two age groups. Furthermore, differences do not seem to be due to the language under scrutiny either, as mixed results have been found for English and Dutch-learning at-risk children. A final factor that might be taken into consideration is the types of tests and analyses applied. The studies that have found significant differences have generally concentrated on pronunciation accuracy measured through percentages of consonants correct (Carroll & Snowling 2004, Scarborough 1990). The studies that have found only subtle differences or absence of difficulties, in contrast, have often applied qualitative analyses, by looking at the types of errors. The type of analysis could influence the (non-)significance of the outcome. Additionally, the qualitative analyses have established that in general, speech production of the at-risk children is delayed, rather than deviant from typical development. The two studies reported in this chapter will provide both quantitative as well as qualitative analyses to assess 1)

whether the two types of analyses yield different results and 2) whether errors are the same or different for the groups of children.

The relationship between reading ability and phonological production is not clear. It has been found that normally developing and at-risk children's speech production correlated with literacy outcome (Turunen 2003), but phonological production skills do not always contribute to this ability (Scarborough 1990). Nevertheless, in Scarborough's study, speech production was related to phoneme discrimination ability. It would thus seem that speech production could impact on other speech and language skills, which in turn affect prerequisites for literacy development. This possibility is supported by findings of Dean, Howell, and Alder (1998), who found that the most significant linguistic predictors of meta-phonological skills of five-year-old normally developing children were phonological memory and speech output. Furthermore, Carroll, Snowling, Hulme, and Stevenson (2003) found that preschool articulation accuracy of normally developing children had significant independent longitudinal influence on the development of phonological awareness. This indicates that it is worthwhile to tap speech production in at-risk children.

The present chapter assesses speech production in two- (Study 1) and three-year-old children at-risk of dyslexia (Study 2). The latter study also compares speech production of children at-risk of dyslexia with that of children with specific language impairment (SLI). Therefore, it is time to turn to the literature on speech production and SLI.

3.3 Speech production of children with SLI

Children with SLI have consistently shown severe difficulties in their speech production (e.g. Aguilar-Mediavilla, Sanz-Torrent and Serra-Raventós 2002, Beers 1995, Bortoloni & Leonard 2000, Orsolini et al. 2001, Roberts, Rescorla, Giroux & Stevens 1998). The phonological production of these children has typically been found to consist of many, and persistent, simplification processes. These processes included difficulties in the word-, syllable-, phoneme- and feature domain. Generally, the processes that have been found to occur signalled a delay in development, because they mirror early simplifications in normally developing children. Unusual production patterns, such as consonant cluster omission (e.g. *bloem* 'flower' realised as /um/), however, have also been noted (Aguilar-Mediavilla, Sanz-Torrent and Serra-Raventós 2002, Beers 1995, Grunwell 1981, Stoel-Gammon & Dunn 1985). In light of these pervasive phonological difficulties in children with SLI, the expectation is that expressive phonological difficulties will be attested in many, if not all, children with SLI in Study 2 of this chapter.

The issue of an ambivalent relationship between speech production and literacy raised in 3.2, is also present in SLI studies. Some studies with children with speech and/or language impairment have found a limited impact of speech production on

the one hand and phonological awareness and reading skills on the other (e.g. Bishop & Adams 1990, Bishop & Edmundson 1987, Catts 1993, Catts, Hu, Larrivee & Swank 1994, Nathan et al. 2004, Young et al. 2002), whereas others suggest a stronger and more direct connection between speech and awareness and reading (e.g. Bird, Bishop & Freeman 1995, Leitão, Hogben & Fletcher 1997, Nauclér & Magnusson 2002, Raitano et al. 2004, Webster, Plante & Couvillion 1997).

Apart from the influence that different tasks administered to the children (at different ages) can have on the outcome, a number of other factors can account for these inconsistent findings. The existence of a co-morbid language impairment opposed to an isolated speech deficit, heterogeneity of the co-occurring language impairment, severity of the speech impairment,[1] and persistence opposed to a transient speech production impairment play a crucial role in these differing findings. The point that should be made here is that both isolated speech difficulties as well as speech and language difficulties relate to reading skills. Speech production of children with a risk of dyslexia as well as children with SLI, assumed to have broader language impairment than just speech delay, thus warrants further investigation here.

Like the investigations into speech production of at-risk children, many studies into SLI and literacy have applied phoneme correct analyses. However, qualitative analyses have established that the types of errors SLI children make seem to matter. Magnusson and Nauclér (1990) found that a subgroup of children with articulation impairments, followed from six to eleven, had a high incidence of reading difficulties. The types of errors determined the risk, with sequential errors (metathesis and assimilation) rendering a greater risk than primarily segmental errors (substitutions and deletions). Similarly, Leitão, Hogben & Fletcher (1997, see also Leitão and Fletcher 2004) found differences in reading performance within a speech-impaired population that seemed to be related to speech production. The speech-impaired children who at age five-six resorted to 'non-developmental error processes', unusual phonological processes such as backing (/t/→[k]), exhibited poorer phonological awareness and reading ability at age seven and 12-13 than the children who generally only showed 'developmental error patterns', simplification processes common in child language. A qualitative analysis yields these insights, whereas they are obscured in a PCC or other accuracy approach. Furthermore, the PCC score is often restricted to measuring performance on the phoneme level; it does not take word- and syllable level into account, or reveal which phonemes are reproduced incorrectly.

The present study assesses the speech production of children of two-year-old at-risk children (Study 1), and three-year-old children at-risk of dyslexia and children

[1] An additional point is that it is difficult to disentangle effects of poor speech from poor language, as children with both speech and language difficulties are likely to show more severe speech impairments than those classified as speech-impaired.

with SLI (Study 2) by both computing the percentage occurrence of different simplification strategies, as well as two types of accuracy scores (percentage consonants correct and phonological mean length of utterance. The simplification processes encompass word-, syllable-, phoneme- and feature-level. One reason for looking at these processes was to find out whether only segmental realisations would be more difficult for the at-risk children. If this were the case, this would suggest that segmental representations would be specified poorly, but word-and syllable-level structure would not. Such a finding would be in line with assumptions that dyslexia is characterised by a deficit in phonological representations with mainly 'fuzzy' segmental boundaries (see also 3.4).

Secondly, the nature of the potential speech problems was of interest. Weak-syllable truncation (e.g. *ballón* 'balloon' realised as [bɔn]), avoidance of onset consonant clusters (e.g. *bloem* 'flower' realised as [bum]), fricatives (e.g. *fiets* 'bicycle' realised as /pits/), and dorsals (e.g. *kip* 'chicken' realised as [tɪp]) often occur in typical phonological development and are evident in children with SLI. With respect to consonant cluster simplification, the process generally applied is reduction of clusters to one consonant. Dorsal and fricative simplification of onsets generally take place through fronting (/k/→[t/] or stopping (/s/→[t]). It might be that the at-risk and SLI children resort to less common processes, such as cluster or onset omission (e.g. *bloem* 'flower' realised as /um/ and *kaas* 'cheese' realised as [as]).

Additionally, the proportion of the at-risk and SLI children displaying difficulty with phonological production will be established. Summarising, the objective of the present study is to gain insight into the expressive phonological skills and phonological processes of at-risk children compared to normally developing children and children with SLI. A second aim is to assess differences within the groups.

3.4 Expectations on the basis of hypotheses of dyslexia and SLI

As indicated in Chapter 1, poor encoding, maintaining, and retrieval of phonological representations is argued to underlie dyslexia. The expectation is that the children at-risk of dyslexia will show errors in speech production as a reflection of their poor representations. Excepting the sub-lexical deficit hypothesis (Ramus 2001) the different versions of the phonological deficit hypothesis do not explicitly refer to such an option, but it seems likely that an interaction between phonological acquisition and representation exists.

Studies into the phonological deficit hypothesis have tended not to be linguistically informed and generally focus on phoneme realisations of children with (a risk of) dyslexia. From a linguistic perspective, the question arises whether difficulties also occur on the suprasegmental level. In other words, are difficulties restricted to the phoneme level, or do they include difficulties on the syllable and word level as well? Secondly, if differences between the groups can be discerned

and avoidance occurs more in the output of at-risk children, are the entwined simplification processes normal or unusual? These questions can be and are addressed in the sub-lexical deficit hypothesis, as this hypothesis is framed within a generative grammar. This hypothesis further assumes that phonological acquisition is delayed from the onset of language learning. It is thus expected that the at-risk children at both two-and three-years of age, will show poorer speech production than their controls.

On the basis of the literature, it is anticipated that both the SLI and at-risk children exhibit (subtle) difficulties on speech production. The models on the relationship between dyslexia and SLI (Chapter 1) are not specific about performance of the groups on expressive phonological tasks, as the focus is on phonological processing abilities, rather than phonological acquisition. Nevertheless, the comorbidity hypothesis suggests that phonological abilities (in general) are not impaired in children with SLI, except when these children are dyslexic. Dyslexic children do display poor phonological skills. Thus, phonological skills should be present in the at-risk, but not necessarily in the (majority of the) SLI group. In contrast, both the single source hypothesis and the qualitative difference hypothesis propose that the overlapping core deficit of dyslexia and SLI resides in phonological skills. The two groups could differ in severity of the phonological disorder, but this would not rule out either of the models. If, however, different error patterns were to be found for the two groups, for example more unusual processes (such as consonant cluster omission) for either group, this could support the qualitative difference rather than the single source hypothesis.

3.5 Study 1

Speech production of two-year-old at-risk and control children was investigated in this study. The following questions are targeted:

1) Can two-year-old at-risk children be distinguished from control children on the basis of their speech production?
2) What is the variability of performance within the at-risk group?
3) Can the data be accommodated within the phonological deficit models of dyslexia?

3.5.1 Method

3.5.1.1 Participants

Data of 16 children (12 girls, 4 boys) at-risk of dyslexia (mean age 2;7, SD 2 months) and 15 control children (9 girls, 6 boys, mean age 2;7, SD 2 months) from the ‘baby’ group were analysed. Data of 89 children were available. A pseudo-random selection was made by selecting one or two children per group of each week of the testing period (approximately eight weeks). More information about subject selection is presented in Chapter 2.

Non-verbal IQ was assessed at a later testing session through a Dutch standardised test (SON-R, Snijders, Tellegen & Laros 1988). The mean IQs for these children were 104.2 (SD 12.8) for the at-risk and 103.5 (SD 16.8) for the control group. The IQ scores did not differ from each other on an independent samples t-test (t(27)=-0.127, p=0.9).

3.5.1.2 Task and materials

Word production was assessed through a picture naming task. The naming task consisted of 108 target words, with pictures divided over two books. Children had to produce at least 75 utterances. The words included mono-, bi-, tri- and quadrosyllabic words, which contained different patterns of word stress, consonant clusters and consonants. Where possible, age of acquisition (Ghyselink, De Moor & Brysbaert 2000) as well as ratings by kindergarten teachers (Kohnstamm et al. 1981) were checked to ensure that words would be familiar to the children. The age of acquisition of these words was generally below five years. The stimuli are presented in Appendix 1.

3.5.1.3 Procedure and data analysis

The word production task was presented as a book-reading session. The task was part of a larger test battery and was second or third in row. The children were shown pictures (in colour) and had to name the depiction (for example, a cap) and features of the picture (a blue cap, with stripes). The task was completed upon having named the pictures in one of the two books, but if the child wanted to continue, this was encouraged.

The children's realisations of the naming task as well as any speech produced during this session, were recorded on DAT (Tascam DA-P1), with a sensitive microphone (Crown PZM-185). Recordings were converted to sound files and transcribed phonetically by the author. In order to check for accuracy, twenty percent of the data were transcribed by a second independent transcriber (student assistant). Agreement was 90%, which was considered adequate for further analysis.

For the *quantitative analyses*, percentages consonants correct (PCC; Shriberg & Kwiatkowski 1982) were calculated. The PCC is calculated by dividing the number of consonants produced correctly by the number of target phonemes, and multiplied by 100. The word *bloem* /blum/ 'flower' realised as [bum], for example leads to a PCC of 2/3=67%. The PCC was based on the accuracy of the first 75-100 identifiable words (depending on the number of realisations of the child) of the children, excluding pronouns, auxiliary verbs, proper nouns, yes/no responses, and onomatopoeia (e.g. *tick-tock* for clock, *woof* for dog). The mean PCC per child was calculated.

Secondly, the children's phonological mean length of utterance (PMLU: Ingram & Ingram, 2001, Ingram 2002) was assessed. Unlike the PCC, this measure focuses

on the child's whole-word productions instead of specific segments. The PMLU takes into account that children generally first learn words, not individual sounds. The method of scoring is as follows: a vowel produced correctly is awarded one point. A correct consonant is awarded two points. The total score of the realisation (the child's PMLU) is divided by the number of children's realisations that are assessed. For the word *bloem* 'flower', for example, the target PMLU is seven (1 vowel = 1 point, 3 consonants = 6). Bloem realised as /bum/, would then yield a PMLU of 5 (1 vowel correct = 1, 2 consonants correct = 4). A minimum of 75 words was used for PMLU calculation.

The reason for including both PCC and PMLU is that the former has traditionally been assessed in at-risk studies and could be used for comparison. The PMLU is included as it takes the word level (complexity of the entire target) into account, which the PCC does not. It can thus be established whether PCC and PMLU lead to similar results.

For the *qualitative analyses*, token counts[2] were conducted on weak syllable truncation, consonant cluster avoidance (through reduction, omission, or epenthesis), dorsal avoidance (through substitution or omission), and fricative avoidance (idem). The counts on consonant cluster, dorsal- and fricative- avoidance were based on the occurrence in onset position of stressed or initial syllables, as prosodic positions have been known to influence the segmental productions of children (e.g. Chiat 1983, 1989, Gnanadesikan 2004, Pater 1997). By selecting the onset or stressed syllable occurrences, the role of salience was kept constant. Avoidance counts include both substitution (e.g. fricative substitution as in *f*<u>*iets*</u> 'bicycle' realised as /pits/) as well as omission (e.g. *fiets* 'bicycle' realised as /its/).

Weak syllable truncation for two-syllable strong-weak (trochaic) words was not included in the general truncation count, as the assumption was that words with this pattern, which statistically forms the dominant stress pattern for Dutch (Vroomen & De Gelder 1995), would not pose a problem for the children.

Consonant cluster avoidance was further divided into obstruent + sonorant cluster avoidance (e.g. <u>*bl*</u>*oem* flower) and /s/ + consonant avoidance (e.g. <u>*sn*</u>*eeuw* snow). This division was made as it has been shown that the two types of clusters are acquired at different stages of acquisition and, when not yet acquired, might lead to different reduction rates (e.g. Barlow 1997, Fikkert 1994, van der Pas 2004).

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[2] Token counts calculate the occurrence of a process for each realisation, even if one word is realised more than once (if, for example, the fricative in the word *fiets* bicycle has been realised twice, once as [pits] and once as [fits], the score for the former is 1 (fricative avoidance) and the latter 0 (no avoidance) Type counts, calculation of a process over all occurrences of one word (in the *fiets* bicycle example above, the type count would be one avoidance out of two instances; 0.5) were also made. The differences between the types and token counts, the calculation of a process over the words separately, generally proved negligible. Thus, only token counts will be reported here.

Dorsal avoidance was measured by counting the number of instances of /k/ and /x/ in onset position of stressed and initial syllables and counting the times that the feature (dorsal) was changed. Substitution of /x/ to [k], or vice versa, was not counted as incorrect, since the dorsal feature was maintained; however, substitution of / x/ to the (-dorsal) [t], for example, was counted as avoidance.

Fricative avoidance involved the avoidance of the feature combination (-sonorant), (+continuant) in /s, z, f, v, x, ʃ, ʒ/. Substitution of /f/ to [s] was not counted as avoidance, as the continuant feature was maintained. However, substitution of /f/ to for, example, the (-continuant) [t] was counted as avoidance. Voicing differences were not taken into account.

The fricatives were also analysed separately, as it has been found that they are acquired one at the time rather than simultaneously as a class (e.g. Beers 1995, Bernhardt & Stemberger 1998). For the /f/, for example, substitution of /f/ by [s], or omission of the onset altogether, was counted as avoidance. It is thus possible that a child shows a low rate of fricative avoidance, but a high avoidance rate of individual fricatives. The /h/ was counted separately, but will not be taken into account here due to its ambiguous characteristics incorporating both + and – sonorant characteristics in Dutch and in child language acquisition (Booij 1995, Fikkert 1994). Separate counts of /ʃ, ʒ/ were not taken into account either, due to their low occurrence in Dutch.

3.5.2 Results

This section is divided into three parts. The first looks at the quantitative analyses (PPC and PMLU), whereas qualitative analyses are the focus of section 3.5.2.2. Finally, results of within-group distribution will be reported.

3.5.2.1 Quantitative analyses

In order to answer the question whether the at-risk and control children differed on their speech production, a mean percentage consonants correct and phonological mean length of utterance was calculated for all children, see Table 1.

Table 1. Mean percentage consonants correct and phonological mean length of utterance (standard deviation) of the two-year-olds per group.

	PCC		PMLU	
Control	69%	(12%)	5.7	(1.0)
Risk	66%	(13%)	5.3	(1.3)

Even though the PCC and PMLU scores of the control group slightly exceeded those of the at-risk group, neither independent samples t-tests with arcsine-transformed

PCC[3] (t(29)=0.74, p=0.47), nor PMLU (t(29)=0.97, p=0.34) led to significant Group differences. Furthermore, it is remarkable that the standard deviation within the at-risk group was not larger than that of the control group, unlike findings by, for example, Carroll & Snowling (2004). Given the assumption that only part of the at-risk group will develop dyslexia, a more sizeable standard deviation was expected.

Thus, the PCC[4] and PMLU analyses failed to find group differences.[5] We will now turn to qualitative analyses to establish whether they alter the picture.

3.5.2.2 Qualitative analyses

Percentages avoidance for the different processes were calculated for each child. The mean results per group are presented in Table 2.

Table 2. Percentage occurrence of error types (standard deviation) of the two-year-olds per group.

	Control		At-risk	
Weak syllable truncation	29.7%	(19.1)	41.4%	(20.9)
Consonant cluster avoidance:	45.0%	(23.0)	38.9%	(24.1)
Obstruent + sonorant avoidance	48.8%	(21.6)	42.5%	(25.1)
/s/ + consonant avoidance	37.5%	(28.6)	34.9%	(25.3)
Dorsal avoidance	25.0%	(20.4)	31.9%	(21.9)
Fricative avoidance:	43.2%	(24.0)	45.4%	(23.5)
/s/ avoidance	53.7%	(35.2)	58.1%	(24.1)
/x/ avoidance	60.4%	(30.4)	61.8%	(32.7)
/f/ avoidance	44.6%	(28.6)	48.8%	(25.1)

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3 All percentage scores were arcsine-converted for statistical analysis.

4 As the PCC and PMLU can be argued to be biased towards production of consonants, it could be anticipated that the counts will lead to similar results. However, analysis of percentage phonemes correct (PPC), taking into accont both consonants and vowels, found similar results. Mean PPC was 73.4 (10.5) for the control group and 70.6 (11.3) for the at-risk group. This difference was not significant on a test of arcsine-transformed PPC (t(29) = 0.71, p = 0.42)

5 Because the PMLU does not distinguish between children unsuccessfully attempting to produce long and complex words and those successfully targeting short and simple words (both could show similar PMLU scores), the proportion of whole-word proximity (PWP) was also calculated. The PWP acknowledges a potential trade-off between length and complexity on the one hand, and realisation on the other. The PWP is calculated as follows: the total score of the realisation (the child's PMLU) is divided by the target PMLU. For the word *bloem*, for example, the target PMLU is seven. Bloem realised as /bum/, would then yield a PMLU of five. The PWP is then 5/7 = 0.7. PWP for the control group was 0.72 (0.11) and 0.68 (0.12) for the at-risk group. Again, there were no group differences on arcsine-transformed PWP (t(29) = 0.67, p = 0.51).

Independent samples t-tests for Percentage avoidance of each process showed that the at-risk and control group did not differ from each other (Truncation: t(29)=-1.6, p=0.12; Consonant cluster avoidance: t(29)=0.65, p=0.52; Obstruent + sonorant avoidance: t(29)=0.66, p=0.51, /s/ + consonant avoidance: t(29)=0.28, p=0.78; Dorsal avoidance: t(29)=-0.88, p=0.38; Fricative avoidance: t(29)=-0.22, p=0.83; /s/ avoidance: t(27)=-0.01, p=0.99; /x/ avoidance: t(28)=-0.25, p=0.80; /f/ avoidance: t(29)=0.06, p=0.95). The largest differences between the two groups were found for truncation, but this also failed to reach significance. More subtle differences can be seen for dorsal, fricative, and /s/ avoidance rates, which were all higher for the at-risk than the control group, and higher consonant cluster avoidance for the control group. Similar to the quantitative measures, standard deviations for both groups were approximately equal on these quantitative counts, suggesting that the variation within the at-risk group was not greater than in the control group.

With respect to the types of simplification processes, the majority were simplification processes common in child language. For example, consonant cluster avoidance was mainly realised through cluster reduction. Epenthesis did occur, but only for obstruent + /r/ or obstruent + /l/ clusters. Consonant cluster omission was rare, and only occurred more frequently for one at-risk child, A (5/31 avoidances). The bulk of her cluster avoidance, nevertheless, consisted of reduction (26/31 avoidances). Avoidance rates of obstruent + sonorant and /s/ + consonant clusters were moderately correlated for all children (Spearman's rho=0.77, p<0.01), as well as the control group (Spearman's rho=0.77, p<0.01) and strong for the at-risk group (Spearman's rho=0.84, p<0.01).

Dorsal and fricative avoidance were mainly realised through substitution rather than omission. For fricatives, stopping was the most common process. For the dorsals, fronting was most often applied, combined with stopping for the fricative dorsal /x/. The process of /h/-sation was infrequent for cluster, fricative, and dorsal avoidance for both groups.

3.5.2.3 Within-group variability

Contrary to expectations, no differences were found on qualitative and quantitative analyses between the at-risk and control group. This makes it unlikely that differences will surface on within-group variability. Two different analyses were conducted. First, PCC was used. Calculations were made to see how many of the children performed at or above the control mean, up to 1sd below, and more than 1sd below the mean PCC score of the control group.[6] A similar analysis was conducted for the PMLU.

[6] This cut-off based on the mean and standard deviation of the control group is an arbitrary measure, but is helpful in answering the question of at-risk performance. A similar >-1sd criterion for *literacy* scores has been used in, for example, Gallagher, Frith and Snowling

Table 3. The number and percentage of two-year-old children performing performing at or above the control mean, up to 1sd below, and more than 1 sd below the controls' mean PPC and PMLU.

Measure	Group	At or above control mean	Up to -1sd below control mean	>-1sd control mean
PCC	Control	9/15 (60%)	3/15 (20%)	3/15 (20%)
	At-risk	7/16 (44%)	7/16 (44%)	2/16 (12%)
PMLU	Control	9/15 (60%)	3/15 (20%)	3/15 (20%)
	At-risk	8/16 (50%)	6/16 (38%)	2/16 (12%)

There were no clear differences between the at-risk and control group on the basis of the cut-off division. Furthermore, the poor performers were the same for PCC and PMLU. The similar division can also be deduced from the fact that the PCC and PMLU measures strongly correlated with each other (Spearman's rho=0.86, p<0.01).

3.5.3 Discussion

Study 1 addressed the following three questions:

1) Can two-year-old at-risk children be distinguished from control children on the basis of their speech production?
2) What is the variability of performance within the at-risk group?
3) Can the data be accommodated within the phonological deficit models of dyslexia?

The answer to *Question 1* is negative. Contrary to findings by Scarborough (1990, 1991), group differences were not found at this age, neither on qualitative, nor on quantitative measures. With respect to phonological processes, avoidance rates were approximately equal for the two groups. However, truncation stood out, as the frequency was lower for the control than the at-risk group. Types of simplification were, on the whole, similar for both groups, with regular types being predominant. This matches findings of Gulpen (2004), who also found that typical processes, on both the phoneme and syllable level, were applied more often than atypical processes by both Dutch three-year-old at-risk and control children.

In light of these findings, it is not surprising that there were no evident differences in the variability of the two groups (*Question 2*). We will return to this issue in the General discussion (Section 3.7).

(2000) and Snowling, Gallagher and Frith (2003). It will be used for all experimental tasks (Chapters 3-7).

The results from this study seem difficult to reconcile with the phonological deficit hypothesis of dyslexia (*Question 3*), as the expectation was that poor production would be attested. The study shows that this is not the case for the small sample of children here. This might be problematic for the sub-lexical deficit hypothesis, which explicitly assumes that phonological acquisition in children with (a risk) for dyslexia is delayed from the onset of language learning. Again, this will be addressed in the General discussion.

Study 2 assesses speech production in an older sample of at-risk children to establish whether age of testing might have played a role in these findings. It also includes a group of children with SLI to compare performance of the at-risk and SLI group on the frequency of errors and the types of simplifications applied.

3.6 Study 2

Study 2 compared speech production of children at risk for dyslexia, children with SLI, and normally developing children. Research questions for this study are:

1) Can three and four-year-old at-risk and SLI children be distinguished from control children on the basis of their speech production?
2) What is the variability of performance within the at-risk group?
3) Can the data be accommodated within the phonological deficit models of dyslexia?
4) Can the findings of the at-risk and SLI group be accounted for by the potential comorbidity, the single source, or the qualitative difference hypothesis?

3.6.1 Method

3.6.1.1 Participants

Participants were 29 children at-risk of dyslexia (8 girls, 21 boys, mean age 3;8, SD 2 months), 10 children with SLI (1 girl, 9 boys, mean age 4;1, SD 3 months) and 10 control children (3 girls, 7 boys, mean age 3;9, SD 2 months) from the 'toddler' group. Data of 125 children were available. The data points analysed here were selected on the basis of the testing time span; for each group, data were selected at the beginning, middle and last period of the data collection. Information on subject selection can be found in Chapter 2.

Non-verbal IQ was assessed through a Dutch standardised test (SON-R, Snijders, Tellegen & Laros 1988) at age five. The mean IQs for the present groups of children were 114.4 (SD 13.6) for the at-risk, 104.0 (SD 13.7) for the SLI, and 114.5 (SD 12.2) for the control group. These differences were not significant ($F(2, 41)=1.8$, $p=0.19$). Nevertheless, as differences were discerned on the three groups as

a whole (see Chapter 2), results with IQ as covariate will also be reported for the PCC and PMLU scores.[7]

3.6.1.2 Task and materials

Similar to Study 1, children were presented with a picture naming task. In Study 2, it was presented as a picture matching game. The task consisted of 73 pictures, but children were encouraged to produce speech beyond picture-naming as well. Similar to Study 1, the mono-, bi-, tri- and quadrosyllabic words, with different word stress, consonant clusters and consonant occurrence, were checked for age of acquisition as well as ratings by kindergarten teachers. The age of acquisition of these words was generally less than five years. Stimuli can be found in Appendix 2.

3.6.1.3 Procedure and data analysis

The word production task was first in the test session. It was presented through a game, in which the children were presented with a picture card. They had to name the depiction and features of the picture and then match the picture to the identical one on a game board. The game was completed upon having matched all picture cards.

Data recording and transcription were the same as in Study 1. Transcription agreement on ten percent of the data was 91%. Data analysis was similar to Study 1. However, for the quantitative analyses, 40 items were taken into account for the calculation of the percentages consonants correct (instead of 75-100 in Study 1) and for the phonological mean length of utterance (instead of 75). This number is relatively low, but it proved difficult to obtain many different word realisations in this test session with a limited time span.

3.6.2 Results

3.6.2.1 Quantitative analyses

Two quantitative measures, mean percentages phonemes correct and phonological mean length of utterance, were calculated per child. Results per group are displayed in Table 4.

Both Anovas on arcsine-transformed PCC ($F(2, 48)=6.2$, $p=0.004$) and PMLU ($F(2, 48)=7.9$, $p=0.001$) as dependent variables and Group as factor led to significant differences.[8] Tukey posthocs established that for both counts, the control and SLI groups differed from each other ($p<0.01$). The at-risk group did not differ from the control group ($p>0.05$) and only differed from the SLI group for the PMLU ($p=0.03$).

[7] Unfortunately, IQ data of two control, two at-risk, and three SLI children are lacking. Their production data will not be taken into account in IQ-controlled analyses.
[8] All percentage scores were arcsine-converted for statistical analysis.

Table 4. Mean percentage consonants correct and phonological mean length of utterance (standard deviation) of the three-year-olds per group.

	PCC		PMLU	
Control	90%	(6%)	8.9	(0.6)
At-risk	79%	(16%)	7.8	(1.4)
SLI	66%	(17%)	6.5	(1.6)

These results remained similar when IQ was taken as a covariate (PCC: F(2, 41)=7.37, p=0.002), PMLU: (F(2, 41)=7.11, p=0.002). Thus, both the PCC and PMLU led to group differences. It will now be assessed whether this is also the case for qualitative analyses.[9]

3.6.2.2 Qualitative analyses

With respect to the qualitative counts, the data in Table 5 show that performance of the at-risk group was in-between the control and SLI group, with the latter group consistently reaching the highest avoidance scores. This was to be expected, as this group's speech and language difficulties have been severe enough to be diagnosed.

Table 5. Percentage occurrence of error types (standard deviation) of the three-year-olds per group.

	Control		At-risk		SLI	
Weak syllable truncation	5.5%	(5.8)	16.7%	(19.0)	22.0%	(24.5)
Consonant cluster avoidance:	9.3%	(5.2)	34.6%	(30.2)	59.9%	(31.8)
Obstruent + sonorant avoidance	12.5%	(6.4)	38.0%	(31.0)	61.0%	(32.6)
/s/ + consonant avoidance	3.5%	(7.6)	32.1%	(34.1)	57.1%	(35.8)
Dorsal avoidance	3.9%	(5.4)	17.1%	(25.1)	25.9%	(35.3)
Fricative avoidance:	4.7%	(6.0)	7.1%	(12.1)	26.7%	(39.3)
/s/ avoidance	3.3%	(10.5)	18.4%	(25.2)	28.1%	(42.4)
/x/ avoidance	2.0%	(6.4)	19.4%	(34.8)	26.6%	(40.3)
/f/ avoidance*	6.7%	(10.0)	10.0%	(18.2)	31.3%	(37.6)

[9] The PWP score further established group differences, with the score for the controls 0.91 (0.05), at-risk 0.81 (0.14) and SLI 0.70 (0.17). Differences were significant (F(2, 48)=6.4, p=0.003). The control group differed from the at-risk (p=0.005) and the SLI group (p=0.007), but the at-risk and SLI group did not differ from each other (p=0.18). Again, results were similar when IQ was entered in the analysis as a covariate (F(2, 42)=7.6, p=0.002). PPC analyses also matched this pattern, with PPC for the control group 92.0 (4.9), at-risk 83.9 (12.1), and SLI group 74.2 (14.9), (F(2, 42)=6.2, p=0.004).

Even though a staircase pattern of performance was present for weak-syllable truncation, dorsal avoidance, /s/ and /x/ avoidance, these were not significant on a one-way Anova with Percentage avoidance as dependent variable and Group as factor (Truncation (F2, 48)=2.0, p=0.15, Dorsal avoidance (F2, 48)=2.0, p=0.15, /s/ avoidance F(2, 48)=2.6, p=0.09, and /x/ avoidance (F2, 48)=1.4, p=0.24).

The three groups displayed most avoidance of consonant clusters. An Anova on Percentage consonant cluster avoidance led to significant Group differences (F(2, 48)=7.1, p=0.002). Games-Howell post-hoc analyses establish that the control group reached lower consonant cluster avoidance scores than the at-risk (p=0.007) and SLI groups (p=0.001). The at-risk and SLI groups did not differ (p=0.16). There was considerable variation of cluster avoidance for the at-risk group (ranging from 0 to 100%) and the SLI group (15-100%). The range was more limited for the control group (2 to 18%). Consonant cluster simplification generally occurred through cluster reduction; epenthesis and omission were infrequent.

The general finding on consonant cluster avoidance is mirrored in the results of the different cluster types; both obstruent + consonant (F(2, 48)=6.0, p=0.005) and /s/+consonant cluster avoidance (F(2, 48)=6.5, p=0.003) led to significant Group differences. Games-Howell posthocs show that obstruent + sonorant and /s/ + consonant avoidance were significantly lower for the control than the SLI (p<0.01) and the at-risk group (p<0.01), but that the results did not differ for the at-risk and SLI groups (p>0.1).

A correlation analysis between avoidance of the two types of consonant clusters found a strong overall correlation (Spearman's rho=0.80, p<0.01), and a moderate correlation for the at-risk (Spearman's rho=0.78, p<0.01) and SLI groups (Spearman's rho=0.79, p<0.01). Such a correlation was absent for the control group (Spearman's rho=-0.43, p>0.05). This could be due to the low avoidance scores of this group.

With respect to the fricatives, a significant effect was found for Percentage fricative avoidance (F (2, 48)=4.5, p=0.02) and /f/ avoidance (F (2, 48)=4.5, p=0.02). Posthoc tests did not show group differences (p>0.05). As with the truncation and dorsal avoidance results, a trend was visible in that the control group outperformed the at-risk group who outperformed the SLI group.

In case of fricative and dorsal avoidance, non-target-like realisations generally led to substitution; omission was highly infrequent in all three groups. The most frequent strategy for simplifying fricative onsets was stopping. Furthermore, unusual processes, such as backing of the front fricatives /f/ and /s/, were not a strategy employed by the children. The process of /h/-sation did occur in all three groups, be it highly infrequently.

Findings show that the children generally did not resort to unusual strategies to avoid fricatives, dorsals, and consonant clusters. In addition, truncation of strong syllables never occurred, and truncation of strong-weak words was rare. Only one

participant, child Q from the SLI group, frequently applied irregular processes; his truncation rate was high (38/42=90%), even for strong-weak words (4/15 26%). It is remarkable that his truncations were not associated with high phoneme accuracy in the produced syllables. Studies have noted that children have different 'trade-off' strategies, where some children apply more truncation, but are more faithful to segmental content of the input, whereas other children are more faithful to input word length at the cost of segmental accuracy (cf. Salidis & Johnson 1997, van der Pas 2004). This is not the case in Q's truncations. With respect to Q's consonant clusters, these were almost always avoided (more than 90% of the cases), and were frequently omitted (in more than half of the avoided instances) rather than reduced. His dorsal and fricative onsets were avoided 100% by either omitting them or exercising /h/-sation. Child Q thus showed a severe phonological impairment.

3.6.2.3 Within-group variability

The findings above showed substantial variation among the at-risk children (and the SLI group). On the basis of the quantitative results, a division was made between children performing well and those performing poorly on speech production. Calculations were made to see how many of the children performed at or above the control mean, up to -1sd below, and more than 1sd below the mean on PCC and PMLU.

Both analyses show differences between the groups. More than half of the at-risk group, and almost all SLI children belonged to the poorly performing group. Unlike the group of SLI children, a substantial proportion of the at-risk children (31% for PCC and for 24% PMLU) performed similarly to the control mean. The overwhelming majority of the SLI group performs at the poor end of the spectrum.

The distribution within the groups was highly similar for PCC and PMLU scores. This is also reflected in the very strong correlation between the two measures (Spearman's rho=0.97, $p<0.001$).

Table 6. The number and percentage of three-year-old children performing performing at or above the control mean, up to 1sd below, and more than 1 sd below the controls' mean PPC and PMLU.

Measure	Group	At or above control mean	Up to -1sd below control mean	>-1sd control mean
PCC	Control	6/10 (60%)	2/10 (20%)	2/10 (20%)
	At-risk	9/29 (31%)	4/29 (14%)	16/29 (55%)
	SLI	1/10 (10%)	1/10 (10%)	8/10 (80%)
PMLU	Control	5/10 (50%)	3/10 (30%)	2/10 (20%)
	At-risk	7/29 (24%)	5/29 (17%)	17/29 (58%)
	SLI	1/10 (10%)	1/10 (10%)	9/10 (90%)

3.6.3 Discussion

Study 2 aimed to answer four questions:

1) Can three and four-year-old at-risk and SLI children be distinguished from control children on the basis of their speech production?
2) What is the variability of performance within the at-risk group?
3) Can the data be accommodated within the phonological deficit models of dyslexia?
4) Can the findings of the at-risk and SLI group be accounted for by the potential comorbidity, the single source, or the qualitative difference hypothesis?

Both quantitative and qualitative analyses established group differences (*Question 1*); the at-risk group performed in-between the control and SLI group for all counts. Even though the results were not statistically significant for all qualitative analyses (truncation, dorsal avoidance, /x/, /s/ counts), a trend in the expected direction was visible. The results of Study 2 suggest a delay in the speech production of the at-risk children as a group, consistent with previous findings (e.g. Carroll & Snowling 2004, Scarborough, 1990).

The fact that differences between the groups on weak syllable truncation were not statistically significant, whereas most of the cluster and phoneme counts were, might imply that the global word representation of the words was relatively intact in the children, but that more detailed information, such as syllable structure and phonemes, was more problematic. However, as there was substantial variation in degree of truncation in the at-risk (and SLI) group, it seems that suprasegmental structure might not be acquired by all children at this stage. Further investigation is thus recommended in relation to acquisition and exploitation of suprasegmental cues in these children. This is also warranted by studies that have found suprasegmental difficulties in at-risk children (de Bree & van der Pas 2003, de Bree, Wijnen & Zonneveld 2006, see Chapter 4), dyslexics (Richardson, Thomson, Scott & Goswami 2004, Wood & Terrell 1998a), and children with SLI (e.g. Corriveau & Goswami 2004, Samuelsson & Nettelbladt 2004).

For all groups, correct production of consonant cluster structures proved the most difficult of the processes measured. This is not surprising, as consonant cluster development is known for its protracted acquisition, in both typical and disordered development (see, e.g. Barlow 1997, Fee 1995, Jongstra 2003). Again, however, there was a staircase pattern with the controls reaching lowest avoidance, the SLI the highest, and the at-risk group in-between. Compared to the control group, the at-risk and SLI groups had more difficulty acquiring the complexities of the syllable onset. The avoidance rates of obstruent + sonorant (e.g. *bloem* flower) and /s/ + consonant clusters (e.g. *sneeuw* snow) were moderately correlated for these groups.

The finding that, with the exception of one child, the language-impaired children in our sample did not frequently resort to abnormal phonological processes,

such as phoneme omission, can be couched in the SLI literature, which has reported abnormal or unlikely processes (e.g. Beers 1995, Grunwell 1981, Stoel-Gammon and Dunn 1985), but generally finds that the majority of processes children with SLI use are typical, not deviant, simplification processes (e.g. Beers 1995, Schwartz, Leonard, Folger & Wilcox 1980).

The general absence of unusual errors in the SLI group is at odds with the results of Leitão, Hogben and Fletcher (1997) and Leitão and Fletcher (2004) who found 'non-developmental error processes' (i.e. unusual processes such as backing (/t/→[k]) in realisations of five-and-six-year-old speech-impaired children. These children performed more poorly on phonological awareness and reading tasks at age seven and age 12-13 than those who applied developmental error patterns. It should be flagged here, however, that even in Leitão et al.'s sample, both speech-impaired children with normal and deviant phonological processes displayed difficulties with phonological awareness and spelling tasks. It is thus conceivable that speech-impaired children's delayed phonological development also impacts on construction of phonological awareness abilities and reading. In short, the data of the current study generally point towards developmental (i.e. normal), rather than unusual processes in the children's productions. The results thus suggest a delay in phonological production.

With respect to the variability within the groups (*Question 2*), results showed that approximately one third of the at-risk group performed as well as the control group and more than half of the children resembled the SLI group. This finding potentially agrees with the statistic that 30-60% of children with a familial risk of dyslexia become dyslexics themselves, which would be the children exhibiting speech and language difficulties. Such a finding would be in line with those of Scarborough (1990). She found that there was a difference in speech performance of at-risk children who went on to develop dyslexia and those who did not. The unaffected at-risk children did not show poorer speech skills than the control children. However, this interpretation is tentative, as the children in the present study have not reached reading age yet. The results on speech production cannot yet be divided on the basis of reading skills, obstructing a direct comparison with the other studies.

The results of this study can be accommodated within the phonological deficit hypothesis of dyslexia (*Question 3*), which assumes poor phonological representations in children with dyslexia. These poorer representations could be expected to have a detrimental effect on speech production. Furthermore, differences surfaced on more than the segmental level, as performance was higher for the control group than the at-risk (and SLI) group on the word (truncation rates) and syllable level (consonant cluster avoidance). These findings suggest that the phonological deficit hypothesis needs to take performance on additional prosodic layers into account, as proposed by the sub-lexical deficit hypothesis. Besides

pinpointing loci of difficulties, these findings thus also argue for a systematic, linguistically-informed, analysis of the phonological deficit of children with (a risk of) dyslexia. Additionally, the present qualitative analyses revealed that the types of errors exhibited in the at-risk data were those common in phonological acquisition and thus lead to the interpretation that phonological development in the at-risk group is delayed rather than deviant.

In terms of the relationship between dyslexia and SLI (*Question 4*), findings showed that both the at-risk and SLI groups performed more poorly than the control group and that the majority of SLI children could be labelled as poor performers. The data do not seem to agree with the comorbidity hypothesis, which would not predict (very) poor speech production in a substantial number of SLI children. In contrast, both the single source as well as the qualitative difference hypotheses assume that difficulties will occur for the groups on phonological skills.

A bold interpretation of these findings is that they point towards the qualitative difference rather than the single source hypothesis. First, the SLI group contained one child with unusual simplification processes, whereas data of the at-risk group only contained processes signalling a delay in phonological acquisition. Secondly, the younger at-risk children (Study 1) could not be differentiated from the control group. SLI children on the other hand, are referred to speech therapists primarily because of poor speech-language development. These two findings tentatively suggest different profiles of the at-risk and SLI group. However, this interpretation should be treated with caution, as support is tenuous.

3.7 General discussion

The occurrence of truncation, consonant cluster, dorsal, and fricative avoidance of the two-and three-year-old control and at-risk children and the SLI children has been charted in Figure 1. Five patterns have been left out in order to enhance the clarity of the figure. The patterns of obstruent + sonorant and /s/ + consonant cluster avoidance resembled those of the consonant clusters, and those of the /f/, /x/, and /s/ avoidance patterned with those of the fricatives. The graph shows that truncation and avoidance decreased for both the control and at-risk group from two to three years (but bear in mind that data were obtained from a cross-sectional sample), but, excepting fricative avoidance, less so for the at-risk than the control group. Performance at two years of age was similar for the control and at-risk groups, but different at three years. Furthermore, the truncation and avoidance scores of the SLI group were evidently higher than those of the other two groups. Consonant cluster avoidance of the SLI children was even higher than those of the two-year-old control children. The figure thus visualises the pronounced delay of the SLI group.

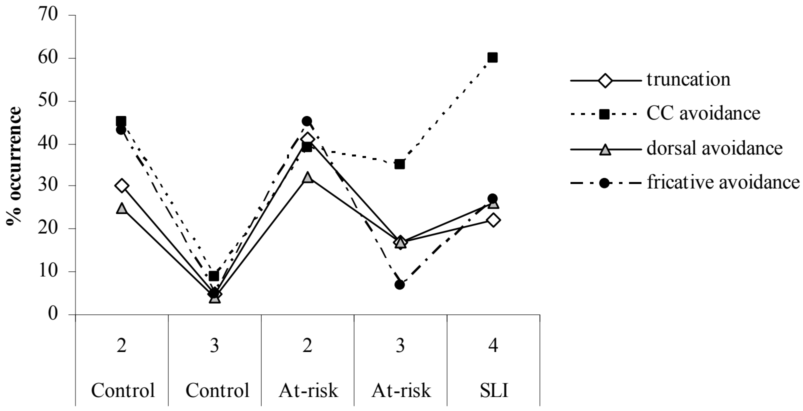

Figure 1. Occurrence of error types per group per age.

Unlike the findings of Study 1 that did not find significant group differences between 2;6-year-old at-risk and control children, the results of Study 2, with three-and-four-year-olds, showed poorer performance on quantitative and qualitative analyses of speech production of the at-risk group. This raises the question what the causes for these different findings are. They cannot be a task or analysis effect as both age groups were presented with a picture naming task with comparable stimuli and similar analyses were conducted. Furthermore, it seems unlikely that the sample of children in Study 1 was too small to obtain significant results; the standard deviations of the control and at-risk groups were similar, which does not suggest potential differences between the groups.

It is possible that the 2;6-year-old at-risk group only included at-risk children who will not develop dyslexia, the ‘unaffected’ at-risk children, whereas both ‘affected’ and ‘unaffected’ at-risk children were included in the older group of children. There is no way of assessing yet whether this was the case, as the children cannot read and write yet. Analysis of the pattern of performance of these children on the other tasks presented to them at this age, such as grammatical production and word recognition, can also shed light on the status of (un)affected at-risk children. Results on these tasks are pending.

A second option related to subject selection could be that the 2;6-year-old control group included children whose phonological development is slower than average, depressing the mean control scores. This option seems doubtful, however, as variation within the control group was limited.

Next to possible sampling effects, it is feasible that differences were not attested, as avoidance of the sounds and patterns assessed here were still substantial for both groups. Thus, pronounced group differences surface at later stages, when

phonological acquisition of the control group takes flight and the development of the at-risk group lags behind. Indeed, Beers (1995) found that simplification processes were evident in the speech of Dutch normally developing children aged between 2;6-2;11, matching the findings of the 2;6-year-old control group of Study 1. These processes had largely disappeared at the age of 3;6-4;0, similar to the findings of the 3;9-year-old control group of Study 2. It could thus be that the control and at-risk children started out similarly, but a delay appears when more subtle distinctions have to be acquired.

Whatever the cause of the differing findings, it is difficult to envisage how the findings of Study 1 and 2 can be aligned with the sub-lexical deficit hypothesis (Ramus 2001), as this hypothesis assumes that phonological difficulties for the at-risk group would surface from a very young age onwards. The results on speech production did not show this result, as differences only surfaced between the older groups. Interpretation of the data, however, is complicated by the fact that results stem from a cross-sectional study, with different children in the two age groups. Furthermore, the present findings do not rule out the interpretation that phonological development of the two-year-old at-risk group is delayed. Perception data, for example, could shed further light on this matter.

A final comment is devoted to the accuracy scores, the percentage consonant correct and phonological mean length of utterance. Both studies showed that they led to similar group and within-group results and that they were highly correlated. It seems that calculation of either PCC or PMLU would have sufficed.

3.8 Conclusions

The two studies in this chapter assessed expressive phonological skills in children at-risk of dyslexia. Differences between the control and at-risk group were not found at 2;6 (Study 1). In contrast, these were clearly visible for the three-and-four-year-olds (Study 2) on quantitative and qualitative analyses. These findings imply at least mildly delayed phonological behaviour of the at-risk group. Furthermore, more than half of the at-risk group performed more poorly than the control group, suggesting that difficulties were present in a substantial part of the at-risk group. The findings of Study 2 can be interpreted within the phonological deficit hypothesis of dyslexia. Additionally, they indicate that this hypothesis needs to take phonological development and phonological theory into account to further qualify the deficit.

Study 2 also compared speech production in children at-risk of dyslexia and children with SLI in order to specify the relationship between SLI and dyslexia. Both the at-risk and SLI group performed more poorly than the control group, but quantitative and slight qualitative differences arose between the SLI and the at-risk group. It is proposed that the data support the qualitative difference hypothesis. Thus, poor phonological skills are present in both disorders, but these difficulties are not the same.

This chapter has shown that investigation of phonological acquisition is a fruitful avenue in at-risk research, as it leads to new findings and provides food for thought on existing hypotheses. The next chapter will continue this line of study by assessing word stress assignment of three-year-old children at-risk and nine-year-old dyslexic children.

Appendix 1. *Stimuli of the picture naming task of Study 1*

S stands for *Streeflijst* (Kohnstamm et al. 1981) and AoA stands for Age-of-Acquisition data from Ghyselinck, de Moor and Brysbaert (2000).[10] Transcription stems from Heemskerk and Zonneveld's (2000) *Uitspraakwoordenboek*, excepting names (preceded by *).

S	AoA	Word	Transcription	Translation
97	3;7	Appel	/ʻɑpəl/	Apple
100	3;8	Baby	/ʼbebi/	Baby
100	-	Ballon	/bɑʼlɔn/	Balloon
100	-	Banaan	/baʼnan/ or /bəʼnan/	Banana
100	-	Bed	/bɛt/	Bed
-	-	Bert	*/bɛrt/	Bert (name)
58	-	Bestek	/bəʻstɛk/	Cutlery
100	-	Bij	/bɛi/	Bee
94	-	Blauw	/blɑu/	Blue
97		Blazen	/ʼblazə(n)/	Blow
97	4;1	Bloem	/blum/	Flower
100	4;8	Boot	/bot/	Boat
100	-	Bord	/bɔrt/	Plate
97	-	Boterham	/ʼbotər(h)ɑm/	Slice of bread
100	5;6	Bril	/brɪl/	Glasses
100	4;5	Broek	/bruk/	Trousers
97	3;9	Brood	/brot/	Bread
97	-	Cadeau	/kaʼdo/	Present
94	-	Citroen	/siʼtrun/	Lemon
97	5;3	Clown	/klɑun/	Clown
97	4;7	Deur	/dør/	Door
97	5;1	Druif	/ʻdrœyf/	Grapes
94	4;7	Eend	/ent/	Duck
100	-	Ei	/ɛi/	Egg
97	5;4	Emmer	/ʻɛmər/	Bucket
-	-	Ernie	*/ʼɛrni/	Ernie (name)
100	4;2	Fiets	/fits/	Bicycle

[10] The percentage listed from the *Streeflijst* reflects the percentage of teachers who assume that children at kindergarten will recognise and know the meaning of these words. The age presented in the Age of Acquisition section is based on the age students said to have gained the meaning of the word in question. The reason why the AoA list does not always include an age for a word that can be found in the *Streeflijst* is due to the fact that the AoA words were only based on nouns, and only those four and five letter nouns in the CELEX database, whereas the *Streeflijst* included more nouns, as well as verbs and adjectives.

100	5;5	Fluit	/flœyt/	Whistle
97	-	Geel	/ɣel/	Yellow
100	-	Gieter	/ˈɣitər/	Watering can
100	-	Giraffe	/ʒi'rɑf/	Giraffe
100	-	Groen	/ɣrun/	Green
-	-	Grover	*/'ɣrovər/	Grover (name)
100	-	Handschoenen	/'hɑntsxunə/	Gloves
97	5;6	Hoed	/hut/	Hat
100	4;4	Huis	/hœʏs/	House
100	-	Jas	/jɑs/	Jacket/coat
100	6;2	Jurk	/'jʏrᵊk/	Dress
100	-	Kabouter	/ka'bɑutər/	Gnome
97	-	Kikker	/'kɪkər/	Frog
100	5;5	Klok	/klɔk/	Clock
94	6;2	Knoop	/knop/	Button
97	-	Konijn	/ko'nɛin/	Rabbit
97	-	Krokodil	/kroko'dɪl/	Crocodile
100	-	Lammetje	*/'lɑməcə/	Lamb (little)
97	4;8	Lamp	/lɑmp/	Lamp
100	4;0	Lepel	/'lepəl/	Spoon
94	5;3	Luier	/'lœyjər/	Nappies
94	-	Mes	/mɛs/	Knife
97	4;2	Muis	/mœys/	Mouse
97	5;0	Muts	/mʏts/	Beanie
84	5;9	Navel	/'navəl/	Belly button
100	-	Olifant	/'olifɑnt/	Elephant
97	-	Oranje	/o'rɑɲə/	Orange (colour)
100	-	Paars	/pars/	Purple
100	-	Paddestoel	/'pɑdəstul/	Mushroom
100	-	Paraplu	/para'ply/	Umbrella
94	4;9	Peer	/pɪr/	Pear
89	-	Pinguins	/'pɪŋgwɪn/ or /'pɪŋɣwɪn/	Penguin
100	4;0	Poes	/pus/	Cat
100	4;0	Raam	/ram/	Window
94	-	Rood	/rot/	Red
94	-	Roos	/ros/	Rose
100	-	Schaap	/sxap/	Sheep
100	5;6	Schep	/sxɛp/	Spade
94	-	Schildpad	/'sxɪltɑt/ or /'sxɪlpɑt/	Turtle
100	-	Schoenen	/'sxunə(n)/	Shoes
100	-	Schoorsteen	/'sxorsten/	Chimney

82	-	Servet	/sɛr’vɛt/	Napkin
100	-	Sinaasappel	/’sinazɑpəl/	Orange (fruit)
97	-	Sinterklaas	/sɪntər’klas/	Sinterklaas
97	6;0	Slak	/slɑk/	Snail
97	6;0	Slang	/slɑŋ/	Snake
97	-	Slapen	/’slapə(n)/	Sleep
100	5;0	Slee	/sle/	Sledge
100	-	Sleutel	/’sløtəl/	Key
94	6;2	Slurf	/’slʏrᵊf/	Trunk
97	-	Snavel	/’snavəl/	Beak
97	-	Sneeuw	/snew/	Snow
100	4;2	Snoepje	/’snupjə/	Sweet
100	-	Sok	/sɔk/	Sock
89	7;3	Spek	/spɛk/	Bacon
100	-	Spiegel	/’spiɣəl/	Mirror
97	-	Springen	/’sprɪŋə(n)/	Jump
97	-	Staart	/start/	Tail
97	5;6	Ster	/’stɛr/	Star
84	5;7	Stippen	/’stɪpə(n)/	Dots
100	3;8	Stoel	/stul/	Chair
94	-	Strand	/’strɑnt/	Beach
97	-	Strepen	/’strepə(n)/	Stripes
94	5;8	Strik	/strɪk/	Bow (gift wrap)
100	3;8	Tafel	/’tafəl/	Table
100	-	Tandenborstel	/’tɑndə(n)bɔrstəl/	Toothbrush
100	-	Tandpasta	/’tɑntpɑsta/ or /’tɑmpɑsta/	Toothpaste
100	4;5	Trein	/trɛin/	Train
97	5;0	Trui	/trœy/	Jumper
92	-	Uil	/œyl/	Owl
100	-	Varken	/’vɑrkə(n)/	Pig
	-	Vlieger	/’vliɣər/	Kite
100	-	Vliegtuig	/’vlixtœyx/	(aero) plane
100	-	Vlinder	/vlɪndər/	Butterfly
100	4;1	Vogel	/‘vo:ɣəl/	Bird
100	4;9	Vork	/vɔrᵊk/	Fork
97	3;6	Water	/’watər/	Water
94	6;4	Zebra	/’zebrɑ/	Zebra
100	-	Zee	/ze/	Sea
100	-	Zwart	/zwɑrt/	Black
97	-	Zwempak	/’zwɛmpɑk/	Bathing suit

Appendix 2. *Stimuli of the picture naming task of Study 2*

S stands for *Streeflijst* (Kohnstamm et al. 1981) and AoA stands for Age-of-Acquisition data from Ghyselinck, de Moor and Brysbaert (2000).[11] Transcription stems from Heemskerk and Zonneveld's (2000) *Uitspraakwoordenboek*, excepting names (preceded by *).

S	AoA	Word	Transcription	Translation
94	5;0	Aap	/ap/	Monkey
97	-	Aardbei	/’ardbɛi/ or /’arbɛi/	Strawberry
97	3;7	Appel	/‘ɑpəl/	Apple
100	-	Banaan	/ba’nan/- or /bə’nan/	Banana
100	-	Bed	/bɛt/	Bed
-	-	Bestek	/bə‘stɛk/	Cutlery
94	-	Blauw	/blɑu/	Blue
97	4;1	Bloem	/blum/	Flower
100	4;8	Boot	/bot/	Boat
100	4;5	Broek	/bruk/	Trousers
97	3;9	Brood	/brot/	Bread
100	-	Bij	/bɛi/	Bee
-	-	Citroen	/si’trun/	Lemon
97	5;1	Druif	/‘drœyf/	Grapes
-	-	Dromedaris	/drɔmə’darɪs/ -or /drɔmə’darəs/	Dromedary
94	4;7	Eend	/ent/	Duck
100	-	Ei	/ɛi/	Egg
97	5;4	Emmer	/‘ɛmər/	Bucket
82	-	Eskimo	/‘ɛskimo/	Eskimo
100	5;5	Fluit	/flœyt/	Whistle
97		Geel	/ɣel/	Yellow
100	-	Gieter	/ˈɣitər/	Watering can
100	-	Giraffe	/ʒi’rɑf/	Giraffe
100		Groen	/ɣrun/	Green
100	-	Handschoenen	/’hɑntsxunə/	Gloves
100	4;4	Huis	/hœys/	House

[11] The percentage listed from the *Streeflijst* reflects the percentage of teachers who assume that children at kindergarten will recognise and know the meaning of these words. The age presented in the Age of Acquisition section is based on the age students said to have gained the meaning of the word in question. The reason why the AoA list does not always include an age for a word that can be found in the *Streeflijst* is due to the fact that the AoA words were only based on nouns, and only those four and five letter nouns in the CELEX database, whereas the *Streeflijst* included more nouns, as well as verbs and adjectives.

100	-	Jas	/jɑs/	Coat
100	6;2	Jurk	/ jʏrᵊk/	Dress
94	-	Kameel	/ka'mel/	Camel
84	-	Kangoeroe	/'kɑŋɣəru/	Kangaroo
97	-	Kasteel	/kɑs'tel/	Castle
97	-	Kikker	/'kɪkər/	Frog
100	5;5	Klok	/klɔk/	Clock
-	-	Koala	/ko'wala/	Koala
100	-	Koe	/ku/	Cow
97	-	Konijn	/ko'nɛin/	Rabbit
97	-	Krokodil	/kroko'dɪl/	Crocodile
97	4;8	Lamp	/lɑmp/	Lamp
100		Lepel	/'lepəl/	Spoon
100	5;1	Leeuw	/lew/	Lion
84	-	Matroos	/ma'tros/	Sailor
94	-	Mes	/mɛs/	Knife
97	4;2	Muis	/mœys/	Mouse
97	5;0	Muts	/mʏts/	Beanie
100	-	Olifant	/'olifɑnt/	Elephant
97	-	Oranje	/o'rɑɲə/	Orange (colour)
100	-	Paddestoel	/'pɑdəstul/	Mushroom
100	-	Paraplu	/para'ply/	Umbrella
94	4;9	Peer	/pɪr/	Pear
89	-	Pinguins	/'pɪŋgwɪn/ or /'pɪŋɣwɪn/	Penguin
94	-	Rood	/rot/	Red
94	-	Roos	/ros/	Rose
100	-	Schaap	/sxap/	Sheep
100	5;6	Schep	/sxɛp/	Spade
94	-	Schildpad	/'sxɪɪltɑt/ or /'sxɪlpɑt/	Turtle
100	-	Schoenen	/'sxunə(n)/	Shoes
97	6;0	Slak	/slɑk/	Snail
100	5;0	Slee	/sle/	Sledge
84	5;7	Stippen	/'stɪpə(n)/	Dots
100	3;8	Stoel	/stul/	Chair
94	-	Strand	/'strɑnt/	Beach
97	-	Strepen	/'strepə(n)/	Stripes
97	5;0	Trui	/trœy/	Jumper
92	-	Uil	/œyl/	Owl
100	-	Varken	/'vɑrkə(n)/	Pig
100	-	Vliegtuig	/'vlixtœyx/	(aero) plane
100	-	Vlinder	/vlɪndər/	Butterfly

100	4;1	Vogel	/ʻvo:ɣəl/	Bird
100	4;9	Vork	/vɔrᵊk/	Fork
92	-	Vrachtwagen	/ʻvrɑxtwaɣə(n)/	Truck
97	-	Ijsbeer	/ʼɛizber/	Polar bear
94	6;4	Zebra	/ʼzebrɑ/	Zebra
100	-	Zee	/ze/	Sea

4

Word stress competence[1]

4.1 Introduction

As Chapter 1 showed, evidence has accumulated over the years that children with (a familial risk of) dyslexia display difficulties in their language acquisition. A widely accepted explanation of dyslexia is that is stems from an underlying phonological deficit. However, despite the popularity of the phonological deficit hypothesis of dyslexia, which argues that phonological representations are poor in dyslexia, the acquisition of the sounds and phonological structures of a language of children with (a risk of) dyslexia has not often been addressed. Word stress acquisition is one such aspect of phonology that has not received much attention. Assessing the state of acquisition of this language-specific skill provides information on phonological skills and thus contributes to theories of a phonological deficit in dyslexia.

This chapter looks into word stress production of both children at risk of dyslexia (Study 1, 4.5) and children with developmental dyslexia (Study 2, 4.6). First, studies on suprasegmental abilities in dyslexia will be discussed (4.2), as well as background information on Dutch word stress and its acquisition (4.3). Subsequently, expectations on the basis of the relevant hypotheses on dyslexia will be presented (4.4).

4.2 Suprasegmental skills in dyslexia

Word stress, together with sentence accent, intonation, and rhythm, is part of suprasegmental phonology. Various studies have shown that *perception* of these suprasegmental cues is more difficult for dyslexics and poor readers than for normal readers (e.g. Foxton et al. 2003, Goswami et al. 2002; Mennell, McAnally & Stein 1999, Muneaux et al. 2004, Richardson et al. 2004, So & Siegel 1997, Talcott et al. 2003, Wood & Terrell 1998a). These findings suggest that poor readers need larger thresholds to detect non-speech and speech cues than normally reading children. The failure to perceive and use these cues has been argued to compromise the development of well-specified phonological representations.

[1] Parts of this chapter have been reported in Bree, E. de, Wijnen, F. & Zonneveld, W. (2006). Word stress production in Dutch children at-risk of dyslexia. *Journal of Research in Reading*, 29, 304-317.

Production data on suprasegmental abilities of dyslexics are hard to find. A study by Wolff (2002) showed that ten-to-twelve-year-old children with dyslexia were poorer at repeating both non-speech rhythms through finger tapping, and speech rhythms through speech production. With respect to the speech task, repetition of two-syllable sequences (pa-pá and pá-pa) was not different for the dyslexic and control group. For three-and four-syllable sequences, however, the dyslexic subjects showed less clear stress contrasts, made frequent errors of stress assignment, and sometimes omitted or inserted syllables that disturbed the overall speech rhythm.

Furthermore, studies of Dutch and Finnish at-risk children have found that weak syllable truncation (*banána* realised as *nána*) occurred more frequently in the productions of at-risk than in typically developing children (de Bree & van der Pas 2004, Turunen 2003, Chapter 3). In both groups, weak, unstressed syllables were more prone to omission than stressed syllables, suggesting that unstressed syllables were not perceived and/or produced correctly. The segmental content of stressed syllables further seemed to be maintained better than in unstressed syllables. The control and at-risk group showed similar patterns, but truncation was more frequent in the realisations of the latter group. The above-mentioned studies suggest that differences between children with (a risk of) dyslexia and their controls exist within the domain of speech and non-speech prosody, especially rhythm.

Findings specifically on word stress production in dyslexics are equally scarce. Coltheart, Byng, Masterson, Prior and Riddoch (1983) briefly mentioned stress errors in word reading of a dyslexic subject, but did not conduct an analysis on these errors.[2] Stress assignment by patients with aphasia with and without dyslexia has been investigated more systematically. Studies have shown that word stress in naming (de Bree, Janse & van de Zande submitted, Cappa, Nespor, Ielazzi & Miozzo 1997, Laganaro, Vacheresse & Frauenfelder 2002) and word stress in reading aloud (de Bree, Janse & van de Zande submitted, Cappa et al. 1997, Galante, Tralli, Zuffi & Avanzi 2000, Janssen 2003, Marshall & Newcombe 1973, Miceli & Caramazza 1993) were impaired in Dutch, German, Italian, and English patients. All studies reported a tendency of the subjects to resort to regular stress patterns and a loss of the ability to produce irregular stress patterns. The question arises whether word stress acquisition in children with (a risk of) dyslexia is similar, with regular stress being more frequent or more prominent in their output than irregular stress.

One previous study assessed stress assignment of Dutch at-risk children. Gulpen (2004) reported on a non-word repetition task that revealed that three-year-old at-risk children tended to repeat stress and reproduce target length as faithfully as the

[2] Coltheart et al. provide examples of the stress errors of a teenage developmental dyslexic, C.D. Errors she makes are: *apex* realised as [əˈpɛks] and *surplus* as [səˈplus].

age-matched control group. However, the study included just twelve non-word targets, divided only in stress on the first (*áalofint*) or final syllable (*sjaróf*, *poorooplá*). Furthermore, the items were based on both real monomorphemic (e.g., *giráf* 'giraffe', *chocolá* chocolate) and compounded (e.g., *kápstok* 'coat rack', *kléurpotlood* 'colour pencil' – 'crayon', *vráchtwagen* 'freight car' - 'lorry') words. Hence, the collection of target words included a mixture of regular and irregular stresses (see section on Dutch word stress below). Additionally, the number of children in the study (seven control and eight at-risk children) was quite low. The present study has a similar focus as Gulpen's, but remedies the problems outlined above. Our goal is to assess differences in word stress acquisition of monomorphemic targets for three-year-old at-risk and nine-year-old dyslexic children and their age-matched controls. Regularity of stress assignment (explained below) is a crucial variable, since it may provide a window into the order of acquisition. Before proceeding with the Method section, an outline of Dutch word stress and its acquisition is indispensable.

4.3 Dutch word stress

Phonetically, stressed syllables in Dutch show longer duration and greater amplitude than unstressed syllables (Slootweg 1988, Sluijter 1995). Unstressed vowels are candidates for reduction, although reduction is much less pervasive than in English (Kager 1989, Trommelen & Zonneveld 1999).

Morphological structure plays a role in Dutch stress assignment (Trommelen & Zonneveld 1989). For example, compound units have stress on the first member (compare *hánddoek* 'hand cloth' – 'towel' with *bádhanddoek* 'bath towel'). In affixation, there is a distinction between stress-neutral affixes (e.g. the Dutch suffix *–aar* cannot be stressed itself and does not 'shift' the stress to another stem syllable, compare *wándel* 'to walk' to, *wándelaar* 'walker') and stress-sensitive affixation (e.g. the Dutch adjectival suffix *-ig*, which shifts the stress peak of its compound base to the syllable directly preceding the suffix, compare *nóódlot* 'fate' to *noodlóttig* 'fatal').

The experiment in the present chapter assesses word stress in forms resembling underived (morphologically non-complex) words. Therefore, I will not discuss the influence of morphology on word stress further here.

The basic stress system for monomorphemic words in Dutch is trochaic, favouring patterns of strong-weak syllables (e.g. *fó*$_s$*to*$_w$ 'photo'). A major characteristic of Dutch monomorphemic word stress is the Three Syllable Window generalisation (Kager 1989, Trommelen & Zonneveld 1989, 1999), which holds that main stress always falls within a three-syllable-window at the right word edge. Thus, stress falls on the antepenultimate, penultimate or ultimate syllable, but never on the pre-antepenultimate syllable (**mácaroni* 'macaroni', **
ródodendron* 'rhododendron', **Jéruzalem* 'Jerusalem'). Furthermore, the Dutch word stress system is quantity-

sensitive: syllable weight, based on the structure of the rhyme (the syllable nucleus and coda), co-determines the position of stress. Taking into account the weight of the final (and prefinal) syllable, the following rules apply to main stress in monomorphemic words (Daelemans, Gillis & Durieux 1994, Kager 1989, Nouveau 1994, Trommelen 1991, Zonneveld & Nouveau 2004):

- If the final syllable is light, (-VV), main word stress is prefinal, regardless of the structure of the penult, e.g. *fa.mí.lie* 'family'*,* *a.gén.da* 'diary', *ma.ca.ró.ni* 'macaroni', *in.flu.én.za* 'influenza', *an.díj.vie* 'endive'. (In closed syllables, doubly-spelled vowels are long, singly-spelled vowels are short. Vowels in open syllables are long, regardless of their spelling. Syllable boundaries are represented by a dot).
- If the final syllable is superheavy (ends in a vowel and two consonants or ends in a long vowel and a single consonant), main word stress is final, e.g. *stu.dént* 'student', *te.le.fóon* 'telephone', *pre.si.dént* 'president'. Superheavies only occur in final position in Dutch underived words (see Zonneveld 1993).
- If the final syllable is heavy (ends in a vowel and single consonant), main word stress is penultimate or antepenultimate, depending on the nature of the penultimate syllable; if it is closed, stress is penultimate, e.g. *e.lék.tron* 'electron'*, ro.do.dén.dron* 'rhododendron', if it is open, stress is antepenultimate, e.g. *bá.ri.ton* 'baritone', *á.na.nas* 'pineapple'*, Je.rú.za.lem* 'Jerusalem'.
- Final diphthongs (vowel sequences of two different vowels) behave like superheavies; *kar.wéi* 'chore', *boer.de.ríj* 'farm'.

Support for these regularisations stems from corpus studies (Daelemans, Gillis & Durieux, 1994, Trommelen 1991), stress assignment on loan words, neologisms, acronyms, vacillating stress patterns in native words (Kager 1989), and stress assignment to non-words in reading (de Bree unpublished data, Nouveau 1994). Findings from these five fields underscore the dominant stress patterns in Dutch.

Besides these main stress rules, irregular stress patterns also occur in Dutch. The irregular patterns are further divided into irregular and highly irregular patterns (Kager 1989, Nouveau 1994, Trommelen 1991, Trommelen & Zonneveld 1989). This further subdivision is based on frequency facts (Daelemans, Gillis & Durieux 1994, Trommelen 1991) and the results of non-word stress experiments (Nouveau 1994). For final light syllables, for example, an irregular pattern is *Cánada '*Canada' and a highly irregular pattern is *paraplú* 'umbrella'. Examples of words with regular, irregular, and highly irregular stress are presented in Table 1.

Acquisition of Dutch word stress competence entails picking up the regularities and exceptions of Dutch. This is not a trivial process, however, as regular stress patterns include stress in different positions of the word (*pyjáma*, *ánanas*, *telefóon*). Children have to gain knowledge of the role of syllable weight to acquire and exploit these stress positions. If they fail to perceive syllable weight as a deciding factor, chances are they will tend only towards the most frequent stress pattern, which in

Dutch is prefinal stress (Daelemans, Gillis & Durieux 1994), irrespective of syllable weight.

Table 1. Stress assignment for Dutch monomorphemic words.

Syllable structure		Stress patterns		
prefinal syllable	final syllable	Regular	Irregular	Highly irregular
Any	Light	*pyjáma*	*Cánada*	*paraplú*
		'pyjamas'	'Canada'	'umbrella'
Any	Superheavy	*telefóon*	*ólifant*	*Prométheus*
		'telephone'	'elephant'	'Prometheus'
Heavy	Heavy	*eléktron*	*bombardón*	*tálisman*
		'electron'	'bombardon'	'talisman'
Light	Heavy	*ánanas*	*krokodíl*	*Celébes*
		'pineapple'	'crocodile'	'Celebes'

4.3.1 Acquisition of Dutch word stress

Acquisition of Dutch word stress demands acquisition of rhythmic patterns, syllable structure, and knowledge about syllable weight. Previous research on Dutch word stress acquisition includes longitudinal studies of young children's spontaneous speech (Fikkert 1994), as well as experimental studies with three-and four-year-old children (Nouveau 1994, Zonneveld & Nouveau 2004). The focus here will be on the experimental studies, as these allow assessment and comparison of stress acquisition at one (st)age under controlled conditions (see Hochberg 1988 and Kehoe 1997, 1998 for similar experimental studies on Spanish and English word stress acquisition, respectively). On the basis of Hochberg's study, Nouveau (1994) created nonsense words for each stress category (from Table 1). Thus, a non-word could contain regular (*karabílo*), irregular (*karábilo*), and highly irregular (*karabiló*) stress. Furthermore, she included an additional category of words with prohibited stress (**kárabilo*). These prohibited targets were non-words without a mono-morphemic equivalent in Dutch, as they violate the three syllable window restriction (**kárabilo*) or mandatory effect of syllable weight (**kánakta*). Children were asked to repeat these non-words and the stress types of their repetitions were scored.

Nouveau found that regular and irregular stress patterns were produced with fewer errors vis-à-vis the target than the highly irregular and prohibited patterns. Prohibited patterns were repeated least correctly. Furthermore, the four-year-olds fared better on the imitation task than the three-year-olds. Her results thus suggest that acquisition of stress is a gradual process, with a preference for regular over irregular patterns. The data also showed that children are sensitive to the stress

domain of monomorphemic words in Dutch from an early age onwards, as prohibited stress proved to be most difficult for the children.

The expectation is thus that the three-year-old normally developing children from the present experiment will display stress placement behaviour similar to the three-year-olds in Nouveau (1994) and Zonneveld and Nouveau (2004). The question arises how stress acquisition of children with a potential mild language disorder, children with (a risk of) dyslexia, proceeds. Are they just as apt to discover stress regularities as their controls? On the basis of the developmental findings of Nouveau, it could be anticipated that if a difference between the at-risk and control children exists, this will surface as a delay in stress acquisition; that is, the at-risk children will show a larger dichotomy of regular vs. (highly) irregular stress production. This begs the question whether, in terms of the stress description in Section 4.3, the at-risk children will have deduced the role of syllable weight in stress assignment. If they have not, stress placement might be dependent on different strategies, such as a tendency for penultimate stress, the dominant stress pattern in Dutch. A delay might also be attested for the children with dyslexia in Study 2.

Furthermore, for both age groups, it is of interest to assess the variability within the group, as group results may obscure individual differences. Moreover, within-group analysis allows us to establish whether a delay in word stress acquisition is present in all children at-risk of dyslexia, or only a subgroup, for example 30-60% of children, the percentage that is expected to develop dyslexia from the at-risk group (see Chapter 1). For the children with dyslexia, it is of interest to assess individual differences, as heterogeneity within dyslexia has widely been attested and acknowledged (e.g. Ramus et al. 2003, Vellutino et al. 2004). The question arises whether word stress difficulties are present in a substantial part of the dyslexic group.

4.4 Expectations on the basis of the phonological deficit hypothesis

As indicated in Chapter 1, the phonological deficit hypothesis assumes that encoding, maintaining, and retrieving phonological representations is poor in children with (a risk of) dyslexia. This renders the (implicit) expectation that acquisition of primary phonological skills will be poorer for these children. Thus, if dyslexia is characterised by poor phonological representations, then the anticipation is that phonological development, including word stress assignment, should also be more difficult for children with (a risk of) dyslexia than for normally developing children.

Furthermore, research into the phonological deficit has mainly focused on phoneme representations, whereas suprasegmental abilities have not received much attention. A first attempt to fill this gap will be made here. Additionally, it will be investigated whether the assumed difference between the at-risk and dyslexic group

compared to the control groups can (partly) be related to a reduced ability of representing the segmental structure of the non-words.

4.5 Study 1

Study 1 assessed word stress production of children at risk of dyslexia and age-matched controls. The research questions addressed are:

1) Can three-year-old children at-risk of dyslexia be distinguished from control children on the basis of their word stress production?
2) What is the variability of performance within the at-risk group?
3) Can the data be accommodated within the phonological deficit model of dyslexia?

4.5.1 Method

4.5.1.1 Participants

Subjects tested were 49 children at-risk of dyslexia (mean age 3;3, SD 4 months) and 28 control children (mean age 3;1, SD 3 months). The data of nineteen additional children (12 at-risk, 8 control) could not be obtained or analysed due to the child's reluctance to participate or failed recordings. More elaborate information on subject selection can be found in Chapter 2.

Children were presented with tasks from the non-verbal intelligence test SON-R (Snijders, Tellegen & Laros 1988). Mean IQ for the at-risk group was 109.5 (SD 13.0) and for the control group 111.6 (SD 14.5), which was not significantly different ($t(74)=0.64$, $p=0.53$).

4.5.1.2 Task and materials

A non-word repetition task was designed to assess stress production. Non-words were selected rather than existing words, as this allowed systematic testing of the different conditions. The task was based on that of Nouveau (1994). It included phonotactically legal non-words varying in length (two to four syllables), final syllable weight (light, heavy, superheavy, and diphthong) and stress position (final, prefinal, antepenultimate and pre-antepenultimate). The ensuing 39 stimuli belong to different categories of regularity, including regular, irregular, highly irregular, and prohibited stress.

In this study, the stimuli were slightly altered in order to 1) minimise occurrence of non-words with syllables that constituted a familiar word for children (such as *jákot*, with *ja* meaning 'yes' in Dutch) and 2) to prevent children from abandoning the game due to repeated occurrence of similarly sounding targets. Thus, instead of presenting *talaktan* three times as *taláktan* (regular type), *talaktán* (irregular type) and *tálaktan* (prohibited type) respectively, the child heard *taláktan*, *kawaptán*, and *pánaktam*. There is a danger of inducing differences due to segmental changes, but the conflicting desire to prevent data loss as much as possible prevailed.

The stimuli (see Appendix) were prerecorded to ensure consistent rate, accuracy, and intonation of presentation. In order to assess whether word stress of these recordings was unambiguous, five naïve adult listeners assigned stress on the basis of the recordings of the 39 non-words. Their stress assignment agreed with those of the design (195/195, 100%)

4.5.1.3 Procedure and data analysis

The word stress task was part of a test battery in which both speech-language skills and IQ were tested. The task was divided into two sessions, which were conducted as third and fifth in row. In the first game, the child was presented with a picture card of a fantasy animal, heard its name over a Fostex 6301B loudspeaker, and had to repeat it.

After responding, the picture was placed on a game board. If all pictures had been presented, the row of pictures reached a picture of a castle and the child was rewarded with a sticker. The second game was constructed in a similar vein; the child had to move a pawn on a game board with fantasy animals on it. At the end of the game, the pawn reached the picture of a present and the child was allowed to select a sticker or balloon. Children's realisations were recorded on a DAT recorder (Tascam DA-P1) with a highly sensitive microphone (Crown PZM-185). Not all children repeated all targets, or not all of them were recorded properly. There were 1193 analysable realisations of the control group and 2120 of the at-risk group.

Recordings, converted to sound files, were independently transcribed by two trained transcribers (author and student assistant), who were blind to the group membership of the children (at-risk or control). The sound files obtained from the two groups were mixed in random order. Agreement on transcription of syllable structure and word length was 82% and agreement on stress was 95%. Differences were resolved among the two transcribers.

It was scored whether the children's realisations were 'identical' or 'non-identical' to the target (see Table 2 for examples). Identical refers to realisations identical in word shape (syllable structure and word length) and word stress. Realisations with identical word shape and word stress as the target, but incorrect phonemes (e.g. *patipón* for *katipón*) were also scored as identical, as stress assignment of these realisations was similar to the target. Non-identical realisations were scored as 'equivalent' if the regularity of the child's rendition matched that of the target, as 'more regular' when it was a more regular realisation (e.g. from (highly) irregular to regular), and 'less regular' when it was a less regular realisation (e.g. from regular to (highly) irregular). The types of changes children applied were also tallied.

Furthermore, as a measure of the quality of phonological representations of the children's realisations, percentages phonemes correct (PPC) were calculated for the children's realisations. The number of correctly repeated phonemes of the target

were divided by the total number of target phonemes. Phoneme omissions and substitutions were scored as incorrect. Twenty percent of the data was checked by a second trained rater (research assistant). Agreement was 94%. Examples of coding and scoring are presented in Table 2.

Table 2. Examples of children's realisations of the non-word /kati'pɔn/, coded for changes of regularity, errors, and degree of regularity. The right-most column presents the percentage of phonemes correct.

Target	Transcription			Regularity	
katipón	kati'pɔn			irregular	
Realisation	Transcription	Identical?	Change	Regularity	PPC
katipón	kati'pɔn	identical	-	irregular	100%
patipón	pati'pɔn	identical	-	irregular	86%
kokatipón	kokati'pɔn	same	syllable addition	irregular	100%
kapón	ka'pɔn	same	syllable omission	irregular	71%
kátipon	'katipɔn	more regular	stress shift	regular	100%
katipónt	kati'pɔnt	more regular	weight gain	regular	100%
katipó	kati'po.	less regular	weight loss	highly irregular	86%
katípon	ka'tipɔn	less regular	stress shift	highly irregular	100%
katípon	katık'po	less regular	weight gain weight loss	highly irregular	57%
kápon	'kapɔn	more regular	syllable omission stress shift	regular	71%

4.5.2 Results

4.5.2.1 Suprasegmental results

Identical, Equivalent, More, and Less regular

The percentage (and numbers) of identical and non-identical realisations of the groups are reported in Table 3. Recall that 'identical' refers to identical stress, word length and syllable shape repetition, not phoneme realisation (see Table 2 above).

A Univariate analysis of variance established that the arcsine proportion of identical realisations of each child differed between the groups ($F(1,77)=5.44$, $p=0.02$). The identical rate exhibited by the at-risk group was substantially lower than that of the control group. More regular and equivalent realisations were higher in the at-risk than the control group. Furthermore, the at-risk group resorted approximately twice as often to one-syllable realisations as the control group.

Table 3. Percentages (and numbers) of occurrences per response class per group.

Group	Identical	Equivalent	More regular	Less regular	One syllable
Control	45.7 (545/1193)	22.2 (265/1193)	22.6 (270/1193)	8.0 (95/1193)	1.5 (18/1193)
At-risk	37.4 (793/2120)	25.0 (530/2120)	25.8 (546/2120)	8.5 (181/2120)	3.3 (71/2120)

When subdividing identical and non-identical realisations according to regularity, a similar pattern emerged for both groups: the more irregular the target, the lower the rate of identical realisations and the higher the rate of regularisation (Table 4).[3] However, a clear difference between the control and at-risk group was found for irregular targets, which were realised identically much more often by the control (57%) than the at-risk (40%) group. The control group even had a higher identical rate for the irregular than for the regular types.

Table 4. Percentages (and numbers) of occurrences per response class per group.

Group	Target type	Identical	Equivalent	More regular	Less regular	One syllable
Control	Regular	51.3 (228/444)	28.6 (127/444)	-	17.3 (77/444)	2.7 (12/444)
	Irregular	56.7 (204/360)	21.7 (78/360)	15.8 (57/360)	4.2 (15/360)	1.7 (6/360)
	Highly irregular	33.2 (89/268)	16.8 (45/268)	48.9 (131/268)	1.1 (3/268)	0.0 (0/268)
	Prohibited	19.8 (24/121)	12.4 (15/121)	67.8 (82/121)	-	0.0 (0/121)
At-risk	Regular	47.3 (356/753)	28.1 (212/753)	-	19.6 (148/753)	5.0 (38/753)
	Irregular	40.3 (260/645	27.7 (179/645)	24.8 (160/645)	4.6 (30/645)	2.5 (16/645)
	Highly irregular	27.9 (140/502)	23.3 (117/502)	45.4 (228/502)	0.0 (3/502)	2.8 (14/502)
	Prohibited	16.8 (37/220)	10.0 (22/220)	71.8 (158/220)	-	1.4 (3/220)

[3] This pattern is also attested in analyses for each non-word series separately.

The realisations of both groups generally obeyed the domain of Dutch word stress. Creation of a prohibited type out of regular, irregular, or highly irregular type targets was highly infrequent. The next section will look at the types of changes occurring in the children's realisations.

Changes to word and syllable structure

In cases where a word shape or stress pattern was realised incorrectly, several types of changes occurred (see Table 2). As percentage identical was lower for the at-risk than the control group, changes occurred more frequently in the data of the former than the latter group. Table 5 presents the percentages of occurrences of several patterns. Note that these errors only take stress, syllable structure, and word length into into account. Furthermore, as processes could co-occur in one realisation, they do not add up to the total repetitions minus the identical rate for each group.

Table 5. Changes per group in percentages (and numbers) of occurrence.

Group	Syllable addition	Syllable omission	Stress shift	Weight loss	Weight gain
Control	6.4 (76/1193)	18.6 (222/1193)	5.6 (67/1193)	24.8 (296/1193)	18.2 (217/1193)
At-risk	7.2 (153/2120)	24.8 (525/2120)	9.4 (200/2120)	25.6 (542/2120)	23.4 (496/2120)

The order of changes was similar for both groups, with weight gain (i.e., making a (final) syllable heavier, as in *genimó* → *genimóos*) and weight loss (i.e., making a (final) syllable lighter, as in *pakídon* → *pakído*), and syllable omission (*genimó* → *gemó*) being most frequent for both groups. Importantly, however, the percentages of changes were always higher for the at-risk group. Multivariate analyses with Change (syllable addition, syllable omission, stress shift, weight loss, weight gain) as dependent variable and Group (Control and At-risk) as fixed factor show that the at-risk group applied significantly more syllable omission ($F(1, 3316)=14.1$, $p<0.01$), stress shift ($F(1, 3316)=13.9$, $p<0.01$), and weight gain ($F(1, 3316)=12.1$, $p<0.01$) than the control group. Syllable addition ($p=0.26$) and weight loss ($p=0.48$) were not significantly different between the groups.

The changes of both groups of children tended towards regularisation. Weight gain, for example, was applied to highly irregular type words like *genimó* (→ *genimóos*), weight loss often occurred for highly irregular type words such as *pakídon* (→ *pakído*), and stress shift for irregular stress such as *parígont* (→ *parigónt*). However, not all changes were stress-pattern induced. For example, the *taláktan* (regular) *kawaptán* (irregular) *pánaktam* (prohibited) series displayed weight loss through medial cluster reduction in all three forms. Medial cluster

reduction led to improved prohibited types, but poorer regular types, and steady irregular types. The change to a poorer realisation appears to be due to phonological complexity of the syllable rather than complexity of stress patterns. Similarly, weight loss of the final syllable in the *monítaron* (regular) *notimalón* (irregular) *tonimáron* (highly irregular) *nómipalon* (prohibited) series seems a consequence more of word length than stress difficulties.

Apart from these instances, it thus seems that the changes generated more regular stress patterns. This is also supported by findings of Multivariate analyses with Changes (syllable addition, syllable omission, stress shift, weight loss, weight gain) as dependent variable and Stress regularity (regular, irregular, highly irregular, prohibited) as fixed factor. Except for syllable addition ($p=0.25$), all processes showed significant effects (syllable omission $F(3, 3314)=15.5$, $p<0.01$, stress shift $F(3, 3314)=8.6$, $p<0.01$, weight loss $F(3, 3314)=49.4$, $p<0.01$, and weight gain $F(3, 3314)=5.7$, $p<0.01$). Games-Howell posthocs (significance level $p<0.05$) further showed that the frequency of all changes was different for the different degrees of regularity (regular < irregular < highly irregular < prohibited stress).

4.5.2.2 Percentages Phonemes Correct

Whereas the previous section looked at suprasegmental outcomes, the impact of target regularity on segmental realisation is assessed here, see Table 6. On the basis of the children's realisations, percentages phonemes correct (PPC) were calculated.

Table 6. Percentages phonemes correct (standard deviation) per degree of regularity.

	Percentage phonemes correct			
	regular stress	irregular stress	highly irregular stress	prohibited stress
Control	70.8 (24.2)	71.9 (23.9)	66.9 (22.8)	59.9 (18.7)
At-risk	68.2 (24.7)	67.8 (23.6)	59.8 (22.8)	53.1 (19.3)

A Univariate analysis of variance with arcsine-transformed PPC as dependent variable and Stress regularity (regular, irregular, highly irregular, prohibited) and Group (Control, At-risk) as fixed factors found an effect of Group ($F(1, 3319)=31.0$, $p<0.0001$) and Stress regularity ($F(2, 3319)=35.6$, $p<0.0001$), but no interaction ($p=0.67$). Games-Howell posthoc tests established that PPC for regular and irregular stress patterns did not differ ($p=0.99$), but all other conditions led to significantly different percentages correct ($p<0.001$). Both groups had more difficulty with phoneme repetition in targets with highly irregular and prohibited stress than in regular and irregular targets.

Thus, an effect of Group and Stress regularity was found for the different conditions. However, there were no interactions between these variables, suggesting

that the phoneme scores of the at-risk group were only poorer and not affected differently by complexity. The phonological representations of both groups were poorer as regularity decreased.

4.5.2.3 Within-group variability

The sections above have established that group differences exist. This paragraph will look at performance on the word stress task within the two groups. The measure used for this individual analysis is the identical score; the score reflecting correct repetition of word length and syllable structure. Calculations were made to see how many of the children performed at or above the control mean, up to 1 sd below the control mean, and more than 1 sd below the mean identical score of the control group.

Table 7. The number and percentage of children performing performing at or above the control mean, up to 1sd below, and more than 1 sd below the controls' mean identical score.

	At or above control mean	Up to -1sd below control mean	>-1sd control mean
Control	15/28 (54%)	9/28 (32%)	4/28 (14%)
Risk	11/49 (22%)	29/49 (59%)	9/49 (18%)

The majority of the at-risk group was classified as performing up to 1sd below the control mean, indicative of only subtle differences. The percentage of at-risk children performing 'poorly' was similar for the at-risk and control group.

4.5.3 Discussion

This study aimed to answer the following questions.

1) Can three-year-old children at-risk of dyslexia be distinguished from control children on the basis of their word stress production?
2) What is the variability of performance within the at-risk group?
3) Can the data be accommodated within the phonological deficit model of dyslexia?

With respect to *Question 1*, it was found that the patterns of results of the three-year-old at-risk children and age-matched normally developing children on non-word stress realisation were similar, and suggest that both groups have essentially acquired the basic regularities of the Dutch stress system. As the irregularity of the target increased on a scale from regular to (highly) irregular to prohibited, both groups displayed a lower rate of realisations identical to the target stress pattern, and showed depressed phoneme percentages correct. For both groups, the three-syllable window for stress-assignment was in place; stress on the fourth to last syllable from

the left was rare in both realisations of prohibited types and creations of new words. These findings confirm those of Nouveau (1994; also Zonneveld & Nouveau 2004).

However, in addition to these similarities, there were marked differences between the groups. First, the at-risk group had significantly more difficulty in identical realisation of the target stress pattern and syllable structure. Instead, the at-risk children resorted more often to monosyllabic realisations and more regular renditions. The control group had high rates of identical realisation for both regular and irregular type targets, whereas the at-risk group only had high scores for the regular types. Secondly, the frequency of phonological changes differed for the two groups. Even though the processes were similar, the at-risk group applied more changes. The changes were mainly used to create more regular realisations, but were also produced to simplify complex syllable structures. These results then also match those that have established difficulties with speech production in children at-risk of dyslexia (e.g. Carroll & Snowling 2004, Scarborough 1990).

An alternative point of view is that the changes leading to irregularisation (such as the regular *taláktan* realised as *talátan*, becoming highly irregular) were deliberate changes based on analogy, rather than caused by phonological complexity. Such a view has been proposed for the data of Nouveau (1994) by Gillis, Daelemans and Durieux (2000). However, Gillis, Daelemans and Durieux did not take the speech production skills of children into account. In order to decide between the possibilities (irregularisations caused by analogy or speech production), data of older children could be assessed. If the less regular realisations are caused by analogy, older children should resort more often to production of less regular realisations. Older children possess a larger vocabulary, which would include more irregular (and less frequent) stress patterns. Furthermore, the control group should resort more often to less regular realisations than the group of dyslexic children, as the control group is assumed to have better language skills and a larger vocabulary. If the less regular realisations are caused by difficulties in production, irregularisations should be less frequent in the output of older children, as they will have acquired word and syllable structure. We will return to this matter in the General discussion (4.7).

Question 2 was concerned with the distribution of performance of the at-risk group on the word stress production task. A minority in both groups displayed severe difficulties on the word stress task compared to the mean of the control group. Nevertheless, there were slight differences. A substantial part of the at-risk group performed between up to 1 standard deviation below the mean. This analysis suggests that there might be a subtle word stress deficit in a large proportion of the at-risk group.

These findings not only suggest that the acquisition of word stress, which is part of the phonology of a child's native language, was delayed in a group of at-risk children, but also show that the phonological deficit hypothesis should take the

acquisition of phonological skills into account (*Question 3*). What is more, these skills should be investigated on the basis of language-specific regularities and thus demand incorporation of linguistic principles.

Furthermore, it could be speculated that there is an interaction between word stress acquisition and phonological (phonemic) representations. The at-risk group reached poorer percentages phonemes correct, suggesting that construction of (novel) phonological representations in this group was poorer (see also Carroll & Snowling 2004, Pennington & Lefly 2001 who too found poorer non-word repetition in at-risk children). For both the at-risk and control group, percentages phonemes correct decreased as irregularity of the targets increased. It seems that construction of phonological representations of irregular targets was more difficult than those of regular targets. In this context, it is interesting to refer to the study of Daelemans, Gillis & Durieux (1994) who found that an instance-based learning (IBL) algorithm was able to learn word stress of monomorphemic Dutch words taken from the CELEX lexical database (Baayen, Piepenbrock & Gulikers 1995). Three different types of encoding were presented to the IBL algorithm: metrical encoding, rhyme encoding, and full segmental encoding, see (1):

(1) The three types of encoding presented to the IBL algorithm in the study by Daelemans, Gillis and Durieux (1994).

target			Metrical encoding	Rhyme encoding	Full encoding
a:ˈχɛnda:	*agénda*	[diary]	light-heavy-light	a: ɛn a:	a:ˈχɛnda:

On the basis of metrical encoding of the words, the algorithm succeeded in capturing the regular stress patterns, but was much less successful in capturing irregular words. Phonemic encoding led to the best results, acquiring both regular and irregular stress patterns, with full phonemic encoding outperforming rhyme encoding. In other words, when the model incorporated segmental information, a more complete description of the data was found.

Hypothetically, the different degrees of encoding could resemble the path of the language learner: children could initially rely on basic weight distinctions for stress placement, which resembles the stage the three-year-olds are in. As word and phoneme segmentation develops, the children could incorporate more irregular patterns in their stress repertoire. If this is the case, and if full encoding is essential for acquisition of stress patterns, then children with (a risk of) dyslexia are at a disadvantage; their phonological representations are notoriously poor. The acquisition of stress patterns could thus be compromised by poor phonological representations, which would in turn hamper development of stress patterns, creating a catch 22 situation. Acquisition of highly irregular stress patterns would be difficult for them to achieve. It is therefore important to assess the word stress production of

older, dyslexic, children, to see which strategies they apply in word stress production. This is reported in Study 2.

The interaction between word stress acquisition and phonological representations might also be visible in vocabulary size. Vocabulary growth has been argued to drive phonological segmentation (Metsala & Walley 1998, Storkel & Morrissette 2002); vice versa, phonological encoding abilities have been found to partly determine vocabulary growth (Gathercole & Baddeley 1989, Storkel & Morrissette 2002). It could thus be anticipated that vocabulary size of the at-risk group is smaller than that of the control group, caused by and yielding poorer phonological representations for the at-risk group. These poorer representations, in their turn, lead to difficulty in word stress acquisition and are also affected by word stress abilities.

Vocabulary data, measured through the N-CDI, (Zink & Lejaegere 2002), the Dutch version of the MacArthur CDI, were available for 58 of the 77 children (23 control children and 35 at-risk children). The mean percentile score (expressive vocabulary) of the control group was 53.6 (SD 26.8), that of the at-risk group 46.0 (SD 23.2). Despite the lower score for the at-risk group, this difference was not significant on an independent samples t-test ($p=0.26$). However, there was a weak, but significant positive correlation between the identical score on the word stress task and vocabulary size of all children (Spearman's rho=0.32, $p=0.01$). There was also a weak significant correlation for the at-risk group (Spearman's rho=0.37, $p=0.026$), but not for the control group (Spearman's rho=0.28, $p>0.05$). Even though these are mixed findings and are not strong, the relationship between a larger vocabulary, higher quality of phonological representations, and a better ability to imitate stress patterns for non-words in our test cannot be ruled out. However, vocabulary data of more three-year-old at-risk children are necessary to make more solid claims about the relationship between word stress acquisition, phonological representations, and vocabulary size.

A further expectation is that word stress abilities and phonological representations impact on phonological awareness skills. Unfortunately, the results of the word stress experiment could not be compared with performance on phonological awareness and reading abilities yet, as the children in the present study were still too young for these tasks. Data of these children at older ages might further establish whether the at-risk children catch up with their age peers or whether the gap between the two groups widens. As a preliminary investigation, word stress production in a group of dyslexic children was assessed in Study 2.

4.6 Study 2

A delay in word stress acquisition was found in three-year-old children at-risk of dyslexia. The question arises whether this delay is also visible in children with established dyslexia. This would point to continuing word stress difficulties.

Furthermore, analysis of within-group variability on the word stress production task could establish whether a word stress delay is present in all, or in only some dyslexic children. Finally, the data of this study might shed more light on the interpretation of the phonological deficit model of dyslexia.

For both the control and dyslexic children, this will be the first assessment of stress acquisition of Dutch eight-and nine-year-olds. Nouveau studied three-and four-year-olds, and found that stress acquisition was still taking place. It will be interesting to see whether this development has been completed at this older age.

In sum, the following questions will be addressed in this study:

1) Can children with developmental dyslexia be distinguished from control children on the basis of their word stress production?
2) What is the variability of performance within the group of dyslexic children?
3) Can the data of the dyslexic group be accommodated in phonological deficit model of dyslexia?

4.6.1 Method

4.6.1.1 Participants[4]

Nineteen children with developmental dyslexia (4 girls, 15 boys, mean age 9;1) and 31 normally reading children without a history of speech and language problems were tested (19 girls, 12 boys, mean age 8;5). The data of six additional children (4 dyslexic, 2 control) were excluded, as the recordings of the task were incomplete.

Children with dyslexia were found through a call on the website of the Dutch remedial teacher website (www.lbrt.nl) and through stichting Taalhulp, a Dutch organisation specialised in assessment and remediation of dyslexic children and adults. The main selection criterion for the dyslexic children was the diagnosis of dyslexia by an educational psychologist. To minimise the interference of a language deficit on the reading deficit, children were selected if they did not have a background of evident language-impairment and were not enrolled in speech-language therapy at the time of testing.

The control children were recruited from three primary schools across de Randstad, the urbanised area of the Netherlands. This group included children without a history of language and reading difficulties and normal IQ (based on teacher rating).

All children were presented with a timed non-word reading task (*de Klepel*, Van den Bos et al. 1994) as a back-up measure of reading assessment, as well as the digit span task backwards (WISC-R, Van Haasen et al., 1986), to gain insight into their short-term working memory abilities. Performance on these measures is traditionally poor in dyslexic children. Group information is presented in Table 8.

[4] I would like to thank Renate van den Berg and Neely Anne de Ronde-Davidse for data collection and transcription.

As expected, the dyslexic group performed significantly more poorly on the Klepel and the digit span task than the control group. There was also a significant age difference between the groups. Nevertheless, as the dyslexic group had a higher mean age, it was not deemed a substantial problem.

Table 8. Background information of the dyslexic and control children, with mean scores (standard deviations).

Group	N	Age**	Klepel**	Digit span*
Control	31	8;4 (5 months)	10.3 (1.5)	4.1 (1.8)
Dyslexic	19	9;1 (7 months)	5.6 (1.8)	3.5 (1.6)

*p< 0.01, **p < 0.001 on independent samples t-test.

4.6.1.2 Task and materials

The task was the same as in Study 1, except that pictures of fantasy animals were now presented on a computer screen instead of picture cards.

4.6.1.3 Procedure and data analysis

Children were tested either at school, at the centre where they received reading support, or in the language laboratory of the Utrecht Institute of Linguistics OTS at Utrecht University. The word stress task was part of a battery of tasks presented to the children and was third in row. Procedure and data analysis were similar to Study 1. Agreement on transcription (author and student) of syllable structure and word length was 88% and stress 97%, which was considered sufficient for further analysis.

4.6.2 Results

4.6.2.1 Suprasegmental results

Identical, Equivalent, More, and Less regular

In order to answer the question whether a delay in word stress acquisition is present in the dyslexic group, identical and non-identical realisations are presented in Table 9. Identical refers to identical stress, word length and syllable shape repetition, not phoneme realisation (see Table 2).

Even though identical scores were high for both groups, an independent samples t-test established that the arcsine proportion of identical realisations per child differed between the groups ($t(48)=2.97$, $p=0.005$). The identical rate exhibited by the dyslexic group was substantially lower than that of the control group. More regular and equivalent realisations were higher in the dyslexic than the control group. Less regular realisations were not significantly different for the groups. Thus, the dyslexic children had more difficulty correctly repeating the stress pattern of the

targets than the control group. Instead, they regularised the (highly) irregular and prohibited targets more often.

Table 9. Percentages (and numbers) of occurrences per response class per group.

Group	Identical	Equivalent	More regular	Less regular
Control	90.0 (1088/1209)	2.6 (31/1209)	5.8 (70/1209)	1.7 (20/1209)
Dyslexic	83.3 (617/741)	5.0 (37/741)	9.0 (67/741)	2.7 (20/741)

When dividing identical and non-identical realisations according to regularity, a similar pattern emerged for both groups: the more irregular the target, the lower the rate of identical realisations and the higher the rate of regularisation (Table 10). However, the dyslexic group showed a lower percentage identical than the control group across the different degrees of regularity. The dyslexic group resorted more often to equivalent, and mostly to more regular realisations. (Highly) irregular and prohibited targets were thus regularised.

Table 10. Percentages (and numbers) of occurrences per response class per group.

Group	Target type	Identical	Equivalent	More regular	Less regular
Control	Regular	95.4 (414/434)	1.4 (6/434)	- (0/434)	3.2 (14/434)
	Irregular	91.4 (340/372)	5.1 (19/372)	2.4 (9/372)	1.1 (4/372)
	Highly irregular	80.6 (225/279)	2.2 (6/279)	16.5 (46/279)	0.7 (2/279)
	Prohibited	87.9 (109/124)	- (0/124)	12.1 (15/124)	- (0/124)
Dyslexic	Regular	90.2 (240/266)	4.1 (11/266)	- (0/266)	5.6 (15/266)
	Irregular	86.0 (196/228)	7.5 (17/228)	5.3 (12/228)	1.3 (3/228)
	Highly irregular	70.2 (120/171)	4.7 (8/171)	24.0 (41/171)	1.2 (2/171)
	Prohibited	80.3 (61/76)	1.3 (1/76)	18.4 (14/76)	- (0/76)

Changes to word and syllable structure

When a word shape or stress pattern was not repeated correctly, several changes were possible (see Table 2). The analyses above have shown that percentage identical was lower for the dyslexic than the control group. It is thus expected that changes will be more frequent in the data of the dyslexic than the control children. Table 11 presents the percentages of occurrences of several strategies. Note that segmental errors were not taken into account.

Table 11. Changes per group in percentages (and numbers) of occurrence.

Group	Syllable addition	Syllable omission	Stress shift	Weight loss	Weight gain
Control	0.25 (3/1209)	0.0 (0/1209)	6.12 (74/1209)	3.56 (44/1209)	3.72 (8/1209)
Dyslexic	0.13 (1/741)	0.27 (2/741)	8.77 (67/741)	5.53 (39/741)	7.02 (18/741)

The order of changes was similar for both groups, with stress shift, weight gain, and weight loss being most frequent for both groups. However, the percentages of changes were always higher for the dyslexic group. Multivariate analyses with Change (syllable addition, syllable omission, stress shift, weight loss, weight gain) as dependent variables and Group (Dyslexic and Control) as fixed factor showed that the dyslexic group applied significantly more stress shift ($F(1, 1949)= 6.4$, $p=0.012$), weight gain ($F(1, 1949)=10.6$, $p<0.001$), and weight loss ($F(1, 1949)=4.4$, $p=0.037$) than the control group. Frequency of syllable addition ($p=0.59$) and syllable omission ($p=0.71$) were not different for the two groups.

Similar to findings of the three-year-olds, the changes of both groups of children tended towards regularisation. This is also supported by findings of Multivariate analyses with Changes (syllable addition, syllable omission, stress shift, weight loss, weight gain) as dependent variable and Stress regularity (regular, irregular, highly irregular, prohibited) as fixed factor. Except for syllable addition ($p=0.09$) and syllable omission ($p=0.23$), all processes showed significant effects (stress shift $F(3, 1949)= 38.1$, $p<0.01$, weight loss $F(3, 1949)=8.4$, $p<0.01$, and weight gain $F(3, 1949)=9.5$, $p<0.01$). Games-Howell posthocs (significance level $p<0.05$) further showed that the frequency of all changes was generally different for the regular and irregular targets compared to the highly irregular and prohibited targets (regular, irregular < highly irregular, prohibited stress).

4.6.2.2 Percentages phonemes correct

Percentage phonemes correct was calculated to establish the impact of regularity on phoneme realisation as well as address the option of a non-word repetition deficit in the dyslexic children. Results are presented in Table 12.

Phoneme correct scores were high for the control group, and surprisingly so, also for the dyslexic group. Nevertheless, a Univariate analysis of variance with arcsine-transformed PPC as dependent variable and Stress regularity and Group as fixed factors found an effect of Group ($F(1, 1949)=26.7$, $p<0.001$), Stress regularity ($F(3, 1949)=26.3$, $p<0.001$), as well as an interaction ($F(3, 1949)=3.1$, $p=0.02$). The dyslexic group reached lower phoneme correct scores than the control group. The interaction between Group and Stress regularity was due to the approximately equal PPC for the dyslexic group for regular, irregular, and highly irregular type targets and the lower PPC for prohibited types, whereas there was a gradual decrease for the control group. Games-Howell posthoc tests on Stress regularity, finally, established that phoneme scores for prohibited types differed significantly from regular, irregular, and highly irregular types ($p<0.05$), as well as the PPC for regular types from all other conditions ($p<0.05$).

Table 12. Percentages phonemes correct (standard deviation) per degree of regularity.

	Percentage phonemes correct			
	regular stress	irregular stress	highly irregular stress	prohibited stress
Control	99.2 (4.4)	97.3 (6.2)	97.4 (7.5)	94.7 (8.5)
Dyslexic	96.2 (9.0)	96.3 (8.1)	96.3 (8.6)	92.2 (8.9)

4.6.2.3 Within-group variability

Group analyses yielded differences between the dyslexic and control group. This section assesses performance within each group. The measure used for this individual analysis is the identical score; the score reflecting correct repetition of word length and syllable structure. Calculations were made to see how many of the children performed at or above the control mean, up to 1sd below, and more than 1sd below the mean identical score of the control group.

Table 13. The number and percentage of children performing performing at or above the control mean, up to 1sd below, and more than 1 sd below the controls' mean identical score.

	At or above control mean	Up to -1sd below control mean	>-1sd control mean
Control	19/31 (61%)	8/31 (26%)	4/31 (13%)
Dyslexic	6/19 (32%)	6/19 (32%)	7/19 (37%)

Whereas approximately one third of the dyslexic children performed at or above the control mean, there was also more than one third who performed more ‘poorly’ (>-1sd) on the word stress production task compared to the control mean.

4.6.3 Discussion

A comparison of word stress production of dyslexic and control children aimed to answer the following questions:

1) Can children with developmental dyslexia be distinguished from control children on the basis of their word stress production?
2) What is the variability of performance within the group of dyslexic children?
3) Can the data of the dyslexic group be accommodated in phonological deficit model of dyslexia?

With respect to *Question 1*, findings showed that, even though for both groups high rates of identical realisations were attested, and both groups displayed lower rates of identical realisations as the target irregularity increased, there were significant differences between the dyslexic and control group.

First, the group of dyslexic children produced a lower rate of identical realisations than the control group, especially for more irregular and prohibited targets. Instead, they resorted to regularisation of the (highly) irregular and prohibited types. These findings of regularisation are in line with those reported for the at-risk children (Study 1), as well as those of patients with aphasia with and without dyslexia (de Bree, Janse & van de Zande submitted, Cappa et al. 1997, Galante et al. 2000, Janssen 2003, Laganaro, Vacheresse & Frauenfelder 2002, Miceli & Caramazza, 1993). Related, phonological changes were applied more frequently by the dyslexic than the control group. The changes were used to create more regular realisations. Even though the processes applied by both groups were similar, the dyslexic group applied more changes.

Furthermore, even though the percentage of phonemes correct (PPC) were high in both groups (>90%), the PPC of the dyslexic group was significantly lower than for the control group. Based on the literature, lower PPC scores for the dyslexic group were expected, as dyslexic children have been found to show difficulty with the construction of (novel) phonological representations (e.g. Catts & Kamhi 1986, de Bree, Rispens & Gerrits submitted). However, whereas there was a decrease of PPC for the control group as irregularity of the targets increases, this was not the case for the dyslexic group, for whom PPC remained approximately equal across the regular and (highly) irregular conditions. The PPC of the dyslexic group was always lower than that of the control group, signifying less adequate segmentation and construction of phonological representations for the dyslexic group.

The distribution of performance of the dyslexic group on the stress production task was different from that of the control group (*Question 2*). More than one third

of the dyslexic group performed 'poorly', i.e., one standard deviation below the mean of the control group, whereas this was less than one sixth for the control group. Thus, word stress difficulties *relative to* normally reading children seemed to be present in a considerable part of the dyslexic group.

The aim of *Question 3* was to assess whether the data of this experiment were in accordance with the phonological deficit hypothesis of dyslexia. Word stress assignment was more difficult for the dyslexic than control children. The present results underscore the need to look at primary (suprasegmental) phonological skills and incorporate these into the phonological deficit hypothesis. Furthermore, the phonological deficit hypothesis purports that poor representation is a core deficit in dyslexia. The possibility that poor phoneme encoding and segmentation could interact with word stress acquisition was entertained in the discussion of Study 1. Children with (a risk of) dyslexia have been argued to possess poor phoneme representations. This could lead to further difficulty with acquisition of stress rules. In order for the claim to hold, not only children at-risk of dyslexia, but also children with established developmental dyslexia, should display difficulties with word stress production compared to the control group, as well as lower percentages phonemes correct. The results of Study 2 suggest that this is indeed the case.

4.7 General discussion

The two studies in this chapter have shown that both children at-risk of dyslexia and children with dyslexia displayed more difficulty on the word stress task than the normally developing three-and eight-year-olds. Across groups and ages, the patterns of performance were similar in that regular targets were easier to produce than irregular and prohibited patterns and regularisation was more frequent than irregularisation. However, the children in the group with (a risk of) dyslexia showed these effects of regularity more strongly than their controls. Across ages, performance improved. The dyslexic group performed better on the task than the at-risk group, and the older control group better than the three-year-old controls.

A residual issue is the occurrence of less regular realisations. Despite the attested preference for regular stress in all groups, a substantial number of regular targets was realised as less regular by the at-risk group. These realisations could be claimed to be effects of analogy, that is, deliberate irregularisation based on analogy of other words (cf. Gillis, Daelemans & Durieux 2000), or as phonological simplifications, caused by (syllable) complexity of the target. Comparison of the data of the two age groups can decide between the two options. In order for analogy-effects to hold, the older children should have resorted more often to production of less regular realisations and the controls more often than the dyslexic children. The interpretation of phonological difficulties could be sustained if irregularisations were less frequent in the output of older children compared to the three-year-olds, with a higher number of less regular realisations in the at-risk and control group compared

to the controls. Comparison of the data of the two age groups reinforces the latter interpretation, see Table 14. There were less irregularisations in the older age groups. Furthermore, in both age groups slightly more irregularisations occurred in the at-risk and dyslexic groups than in the control groups.

Table 14. Percentage of Less regular realisations per group per age.

	3-year-olds		9-year-olds	
	control	at-risk	control	dyslexic
Less regular	7.9%	8.5%	1.7%	2.7%

The findings of the two studies suggest continuity of poorer phonological skills of at-risk and dyslexic children. With respect to within-group variability, findings between the at-risk and dyslexic group differed. Whereas less than one fifth of the *at-risk* group performed poorly (>-1sd), one third of the *dyslexic* group showed a more severe delay (>-1sd) compared to their controls. Relative to the control group, the delay was more apparent in the older children. Even though a word stress delay cannot characterise all the children with (a risk of) dyslexia, it seems that it is more apt to characterise a considerable number of the dyslexic than the at-risk group.

Despite the relatively high correct scores of the dyslexic group, the data pattern can be framed in the phonological deficit hypothesis of dyslexia. It has also become clear that primary phonological skills should be incorporated into the hypothesis, and that the investigated level of acquisition should extend beyond segmental acquisition and take higher prosodic levels into account when discussing (acquisition of) phonological representations.

4.8 Conclusions

A non-word repetition task was used to assess whether stress assignment difficulties were present in children with (a risk of) dyslexia. Both the at-risk and dyslexic children showed more difficulties on stress production than the age-matched control groups. The at-risk and dyslexic children especially had more difficulty with (highly) irregular and prohibited stress patterns than their age-matched peers. Furthermore, the at-risk and dyslexic children reached lower percentages phonemes correct.

These findings then point towards continuing stress difficulties and can be framed in the phonological deficit hypothesis of dyslexia. They also underscore the need to study the acquisition of language-specific phonological regularities that extend beyond the segmental level to gain more insight into the phonological deficit.

The next chapter will assess whether morpho-phonological alternation provides further insight into the phonological skills of children at-risk of dyslexia and the subsequent interpretation of the phonological deficit hypothesis.

Appendix 1. *Stimuli of the non-word repetition task*

	Regularity			
Final syllable weight	Regular stress	Irregular stress	Highly irregular stress	Prohibited stress
Light	bóla		sotá	
	fenímo	kémito	genimó	
	kanákta		tamaktá	págakta
	karabílo	taládilo	pawatiló	bálapulo
Heavy	kákot	watóp		
	dápikon	katipón	pakídon	
	taláktan	kawaptán		pánaktam
	monítaron	notimalón	tonimáron	nómipalon
Superheavy	bokáat	kóbaat		
	karimóon	tánidoom	palíkoon	
	kadónt	tágont		
	falidónt	sánitont	parígont	
Diphthong	katéi	tánei		
	dotiféi	kópitei	pokídei	

5

Voicing alternation of the plural[1]

5.1 Introduction

The results of the expressive phonology (Chapter 3) and word stress (Chapter 4) analyses have established that three-year-old at-risk children performed more poorly on these tasks than the control group. These findings indicate a delay in phonological acquisition and emphasise the need to address the acquisition of primary phonological skills in (young) children at-risk of dyslexia.

The expectation on the basis of the phonological deficit hypothesis of dyslexia is that children with (a risk of) dyslexia have a core deficit in constructing, maintaining, and accessing phonological representations. Based on this hypothesis, problems are expected to arise in the acquisition of phonology. This chapter assesses voicing alternation in Dutch plurals, a morpho-phonological process, in children at-risk of dyslexia. This alternation takes the form of a contrast between [pɛt] singular ~ [pɛtən] plural 'caps' and singular [bɛt] and plural [bɛdən] 'beds'. Pairs with voicing in their plural are known to appear relatively late in young children, with overgeneralisations of voicelessness (*[bɛtən] rather than of voicing (*[pɛdən]) typically appearing at earlier stages. It will be investigated whether the presumed phonological difficulties impact on the occurrence of this alternation.

Another group for which phonological difficulties have been reported is children with specific language impairment (SLI). Since one of the aims of this thesis is to consider the relationship between dyslexia and SLI, investigating how both groups perform on a voicing alternation task will establish whether five-year-old at-risk and SLI children have similar morpho-phonological difficulties.

The outline of this chapter is as follows. Background information on the alternation of voicing in Dutch plurals (5.2) is followed by a section on section on what is known about the morpho-phonological abilities of children with dyslexia and language impairment (5.3). The expectations on the basis of the relevant

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[1] This experiment was conducted in collaboration with Annemarie Kerkhoff, see also Kerkhoff (in preparation). Preliminary findings of the control and SLI group were reported in Kerkhoff, A. & de Bree, E. (2005). Acquisition of morpho-phonology in children with specific language impairment and typically developing children. In A. Kerkhoff, J. de Lange and O. Sadeh Leicht (eds.) *UiL OTS Yearbook 2004*, 37-52.

hypotheses on dyslexia and the relationship between dyslexia and SLI are addressed in section 5.4. The study is then presented (5.5), followed by the conclusion (5.6).

5.2 Voicing alternation in the Dutch plural

The term alternation refers to the phenomenon of a single morpheme having two or more alternative forms depending on the phonological or morphological context in which it appears. An example of a (phonologically conditioned) alternation is the voicing alternation that occurs in the English plural suffix, in which /z/ occurs in *dogs* [dɔgz], /s/ in *bats* [bæts]) and /ɨz/ in *busses* [bʌsɨz]). The English plural alternation is determined by the phonological features of the final segment of the noun stem: /z/ always occurs after voiced obstruents (e.g. *dogs* [dɔgz]), /s/ always occurs after voiceless obstruents (e.g. *bats* [bæts]) and /ɨz/ always occurs after sibilants (e.g. *busses* [bʌsɨz]). This alternation is productive for both adults and children, who are able to extend it to loanwords and non-words (Berko 1958, Derwing & Baker 1980, Halle 1978). Interesting among these latter cases is that Halle reports on native speakers of English being able to extend their (apparently rule-governed) behaviour to accidental gaps, such as *Bach/Bach-s* ‘members of the Bach family’, the voiceless velar fricative being absent from the native phoneme inventory of English.

The Dutch alternation assessed in this study is the voicing alternation of plosives.[2] Voicing is distinctive for bilabial /p/ ~ /b/ ([pɑk] ‘suit’ ~ [bɑk] ‘container’) and alveolar /t/ ~ /d/ ([tɑk] ‘branch’ ~ [dɑk] ‘roof’). However, this voicing contrast is neutralised in syllable-final position because of final devoicing, rendering, for example, the pronunciation [bɛt] for singular ‘bed’. In the plural the voicing contrast surfaces; [bɛdən] ‘beds’ (as opposed to [pɛt] ~ [pɛtən] ‘caps’). The noun stems involved have a consistent orthographic representation, [bɛt] being spelled as *bed* and its plural as *bedden* and [pɛt] spelled as *pet* and its plural as *petten*.

Final voicing neutralisation is a productive process in Dutch, as loanwords also undergo devoicing of final obstruents, and learning by Dutch speakers of a non-devoicing language such as English is characterised by persistent voicing neutralisation (e.g. *job* /dʒɔb/ being notoriously realised with a final voiceless plosive by Dutch learners of English).

[2] Voicing is often said to be distinctive for fricatives too, and voicing alternation also occurs in fricatives (e.g. [pɛrs] ~ [pɛrzən] *perzen* ‘Persian rugs’ and [pɛrs] ~ [pɛrsən] *persen* ‘citrus presses’). However, the focus here is on plosive alternation, as the phonetic-phonological status of the feature [voice] in Dutch fricatives is an intensively debated issue (e.g. Slis & van Heugten 1989).

The present study focuses on the voicing alternation in the Dutch plural.[3] Dutch plurals are formed by attaching either /s/ *-s* (e.g. *tafels* 'tables') or /ə(n)/ *-en* (e.g. *petten* 'caps') to the stem.[4] The choice between the two productive suffixes depends on phonological characteristics (see Booij 1995, de Haas & Trommelen 1993, van Haeringen 1947, Haesereyn, Romijn & Geerts 1997, van Wijk 2007). Alternations occur in the stems of plural pairs that take the -ən plural suffix. They occur in those pairs that are argued to possess an 'underlying' voiced final plosive, as [bɛt] ~ [bɛdən] 'beds'. As pointed out above, Dutch also includes non-alternating pairs, such as singular [pɛt] and plural [pɛtən] 'caps'. The existence of non-alternating pairs shows that there is no rule of intervocalic voicing in Dutch.

Alternation does not necessarily occur in obstruents in just all contexts made available by the language's phonology. Table 1 below provides the distribution for the obstruents p~b and t~d. The table shows there is an accidental gap in the data concerning labials: stems fail to occur in which a voiced labial plosive ends a rhyme with either a long vowel or a vowel-sonorant sequence.

Table 1. Distribution of the plosive voicing alternation for the Dutch plural.

context	p~b		t~d	
	p	b	t	d
short vowel	[kɪp] ~ [kɪpən] 'chickens'	[krɑp] ~ [krɑbən] 'crabs'	[pɛt] ~ [pɛtən] 'caps'	[bɛt] ~ [bɛdən] 'beds'
long vowel	[ap] ~ [apən] 'monkeys'	*	[vut] ~ [vutən] 'feet'	[hut]~[hudən] 'hats'
vowel + sonorant	[lɑmp]~[lɑmpən] 'lamps'	*	[kɑnt] ~ [kɑntən] 'sides'	[hɑnt] ~ [hɑndən] 'hands'

Thus, there is no voicing alternation in singulars vs. plurals for p~b in (absent) targets such as [ap]~*[abən], or [lɑmp]~*[lɑmbən]. These environments can be considered accidental gaps (in fact, the alternation occurs in the highly infrequently loan words *Swaab ~Swaben* 'Swabians' and *(homo-)foob ~ foben* '-phobes', which are completely unknown to most native speakers of Dutch; for further discussion see Zonneveld 1978).

Acquisition of the voicing contrast in the Dutch plural involves morphology and phonology. It demands the morphological skill of plural formation, knowledge of

[3] Final devoicing is a phenomenon of very wide application in the language. Plosive voicing alternation of nominal plurals has been selected as focus of this study, rather than, for example, verbal or adjectival inflection, as it is easier to elicit than the other categories.
[4] For the /ən/ plurals, pronunciation of final [n] is optional.

Dutch phonotactics (no voiced syllable-final consonants, no across-the-board intervocalic voicing, the difference between short and long vowels, the opposition between binary branching rhymes and more complex ones), and the ability to produce a voicing contrast.

In order to test the acquisition of this alternation, an experiment was designed that includes existing words and non-words. Whereas existing words are familiar to children such as those of our project, and alternations could thus have been learnt lexically, non-words can be used to test the productivity of the alternation. Presented with the singular of a non-word, (e.g. [flɑnt]) children can be tested regarding their ability to produce the phonological representation of the plural, for which they have a choice between, [flɑntən] or [flɑndən]. Behaviour on non-word plural formation thus allows us to assess whether children may extend alternation to non-words and which factors affect their performance.

Before proceeding with the experimental section, we will turn to what is known about morpho-phonology and alternation in children with (a risk of) dyslexia and children with SLI.

5.3 Morpho-phonology in dyslexia and SLI

Acquisition of the voicing alternation of normally developing Dutch children has only recently been receiving detailed attention. Zonneveld (2004) assessed plural acquisition of a child on the basis of a corpus study and found that stem-faithfulness based on the singular, rather than alternation, occurred in her output (e.g. *[part̲ə] for [part]~[pardə] 'horses' at age 1;9 petering out until 2;10), even in cases of adult singulare tantums (*pindakase* [-kas̲ə] at age 2;6 for non-existing 'peanut butters', cf. adult [kas]~[kazən] 'cheeses').

Kerkhoff (2004, in preparation) reports on an elaborate experimental study towards the production of the alternation in children between 2;9-7;8, in which normally developing children were presented with a plural elicitation task for existing words and non-words. With respect to existing words, Kerkhoff found that plural devoicing (*[bɛtən] 'beds') was the most frequent error, contrasting with only a very small percentage of incorrect voicing (*[pɛdən] 'caps'). Incorrect voicing generally occurred in environments that allow alternation, see Table 1. Alternation in both accidental gap environments (*[abən] and *[lɑmbən]) was infrequent, and was only displayed by the youngest children in the test.

Regarding *non-words*, voicing alternation was infrequent, with only 3% alternation ([flɑnt]~[flɑndən]) overall. Alternation was generally realised in the correct environments for the non-words. Only 2 children (aged 3;5 and 4;0) produced plural alternations in the accidental gap environment of a long vowel followed by /p~b/ ([tap]~*[tabən] and [dep]~*[debən]); just three such accidental gap alternations occurred in the overall results, however.

Alternation, including the Dutch voicing alternation has not been investigated in children with (a risk of) dyslexia. Nevertheless, as a language acquisition delay has been attested in at-risk children, it can be speculated that the group of five-year-old at-risk children in the present study will show a delay in the acquisition of alternation. Their alternation performance could be expected to resemble that of the youngest children described in Kerkhoff (2004, in preparation). In other words, devoicing would be the most frequent strategy in word and non-word plural production and accidental gap alternation could occur (rarely) in non-word realisation.

In order to assess alternation, several conditions have to be met. First, the at-risk children should possess the rule of plural formation. De Jong, Wijnen & de Bree (in preparation, see also van Alphen et al. 2004) found that a group of three-year-old Dutch at-risk children were delayed in plural acquisition (see also Elbro, Borstrøm & Petersen 1998 for six-year-old Danish at-risk children). The at-risk children realised more singulars and zero responses on an elicited production task than normally developing children. If plural marking is still delayed for the five-year-old at-risk children, insight into alternation abilities could be hampered.

Secondly, in order to observe alternation in children's realisations, it is important that the children have acquired the voicing contrast. In terms of production, the Dutch voicing contrast has been found to be acquired relatively late. Both Beers (1995) and van der Feest (2007) have shown that around the age of 2;6-3;0 children can still make errors in the production of voiced stops. Nevertheless, error percentages are quite low in this age group. Whereas Beers showed that the children reached an accuracy level of at least 75% cases correct for voicing in syllable-initial position around age 2;11, this was approximately 10% in data of the two-to-three-year-olds in van der Feest. Acoustically, durational differences between voiced and voiceless intervocalic stops of normally developing Dutch children have been found to be similar to those of adults (Kerkhoff in preparation, Kuijpers 1993).

Children with a risk of dyslexia could show delayed acquisition of the feature [voice] or of articulatory control. However, acquisition of the voicing contrast has not been studied in these children. Results of voicing production of *dyslexic* children have been mixed. Post, Foorman, and Hiscock (1997) did not find speech production difficulties of /t/ and /d/ in a group of 20 less skilled American English eight-year-old readers compared to 20 skilled readers. There was no difference between the two groups in voice onset time when reading non-words such as *dippy* and *tippy*. A study with French dyslexic ten-to-thirteen-year-old children, however, found that, even though these children were able to produce a voicing contrast for /p/ and /b/, their realisations showed different timing of articulatory movement than those of a reading-age matched and chronological age-matched group (Lalain, Joly-Pottuz, Nguyen & Habib 2003). These findings suggest that it is necessary to assess the voicing realisations of the at-risk children in the present study acoustically.

An additional factor, that has not been taken into account here, is perception of the voice contrast. Van der Feest (2007) found that the perception of this contrast in normal development has partly been acquired at 24 months: in contrast to 20-month-olds, 24-month-old normally developing children were able to perceive changes of a voiceless word-initial consonant to a voiced one (*pop* 'doll' presented as *bop*) but not the reverse (*boom* 'tree' as *poom*). It has been found that eight-year-old Dutch children with dyslexia show delayed performance on identification and discrimination on a /p/~/b/ continuum with the word pair [pɑk] *pak* 'package' and [bɑk] *bak* 'container' (Maassen et al. 2001). If children fail to perceive this voicing contrast, they are not likely to produce it either. Consequently, assessment of alternation would be impossible. However, the results obtained by Maassen et al. suggest that categorisation is less mature in dyslexics, but they do not mean to imply that voicing is not perceived at all; difficulties are subtle. Furthermore, Post et al. (1997) did not find that American English poor readers had difficulty with perception of words differing in the voiced or voiceless onset, such as *dippy* and *tippy*. Thus, it is assumed that speech perception abilities will not interfere with alternation performance.

Similar to the at-risk group, the Dutch voicing alternation has not been assessed in children with SLI before.[5] However, alternation of the English plural suffix (with allomorphs /z/, /s/ and /ɨz/) has been investigated in (American) English children with SLI. Conti-Ramsden and Windfuhr (2002), for example, found that three-year-old children with SLI had more difficulty inflecting stems with the /ɨz/ allomorph than their age-matched peers. Similarly, Marshall (2004) found that thirteen-year-old SLI children still exhibited more difficulty on plural formation than language- and age-matched controls. For all groups, plural realisation with the /ɨz/ allomorph was most difficult. This finding matches results of late appearance of the /ɨz/ allomorph in normally developing children (Derwing & Baker 1980). Goad and Rebelatti (1994) found that SLI children's correct use of noun plural inflections seemed to be based on explicit rule-learning (add *–s* to create a plural). This led to slow and effortful realisation of the plural and affected the phonological realisation: the children only used the phoneme /s/ in their plural construction and could not apply alternating forms (/z/ and /ɨz/) in the appropriate phonological contexts. Thus, alternation in children with SLI seems to deviate from the normal pattern. It should be borne in mind here, however, that the plural alternation in English affects the suffix (and potentially the metrical structure of the plural, compare *dogs* [dɔgz] and *bats* [bæts] to *busses* [bʌsɨz]), whereas in Dutch the alternation takes place in the stem. Nevertheless, in both languages, insensitivity to phonological characteristics and focus on the plural rule could lead to only one type of output (in English, for

[5] The findings that have been reported on here for this population will be independently discussed in Kerkhoff (in progress), as they are based on a joint study.

example, only *–s*, and in Dutch, no alternation), or an incoherent production pattern of alternation.

As indicated by the study of Goad and Rebelatti (1994) and Marshall (2004), plural formation has been found to be poorer in children with SLI than in their age-matched peers (e.g. Dutch: van Alphen et al. 2004 de Jong, Wijnen & de Bree in preparation, British English (BE): Conti-Ramsden 2003, American English (AE): Leonard, Eyer, Bedore & Grela 1997, Oetting & Rice 1993) or language-matched peers (e.g. AE and Italian: Leonard et al. 1992, 1997, Windsor, Scott & Street 2000) but it is relatively intact compared to other areas of morphological inflection (BE: Bishop 1994, Marshall 2004, German: Clahsen, Rothweiler & Woest 1992, Swedish: Leonard, Salameh & Hansson 2001, AE: Rice & Oetting 1993). Nevertheless, if difficulties with plural formation are still present at five-years of age, they could interfere with assessment of the children's alternation abilities.

In terms of the ability to produce the voicing contrast, several studies have shown that, compared to other phonological and articulatory abilities, voicing in word-initial and prevocalic position is a relative strength for American children with SLI (e.g. Forrest & Morrissette 1999, Ingram 1981, Leonard et al. 1985). However, voicing has not been investigated in Dutch children with SLI yet, which renders phonetic analysis of the productions of the five-year-old children with SLI necessary in the present study.

This section has reviewed findings of skills required to learn and produce voicing alternation in the Dutch plural. The following section will formulate expectations on the basis of the phonological deficit hypothesis of dyslexia and on the basis of hypotheses about the relationship between dyslexia and SLI.

5.4 Expectations on the basis of hypotheses of dyslexia and SLI

The phonological deficit hypothesis of dyslexia proposes that dyslexics possess poor phonological representations and have poor access to them. They have difficulties with constructing phonological representations of new (and thus also non-)words (see Chapter 1). As indicated in Chapter 1, phonological acquisition has not often been addressed in populations with (a risk of) dyslexia, but it can be anticipated that, if phonological representations of these children are poor, as argued by the phonological deficit hypothesis, then their phonological acquisition is likely to display difficulties as well.

The question arises whether a phonological deficit impacts on the acquisition of alternation. Thus, there are two issues to address. First, it can be explored whether the phonological representations are more poorly specified for children at-risk of dyslexia than for the control group. The representations of words should be better specified than those of non-words, as the former are more familiar and frequent than non-words. It can furthermore be anticipated that between 30-60% of the at-risk

group, the percentage that is expected to become dyslexic, will show less specified representations compared to the control group.

Secondly, these presumed phonological difficulties can be expected to affect alternation. If representations are poorer, then the at-risk group might not be able to perceive that alternation is restricted to certain phonologically-conditioned environments. Consequently, alternation could be absent in the children's realisations altogether, or overgeneralisation could occur, including alternation in accidental gap environments.

Alternation in both words and non-words will be evaluated. Plurals (including alternating plurals) of real words are most likely to be familiar to the at-risk children, whereas the plurals of non-words are to be generated afresh. Thus, alternation could be relatively intact in word plural production on the basis of lexical learning. For non-words, on the other hand, no stored plural is present. Thus, correct segmentation of and sensitivity to phonological environments is demanded. Poor abstraction of these patterns could either lead to frequent accidental gap alternation in non-word plural realisation given the phonetic likelihood of voicing in these environments, or to the absence of alternation altogether. In short, differences in performance on words and non-words could occur.

Studying morpho-phonological alternation is also relevant for gaining insight into the relationship between dyslexia and SLI (Chapter 1). The single source hypothesis, which claims that dyslexia and SLI are the same disorder, is only attuned to impaired phonological processing abilities in both disorders. These difficulties could interfere with other language abilities. If this is the case, then phonological difficulties will be found in both at-risk and SLI children and they could partly determine or relate to the alternation behaviour of these groups.

In contrast to the single source hypothesis, two models claim that dyslexia and SLI are separate disorders: the comorbidity hypothesis and the qualitative difference hypothesis. The former proposes that phonological difficulties are characteristic only of SLI children with dyslexia (not in SLI children without dyslexia). Morphological difficulties, such as plural marking, can predominantly be attested in children with SLI (and not in dyslexia). The qualitative difference hypothesis, on the other hand, assumes that the overlap between dyslexia and SLI resides in phonological processing difficulties. Morphological abilities could be argued to be a deficit in SLI children, but less so in children with (a risk of) dyslexia. Expectations on the basis of the comorbidity hypothesis would be that phonological difficulties should not be pervasive in the SLI group, but plural (and possibly alternation) difficulties would. The qualitative difference hypothesis yields the expectation that phonological difficulties are attested in both the at-risk and SLI group, and that morphological difficulties could be present in both groups, but more so in the SLI group.

5.5 Study

The present study compares voicing alternation in the Dutch plural by children at risk for dyslexia, children with SLI, and normally developing children. The research questions addressed are:

1) Can preschool children at-risk of dyslexia and children with SLI be distinguished from control children on the basis of their realisations on the alternation task?
2) Can the data be accommodated within the phonological deficit hypothesis of dyslexia?
3) Can the findings of the at-risk and SLI group be accounted for by the single source, comorbidity, or qualitative difference hypothesis?

5.5.1 Method

5.5.1.1 Participants

Three groups of children of children participated in this study; 57 children at-risk of dyslexia (16 girls, 40 boys) with a mean age of 5;1 (SD 4 months), 24 children diagnosed with SLI (4 girls, 20 boys) with a mean age of 5;2 (SD 5 months), and 26 control children (14 girls, 13 boys, mean age 5;1, SD 3 months). More information on subject selection can be found in Chapter 2.

Mean IQ was average for all three groups, with a mean IQ of 111.2 (SD 14.2) for the at-risk group, 100.1 (SD 12.0) for the SLI group, and 117.4 (SD 13.2) for the control group.[6] However, there was a significant effect of Group on IQ on a one-way Anova ($F(2, 105)=9.54$, $p<0.001$). Tukey HSD posthocs established that a difference was found between the SLI and control group ($p<0.001$), as well as the SLI and at-risk group ($p=0.006$), but not between the control and at-risk group ($p>0.1$).

5.5.1.2 Task and materials

Morpho-phonological alternation was assessed through a plural elicitation task. This task was designed by Kerkhoff (see Kerkhoff in preparation) and had the format of a plural elicitation task, eliciting plurals of words and non-words. For the real words, 15 high-frequency words were selected, seven of which were non-alternating (e.g. [pɛt] 'hat', [kɪp] 'chicken') and eight of which were alternating (e.g. [bɛt] 'bed', [krɑp] 'crab').

The stimulus set of non-words consisted of twelve non-words that were created to match the six environments described above (Table 1), yielding two items in each environment. For example, in the short vowel condition, there were two items with final [t] ([jɪt] and [slɑt]) and two with final [p] ([dɑp] and [ɣɔp]). The singular of the non-word was pre-recorded by a female native speaker of Dutch to ensure adequate

[6] Unfortunately, IQ data were not available for 1 control, 1 at-risk, and 5 SLI children.

and consistent presentation.[7] Singulars of words were not prerecorded, as it was assumed that the words would be familiar to the children.

Words and non-words were mixed and interspersed with five fillers, which took either *–s* plurals (e.g. *vlinder~vlinders* 'butterflies') or were irregular plurals (e.g. *ei~eieren* 'eggs'). The task was administered in two different orders to control for effects of fatigue and task novelty. Stimuli are presented in Appendix 1.

5.5.1.3 Procedure and data analysis

Children were tested at the child language laboratory of the Utrecht Institute of Linguistics OTS or in a quiet room at their school. The task was fifth in a session that included other language tests as well as IQ measures. Plurals were elicited through presentation of pictures in a PowerPoint slide show. For existing words, the child saw a picture of the object and had to name it. A second picture of the same object then appeared and the child was prompted with the sentence "Now there are two .. ".

For non-words, the child saw a fantasy animal and its name was presented through a loudspeaker. The child had to repeat the name and was then presented with the second image. The child was then asked to form the plural with the same prompt as for the words. Data were recorded on a DAT recorder (Tascam DA-P1) through a sensitive microphone (Crown PZM-185).

Children's realisations of both the singulars and the plurals were converted into .wav files. Phonological transcription of all utterances were made independently by two transcribers (Kerkhoff and author). Acoustic analysis of the children's plosives were then made by the same researchers (independently) and a portion of the data was judged by an additional 3 raters, with agreement reaching 90%.

The items that were classified as voiced or voiceless by at least 4 out of 5 raters were used for further acoustic analysis using the PRAAT programme (Boersma & Weenink 1996). Waveform examples are provided in Figure 1. As closure duration and burst duration are two prominent acoustic features of the Dutch voicing contrast, they were selected as acoustic variables. Both closure and burst duration are relatively short for voiced stops, since voicing can only be maintained for a certain amount of time (Slis & Cohen 1969). The beginning of closure was measured by the change in formant structure and amplitude, the end was marked at the release burst or the characteristic periodicity and amplitude of the vocalic segment (Kuijpers 1993). The end of the burst duration was located at the onset of voicing for the following schwa for intervocalic /t/ and the end of broadband burst noise in the case of intervocalic /d/.

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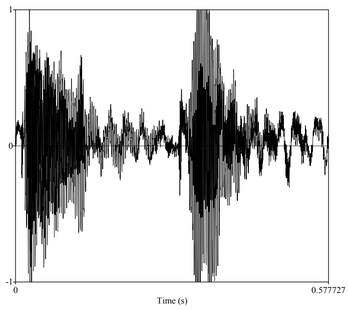
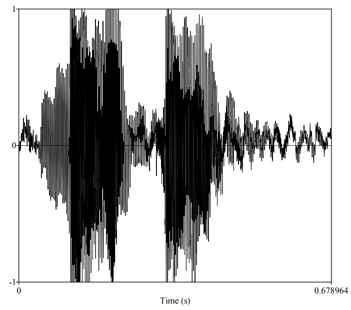
[7] I am grateful to Maya van Rossum for data recording.

Figure 1. Productions of /t/ and /d/ in *petten* and *bedden* by at-risk child Lin [5;4], with values for closure (CD) and burst duration (BD).





Item	[pɛtən]	[bɛdən]
CD	170 ms	57 ms
BD	19 ms	20 ms

Plural realisations of words were coded for correct alternation ([bɛdən]) or correct non-alternation ([pɛtən]), for an error through non-alternation (*[bɛtən]), or alternation (*[pɛdən]) and ‘Other’ realisations, such as bare stem plurals (*[pɛt_]), -*s* plurals (*[pɛts]), coda change (*[hɔnə] for [hɔndə] *honden* ‘dogs’), and diminutive plural creation ([bɛtjəs] *bedjes* ‘little beds’).

Plural realisations of non-words were coded similarly, with the difference that only alternation (e.g. [flɑndə]) and non-alternation ([flɑntə]) were scored (instead of (in)correct (non-)alternation), as there was, by definition, no correct target.

Additionally, singular realisations of both word and non-words were scored for rhyme realisation (correct or incorrect, e.g. *[lɑp] for [lɑmp]) to assess whether incorrect rhyme realisation or repetition of the target could impact on the plural.

5.5.2 Results

The results are presented in five consecutive sections. First, production of the plural is assessed (5.5.2.1), followed by acoustic analysis of the voicing contrast (5.5.2.2). After these preliminaries, results of rhyme realisation (5.5.2.3) are discussed, followed by alternation patterns in words (5.5.2.4) and non-words (5.5.2.5). These two sections also include correlations with the rhyme realisation results.

5.5.2.1 Plural marking

Alternation can only be assessed when a plural is realised. Figure 2 and Table 2 below show the proportions correct plurals per child (proportions rather than numbers, as not all children completed the entire task) for the words and non-words.

Whereas plural realisation of the control group was approximately equal for the word and non-word conditions, the at-risk and SLI groups showed poorer plural realisations for non-words than words. Nevertheless, a Univariate analysis of variance with arcsine-transformed Proportion plural correct as dependent variable and Group (Control, At-risk, SLI) and Stimulus type (Word, Non-word) as fixed factors did not demonstrate an interaction between Group and Stimulus type ($F(2, 217)=0.76$, $p=0.47$). There was, however, an effect of Group ($F(2, 217)=5.09$, $p=0.007$), but not of Stimulus type ($F(1, 217)=2.66$, $p=0.10$). Games-Howell post-hoc tests to investigate the Group effect established that only the SLI group's plural scores were significantly poorer than those of the control group ($p=0.01$).[8]

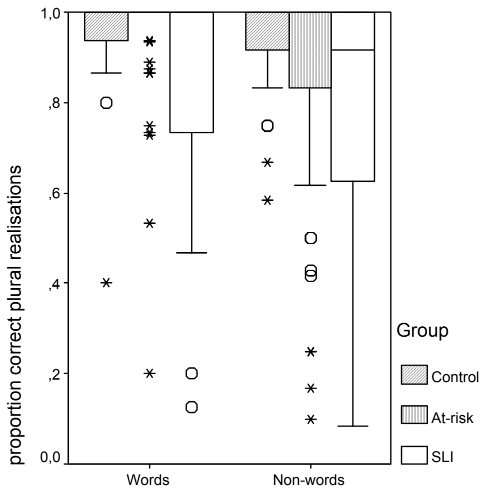


Figure 2. Proportions correct plural realisation for words and non-words per group. The boxes in this boxplot contain the middle 50% of the data, with the line in the box indicating the median value. The whiskers indicate the minimum data values. The open circles refer to mild outliers and the stars to extreme outliers.

The number of children within each group showing difficulties with plural formation relative to the mean of the control group was determined by assessing how many children reached a proportion correct score more than one standard deviation below

[8] Results remained the same when taking IQ as covariate. Furthermore, a significant interaction between Group and Stimulus ($F(2, 2933)=5.05$, $p=0.006$), as well as an effect of both Group ($F(2, 2933)=41.8$, $p<0.001$) and Stimulus ($F(1, 2933)=21.4$, $p<0.001$) were attested on an *item analysis* rather than a subject analysis. Plural formation of words was easier than for non-words for the at-risk group, and, to a lesser extent, for the SLI group. Plural realisation of the control group was not facilitated by stimulus type.

the control mean plural proportion correct of words and non-words. Only 2/26 control children (8%) belonged to this group of 'poor' performers, whereas this number was higher for the at-risk group (10/59, 17%) and much higher 8/24 (33%) for the SLI group. The lowest score of the at-risk group was 0.11, for the SLI group 0.14, whereas the minimum score of the control group was 0.48.

Table 2. Percentages plurals correct per stimulus type per group.

	Words	Non-words	All
Control	95% (12)	94% (12)	95% (11)
At-risk	95% (13)	86% (24)	90% (18)
SLI	83% (26)	80% (29)	80% (28)

Despite the between-group and within-group differences, mean plural production was quite high for the groups and should not interfere substantially in assessment of alternation. It will now be assessed whether the same can be said for the realisation of the voicing contrast.

5.5.2.2 Voicing contrast

Acoustic analysis of the voicing contrast was conducted to validate the transcription, i.e. to make sure the perceived voicing contrast was present acoustically. In order for this to be the case, closure and burst duration should be shorter for the voiced stops compared to the voiceless stops. A second aim was to measure whether the voicing contrast was made in the same way by the different groups.

Realisations rated as voiced and voiceless were subjected to acoustic analysis. However, whereas p~b alternations were infrequent, alternation of t~d occurred more often. Therefore acoustic analysis of this latter voicing contrast is more reliable. Results of the closure and burst duration of 155 /t/ and 96 /d/ items, matched as closely as possible for items (word and non-word, phonological environment) and child, are listed in Table 3 below.

The pattern was the same for all three groups, with a longer closure and burst duration for voiceless than voiced sounds. All three groups seemed to produce a reliable contrast in both closure and burst duration. This is confirmed by a Multivariate analysis with Closure duration and Burst duration as dependent variables and Group (Control, At-risk, SLI) and Auditory analysis (Voiceless and Voiced) as fixed factors. The analysis yielded an effect of Auditory analysis for Closure ($F(1, 300)=336.9$, $p<0.001$), and Burst duration ($F(1, 300)=125.5$, $p<0.001$). Closure and Burst duration were longer for voiceless than voiced realisations, in line with previous findings (Kerkhoff in preparation, Kuijpers 1993).

Table 3. Mean closure duration and burst duration in milliseconds for t~d (standard deviation).

		Closure duration	Burst duration
Control	/t/	104 (30)	42 (20)
	/d/	58 (16)	18 (11)
At-risk	/t/	106 (30)	41 (20)
	/d/	47 (14)	20 (8)
SLI	/t/	124 (26)	30 (12)
	/d/	47 (11)	15 (6)

There was no effect of Group on Closure duration ($p=0.09$) and it approached significance for Burst duration ($p=0.053$). There was, however, an interaction between Group and Auditory analysis for Closure ($F(2, 300)=5.9$, $p=0.003$), but not for Burst duration ($p=0.19$). This interaction was caused by the closure duration of the SLI group, which was the most pronounced contrast between voiced and voiceless realisations. The SLI group showed longer closure duration for the voiceless condition compared to the other two groups, but approximately equal closure duration for the voiced condition.

The closure duration of the SLI group resembles that of younger normally developing children (Kerkhoff in preparation, Kuijpers 1993). Thus, whereas the control and at-risk group seemed to produce the voicing contrast in this context in the same fashion, this was different for the SLI group. Ideally, closure duration would be measured in relation to the duration of the entire word, to assess whether overall speech rate of the SLI group was slower. Nevertheless, the findings show that the voicing contrast was present for all three groups. Before the alternation findings are presented, the results on proportions correct of the rhyme realisations of the singular will be discussed.

5.5.2.3 Rhyme realisation singular

Children's singular realisations of the targets were analysed to establish if rhymes were represented correctly. Rhyme representation might be necessary for alternation if sensitivity to the environment is required to acquire the distribution of voicing alternation. It is expected that representations of words should lead to higher correct scores than those of non-words. Furthermore, as the non-words contained only one syllable, correct scores could be fairly high.

Proportions rhyme correct per child were calculated for words and non-words. Note that singulars were not always produced by the children, as they were not always prompted by the experimenter, or refused. Errors predominantly consisted of consonant substitutions (e.g.[flɑnt] as [flɑmp]) and omissions (e.g. [flɑnt] as [flɑt]). Vowel substitution was rare. Results are presented in Figure 3.

Despite the high correct scores for all three groups, differences between the groups and stimulus types can be discerned. A Univariate analysis with arcsine-transformed Proportion rhyme correct as dependent variable and Group (Control, At-risk, SLI) and Stimulus (Word and Non-word) as fixed variables, showed an effect of Stimulus ($F(1, 204)=96.15$, $p<0.001$). For all three groups, words led to higher correct scores than non-words, suggesting that novel phonological representations of the latter stimuli are less specified than those of the words. There was no effect of Group ($F(2, 204)=0.99$, $p=0.37$) or interaction between Group and Stimulus ($F(2, 204)=2.49$, $p=0.08$). Even though the at-risk group showed a larger difference between proportion rhyme correct for words and non-words, this was not confirmed statistically.[9]

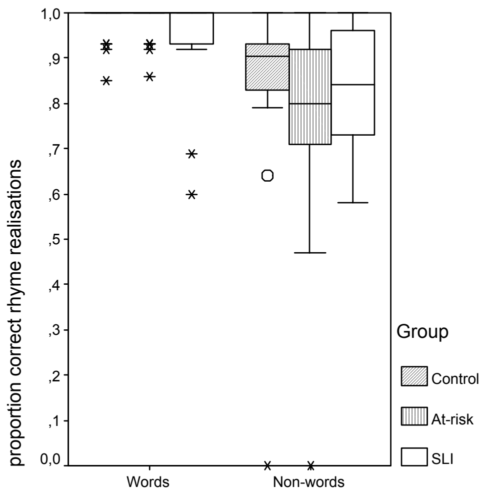


Figure 3. Mean proportions correct rhyme realisation singular for words and non-words per group.
The boxes in this boxplot contain the middle 50% of the data, with the line in the box indicating the median value. The whiskers indicate the minimum data values. The open circles refer to mild outliers and the stars to extreme outliers.

Absence of a significant Group effect could be due to the fact that familiar words and only one-syllable non-words were repeated by the children. Nevertheless,

[9] It should be noted that results on an *item analysis*, rather than subject analysis, did yield a significant interaction between Group and Stimulus ($F(2, 2586)=6.2$, $p=0.002$), as well as effects of Group ($F(2, 2586)=5.2$, $p=0.005$), and Stimulus ($F(1, 2586)=155.9$, $p<0.001$). The interaction was caused by the at-risk group, which showed a more substantial difference between correct scores of words and non-words than the other two groups.

within-group variation might show differences. The at-risk group (with a mean of 0.90 rhyme correct, SD 0.08), for example, could contain children both performing like the control group (mean 0.94 rhyme correct, SD 0.04) and those with a lower correct score, resembling the SLI group (mean 0.89 correct, SD 0.09). Table 4 presents the within-group distribution.

Many at-risk and SLI children performed within the mean of the control group. A substantial number, however, belonged to the 'poorly' performing group, with 'poorly' being an extremely relative term as mean correct scores were high.

Table 4. The number and percentage of children performing performing at or above the control mean, up to 1sd below, and more than 1 sd below the controls' mean rhyme proportion correct score.

	At or above control mean	Up to -1sd below control mean	>-1sd control mean	No singulars
Control	11/26 (42%)	10/26 (38%)	4/26 (15%)	1/26 (4%)
At-risk	21/57 (37%)	9/57 (16%)	26/57 (46%)	1/57 (2%)
SLI	7/24 (29%)	3/24 (12%)	10/24 (42%)	4/24 (17%)

If phonological representations directly contribute to the acquisition of alternation, a relationship should be attested between these rhyme scores and alternation behaviour. Bearing these findings in mind, let us turn to the alternation results. The alternation patterns of words and non-words will be reported and it will be assessed whether a relationship between the rhyme correct score and alternation performance exists.

5.5.2.4 Alternation in words

Children were presented with singulars of alternating and non-alternating words. For each type, three categories of responses were made on the basis of the children's realisations. Correct results were correct non-alternation ([pɛtən] 'hats') or correct alternation ([bɛdən] 'beds'), depending on the stimulus type. For non-alternating targets, voicing (*[pɛdən] 'hats') was calculated separately, for alternating plurals devoicing of the alternating plural (*[bɛtən] 'beds'). For both target types, there was a category 'Other'. This latter category included null-marking (*[bɛt_]'beds'), *–s* plurals (*[bɛts] 'beds'), onset substitutions ([hɑndən] realised as *[hɑnən] 'hands'), and diminutive formation, usually with correct *–s* plural ([bɛtjəs] 'little beds'). Results are summarised in Table 5.

For all three groups, correct non-alternation was more frequent than correct alternation. Consequently, devoicing errors of alternating targets were more frequent than errors of incorrect voicing of non-alternating words. The SLI group displays a much higher percentage of 'Other' responses; difficulties with phonological

production and plural creation prevent the SLI group from similar correct scores as those of the other two groups.

Analyses were conducted separately for alternating and non-alternating words. For alternating words, a one-way Anova with Proportion correct alternation (per child) as dependent variable and Group as factor rendered a significant effect ($F(2, 109)=11.53$, $p<0.001$). Tukey posthoc analyses showed that the control and at-risk groups differed significantly from the SLI group ($p<0.001$), but that the control and at-risk groups did not differ ($p>0.5$). The SLI group showed lower numbers of correct alternation, and both increased frequencies of devoicing and 'Other' realisations

Table 5. Performance on words in numbers (and percentages).

	Alternating words			
	Correct alternation	Error (p,t): *bɛ[t]ən	Other	Total
Control	106 (49%)	96 (44%)	14 (6%)	216 (100%)
At-risk	184 (40%)	245 (52%)	36 (8%)	465 (100%)
SLI	32 (17%)	99 (53%)	56 (30%)	187 (100%)
	Non-alternating words			
	Correct non-alternation	Error (b,d): *pɛ[d]ən	Other	Total
Control	167 (88%)	9 (5%)	14 (7%)	190 (100%)
At-risk	366 (89%)	16 (4%)	27 (7%)	409 (100%)
SLI	116 (69%)	6 (4%)	46 (27%)	168 (100%)

In terms of the percentage of children producing alternations, another difference surfaces between the control and at-risk groups on the one hand, and the SLI group on the other. All control children (27/27, 100%) and almost all at-risk children (55/56, 98%) showed at least one correct alternation. In the SLI group, however, only 13 of the 24 children (54%) displayed correct alternation at least once.

For non-alternating words, a one-way Anova with Proportion correct non-alternation (per child) as dependent variable found an effect of Group ($F(2, 109)=6.69$, $p=0.002$). Games-Howell posthocs confirmed that the SLI group had significantly lower correct non-alternation than the control group ($p=0.009$), but not compared to the at-risk group ($p=0.07$). The control and at-risk group did not reach different scores either ($p>0.5$).

Next to correct (non-)alternation of words, incorrect alternation (*[pɛdən]) was also present in the children's output, although infrequently. Despite these low frequencies, there was a different pattern for the control and at-risk group on the one

hand, and the SLI on the other. For the at-risk and controls, alternation in t~d environments was more frequent than for p~b, as only 1 alternation occurred in each group in a p~b environment. However, alternation rates were equal for p~b and t~d for the SLI group (3:3). This is also the only group in which alternation occurred in both accidental gap environments (long vowel: *[sxabə] 'sheep' and vowel+ nasal: *[lɑmbə] 'lamps', by one child). This could suggest that the SLI group is less sensitive to the domains for alternation than the other two groups. Evidently, however, such a claim is too strong for these infrequent occurrences. Furthermore, in order for such an interpretation to hold, the pattern should also be replicated in non-word realisation. This will be analysed in 5.5.2.5. Additionally, it should be borne in mind that the percentage of children applying incorrect alternation of words was low in all three groups (controls: 6/27 (22%), at-risk 8/56 (14%), and SLI 3/24 (12%)).

The findings on word realisations have yielded differences between alternating and non-alternating targets, as well as group differences, especially between the control and at-risk groups on the one hand, and the SLI group on the other. Hypothetically, five different correlations could shed light on the relationship between phonological representations, measured through rhyme realisations correct of the singulars of words and the alternation results. There would be a correlation between the rhyme measure and 1) correct non-alternation ([pɛtən] 'hats'), 2) correct alternation ([bɛdən] 'beds'), 3) incorrect non-alternation (*[bɛtən] 'beds'), 4) incorrect alternation (*[pɛdən] 'hats'), and 5) accidental gap alternation (*[lɑmbə] 'lamps') of words. However, because accidental gap alternation is rare, correlation values can never be high. Therefore, such an analysis will not be conducted.

The results of the remaining correlation analyses are reported in Appendix 2. There were only three significant, but weak correlations: rhyme realisation singular and correct non-alternation ([pɛtən] 'hats') for all children (Spearman's rho r=0.28, p=0.005) and for the at-risk group (Spearman's rho=0.28, p=0.03). The third was found for rhyme realisation singular and correct alternation ([bɛdən] 'beds') for all children (Spearman's rho=0.22, p=0.02). A better rhyme correct score was related to more correct non-alternation as well as alternation, but only slightly so and generally not for the groups separately. Thus, the poorer rhyme realisations of the singular of the at-risk and SLI group did not seem to greatly affect the (non)-alternation realisations of words. The next section explores whether the results are different for behaviour of non-word realisation.

5.5.2.5 Alternation in non-words

The results of the word productions showed that correct alternation and overgeneralisation of voicing were much less frequent than correct non-alternation and overgeneralisation of devoicing for all three groups. This section looks at the

strategies applied for targets for which no plural is lexically available, the non-words. The non-word results are presented in Table 6.

Table 6. Performance on non-words in numbers (and percentages).

	Non-alternation (p,t)	Alternation (b,d)	Other	Total
Control	270 (84%)	11 (3%)	42 (13%)	323 (100%)
At-risk	535 (76%)	20 (3%)	146 (21%)	701 (100%)
SLI	148 (53%)	15 (5%)	117 (42%)	280 (100%)

Non-alternation was the most frequent strategy for all three groups. This means that most targets were created as plurals with a voiceless intervocalic consonant ([flɑntən]). Alternation did occur ([flɑndən]), but infrequently. Changes within the ‘Other’ category were null-marking (*[flɑnt]), *–s* plurals (*[flɑnts]), onset changes of the second syllable (*[flɑnən]), and diminutives ([flɑntjəs]).

A one-way Anova with Non-alternation as dependent variable found an effect of Group ($F(2, 1303)=42.6$, $p<0.001$). Games-Howell posthoc analyses established that all three groups showed different degrees of non-alternation, with the control group producing most plurals without alternation and the SLI group the least (control > at-risk > SLI, $p<0.001$). Both the at-risk and SLI groups showed a higher number of ‘Other’ realisations compared to the control group and a lower number of non-alternating realisations. The SLI group showed more alternation and ‘Other’ realisations than the control group and less non-alternations. Results of non-alternation moved in tandem with null-marking; a higher rate of non-alternation went hand in hand with a lower degree of null-marking.

The low alternation frequencies for all three groups suggest that alternation was not a productive process. This is underpinned by the finding that generally, whenever a child produced overgeneralisations, this was not consistent within a phonological context.[10] Thus, the same child could produce both [slɑt]~[slɑḏən] and [jɪt]~[jɪṯən], for example. In both targets, the /t/ is preceded by a short vowel, but in one instance alternation occurs and in the other it does not. Thus, the alternating pattern was not easily extended to novel plurals. The low percentage of children resorting to non-word alternation within each group (control: 6/27 (22%), at-risk: 12/56 (21%), and SLI 7/24 (29%)) also indicate that alternation was not a productive process.

[10] Control child JV produced both [slɑt]~[slɑḏən] and [jɪt]~[jɪḏən]. Her realisations were consistent within this short vowel environment. However, this was not the case for the other t~d environments, compare [flɑnt]~[flɑnṯən] and [dɪnt]~[dɪnḏən]. Similarly, at-risk child DH and SLI child JG produced alternation in nasal contexts [flɑnt]~[flɑnḏən] and [dɪnt]~[dɪnḏən] but not consistently in other environments.

Similar to the results on words, the at-risk and control groups showed a tendency for t~d alternations, whereas numbers of t~d and p~b alternations were equal for the SLI children. Furthermore, the SLI group displayed more alternation in accidental gap environments ([bɛmp]~*[bɛmbə] and [dep]~*[debə]) than the other two groups. Thus, despite the low frequencies of alternation in non-words, there was a difference between the SLI group and the at-risk and control group.

The higher number of non-word alternation in accidental gap environments of the SLI group was due to more instances and more SLI children applying this alternation. Whereas only one of the 27 control children (4%) resorted to accidental gap alternation and only two of the 56 at-risk children (4%), there were six out of 24 SLI children (25%) who applied alternation in incorrect environments.

Alternation was never produced consistently by one child in all (accidental gap) environments. These findings could lend support to the interpretation that the SLI children had more articulatory difficulties and resorted to intervocalic voicing and postnasal voicing. This would suggest a delay in articulatory development. Alternatively, the SLI children possessed incorrect phonological representations and generalisations. Alternation in t~d environments is translated to alternations in /p/ environments. However, it is difficult to reconcile this latter interpretation to the low rates of alternation of the SLI group, as in that case a more systematic pattern of alternation would have been expected.

Whereas the rhyme correct scores of both the at-risk and SLI groups were slightly lower than those of the control group (5.5.2.3), only the SLI group showed alternation behaviour differing from the control group. The difficulties with the production of the rhymes of the singular do not seem to be the factor to differentiate the three groups in terms of alternation. Indeed, correlation analyses with rhyme correct of the non-words singular and non-word non-alternation ([flɑntən]) did not show significant correlations between rhyme realisation and non-word non-alternation, neither for all children, nor the groups separately (see Appendix 3).

However, for rhyme realisation and non-word alternation ([flɑndən]), the picture was different. There was no overall correlation, but a significant moderate negative correlation was attested for the control group (Spearman's rho=-0.59, p=0.002). Thus, for the control group, a higher rhyme correct score is related to a lower rate of non-word alternation. No correlations were found for the rhyme realisations and alternations of the at-risk and SLI groups. These findings suggest that phonological representations of the singular did not have great bearing on alternation output. Alternatively, if they did impact on alternation, then better specified representations led to fewer cases of alternation.

5.5.3 Discussion

This study aimed to answer the following questions:

1) Can preschool children at-risk of dyslexia and children with SLI be distinguished from control children on the basis of their realisations on the alternation task?
2) Can the data be accommodated within phonological deficit hypothesis of dyslexia?
3) Can the findings of the at-risk and SLI group be accounted for by the single source, comorbidity, or qualitative difference hypothesis?

The answer to *Question 1* was determined by different measures: plural realisation, production of the voicing contrast, rhyme realisation of the singular and (non-) alternation of words and non-words. The SLI group performed differently from the control group on all analyses. The at-risk group could only subtly be distinguished from the control group in terms of proportions correct of the rhyme singulars and plural realisation, not on the basis of alternation patterns and voicing realisation.

The SLI group showed a trend of lower proportions plural correct and lower rhyme scores compared to the control group. Their voicing contrast was different to that of the control group, contained a smaller number of children producing alternations in words, displayed a different pattern of incorrect alternation of words and alternation of non-words, including accidental gap alternation, and assessment of alternation was restricted more by their morphological and phonological production difficulties. The performance of the SLI group resembled that of the youngest children (2;9-4;0) in Kerkhoff's (2004, in preparation) study, with respect to voicing realisation, accidental gap alternation, and lower rate of plural inflection. The findings thus suggest a delay of the SLI group.

Question 2 was concerned with interpretation of the data in the phonological deficit hypothesis of dyslexia. It is difficult to accommodate the present data in this hypothesis, as the control and at-risk groups did not differ on the mean proportion rhyme realisation correct. Furthermore, the proportion correct rhyme realisation singular of non-words of the at-risk group was only slightly lower than that of the normally developing children. This was to be expected, as the non-words were only one syllable long and therefore not difficult to repeat. The only indication that a deficit relative to the control group was present was found in within-group distribution, where almost half of the at-risk group reached a rhyme correct score more than one standard deviation below the mean of the control group.

Correlation analyses did not establish an impact of poorer phonological representations on the alternation patterns. Such a finding suggests that poorer phonological representations do not necessarily inhibit acquisition of this voicing alternation. However, the current experiment has also shown that voicing alternation of the plural is not a productive process in Dutch. For all three groups, correct non-

alternation of words was much more frequent than correct alternation and errors of non-alternation were much more frequent than errors of alternation. With respect to non-words, non-alternating plurals outnumbered alternating realisations, which were highly infrequent. These findings replicate those of the normally developing children reported by Kerkhoff (in preparation) and imply that correctness of phonological representations and alternation do not necessarily go hand in hand.

The findings established that the at-risk and SLI group showed both similarities and differences on this alternation task. The similarities were mainly attested in the rhyme realisations of the singular, where both showed slightly lower rhyme scores, especially for non-words and where more than 40% of both groups obtained scores more than one standard deviation below the control mean. A second similarity was the lower rate of plural production. However, the SLI group displayed more difficulties with plurals than the at-risk group. Furthermore, alternation behaviour was different for the at-risk and SLI groups. These results provide insight into the relationship between dyslexia and SLI (*Question 3*).

The data seem to fit the two hypotheses that propose that dyslexia and SLI are distinct disorders, the comorbidity hypothesis and the qualitative difference hypothesis, rather than the hypothesis that proposes that one single source can account for all difficulties. In order for the latter hypothesis to hold, difficulties on phonological measures should be similar for both groups and they should yield similar difficulties on other levels, as, for instance, alternation behaviour.

The at-risk and SLI groups showed subtly lower rhyme realisation singular scores. This is commensurate with the qualitative difference hypothesis of dyslexia and SLI, which argues for an overlap on phonological abilities, but a difference between the groups on other (linguistic) skills. The comorbidity hypothesis can also account for the results. The finding that more than 40% of the SLI group belonged to the poor performers would match statistics of SLI children diagnosed with dyslexia (between 40-60%). Thus, it could be that phonological difficulties are only present in those children with SLI that will turn out to be dyslexic. Furthermore, the comorbidity model as well as the qualitative difference hypothesis can account for the plural production findings of the SLI and at-risk groups.

We will have to wait and see which at-risk and SLI children will become dyslexic in order to differentiate between the qualitative difference and comorbidity hypothesis. Until that time, the present data point towards to the interpretation that dyslexia and SLI are distinct disorders.

5.6 Conclusions

A comparison of voicing alternation in the Dutch plural in existing words and non-words was made in this chapter between at-risk, SLI, and normally developing children. It was assessed whether phonological difficulties would arise and whether these determined alternation behaviour in the groups.

There were indications of phonological difficulties in the at-risk and SLI groups compared to the control group. Nevertheless, no firm or consistent relationship was found between the measure of phonological representations and alternation.

Furthermore, the findings of this study showed similar performance of the SLI and at-risk groups on a measure of phonological representations, but different behaviour outside this domain. It can thus be argued that dyslexia and SLI should be treated as separate disorders. The qualitative difference and comorbidity hypothesis can better account for the data than the single source hypothesis.

Chapter 6 further explores the phonological deficit in children at-risk of dyslexia and children with SLI by comparing the groups on a measure of phonological processing, a non-word repetition task.

Appendix 1. *Stimuli of the plural elicitation task* (Kerkhoff in preparation)

Test stimuli (Words and Non-words)

	Word stimuli				Non-word stimuli	
	p~b		t~d		p~b	t~d
context	singular		singular		singular	singular
short vowel	kɪp	'chicken'	pɛt	'cap'	ɣɔp	slɑt
	krɑp*	'crab'	sxɪlpɑt*	'turtle'	dɑp	jɪt
	wɛp*	'web'	bɛt*	'bed'		
long vowel	sxap	'sheep'	vut	'foot'	bop	knot
			pɔtlot*	'pencil'	dep	klat
			hut*	'hat'		
vowel + nasal	lɑmp	'lamp'	olifɑnt	'elephant'	kɪmp	flɑnt
			tɛnt	'tent'	bɛmp	dɪnt
			hɔnt*	'dog'		
			hɑnt*	'hand'		

* refers to words that show voicing alternation in the plural

Filler stimuli (Words)

type	singular	plural	transcription	
-s plural	paraplu	paraplu's	paraplys	'umbrella'
	vlinder	vlinders	vlɪndərs	'butterfly'
-en plural	vis	vissen	vɪsə	'fish'
irregular plural	ei	eieren	ɛɪərən	'egg'
	koe	koeien	kuijən	'cow'

Appendix 2. *Correlation statistics of Rhyme realisation and Alternation of words*

Measure 1	Measure 2	Group	Spearman's rho
Rhyme correct singular words	Correct non-alternation ([pɛtən])	All	0.28**
		Control	-0.16
		At-risk	0.28*
		SLI	0.38
Rhyme correct singular words	Correct alternation ([bɛdən])	All	0.22*
		Control	-0.03
		At-risk	0.11
		SLI	0.33
Rhyme correct singular words	Incorrect non-alternation (*[bɛtən])	All	0.04
		Control	0.13
		At-risk	0.13
		SLI	-0.04
Rhyme correct singular words	Incorrect alternation (*[pɛdən])	All	0.09
		Control	0.20
		At-risk	-0.02
		SLI	0.19

*p<0.05, ** p<0.01

Appendix 3. *Correlation statistics of Rhyme realisation and Alternation of non-words*

Measure 1	Measure 2	Group	Spearman's rho
Rhyme correct	Non-alternation	All	-0.05
singular non-words	([flɑntən])	Control	0.07
		At-risk	-0.12
		SLI	0.03
Rhyme correct	Alternation	All	-0.09
singular non-words	([flɑndən])	Control*	-0.59**
		At-risk	0.05
		SLI	0.16

*p<0.05, ** p<0.01

6

Non-word repetition

6.1 Introduction

The experiments and results of Chapters 3 to 5 have shown evidence from phonological acquisition for the hypothesis that dyslexia is caused by a phonological deficit. Areas investigated were expressive phonology, stress competence, and voicing alternation of the plural. The present chapter investigates whether a group of children at-risk of dyslexia also displays difficulties on a task focusing on phonological processing abilities, that of non-word repetition.

Non-word repetition was also assessed in Chapter 3 to measure word stress assignment and in Chapter 5 to morpho-phonological alternation of the plural. The difference between this non-word repetition task (NWR) and those of the previous chapters is that language-specific influences were minimalised here, whereas they were the focus of attention in the other two chapters. Thus, whereas a phonological processing component is involved in all three non-word repetition tasks, the present NWR predominantly taps phonological processing and linguistic competence was the focus in the other two tasks.

There appears to be a close similarity between dyslexia and specific language impairment (SLI) in language and reading performance. It will be assessed here whether both disorders can be characterised by poor phonological processing and whether they result in similar errors. Such an investigation can further help to determine whether dyslexia and SLI are the same or distinct disorders. A comparison between children at-risk of dyslexia and children with SLI on non-word repetition with an elaborate error analysis, has, to the best of my knowledge, not been reported before.

The present chapter thus compares non-word repetition performance of children at-risk of dyslexia with that of children with SLI. Preceding this study (6.5), issues arising from the literature on non-word repetition in dyslexia and SLI (6.2) and the nature of non-word repetition errors (6.3) will be reviewed, and expectations on the basis of the relevant hypotheses on dyslexia and SLI will be discussed (6.4).

6.2 Non-word repetition as a marker of dyslexia and SLI?

A prominent hypothesis with respect to dyslexia is that results from a phonological processing deficit (e.g. Paulesu et al. 2001, Ramus 2003, Snowling 2001, Vellutino et al. 2004). The main tenet of this hypothesis is that dyslexics have difficulties in encoding, retrieving, and storing phonological information. These poor phonological representations have repercussions for literacy development, as visual word recognition and grapheme-phoneme conversion are hampered by poor phonological representations. Poor word recognition, in turn, could affect reading comprehension.

A non-word repetition task (NWR) reflects encoding, storage, and retrieval of phonological representations. Children with dyslexia, as well as young preschool children with a risk of dyslexia, have been found to obtain lower scores on NWR compared to normally developing age peers (e.g. Carroll & Snowling 2004, Kamhi & Catts 1986, Gallagher, Frith & Snowling 2000, Kamhi et al. 1988, Marshall, Snowling & Bailey 2001, Pennington & Lefly 2001, Rispens 2004, Roodenrys & Stokes 2001, Snowling et al. 1986, Snowling & Nation 1997, Snowling, Gallagher & Frith 2003). Generally speaking, a non-word repetition deficit appears to be present in dyslexic populations, even into adolescence and adulthood (Bruck 1990, Ramus et al. 2003).

Poor phonological processing and representation have also been attested in (e.g. English, French, Swedish, and Dutch) children with SLI. Preschool and school-going children and adolescents with language impairment show pronounced difficulties with non-word repetition (e.g. Archibald & Gathercole 2006b, Conti-Ramsden 2003, Conti-Ramsden, Botting & Faragher 2001, Conti-Ramsden & Hesketh 2003, Conti-Ramsden & Durkin 2007, Dollaghan & Campbell 1998, Edwards & Lahey 1998, Ellis Weismer et al. 2000, Goulandris, Snowling & Walker 2000, Gray 2003, Kamhi et al. 1988, Majerus, Vrancken & Van der Linden 2003, Montgomery 1995, Nathan, Stackhouse & Goulandris 1998, Rispens 2004),[1] even when their overt language difficulties have resolved (Bishop, North & Donlan 1996, Stothard et al. 1998). Non-word repetition has thus been put forward as a powerful (cross-linguistic) indicator of presence of language impairment. Notwithstanding the heterogeneity of language profiles of SLI children, the population is homogeneous in its non-word repetition performance. This has led to the proposal that poor non-word repetition is a strong clinical marker of language impairment (Bishop, North & Donlan 1996, Botting & Conti-Ramsden 2001, Conti-Ramsden, Botting & Faragher 2001, Conti-Ramsden & Hesketh 2003, Dollaghan & Campbell 1998, Tager-Flusberg & Cooper 1999).

Since a non-word repetition deficit has been attested in children with SLI and children with (a risk of) dyslexia, the question arises whether the performance of

[1] See, however, Stokes, Wong, Fletcher and Leonard (2006) for discrepant findings obtained of Cantonese SLI children.

these two groups is quantitatively and/or qualitatively similar. A non-word repetition deficit might represent a common underlying difficulty for both disorders. Comparisons between NWR abilities in dyslexic and SLI populations have not often been made, but findings are consistent in that poor results were attested in both groups (Catts et al. 2005, Kamhi & Catts 1986, Kamhi et al. 1988, Goulandris et al. 2000, Scheltinga, van der Leij & van Beijnum 2003, Rispens 2004), with the dyslexic groups generally outperforming the children with SLI (but see Catts et al. 2005 who found the reverse). These studies establish that both older children and adolescents with dyslexia or SLI exhibit difficulties with non-word repetition. Furthermore, they found that the impairment in SLI is more pronounced, suggesting that an overlap between the two might be present, but that the two groups differ in severity.

In the context of the research in this thesis, this begs the question whether this severity difference is also visible at younger ages, between at-risk and SLI children. Carroll and Snowling (2004) recently reported a non-word repetition study with children with a familial risk of dyslexia and children with speech impairment (not SLI). They found that these groups of four-to-six-year-old children performed more poorly on non-word repetition than their age-matched controls, with the at-risk children performing better than the speech-impaired group. This study thus suggests an overlap between a speech-impaired and an at-risk group in terms of non-word repetition. Unfortunately, no within-group or qualitative error analyses were conducted on the children's repetitions. These analyses could have shed light on the variation within the at-risk population, as well as assess whether qualitative differences between the at-risk and speech-impaired children occurred. However, their results suggest that a difference in severity is present between the speech-impaired and at-risk group.

This chapter evaluates NWR performance of Dutch four-year-old children at-risk of dyslexia and children with language impairment to assess whether a NWR deficit is present in these groups. It provides qualitative analyses of children's NWR performance and group distribution results in order to address the relationship between dyslexia and SLI. The remainder of the introductory section provides more details on the specific approach and purpose of this type of analysis.

6.3 Nature of errors in non-word repetition

Studies of non-word repetition generally report a raw score or percentages of phonemes correctly produced. This allows comparison between children as well as groups. However, these scores do not characterise the nature of repetition errors. Complementing group comparisons with qualitative error analyses may shed light on the nature of the children's processing difficulties and/or representation of phonological information. A comparison between the errors of the two groups indicates whether the type of errors are the same, differing only in frequency of

occurrence, or whether they are qualitatively different, pinpointing factors at play in both or either groups. This may provide insight into the relationship between dyslexia and SLI.

Error analyses of at-risk children's repetitions have not been reported before. Qualitative analyses with SLI populations have established differences between control and SLI children. Edwards and Lahey (1998), Marton and Schwartz (2003), and Montgomery (1995), who all assessed non-word repetition in school-aged SLI and control children, found that phoneme substitution was more frequent than phoneme omissions for both groups, and addition was infrequent. Furthermore, the SLI groups produced more phoneme omission than the controls. Even though the frequencies of errors between the SLI and non-SLI groups differed, the error pattern was similar. A similar pattern is also attested in reproduction of prosodic contours of the non-words in children's repetitions, as studies with both normally developing and SLI children have found that children's repetitions generally consist of the correct number of syllables (Dollaghan, Biber & Campbell 1995, Edwards & Lahey 1998, Roy & Chiat 2004, Sahlén, Reuterskiöld-Wagner, Nettelbladt & Radeborg 1999).

Both normally developing children (Dollaghan, Biber & Campbell 1995, Ellis Weismer & Hesketh 1996), as well as children with SLI (Edwards & Lahey 1998, Marshall, Harris & Van der Lely 2003) have been found to display lexicalisation through phoneme changes (turning (part) of a non-word into a real word, as in. /næblədi/ realised as 'nab baby', taken from Edwards & Lahey 1998). Thus, the data suggest that there are no major qualitative differences between the repetitions of the SLI and non-SLI group. This is also true for the factor of word length. The longer the word, the lower the correct scores. However, both dyslexic and SLI subjects have been found to show a stronger effect of word length than normally developing subjects (Bishop, North & Donlan 1996, Montgomery 1995, Snowling 1981).

Summarising, this study addresses non-word repetition abilities of children at-risk of dyslexia and children with SLI. Such a comparison could, for example, assess whether difficulties arise on the suprasegmental or the phoneme level. Both groups might show difficulties with non-word repetition, but these difficulties might be of a different nature. On the basis of the SLI studies discussed above, it is expected that there will be no (major) qualitative differences between the SLI and control group. A direct comparison between the errors of at-risk and SLI children has not been made yet. The next paragraph will formulate predictions on the basis of the relevant hypotheses.

6.4 Expectations on the basis of hypotheses of dyslexia and SLI

The phonological deficit hypothesis of dyslexia assumes that phonological processing and awareness difficulties underlie dyslexia (see Chapter 1) and thus yields the expectation that non-word repetition will be poorer in children with (a risk

of) dyslexia than their age-matched controls. This hypothesis tends to focus on segmental representations, leading to the assumption that difficulties will occur on the phoneme, not the syllable level. The sub-lexical deficit hypothesis (Ramus 2001), however, proposes that application of language-specific phonological information is more difficult for children with (a risk of) dyslexia than normally developing children. Such a view allows for the occurrence of difficulties on more than just the phoneme level. Difficulties with, for example, (weak) syllable substitution and omission can also be accounted for by this hypothesis. Nevertheless, the main assumption is the same for both hypotheses: non-word repetition of children with (a risk of) dyslexia will be poorer than that of normally developing children. Additionally, a stronger word length effect can be inferred from both hypotheses: the longer the word, the more difficult it is to maintain the correct phonological representation and the correct order of the phonemes.

In terms of the relationship between dyslexia and SLI, there are three different models to consider (see Chapter 1). The comorbidity hypothesis argues that phonological processing difficulties only underlie dyslexia, not SLI. Thus, such difficulties only surface in those subjects with both dyslexia and SLI, not in populations with only language impairment. On the basis of this hypothesis, it can be anticipated that a substantial number of children in the at-risk group will exhibit poor non-word repetition. It is not expected, however, that poor NWR performance will characterise the majority of SLI children, as only a part of that group (approximately 40-60%) is expected to develop dyslexia.

The other two hypotheses, the single source hypothesis and the qualitative difference hypothesis, both assume that phonological processing difficulties are the core deficit of dyslexia and SLI. Thus, in order for these hypotheses to hold, the at-risk and SLI groups should both perform more poorly than the control group and substantial number of SLI (and at-risk) children should display evident difficulties on this task. As phonological processing difficulties are assumed to be the core of the overlap between dyslexia and SLI in both models, it is difficult to tease the models apart. Nevertheless, error analyses as well as within-group variability could provide some food for thought on the relationship.

6.5 Study

The present study compares non-word repetition skills of four-year-old Dutch children with a risk of dyslexia, children with SLI, and control children. The questions addressed are:

1) Can preschool children at-risk of dyslexia and children with SLI be distinguished from control children on the basis of their non-word repetition performance?
2) What is the variability of non-word repetition performance within each group?

3) Can the data be accommodated within the phonological deficit hypothesis of dyslexia?
4) Can the findings of the at-risk and SLI groups be accounted for by the single source, potential comorbidity, or qualitative difference hypothesis?

6.5.1 Method

6.5.1.1 Participants

Fifty-seven children (19 girls, 38 boys) with a familial risk of dyslexia (mean age, 4;4, SD 3 months), 22 children (3 girls, 19 boys) diagnosed with SLI (mean age 4;7, SD 5 months), and 31 children (15 girls, 16 boys) without reported language difficulties and dyslexia in their family (mean age 4;5, SD 3 months) participated. Subject selection is described in Chapter 2.

Mean IQ, assessed through a Dutch standardised test (SON-R, Snijders, Tellegen & Laros 1988) at age five was 117.3 (SD 14.2) for the control group, 111.6 (SD 15.0) for the risk, and 103.0 (SD 11.2) for the SLI group. Even though mean IQ was above average for all three groups, there was an effect of IQ on a one-way Anova ($F(2, 102)=5.9$, $p=0.004$). The control and SLI group differed significantly from each other on a Tukey HSD posthoc ($p=0.002$).

However, the task presented to the children was a non-word repetition task, which is largely independent of (non-verbal) IQ (Bishop, North & Donlan 1996, Conti-Ramsden et al. 2001, Dollaghan & Campbell 1998, Edwards & Lahey 1998, Ellis Weismer et al. 2000, Stanovich 1994). This suggests that IQ differences between the groups should not affect the results of the task. Nevertheless, Snowling, Gallagher and Frith (2003) found that when IQ was taken into account as covariate in analysis of NWR performance at 3;9 for high-risk impaired, high-risk unimpaired, and control children with reading outcome at age 8, the differences on NWR performance were no longer significant. Therefore, analyses both with and without IQ as covariate were conducted for the scores traditionally reported in NWR studies, the raw score and the phoneme percentage correct scores. [2]

6.5.1.2 Task and materials

The majority of English studies on non-word repetition have used either Gathercole and Baddeley's (1996) CNRep or Dollaghan and Campbell's (1998) non-word repetition task (for a direct comparison of these tasks presented to school-going SLI and age and language-matched control children, see Archibald & Gathercole 2006a). The present study used a NWR task for Dutch based on Dollaghan and Campbell's, which was designed to minimise wordlikeness and interference of language

[2] Unfortunately, IQ data are absent for one control child, three at-risk children, and three children with SLI. This means that for the IQ-controlled analyses non-word repetition data of these children were not taken into account.

background and speech production difficulties. The non-words and task met the following criteria, based on Dollaghan and Campbell (1998):

- Neither the non-words nor their constituent syllables correspond to lexical items (e.g. */wa’mœys/ containing the syllable /mœys/ ‘mouse’), to decrease the likelihood that subjects with larger vocabularies can use their vocabulary knowledge to support repetition performance.
- The non-words comprised consonants and syllable types that are typically acquired early in development (i.e., excluding /x/ and consonant clusters) to minimise the articulatory difficulty of the repetition task.
- Only tense vowels are used (/ji’nus/), no lax vowels (*/jɪ’nus/). Unlike English, tense vowels can occur in unstressed syllables in Dutch. Tense vowels have longer duration and increased perceptibility.
- There is only one occurrence of a particular consonant or vowel per non-word (*/ni’nus/,*/junus/) to ensure that accurate repetition required that each of its phonemes be recalled independently.
- The non-words were prerecorded, allowing consistent rate, accuracy and intonation of presentation.
- In order to control for learning effects that might result from hearing progressively longer targets, the non-words were presented pseudo-randomly with the restriction that the length of two successive non-words was always different.

Stimuli are presented in Appendix 1.

6.5.1.3 Procedure and data analysis

The non-word repetition task was second in a battery of tests presented to the children in one session. At-risk children were tested in the child language laboratory of the Utrecht Institute of Linguistics OTS of Utrecht University. Control and SLI children were tested either at the lab or in a quiet room at their school. Each trial started with the presentation of a picture of a fantasy animal. The name of the animal, the non-word, was pronounced by a female speaker of Dutch[3] on a CD player and played over a Fostex 6301B loudspeaker.

The children were then asked to repeat the name of the animal. Every word was preceded by a beep to ensure children’s attention. The children’s utterances were recorded on a DAT recorder (Tascam DA-P1) with a sensitive microphone (Crown PZM-185). All participants heard the non-words once. In case of multiple responses of the word, the most complete and correct realisation of the child was taken into account in data analysis.

A broad transcription was made of the children’s realisations (author) and 10 percent of the data was transcribed by a second trained transcriber (research

[3] I am grateful to Ellen Gerrits for data recording.

assistant). Agreement was 93%, which was considered sufficient for further analysis. Transcriptions of items where disagreement arose were resolved by consensus, or were checked by a third transcriber (student). On the basis of these transcriptions, three types of scores were calculated (see Table 1):

Raw score: a binary score was linked to the child's output (0 or 1). A completely correct repetition of the target resulted in a score of 1. A repetition with one or more deviations from the target led to a 0 score. The maximum total was a score of 16 (16 targets). Phoneme substitutions and omissions were scored as incorrect. Additions were counted separately. They were not judged as incorrect (similar to Dollaghan & Campbell 1998) as addition does not necessarily reflect a loss of information of the target phonemes, which substitution and omission do indicate.

Phoneme score: the percentage of correctly repeated phonemes, substituted, omitted, and added phonemes was calculated. For example, the percentage phonemes correct score was counted by dividing the number of correctly repeated phonemes in each word by the total number of phoneme targets, multiplied by 100. Percentage phonemes incorrect, i.e., percentage phoneme substitution (ji'nus → b̲i'nus) and percentage phoneme omission (ji'nus → i'nus) were also calculated. A word such as /ji'nus/ contains five target phonemes. Repeated as /ti'ku/ renders a phoneme correct score of (2/5) 40%, a substitution score of (2/5) 40% and an omission score of (1/5) 20%. Correct, substitution, and omission scores thus add up to 100%. Cases in which a child 'did not re-create the syllable structure of the non-word (adding or omitting one or more syllables), individual phoneme scoring proceeded after aligning the syllable sequence produced by the subject to that of the target, using vowels repeated as syllable anchors to maximize the subject score' (Dollaghan & Campbell 1998, p.1139). Percentage phoneme addition, finally, was calculated for onset addition (ji'nus → k̲ji'nus) and coda addition (ji'nus → jim̲'nus or ji'nust̲).

Syllable score: percentages of completely correct, substituted (ji'nus → b̲a̲'nus), and omitted syllables (ji'nus → nus) were calculated in order to provide further information about the prosodic representations of the children. Syllable substitution and omission were further determined for weak and strong syllables. In contrast to the phoneme percentages correct, substituted and omitted, the percentages syllables completely correct, substituted, and omitted do not add up to 100%. Percentage syllable addition (ji'nus → jim̲i̲'nus) was counted separately.

The percentages correct and incorrect were calculated for the different stimulus lengths (2, 3, 4 and 5 syllables). The scorer (author) was blind to the group (Control, At-risk, SLI) the child belonged to. A random sample (10% of the total responses) was scored twice by different analysts (author and research assistant). Inter-rater reliability for the raw score was 100%, for phoneme and syllable scores 99%.

Difficulties with production of particular sounds could unjustly depress the NWR score. To ensure that expressive phonology did not have a confounding effect on phonological processing measures, a picture naming task in which phonemes were targeted in different syllable positions was presented to the children first. For more details on this task, see Chapter 3 (Study 2). Acquisition scores were calculated for vowels and consonants (a distinction was made between syllable-initial and syllable-final consonants, and position of the phoneme in a stressed or unstressed syllable). If a child had not acquired a sound (i.e. failed to produce it correctly more than 75% of the occurrences) the phoneme was not counted as incorrect (but as correct) when scoring the NWR. This was the case for five SLI, four at-risk, and none of the control children.

Table 1. Examples of scoring for different realisations of the two-syllable non-word /ji'nus/. subs stands for substitution; omiss for omission, and add for addition.

	Raw	Phonemes (%)					Syllables (%)			
		correct	subs	omiss	onset add	coda add	correct	subs	omiss	add
ji'nus	1	100	0	0	0	0	100	0	0	0
bi'nus	0	80	20	0	0	0	50	0	0	0
i'nus	0	80	0	20	0	0	50	0	0	0
ti'ku	0	40	40	20	0	0	0	0	0	0
ba'nus	0	60	40	0	0	0	50	50	0	0
'nus	0	60	0	40	0	0	50	0	50	0
kji'nus	1	100	0	0	50	0	100	0	0	0
ji'nust	1	100	0	0	0	50	100	0	0	0

6.5.2 Results

6.5.2.1 Raw score

Three control (9%), 11 at-risk (19%), and 5 SLI children (23%) repeated fewer than 16 targets due to shyness or fatigue: their raw scores are not taken into account for the mean raw score (but they are included in the phoneme and syllable percentage scores). Generally, these children missed one or two items (mean number of repetitions for these children 14.1 (SD 0.9) items). Four and five-syllable items constituted the bulk of these non-responses. The results of the children who completed the NWR are presented in Figure 1.

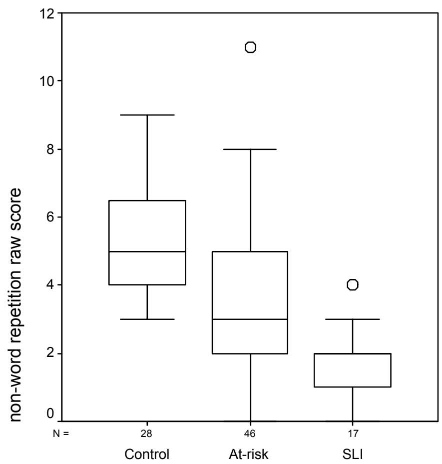


Figure 1. Raw score on the non-word repetition task according to group.
The maximum score is 16. The boxes in this boxplot contain the middle 50% of the data, with the line in the box indicating the median value. The upper whiskers indicate the maximum data values and the lower whiskers the minimum data values. The open circles refer to mild outliers.

There was a significant effect of Group ($F(2,109)=37.0$, $p<0.001$) on a one-way Anova with Raw score as dependent variable ($F(2, 103)=27.1$, $p<0.001$ when taking IQ as covariate). Games-Howell posthocs further established that all three groups performed significantly differently from each other ($p<0.01$).

6.5.2.2 Phoneme scores

This section looks at the performance of the three groups on the NWR measured through phoneme scores. First, the mean percentage phonemes correct per non-word length is presented in Figure 2.

A two-way repeated measures Anova with arcsine-transformed Percentage phonemes correct[4] as dependent variable, Group (Control, At-risk, SLI) as the between-subjects factor, and Length (2, 3, 4, 5 syllables) as the repeated within-subjects factor demonstrated a significant main effect for Group ($F(2,107)=29.4$, $p<0.001$), of Length ($F(2.9, 311.9)=154.5$, $p<0.001$), but no interaction between Group and Length ($F(5.8, 311.9)=.78$, $p=0.59$) The effects remained the same when IQ was entered as a covariate (Group $F(2, 99)=20.6$, $p<0.001$, Length $F(2.9, 293.3)=3.8$, $p=0.011$, no Group and Length interaction). Post-hoc Tukey HSD

[4] All phoneme and syllable percentages were converted to arcsine scores to equalise the sample variances.

analyses of Group confirmed that all three groups differed significantly from each other (p<0.001).

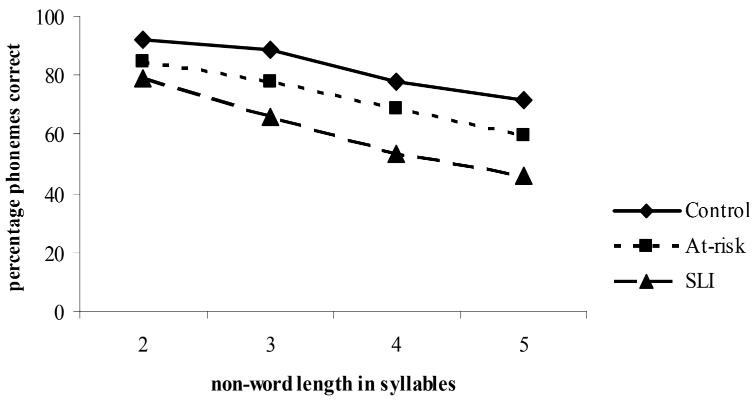


Figure 2. Percentage phonemes correct for each group per target length.

Next to the phoneme correct score, different error scores were calculated (see Table 1). The results of these phoneme error scores are presented in Table 2. The results of the statistical analyses are reported in Appendix 2 and will be described here. With respect to Percentage phoneme substitution (ji'nus → b̲i'nus), a repeated measures analysis with Group and Length found an effect of Group, Length, and an interaction between Group and Length. The substitution rates of the at-risk and control groups resembled each other and steadily increased as target length increased, whereas they increased more sharply for the SLI group up to four-syllable targets. Post-hoc analyses of Group found significant differences between the three groups. Substitution to lexicalise non-words was infrequent. The only substitution that occurred regularly was [mi'nus] for /ji'nus/. This substitution was attested in all three groups and was most likely caused by a childrens' movie titled *Minoes* (/mi'nus/) showing in cinemas at the time of testing.

Similarly, analyses of Percentage phoneme omission (ji'nus → i'nus) per non-word length established an effect of Group, Length, and an interaction between Group and Length. The interaction was caused by a difference between the control and at-risk groups on the one hand, and the SLI on the other. Phoneme omission increased more sharply for the SLI group in repetitions of five-syllable targets compared to the other two groups. Posthoc analyses of Group revealed that the control group obtained lower omission scores than the at-risk and SLI groups, but the at-risk and SLI groups did not differ.

Occurrences of onset and coda addition were low. There were no significant differences of Percentage onset addition (ji'nus → k̲ji'nus) for Group and Length.

Repeated measures of Percentage coda addition (ji'nus → ji'nust) found an effect of Group and Length, but no interaction. Posthoc analyses on Group showed that only the SLI group resorted significantly more often to final consonant addition than the control and at-risk groups ($p<0.01$). It should be borne in mind, however, that percentages coda addition were low. Lexicalisation of the targets through addition was infrequent. The only instance where all three groups of children showed some lexicalisation was in the case of /wa'fɛisin/, where consonant addition occurred often to create [wa'fɛifsin] (creating the Dutch word /fɛif/, 'five') and, rarely, [wa'fɛinsin] (creating the Dutch word /fɛin/, 'pleasant').

Table 2. Phoneme percentages (standard deviations) per group and target length.

Phoneme percentage substitution

	Length in syllables				
	2	3	4	5	mean
Control	7.3 (6.0)	9.0 (7.4)	18.0 (7.9)	21.4 (10.0)	15.4 (5.7)
At-risk	12.3 (9.5)	16.9 (10.8)	24.3 (8.8)	30.3 (10.1)	22.6 (7.0)
SLI	17.9 (12.7)	27.5 (14.2)	37.1 (13.2)	36.4 (11.3)	31.9 (9.1)

Phoneme percentage omission

	2	3	4	5	mean
Control	0.8 (1.9)	2.9 (3.2)	3.9 (5.0)	7.2 (6.9)	4.3 (3.6)
At-risk	2.8 (4.8)	5.1 (6.7)	7.3 (8.4)	10.2 (11.8)	7.0 (7.1)
SLI	2.9 (4.0)	6.8 (8.1)	9.4 (7.8)	16.9 (10.8)	10.6 (7.0)

Phoneme percentage onset addition

	2	3	4	5	mean
Control	0.8 (3.1)	0.5 (2.1)	0.0 (0.0)	0.2 (0.9)	0.3 (0.7)
At-risk	0.0 (0.0)	0.7 (2.8)	0.5 (1.8)	0.4 (1.4)	0.5 (0.9)
SLI	0.6 (2.7)	0.7 (2.4)	0.6 (1.8)	0.2 (1.1)	0.6 (0.8)

Phoneme percentage coda addition

	2	3	4	5	mean
Control	2.8 (6.2)	2.9 (4.6)	1.7 (5.9)	0.9 (2.7)	1.9 (2.6)
At-risk	2.0 (5.2)	3.8 (5.7)	2.4 (4.8)	2.2 (4.0)	2.5 (2.7)
SLI	8.5 (10.8)	6.4 (7.2)	4.6 (7.0)	3.7 (3.6)	5.2 (3.4)

Summarising, phoneme analyses showed different degrees correct for all three groups (Control > At-risk > SLI). For all groups, substitution was a more frequently applied strategy in non-word repetition than omission. Length and syllable structure were often maintained in the output, whereas the phonemes were often substituted.

Furthermore, the interaction between groups and target length for substitution and omission were due to differences between the control and at-risk groups on the one hand, and the SLI group on the other. Both onset and coda addition were infrequent, and only coda addition proved to distinguish the SLI group from the control and at-risk groups. The pattern of findings of the SLI group is highly similar to those of Montgomery (1995).

6.5.2.3 Syllable scores

Results of syllable-level counts are presented in Table 3. They were made to establish whether non-word repetition difficulties of the at-risk and SLI extend beyond the phoneme level.

Table 3. Syllable percentages (standard deviation) per group and target length.

Syllable percentage completely correct

	Length in syllables				
	2	3	4	5	mean
Control	82.7 (13.6)	80.1 (11.9)	65.5 (14.5)	59.8 (16.4)	69.3 (9.4)
At-risk	72.1 (22.5)	65.6 (17.7)	53.7 (15.5)	46.2 (19.0)	56.4 (14.5)
SLI	61.4 (19.4)	48.1 (17.4)	32.6 (17.4)	30.1 (13.7)	39.2 (11.2)

Syllable percentage complete substitution

	2	3	4	5	mean
Control	1.2 (4.9)	0.8 (4.5)	5.3 (5.1)	8.9 (9.3)	5.0 (4.3)
At-risk	1.5 (4.1)	3.4 (6.7)	9.0 (8.6)	13.5 (10.7)	8.3 (5.6)
SLI	4.5 (9.1)	10.3 (11.5)	20.9 (15.0)	25.8 (14.4)	17.7 (9.5)

Syllable percentage complete omission

	2	3	4	5	mean
Control	0.0 (0.0)	0.8 (2.5)	2.8 (4.6)	4.3 (7.3)	2.5 (3.6)
At-risk	1.3 (4.5)	2.0 (6.1)	5.0 (7.9)	6.2 (10.8)	4.1 (6.4)
SLI	1.7 (4.4)	3.5 (7.2)	6.4 (7.2)	13.3 (10.7)	7.6 (6.3)

Syllable percentage addition

	2	3	4	5	mean
Control	0.0 (0.0)	0.5 (2.1)	1.1 (2.9)	0.9 (3.3)	0.8 (1.4)
At-risk	1.8 (4.6)	3.0 (5.4)	2.5 (4.1)	1.6 (3.6)	2.2 (2.7)
SLI	1.7 (5.8)	3.1 (4.3)	3.9 (5.0)	1.6 (2.8)	2.6 (2.6)

The results of the statistical analyses of the syllable scores are reported in Appendix 3. A repeated measures analysis with Percentage syllable completely correct as

dependent variable, Group (Control, At-risk, SLI) as between-subjects factor and Length (2, 3, 4, 5 syllables) as within-subjects factor scores showed an effect of Group, Length, and an interaction between Group and Length. The interaction was caused by a steeper decrease of correct scores for the SLI group compared with the control and at-risk groups. Posthoc analyses on Group established that all three groups performed significantly differently from each other.

Percentage syllable substitution calculates the percentage of syllables that were substituted completely (ji'nus → ba'nus). Thus, the syllable was maintained but with different segmental make-up. Repeated measures found an effect of Group, with all three groups differing from each other, of Length, and an interaction between Group and Length. The pattern in the at-risk and control groups was similar, with a steady increase of substitution, whereas the substitution pattern of the SLI group, especially up to four syllable target length, was much steeper.

Generally, complete syllable substitution increased as target length increased. The data in Table 4 lead to the conclusion that the predominant pattern was weak (unstressed) syllable substitution. Furthermore, a subdivision into pre-stress and post-stress weak syllable substitution unearthed a difference between the groups: both the control and at-risk group favoured pre-stress weak syllable substitution over post-stress weak syllable substitution (pre-stress substitution of 51/68=75% and 137/221=62% for the groups respectively), whereas this preference was not present for the SLI group (pre-stress substitution 85/167=51%). All weak syllables were equally in peril of complete substitution for the SLI group.

Table 4. Number and percentage weak and strong syllable substitution per group and target length. Calculation is based on the number of weak or strong syllable substitution divided by the total number of syllable substitution per condition.

		Control		At-risk		SLI	
2 syllable	Weak	2/3	(67%)	7/7	(100%)	6/8	(75%)
	Strong	1/3	(33%)	0/7	(0%)	2/8	(25%)
3 syllable	Weak	3/3	(100%)	20/23	(87%)	22/27	(81%)
	Strong	0/3	(0%)	3/23	(13%)	5/27	(19%)
4 syllable	Weak	21/26	(81%)	69/80	(86%)	56/69	(81%)
	Strong	5/26	(19%)	11/80	(14%)	13/69	(19%)
5 syllable	Weak	42/55	(76%)	125/145	(86%)	83/108	(77%)
	Strong	13/55	(24%)	20/145	(14%)	25/108	(23%)
Total	Weak	68/87	(78%)	221/255	(87%)	167/212	(79%)
	Strong	19/87	(22%)	34/255	(13%)	45/212	(21%)

A repeated measures analysis on Percentage syllable omission (ji'nus → 'nus) with Group and Length showed an effect of Group, with the control and SLI groups

differing from each other ($p<0.01$), of Length, and a significant interaction. The SLI group exhibited a sharp omission increase at five syllable targets, which the other two groups did not.

Syllable omission was infrequent and gradually increased as targets were longer. A division between primary stressed and unstressed (weak) syllables shows that weak syllables were generally omitted (see Table 5). For all groups, the majority of weak syllable omission occurred when the weak syllable(s) preceded the primary stressed syllable (pre-stress omission of control: 27/40 = 68%, at-risk: 83/117 = 71%, and SLI: 67/83 = 81%). A trochaic structure was often maintained in repetitions of all three groups. This tendency was very clear in repetitions of three-syllable targets, which always contained a weak-strong-weak metrical pattern. In these repetitions, syllable omission was always pre-stress, never post-stress. These findings are similar to those of Roy and Chiat (2004) and Sahlén et al. (1999).

Table 5. Number and percentage weak and strong syllable omission per group and target length. Calculation is based on the number of weak or strong syllable omission divided by the total number of syllable omission per condition.

		Control		At-risk		SLI	
2 syllable	Weak	0/0	(0%)	6/6	(100%)	3/3	(100%)
	Strong	0/0	(0%)	0/6	(0%)	0/3	(0%)
3 syllable	Weak	3/3	(100%)	13/13	(100%)	9/9	(100%)
	Strong	0/3	(0%)	0/13	(0%)	0/9	(0%)
4 syllable	Weak	13/14	(93%)	40/45	(89%)	18/20	(90%)
	Strong	1/14	(7%)	5/45	(11%)	2/20	(10%)
5 syllable	Weak	24/27	(89%)	58/60	(97%)	53/58	(91%)
	Strong	3/27	(11%)	2/60	(3%)	5/58	(9%)
Total	Weak	40/44	(91%)	117/124	(94%)	83/90	(92%)
	Strong	2/44	(9%)	7/124	(6%)	7/90	(8%)

Syllable addition (ji'nus → jimi'nus), finally, was an infrequent strategy. There was an effect of Group, of Length, but no interaction between Group and Length. The control group differed from the at-risk and SLI groups ($p<0.05$) with less syllable addition, but the at-risk and SLI groups did not.

The findings on syllable percentages suggest that target length was often used as cue for non-word repetition. The realisations of the children generally consisted of the correct number of syllables and occurrences of syllable addition and syllable omission compared to syllable substitution were infrequent. The interactions between groups and target length for syllable correct, substitution and omission were due to the more pronounced effects of target length of the SLI group compared with

the control and at-risk groups. The SLI group seemed to be affected disproportionally by increasing non-word length.

6.5.2.4 Within-group variability

In order to evaluate differences within the three groups, a division based on the percentage phonemes correct of the control group was determined.[5] Calculations were made to see how many of the children performed at or above the control mean, up to -1 sd below the control mean, and more than 1sd below the mean of the control group. The latter group was labelled as poorly performing.

Table 7. The number and percentage of children per group performing at or above the control mean, up to 1sd below, and more than 1 sd below the controls' mean PPC score.

Group	At or above control mean		Up to -1sd below control mean		>-1sd control mean	
Control	16/31	(52%)	9/31	(29%)	6/31	(19%)
At-risk	9/57	(16%)	16/57	(28%)	32/57	(56%)
SLI	0/22	(0%)	1/22	(5%)	21/22	(95%)

Virtually all SLI children belonged to the poorly performing group. The distribution thus confirms a non-word repetition deficit for the SLI group. In the control group, only a few control children performed poorly on non-word repetition.

The minimum score of the at-risk group exceeded that of the SLI group (36% compared to 22%), and the maximum score in the at-risk group was slightly lower than the highest of the control group (88% compared to 91%), indicating great variation in the at-risk group. Furthermore, more than half of the at-risk children belonged to this 'poor' category. These findings match the expectation that between 30 and 60% of the at-risk children will become dyslexic.

6.5.3 Discussion

This study compared non-word repetition of children at-risk of dyslexia and children with SLI to answer questions about precursors of poor reading development as well as the relationship between dyslexia and SLI. It aimed to answer the following research questions:

1) Can preschool children at-risk of dyslexia and children with SLI be distinguished from control children on the basis of their non-word repetition performance?
2) What is the variability of non-word repetition performance within each group?
3) Can the data be accommodated within the phonological deficit hypothesis of dyslexia?

[5] Analysis on the basis of the raw score (phoneme-based) led to similar results.

4) Can the findings of the at-risk and SLI groups be accounted for by the single source, comorbidity, or qualitative difference hypothesis?

Question 1, whether a non-word repetition deficit is present in the at-risk and SLI groups, leads to an affirmative answer. The non-word repetition task yielded different scores for the at-risk, SLI, and control groups, with a staircase pattern of performance ranked control > at-risk > SLI. These differences were visible on the raw scores as well as percentage phonemes and syllables correct. Furthermore, an effect of stimulus length was traceable for all groups on the phoneme and syllable correct scores.

The error patterns indicated that the SLI group performed more poorly but also differently on the NWR than the control and at-risk groups. Phonemes and syllables were more often substituted than omitted by all three groups. However, the SLI group showed steeper curves of phoneme substitution and omission, and syllable correct, substitution, and omission than the other two groups. The performance of this group was affected more by target length than that of the at-risk and control groups, aligning with previous findings that SLI populations are affected more by stimulus length than normally developing children (Bishop, North & Donlan 1996, Gathercole & Baddeley 1990, Montgomery 1995). Furthermore, the SLI group resorted more often to phoneme addition than the control and at-risk groups. Additionally, whereas for the at-risk and control groups syllable omission and substitution generally occurred in pre-stress syllables, this pattern was different for the SLI group. Syllable omission was most frequent of pre-stress syllables, but syllable omission occurred equally frequently of both pre- and post-stress syllables. We will return to these quantitative and qualitative differences between the at-risk and SLI groups when answering Question 4.

Question 2 assessed the variability of NWR performance within the three groups to determine whether poor non-word repetition is a possible core marker of both dyslexia and SLI and whether poor NWR is a possible precursor of reading difficulties. More than half of the at-risk group and virtually all SLI children belonged to the poorly performing group. The findings of the present study thus lend support to the claim that non-word repetition is a marker of both SLI and dyslexia. The at-risk children showing poor NWR abilities might be the real-at risk children for reading disorders. Future research of these children will have to compare literacy abilities and the non-word repetition results to assess whether NWR performance is indeed a predictor of reading skill.

The purpose of *Question 3* was to compare the data and the expectations on the basis of the phonological deficit hypothesis of dyslexia. The first expectation of this hypothesis is that non-word repetition is poorer in children with a risk of dyslexia. This was indeed the case. A second confirmed expectation was that increasing target length would render poorer repetition. Thirdly, the phonological deficit hypothesis

implicitly assumes that difficulties arise on the phoneme rather than the syllable level. Again, the data matched these expectations. Nevertheless, difficulties on the syllable level were also attested, as complete syllable substitution, and, rarely, syllable omission did occur. These difficulties arose in weak syllable environments, suggesting that the prominence of the syllable at least partly determined the outcome of the repetition. Furthermore, there was a clear tendency to retain a trochaic structure in the output. These findings indicate that the at-risk group used the language-specific metrical regularity of trochaic structure as a cue in non-word repetition.

Finally, *Question 4* was concerned with the relationship between dyslexia and SLI. The present findings suggest that the comorbidity hypothesis cannot account for the data. The children with SLI performed most poorly on the non-word repetition task, the lowest scores of this group was lower than those of any at-risk child, and the majority of the SLI group (95%) belonged to the poorly performing group. The comorbidity hypothesis assumes that only those children with SLI that develop dyslexia display poor phonological processing. It seems unlikely that 95% of this SLI group will develop dyslexia at school age, but future research will have to confirm this. The present data suggest that poor non-word repetition could very well be a marker for dyslexia, as well as for SLI.

The results substantiate phonological processing difficulties for the at-risk and SLI groups, in line with both the single source and qualitative difference hypotheses. Furthermore, error analyses showed differences in severity of impairment, as well as different error patterns between (control and) at-risk children and SLI children. These findings suggest that the at-risk and SLI groups are distinct, with different factors contributing to the disorders. Thus, the data seem to favour the qualitative difference rather than the single source model.

Remaining questions are whether it is the storage, encoding, or retrieval of phonological information that causes the NWR difficulties and whether these factors contribute differently to the NWR deficit in the at-risk and SLI groups. These questions have been receiving renewed attention (e.g. Archibald & Gathercole 2006b; Gathercole 2006, see also special issue of *Applied Psycholinguistics* 27(4) 2006). Storage is related to skills of phonological short-term memory (PSTM) and encoding and retrieval demands speech input and output abilities skills, as well as vocabulary. A deficit at any of these levels could cause non-word repetition difficulties. Indeed, PSTM (Wilsenach 2006) and phonological difficulties (van Alphen et al. 2004, Gerrits 2003, Chapter 3) have been attested in these at-risk and SLI groups. Further research is thus warranted to systematically assess the impact of these factors on non-word repetition scores for these different populations (Rispens in progress). Such a study can further evaluate the interpretation of a qualitative difference between the at-risk and SLI groups.

6.6 Conclusions

This chapter assessed non-word repetition in children at-risk of dyslexia and children with SLI. Additionally, within-group variability was inspected to establish whether poor performance was found for part or all the at-risk and SLI children. Error analyses were conducted to establish whether error patterns for the at-risk and SLI group were similar or different.

A non-word repetition deficit was attested in the at-risk and SLI children. The majority of the SLI and more than half of the at-risk children performed poorly on the non-word repetition task compared to the control mean. Poor non-word repetition is thus a core characteristic of both groups.

The data of the at-risk children match the expectations of the phonological deficit hypothesis of dyslexia. Furthermore, findings of the group and within-group distribution and the error patterns support the qualitative difference rather than the single source and comorbidity model.

These results have shown that at-risk and SLI children performed more poorly on a task involving phonological processing. The next chapter assesses performance of these groups on a measure of phonological awareness.

Appendix 1. *Stimuli of the non-word repetition task*

Item	Nr syllables	Non-word
practice	1	’tus
practice	2	jœy’fot
practice	4	je’mœybovaʊs
trial	2	so’tɛɪf
trial	2	fø’pan
trial	2	wa’dœys
trial	2	ji’nus
trial	3	ju’sewaʊp
trial	3	wa’fɛɪsin
trial	3	sy’taʊmif
trial	3	do’linɛɪf
trial	4	hi’jemytɛɪp
trial	4	be’putamyf
trial	4	py’sudaʊjin
trial	4	to’pøsiwum
trial	5	hipø’sufytem
trial	5	fonɛɪ’wœysutam
trial	5	bawo’vyjizaʊn
trial	5	wyta’mobejœyn

Appendix 2. *Statistics for Phoneme percentages per target Length and Group*

Factor	F value	p value	Posthoc differences (p<0.05)
Percentage phonemes correct			
Group	F(2,107)=29.4	p<0.001	Control-At-risk Control-SLI At-risk-SLI
Length	F(2.9, 311.9)=154.5	p<0.001	2-3, 2-4, 2-5 3-4, 3-5 4-5
Group * Length	F(5.8, 311.9)=0.77	p=0.59	
Percentage phonemes substitution			
Group	F(2, 107)=31.6	p<0.001	Control-At-risk Control-SLI At-risk-SLI
Length	F(3, 321)=82.9	p<0.001	2-4, 2-5 3-4, 3-5
Group * Length	F(6, 321)=2.2	p=0.039	
Percentage phonemes omission			
Group	F(2, 107)=5.9	p=0.004	Control-SLI Control-At-risk
Length	F(2.4, 250.1)=44.4	p<0.001	2-3, 2-4, 2-5 3-5 4-5
Group * Length	F(4.7, 250.1)=4.8	p=0.033	
Percentage phonemes onset addition			
Group	F(2, 107)=0.20	p=0.82	-
Length	F(2.6, 281.3)=0.71	p=0.29	-
Group * Length	F(5.3, 281.3)=1.0	p=0.42	
Percentage phonemes coda addition			
Group	F(2, 107)=11.9	p<0.001	Control-SLI At-risk-SLI
Length	F(2.6, 280.3)=3.6	p=0.018	-
Group * Length	F(5.2, 280.3)=1.5	p=0.22	

Note: Huynh-Feldt corrections for asphericity lead to corrected degrees of freedom

Appendix 3. *Statistics for Syllable percentages per target Length and Group*

Factor	F values	p values	Posthoc differences (p<0.05)
Percentage syllable correct			
Group	F(2,107)=22.0	p<0.001	Control-At-risk Control-SLI At-risk-SLI
Length	F(3, 321)=119.7	p<0.001	2-3, 2-4, 2-5 3-4, 3-5 4-5
Group * Length	F(6, 321)=2.8	p=0.012	
Percentage syllable substitution			
Group	F(2, 107)=25.8	p<0.001	Control-At-risk Control-SLI At-risk-SLI
Length	F(2.7, 294.6)=61.1	p<0.001	2-4, 2-5 3-4, 3-5 4-5
Group * Length	F(5.5, 294.6)=4.3	p=0.001	
Percentage syllable omission			
Group	F(2, 107)=4.2	p=0.018	Control-SLI
Length	F(2.2, 236.2)=31.6	p<0.001	2-4, 2-5 3-4, 3-5
Group * Length	F(4.4, 236.2)=3.1	p=0.014	
Percentage syllable addition			
Group	F(2, 107)=5.5	p=0.005	Control-At-risk Control-SLI
Length	F(3, 321)=2.6	p=0.049	-
Group * Length	F(6, 321)=0.76	p=0.60	

Note: Huynh-Feldt corrections for asphericity lead to corrected degrees of freedom

7

Rhyme sensitivity[1]

7.1 Introduction

The previous chapters have established that children at-risk of dyslexia exhibit difficulties on several phonological tasks, including the acquisition of language-specific sound patterns and rules as well as a measure of phonological processing. These findings are generally in line with the assumption that a phonological deficit underlies dyslexia. This chapter investigates whether the at-risk group also displays difficulties on a task of phonological awareness, a rhyme oddity task.

Additionally, the performance of the at-risk children will be compared with that of children with SLI. This comparison will shed further light on the relationship between dyslexia and SLI.

The organisation of this chapter is as follows. First, the relationship between phonological awareness, literacy, dyslexia, and SLI will be discussed (7.2), followed by the expectations based on the phonological deficit hypotheses of dyslexia, as well as those on the relationship between dyslexia and SLI (7.3). The rhyme oddity experiment is presented in 7.4. The findings and interpretations are discussed in the final section (7.5).

7.2 Phonological awareness in dyslexia and SLI

Phonological awareness refers to sensitivity to speech sounds, as well the ability to think about and manipulate speech units. Phonological awareness can be assessed through implicit and explicit tasks. The former involve implicit knowledge of representations, as in oddity tasks. A child hears a list of spoken words and has to decide which is the ‘odd-one-out’ on the basis of the onsets, vowels or codas. Tests that demand the ability to manipulate sounds (syllables, rhymes, and phonemes) assess awareness explicitly. An example is a phoneme deletion task (deleting a phoneme from a word and saying aloud the resulting word form). Furthermore,

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[1] Design and preliminary analysis of this experiment were done in collaboration with Petra van Alphen. Preliminary findings on this task were reported in van Alphen, P., de Bree, E., Gerrits, E., de Jong, J., Wilsenach, C. & Wijnen, F. (2004). Early language development in children with a genetic risk for dyslexia. *Dyslexia* 10, 265-288.

phonological awareness can be assessed for different speech-language units, such as words, syllables, onsets and rhymes, and phonemes. Phonological awareness tasks generally involve speech perception, storage of phonological information, and verbally derived responses.

Nowadays, the relationship between phonological awareness and reading acquisition is viewed as reciprocal (Hatcher, Hulme & Ellis 1994, Perfetti, Beck, Bell & Hughes 1987). This viewpoint has accommodated several competing findings. On the one hand, studies found that phonological awareness is the starting point for literacy acquisition. This was endorsed by studies showing that phonological awareness of pre-literate children was an indicator of reading problems (e.g. Bradley & Bryant 1983, Mann 1993, Muter, Snowling, Hulme & Taylor 1997, Muter, Hulme, Snowling & Stevenson 2004, Wood & Terrell 1998b). Furthermore, phonological awareness intervention prior to reading instruction has also been found to influence reading development (e.g. Hatcher et al. 1994, Lovett 1999, Torgesen, Wagner & Rashotte 1997, Van Kleeck, Gillam & MacFadden 1998). These findings suggest that at pre-school age, phonological awareness is a first indicator of future reading development.

On the other hand, studies have asserted that phonological awareness, specifically phoneme awareness, is the result rather than the starting point of reading acquisition, as, for example, neither illiterate participants nor those that have been taught non-alphabetic scripts demonstrate phoneme awareness (e.g. Lukatela, Carello, Shankweiler, & Liberman 1995, Morais, Cary, Algeria & Bertelson 1979, Read, Zhang, Nie & Ding 1986). Furthermore, reading ability has been found to facilitate phonological awareness (Wimmer, Landerl, Linortner & Hummer 1991).

These two viewpoints have merged into one concept of phonological awareness that does not necessarily claim causality, but claims a relationship between literacy and phonological awareness. Such an approach also allows for the option that the association reflects the influence of a third factor, for example, orthographic skill (see Castles & Coltheart 2004).

A substantial number of studies into precursors of dyslexia, investigating language development of children with a familial risk of becoming dyslexic, have found impaired phonological awareness in these children (e.g. Boets et al. 2006, Catts et al. 2001, Elbro, Borstrøm & Petersen 1998, Gallagher, Frith & Snowling 2000, Lefly & Pennington 1996, Locke et al. 1997, Lyytinen et al. 2004, Pennington & Lefly 2001, Scarborough 1990, Snowling, Gallagher & Frith 2003). Furthermore, dyslexic children and (compensated) dyslexic adults still perform more poorly on tasks of phoneme awareness than normal readers (Ackerman & Dykman 1993, Bradley & Bryant 1983, Bruck 1990, Joanisse et al. 2000, Pennington et al. 1990, Pennington, Cardoso-Martins, Green & Lefly 2001, Ramus et al. 2003, Rispens 2004).

Similarly, the literature is replete with findings that children with speech and/or language impairment lag behind in phonological awareness skills (e.g. Bird, Bishop & Freeman 1995, Boudreau & Hedberg 1999, Carroll & Snowling 2004, Catts et al. 2002, Larrivee & Catts 1999, Leitão, Hogben & Fletcher 1997, Leitão & Fletcher 2004, Menyuk et al.1991, Nathan et al. 2004, Magnusson & Nauclér 1990, Raitano et al. 2004, Stackhouse & Snowling 1992, Webster, Plante & Couvillion 1997). Children with both language and reading impairment have been found to perform most poorly on phonological awareness tasks (Eisenmajer, Ross & Pratt 2005). Adolescents with (a history of) SLI still exhibit phonological awareness difficulties (Goulandris, Snowling & Walker 2000, Snowling, Bishop & Stothard 2000, Stothard et al. 1998). Thus, phonological awareness is affected in subjects with dyslexia and SLI.

In the current study, phonological awareness abilities of five-year-old at-risk and SLI children were under scrutiny. At this young age, complicated phonological awareness tasks, such as onset deletion or synthesis, cannot be conducted yet. Rhyming, on the other hand, can be tested, as rhyming ability is one of the first signs of emergent phonological awareness. Rhyming implies that children can segment syllables into an onset and rhyme and can connect words on the basis of the intrasyllabic rhyme unit. Ability to rhyme has been estimated to develop around four years of age (e.g. Menn & Stoel-Gammon 1995, but see Inkelas 2003 for a much earlier case study).

The present chapter thus reports on the results on a rhyme oddity task, a task in which a subject has to select a (non-)word that does not rhyme in a row of three or four words (e.g. cheese-knees-bees-l*amp*). We appreciate that this task has been criticised in the phonological awareness literature (for an overview, see Castles & Coltheart 2004 and MacMillan 2002) as it has been found that it does not predict or correlate (as strongly) with literacy measures as phoneme awareness (Castles & Coltheart 2004, Hulme et al. 2002, de Jong & Van der Leij 1999, MacMillan 2002, Muter et al. 1997, 2004, Muter & Snowling 1998, Nation & Hulme 1997, Wood 2000). It is important to underscore that we do not dispute that phoneme awareness is a better predictor of literacy than onset-rime awareness, but a phoneme awareness task proved too difficult for the children at this age.

7.3 Expectations on the basis of hypotheses of dyslexia and SLI

The phonological deficit hypothesis of dyslexia assumes that dyslexia is characterised by poor phonological representations (Chapter 1). It has been argued that the poor performance of dyslexic children on phonological awareness tasks reflect inaccuracies in the phonological representations of the words that they are asked to analyse. Thus, if phonological representations are compromised, then difficulties with performing (segmental) operations on those representations will also arise. Consequently, it is anticipated that children at-risk of dyslexia, assumed

to possess poorer phonological representations, will perform worse on a phonological awareness task than normally developing children.

Additionally, it is worth investigating whether results will be different between conditions containing evident changes, such as those in which the entire rhyme is altered, compared to those that assess more subtle changes in representation, such as those in which only the final consonant is different (the coda condition). The latter condition is expected to be more difficult than the former. Although different degrees of changes have often been included in the rhyme oddity task presented to children with (a risk of) dyslexia, results have generally not been reported separately. Findings with normally developing children, however, have established that the coda oddity condition was the most difficult condition for normally developing five and five-to-seven-year-old children (De Cara & Goswami 2003, Kirtley, Bryant, Maclean & Bradley 1989). It will be interesting to assess whether this is the case for the at-risk children of our study as well.

With respect to the comparison between the at-risk and SLI children, there are again the three hypotheses discussed in Chapter 1: the single source, the comorbidity, and the qualitative difference hypothesis. On the basis of the comorbidity hypothesis, poor performance of the majority of SLI children on a phonological awareness task is not expected, but a substantial part of children at-risk of dyslexia can be assumed to reach poorer scores compared with the control group. The model proposes that phonological processing difficulties characterise SLI *only* for SLI children who have both dyslexia and SLI (approximately 40-60%), not in populations with only a language impairment.

The other two models, the single source and qualitative difference hypothesis, argue that phonological representations are poor in dyslexia and SLI. Both the at-risk and SLI groups are therefore expected to show difficulties on a phonological awareness task. It is difficult to envisage how results on the phonological awareness task could disentangle the two hypotheses. Such a distinction would only be possible if performance across the different conditions diverge for the SLI and at-risk groups.

7.4 Study

The rhyme oddity task addressed the following questions:

1) Can five-year-old at-risk and SLI children be distinguished from control children on the basis of their performance on a phonological awareness task?
2) What is the variability of performance within the at-risk group?
3) Can the data be accommodated within the phonological deficit hypothesis of dyslexia?
4) Can the findings of the at-risk and SLI group be accounted for by the single source, comorbidity, or qualitative difference hypothesis?

7.4.1 Method

7.4.1.1 Participants

The oddity task was completed by 55 children (18 girls, 37 boys) with a familial risk for dyslexia (average age 5;1 SD 4 months), 23 children (2 girls, 21 boys) with SLI (average age 5;4; SD 4 months) and 22 children (12 girls, 10 boys) without reported language difficulties and dyslexia in their family (average age 5;1 SD 3 months). The task was presented to more children, but five at-risk, two SLI, and one control child did not complete the task. These children did not understand the concept of rhyme and, despite practice and feedback, could not work out what it entailed and required or lacked the motivation to complete the task. Their data was excluded from further analysis. Information about subject selection can be found in Chapter 2.

The children's non-verbal IQ was measured at this age through a Dutch standardised test (SON-R, Snijders, Tellegen & Laros 1988). Mean IQ was 116.9 (SD 14.0) for the control group, 111.9 (SD 14.9) for the risk, and 103.3 (SD 11.2) for the SLI group. Even though mean IQ is above average for all three groups, there was an effect of IQ on a one-way Anova ($F(2, 96)=4.9$, $p=0.009$). A Tukey HSD posthoc showed that the control and SLI group differed significantly from each other ($p=0.007$).

Despite findings that IQ does not necessarily determine performance on phonological awareness (Catts et al. 1999) it has been found that phonological awareness also partly taps cognitive skills (Ackerman & Dykman 1993, McBride-Chang, Wagner & Chang 1997). Hence, analyses both with and without IQ as covariate were conducted for the rhyme oddity scores.[2]

7.4.1.2 Task and materials

The odd-one-out task contained monosyllabic existing words, predominantly nouns, which attempted to include words familiar to five-year-old children (based on data of Ghyselink, de Moor and Brysbaert 2000 and Kohnstamm et al. 1981).[3] To reduce the memory load, pictures were taken from the Max Planck Institute for Psycholinguistics picture database and used next to an auditory presentation of the words.

The oddity task consisted of three conditions:

- VC change: the entire rhyme, i.e., both the nucleus and the coda (VC(C)) of the odd-one-out, were different (plant-mand-want-j*urk*); 10 items

[2] Unfortunately, IQ data are absent for four children with SLI. This means that for the IQ-controlled analyses oddity scores of these children were not taken into account.

[3] Initially, an odd-one-out task was constructed with auditorally presented monosyllabic non-words (e.g. swiem-niem-giem-k*aam*).This non-word rhyme construction was designed to eliminate lexical influence. However, a pilot-test proved that this task was too demanding for the children. They could not remember the words and were inhibited by the use of non-words in this fairly difficult task.

- V change: the nucleus of the odd-one-out (V) differs (jas-glas-tas-fl*e*s); 5 items
- C change: the final consonant (C) of the odd-one-out differs (schip-kip-lip-vi*s*); 5 items.

Inclusion of these conditions aimed to assess whether more salient changes, such as VC and V change, would render higher correct scores than changes in a less prominent position which are more difficult to perceive (C change). Position of the odd-one-out was randomly distributed. Stimuli are presented in the Appendix.

It should be noted here that nascent literacy abilities were not assessed in the three groups. No conclusions can thus be drawn about the potential influence these potential literacy skills had on the performance on the task. Nevertheless, reading instruction in the Netherlands generally only commences when children enter 'Group 3' at six years of age.

7.4.1.3 Procedure and data analysis

The oddity task was fourth in a large test battery presented to the children. The control and at-risk children were tested at the child language laboratory of the Utrecht Institute of Linguistics OTS of Utrecht University, whereas the children with SLI were seen either at the language lab or in a quiet room at their school.

The task started with the experimenter producing a rhyming sequence. Children were then encouraged to produce rhyming words as well, to see if they could understand the concept of rhyming.

Children were shown four pictures. The words were presented auditorally and the relevant pictures were simultaneously pointed at. The words could be repeated as often as necessary before the child selected the odd-one-out, either by pointing to the picture or by pronouncing the odd-one-out. The oddity task contained two practice series with extensive feedback, but feedback was not provided on test items. Performance was scored on-line.

7.4.2 Results

7.4.2.1 Correct score

The oddity task was designed with three different rhyme conditions. Position of the odd-one-out was randomly distributed. Figure 1 displays the correct scores of the three groups based on the three rhyme conditions (VC change, V change, and C change) and the position of the odd-one-out (1, 2, 3 or 4). Even though the latter factor was not originally designed to be included in the analysis, it became obvious during testing that position needed to be taken into account. Differences between the groups (control mean 0.70, at-risk mean 0.62, SLI mean 0.57), conditions (mean VC change 0.70, V change 0.67, C change 0.43), and position (mean 1 0.33, mean 2 0.69, mean 3 0.65, mean 4 0.82) can be discerned from this graph.

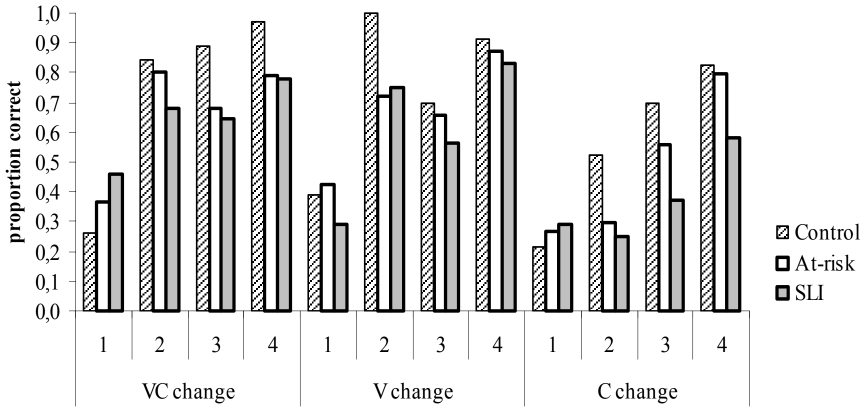

Figure 1. Proportion correct per rhyme condition and position of the odd-one-out per group.

Item analysis with the Correct score as dependent variable, and Group (Control, Risk, SLI), Rhyme condition (VC, V, and C change), and Position of the odd-one-out (1, 2, 3, 4) established a significant effect of Group ($F(2, 2029)=10.7$, $p<0.001$), Rhyme condition ($F(2, 2029)=33.7$, $p<0.001$), and Position ($F(3, 2029)=80.9$, $p<0.001$), as well as an interaction between Group and Position ($F(6, 2029)=3.0$, $p=0.006$) and Rhyme condition and Position ($F(6, 2029)=5.5$, $p<0.001$), but not for Group and Rhyme, or Group, Rhyme, and Position.

The interaction for Group and Position was due to the substantial difference the control group showed between detection of the odd-one-out in first position and the other positions, whereas this difference was clearly visible but less strong for the at-risk and SLI groups. Posthoc analyses of Group established that the control group reached higher correct scores than the at-risk and SLI groups ($p<0.01$), but that the at-risk and SLI groups did not differ from each other ($p=0.09$). Posthoc analyses of Rhyme condition found that the odd-one-out with a C change led to significantly lower correct scores than those with a VC or V change ($p<0.001$), but the odd-ones-out with a VC and V change did not differ ($p=0.4$). Posthoc analyses on Position of the odd-one-out, finally, showed that odd-ones-out in the primary position were much more difficult to detect than those in the other conditions ($p<0.001$) and that those in fourth position were much easier to detect ($p<0.001$). There were no differences between odd-ones-out in second or third position ($p=0.5$). This effect of position is clearly an undesirable characteristic of the oddity task (see also Schatschneider et al. 1999).

Furthermore, the findings of a Group effect should be treated with caution, as they are based on item analysis. When entering the group mean arcsine-transformed proportion correct based on the mean proportion correct per child (subject analysis) in an Anova with Group as factor, there was no effect of Group ($F(2, 99)=2.3$, $p=0.10$). This result remained the same when IQ was entered as a covariate ($F(2, 96)=0.5$, $p=0.58$). A difference between the groups remained visible (control mean 0.67, SD 0.15, at-risk mean 0.60, SD 0.24, SLI mean 0.53, SD 0.22) but did not reach significance.

As indicated by the item analysis above, the odd-one-out was easier to detect in the VC and V change than in the final consonant condition. Preliminary investigation *within* the C changes suggests that a higher number of feature changes led to higher correct scores, as Table 1 shows. For example, an odd-one-out from /s/ → /n/ contains a change of manner and voice, whereas a change of /k/ → /p/ only includes a change of place of articulation.

Table 1. Mean proportions correct (SD) per final consonant change item.

Sound change	Correct	Observations	Altered features	Position odd-one-out
/p/ → /s/	0.19 (0.39)	101	2	1
/s/ → /t/	0.34 (0.48)	101	1	1
/k/ → /p/	0.33 (0.47)	101	1	2
/s/ → /n/	0.75 (0.43)	101	2	4
/s/ → /n/	0.54 (0.49)	101	2	3

Because the positions of the odd-one-out differed within the coda condition, which could influence item difficulty, and because there are only a limited number of items in this C change condition, it is impossible to make rigorous claims about the role of feature changes. Nevertheless, these findings tentatively suggest that number of features, a speech perception and phonologically-determined factor, could have contributed separately to the correct scores.

7.4.2.2 Within-group variability

It was anticipated that a division within the at-risk group could be made, with a subset of at-risk children displaying poor performance on the rhyme oddity task. However, since no statistical group differences were found on the child-based proportion correct analysis above, these expectations might not hold true.

The mean proportion correct of the control group, on the basis of the proportions correct of the children, was 0.67, with a standard deviation of 0.15. Calculations were made to see how many of the at-risk and SLI children performed the same as or better than the mean of the control group, up to 1 sd below the control

mean, and more than 1sd below the mean of the control group. This arbitrary cut-off yielded the following division (Table 2).

Approximately one third of the at-risk children (mean proportion correct of the at-risk group 0.60, SD 0.24) and the SLI group (mean proportion correct of the SLI group 0.53, SD 0.22) performed poorly (>-1 sd) on the rhyme task compared to the control mean. The minimum score of the at-risk group was higher than that of the SLI group (33% compared to 10%), and the maximum score in the at-risk group exceeded that of the control group (97% compared to 90%). These findings indicate substantial variation in the at-risk group. This was anticipated, as only part of the at-risk group will become dyslexic.

Table 2. The number and percentage of children per group performing at or above the control mean, up to 1 sd below, and more than 1 sd below the controls' mean proportion correct score.

Group	At or above control mean		Up to -1sd below control mean		>-1sd control mean	
Control	15/23	(65%)	4/23	(17%)	4/23	(17%)
At-risk	28/54	(52%)	10/54	(19%)	16/54	(30%)
SLI	8/23	(35%)	7/23	(30%)	8/23	(35%)

7.4.3 Discussion

The last experiment of this thesis targeted the following questions:

1) Can five-year-old at-risk and SLI children be distinguished from control children on the basis of their rhyme oddity performance?
2) What is the variability of performance within the at-risk group?
3) Can the data be accommodated within the phonological deficit hypothesis of dyslexia?
4) Can the findings of the at-risk and SLI group be accounted for by the single source, comorbidity, or qualitative difference hypothesis?

The answer to *Question 1* is that, despite discernible differences between the three groups on the oddity task, these differences failed to reach significance on subject analysis. There is thus only a trend of poorer performance of the two groups. Nevertheless, it moves in the expected direction, with the control group showing best performance, followed by the at-risk group, and the SLI group. A possible explanation for this absence of a significant group effect is the substantial standard deviation, especially in the at-risk and SLI groups.

All three groups showed a similar pattern, with rhyme and nucleus odd-ones-out leading to higher proportions correct than the condition in which only the final consonant changed. This matches findings of normally developing children (De

Cara and Goswami 2003, Kirtley et al. 1989) and extends them to at-risk and SLI children.

These findings are not surprising from the point of view of phonological acquisition and phonological theory. Development of perception and production of codas is relatively late compared to onset and vowel acquisition (Fikkert 1994, Zamuner 2006). In terms of phonological theory, it has been noted that codas are psychologically less prominent positions and are more subject to (neutralising) changes, than, for example, onsets (Beckman 1998, Steriade 1995). They are typologically less frequent (Levelt & van de Vijver 2004) and more marked (e.g. Blevins 1995).

Furthermore, differences were visible within the coda condition. Odd-one-out items with more feature changes (being more phonetically distinct) led to higher correct scores than those with single feature changes, as found by Snowling, Hulme, Smith and Thomas (1994) for six-and eight-year-old normally developing children. However, these findings should be interpreted with caution, as there were confounding factors, such as the position of the odd-one-out in the series, and only a limited number of test items. A more controlled design with more items could shed light into the nature of the difficulties, whether they are, for example, caused by perception, phonological restrictions, and attention and memory span.

Within-group variability of the rhyme data (*Question 2*) found heterogeneous group results. Approximately one third of the at-risk and SLI groups performed poorly on the oddity task. The majority of the at-risk group performed well, whereas only one third of the SLI children did. The results thus showed only subtle between-group and within-group differences. This could partly be due to the finding that the rhyme oddity task it not a strong predictor of phoneme awareness or literacy (for an overview, see Castles & Coltheart 2004 and MacMillan 2002). Rhyme detection or production, instead of oddity, could have led to stronger results (see Carroll & Snowling 2004, Muter et al. 1997, 2004) or an oddity task could have been presented using different test methodology, such as eyetracking (Desroches, Joanisse & Robertson 2006).

The present findings tend towards phonological awareness difficulties in the at-risk group. A stronger effect was expected on the basis of the phonological deficit hypothesis (*Question 3*). A different experiment might have yielded stronger evidence for this hypothesis. The present results, however, can also be subsumed in this model. Furthermore, they indicate the need for tasks to be phonologically-informed, as different results were obtained for different syllable constituents.

The data also established lower scores for the at-risk and SLI group, with a mean lower performance of the SLI group. Nevertheless, only one third of both groups performed poorly compared to the control group. These findings can be accounted for by the comorbidity, the single source, and the qualitative difference hypothesis (*Question 4*). The comorbidity model suggests that only those SLI

children that will develop dyslexia will display poor phonological awareness. The present data cannot rule out this option, as the poor performers could be the ones to develop dyslexia. If this assumption is true, then on the basis of these data, one third of the at-risk group (the poor performers of this group) is expected to become dyslexic as well. The validity of these suppositions can only be assessed once the children have started reading instruction.

With respect to the single source and qualitative difference hypothesis, both predicted phonological difficulties in the at-risk and SLI group. It is difficult to contribute to the debate between the models on the basis of the current findings, as the error patterns of both groups were the same, and scores only differed in severity. Thus, later measures of reading ability of these children are necessary to decide between these three models.

7.5 Conclusions

A rhyme oddity task was presented to five-year-old children at-risk of dyslexia, children with SLI, and normally developing children. The aim was to establish whether difficulties were present for the at-risk and SLI groups on this task. This would be expected on the basis of the phonological deficit hypotheses of dyslexia and the models on the relationship between dyslexia and SLI.

The findings of a trend of poorer correct scores of the at-risk and SLI groups compared to the control group can be aligned with the phonological deficit hypothesis, which assumes that phonological representation and subsequent phonological awareness abilities are poorer in children with (a risk of) dyslexia than in normally developing children.

The results of the rhyme oddity task can be accounted for by all three hypotheses on the relationship between dyslexia and SLI, the single source, the comorbidity, and the qualitative difference hypothesis.

This concludes the experimental section of this thesis. Chapter 8 will summarise the findings and answer the general research questions presented in Chapter 1.

Appendix 1. *Stimuli of the rhyme oddity task*

Change	Position				Odd-one
	1	2	3	4	
practice	Rat (Rat)	Mat (Mat)	Kat (Cat)	*Trui* (Jumper)	4
practice	Glas (Glass)	Jas (Jacket)	*Stoel* (Chair)	Tas (Bag)	3
VC	Kast (Cupboard)	Mast (Mast)	Kwast (Brush)	*Fiets* (Bicycle)	4
VC	Plant (Plant)	*Jurk* (Dress)	Mand (Basket)	Want (Mitten)	2
VC	Trein (Train)	Wijn (Wine)	Lijn (Line)	*Ster* (Star)	4
VC	*Bank* (Sofa)	Mond (Mouth)	Rond (Round)	Hond (Dog)	1
VC	Zwaard (Sword)	Paard (Horse)	*Bloem* (Flower)	Taart (Cake)	3
VC	Bed (Bed)	*Tor* (Beetle)	Net (Net)	Pet (Cap)	2
VC	*Riem* (Belt)	Beer (Bear)	Veer (Feather)	Peer (Pear)	1
VC	Slak (Snail)	Dak (Roof)	Zak (Bag)	*Oog* (Eye)	4
VC	Vlam (Flame)	*Bot* (Bone)	Kam (Comb)	Lam (Lamb)	2
VC	Sok (Sock)	Hok (Kennel)	*Wieg* (Cradle)	Klok (Clock)	3
C	*Vis* (Fish)	Schip (Ship)	Kip (Chicken)	Lip (Lip)	1
V	*Oor* (Ear)	Vier (Four)	Mier (Ant)	Stier (Bull)	1
V	Kraan (Tap)	Maan (Moon)	Zwaan (Swan)	*Been* (Leg)	4
V	Kan (Jug)	Man (Man)	*Zon* (Sun)	Pan (Pan)	3
V	Web (Web)	Step (Scooter)	*Pijp* (Pipe)	Schep (Spade)	3
C	*Fluit* (Whistle)	Muis (Mouse)	Kruis (Cross)	Huis (House)	1

C	Blok (Block)	*Pop* (Doll)	Rok (Skirt)	Kok (Cook)	2
C	Mes (Knife)	Fles (Bottle)	Zes (Six)	*Pen* (Pen)	4
C	Haas (Hare)	Kaas (Cheese)	*Haan* (Cock)	Vaas (Vase)	3
V	Boek (Book)	*Draak* (Dragon)	Doek (Cloth)	Broek (Trousers)	2

8

Synthesis of the findings

8.1 Introduction

The present chapter summarises the main findings of this thesis and provides answers to the research questions addressed in Chapter 1. These questions were concerned with the phonological abilities of Dutch-speaking children at familial risk of dyslexia and children with specific language impairment (SLI). It was assessed whether difficulties arose on several tasks, and whether the difficulties were the same for the at-risk and SLI groups. Furthermore, the results were used to evaluate the phonological deficit hypothesis of dyslexia, as well as three hypotheses on the relationship between dyslexia and SLI, the single source, the comorbidity, and the qualitative difference models.

This chapter is organised as follows. First, a summary of the findings is presented (8.2) containing the results of Chapters 3 to 7 (8.2.1), as well as correlation analyses between the different tasks (8.2.2). A discussion of the implications of these results for the relevant theories on dyslexia and SLI follows in the next paragraph (8.3). This evaluation is followed by the clinical implications (8.4), and suggestions for further research (8.5). The conclusion (8.6) wraps up the findings of this thesis.

8.2 Summary of findings

To recapitulate, the general research questions were:

1) Do children at-risk of dyslexia experience difficulties in their phonological acquisition?
2) Do the children at-risk of dyslexia and children with SLI show similar areas of weakness and similar performance in phonological acquisition?

A number of different tasks were presented to the at-risk, control, and SLI children, tapping phonological acquisition (speech production, word stress, morpho-phonological alternation of the plural), as well as phonological processing and awareness (non-word repetition and rhyme oddity). Summaries of the results of these experiments are provided in this section, as well as correlation analyses between the tasks.

8.2.1 Summary per chapter

The results per chapter will be described. An overview is also presented in Table 1. *Chapter 3* reported on two studies assessing *speech production* of at-risk children through a picture naming task. Study 1 contained 2;6-year-old at-risk and control children. Study 2 included three-and-four-year-old at-risk, SLI, and control children. Whereas differences on quantitative (percentages phonemes correct and phonological mean length of utterance) and qualitative measures (truncation, onset consonant cluster-, dorsal-, and fricative avoidance) were not found between the control and at-risk group at 2;6, differences were clearly visible for the three-and-four-year-olds. An interpretation that was put forward for the absence of differences at 2;6 was that at this young age, normally developing children were still acquiring their phonology as well. Differences can only be discerned when the phonology of these children has developed. Indeed, the differences between the three-and four-year-old control and at-risk groups imply at least mildly delayed phonological behaviour of the at-risk group. Furthermore, more than half of the at-risk group performed more poorly than the control group, indicating that difficulties were present in a substantial number of the at-risk children. This finding could align with the finding that between 30 and 60% of the at-risk children will turn out to be dyslexic on the prediction that the language-delayed children become dyslexic (see Chapter 1).

Additionally, whereas both the at-risk and SLI group performed more poorly than the control group, difficulties were more severe in the SLI than the at-risk group. The types of phonological simplifications were generally the same and suggested a delay in acquisition. The majority of children with SLI displayed difficulties on the speech production measure.

Stress competence of three-year-old at-risk and control children was investigated in *Chapter 4*. The children had to repeat non-words with stress patterns varying in regularity, ranging from highly regular to highly irregular to prohibited stress. Both the at-risk and control children performed better on imitation of regular stress targets and worse on irregular and prohibited stress patterns. However, the at-risk children showed more difficulty imitating irregular and prohibited patterns, and had lower percentages phonemes correct than the control group. The results suggest a delay in word stress acquisition in the at-risk group. Approximately one fifth of the at-risk children showed word stress difficulties relative to the control group. Furthermore, there seemed to be a relationship between stress regularity and percentages phonemes correct, with regular stress patterns yielding the highest percentages correct and irregular and prohibited patterns the lowest.

The second part of the chapter compared word stress abilities of school-going dyslexic and normally reading children. The former group still showed more difficulty with word stress assignment, especially with realisation of highly irregular

and prohibited stress types. More than a third of the dyslexic children performed more poorly than the control group on this measure. Furthermore, the percentages phonemes correct were lower for the dyslexic than the control children. The results thus pinpoint a persistent word stress deficit in dyslexia.

Chapter 5 dealt with the question of whether potential poor phonological representations of five-year-old at-risk children would impact on the morpho-phonological process of *voicing alternation of the plural*. Performance of the at-risk group was compared to that of the SLI group on a plural elicitation test with words and non-words. Alternation, a measure of phonological representation, plural realisation, and realisation of the voicing contrast of the three groups were compared.

Alternation was a markedly infrequent strategy in all three groups. The alternation pattern of the SLI group differed from those of the at-risk and control children, and resembled those of younger normally developing children. The phonological measure, rhyme realisation of singulars, did not yield significant differences between the three groups. This measure was not correlated with alternation behaviour. Thus, the quality of phonological representations did not affect the pattern of morpho-phonological alternation.

Furthermore, the SLI group showed more difficulty with plural marking and realised the voicing contrast differently, reminiscent of younger normally developing children. The results indicate differences between the control and at-risk groups on the one hand, and the SLI group on the other.

The literature on dyslexia and SLI has established that non-word repetition is a (potential) marker of dyslexia and language impairment. The comparison on this measure of *phonological processing* between four-year-old children at-risk of dyslexia and children with SLI was reported in *Chapter 6*.

A non-word repetition deficit was attested for the at-risk and SLI groups. Within-group distribution found that the 95% of the SLI and 56% of the at-risk children performed poorly on the non-word repetition task compared to the control mean, suggesting that poor non-word repetition is a core characteristic in both groups. Furthermore, differences were found between the error patterns of the (control and) at-risk and SLI groups. Performance of the SLI group, for example, was affected more by increasing target length of the non-words, showed significantly more coda addition and syllable omission, and exhibited both pre- and post-stress syllable substitution, whereas the control and at-risk group mainly applied pre-stress syllable substitution.

Chapter 7, finally, described the results of a rhyme oddity task presented to five-year-old at-risk and SLI children. Despite a staircase pattern of performance of

control > at-risk > SLI, significant group differences were not attested on subject analysis on this measure of *phonological awareness*. Approximately one third of the at-risk and SLI groups performed more than one standard deviation below the mean of the control group. The findings thus showed subtle differences on this measure of phonological awareness.

The design further revealed that for all three groups, it was more difficult to find the odd-ones-out that only differed on the final consonant, compared to changes of the entire rhyme or the vowel. This shows that the prominence of the change affects performance on the oddity task. Additionally, the position of the odd-one-out turned out to have an undesired impact on the selection of the odd-one-out.

Table 1. Overview of the results per age group and experiment.

Age	Cohort	Measure	Chap	Significant differences	>-1sd	
2;6	Baby	Speech production	3	---	Control At-risk	20% 12%
3;10	Toddler	Speech production	3	- Quantitative measures: PPC, PMLU - Qualitative measures: avoidance counts	Control At-risk SLI	20% 55% 90%
3;0	Baby	Word stress competence	4	- Identical stress score - PPC	Control At-risk	14% 18%
9;1	School	Word stress competence	4	- Identical stress score - PPC	Control Dyslexic	13% 37%
5;0	Toddler	Voicing alternation of the plural	5	- Plural correct - Correct alternation words - Correct non-alternation words - Non-alternation of non-words	Control At-risk SLI	15% 46% 42%
4;6	Toddler	Non-word repetition	6	- Raw score - Phoneme analyses - Syllable analyses	Control At-risk SLI	19% 56% 95%
5;0	Toddler	Rhyme oddity	7	---	Control At-risk SLI	17% 30% 35%

These findings suggest that a phonological deficit is present in part of the at-risk and SLI children. However, despite the finding that the at-risk and SLI groups generally showed difficulties on similar skills, differences between the groups were also

clearly discernible. The implications for the hypotheses on dyslexia and SLI will be discussed in Section 8.3.

An issue that remains to be explored is whether the at-risk children whose performance was lower than that of the control mean will turn out to be the true at-risk children, i.e., those who will actually develop dyslexia. Once reading abilities can be determined the relationship between reading performance and results of the experimental tasks can be established.

8.2.2 Correlations between the tasks

One main aim of this thesis was to further explore the phonological deficit hypothesis of dyslexia. Tasks were designed to tap phonological skills of children at-risk of dyslexia. Secondly, the comparison between at-risk and SLI children was conducted to gain further insight into the phonological skills of both groups. The fact that five different tasks measuring phonological representations all converged on the same general pattern of results strongly suggests phonological difficulties in the at-risk group. Difficulties on the same tasks were also attested in the SLI group. In order to assess whether all tasks at least partly assessed phonological abilities and whether the results of the different tasks were related, correlation analyses were conducted.

With respect to the *baby group*, correlation analyses could be conducted for two tasks, the task measuring speech production (Chapter 3, Study 1), obtained when children were 2;6, and the non-word repetition task assessing word stress competence (Chapter 4, Study 1), assessed at 3;0. Data of only a limited number of the sample could be used for the analysis, as the sample studied in Chapter 3 was small. The results are presented in Table 2. Only significant results will be discussed here.

Table 2. Correlation values of the tasks conducted with the 'baby' group.

Variable	Speech production PPC (Chapter 3)	
Word stress Identical score (Chapter 4)		
All participants	0.51*	n=20
Control group	0.53	n=9
At-risk group	0.56	n=11

Note: correlation values are Spearman's rho. *p<0.05, ** p<0.01

Data of the children who completed both tasks show a moderate correlation between speech production, measured through the percentages of phonemes correct (PPC), and the word stress task, measured through the proportion of identically realised targets. Thus, a higher score on the speech production task could move in tandem

with a higher score on the word stress task. For the control and at-risk group, separately, however, no significant correlations were obtained. This is most likely due to the low number of children within this analysis.

For the *toddler group*, correlation analyses were computed for four tasks; speech production (Chapter 3, Study 2, three-and-four-year olds), the repetition of word and non-word singulars (Chapter 5, five-year-olds), the non-word repetition task (Chapter 6; four-year-olds), and the rhyme oddity task (Chapter 7; five-year-olds). Statistics are reported in Tables 3 to 6.

The correlations between the tasks with all available data were all significant. Correlations were moderate for the percentage consonants correct on speech production (PCC) and the non-word repetition task's (NWR) percentage phonemes correct, as well as speech production and the proportion correct in the rhyme oddity task. A weak correlation was attested for all other pairs of tasks.

Table 3. Correlation values of the tasks conducted with the 'toddler' group, all data.

Variables		1		2		3		4
1	Speech production PPC (Chapter 3)							
2	Rhyme realisation correct (Chapter 5)	0.34*	n=40					
3	Non-word repetition PPC (Chapter 6)	0.63**	n=41	0.29**	n=94			
4	Rhyme oddity correct (Chapter 7)	0.51**	n=37	0.30**	n=88	0.38**	n=89	

Note: correlation values are Spearman's rho. *p<0.05, ** p<0.01

Table 4. Correlation values of the tasks conducted with the 'toddler' group, control data.

Variables		1		2		3		4
1	Speech production PPC (Chapter 3)							
2	Rhyme realisation correct (Chapter 5)	0.04	n=8					
3	Non-word repetition PPC (Chapter 6)	0.00	n=8	0.05	n=26			
4	Rhyme oddity correct (Chapter 7)	-0.03	n=10	-0.27	n=20	-0.27	n=23	

Note: correlation values are Spearman's rho. *p<0.05, ** p<0.01

Table 5. Correlation values of the tasks conducted with the ‘toddler’ group, at-risk data.

	Variables	1	2	3	4
1	Speech production PPC (Chapter 3)				
2	Rhyme realisation correct (Chapter 5)	0.36 n=26			
3	Non-word repetition PPC (Chapter 6)	0.52** n=25	0.31* n=51		
4	Rhyme oddity correct (Chapter 7)	0.49* n=20	0.28* n=52	0.55** n=46	

Note: correlation values are Spearman’s rho. *p<0.05, ** p<0.01

Table 6. Correlation values of the tasks conducted with the ‘toddler’ group, SLI data.

	Variables	1	2	3	4
1	Speech production PPC (Chapter 3)				
2	Rhyme realisation correct (Chapter 5)	-0.71 n=6			
3	Non-word repetition PPC (Chapter 6)	0.62 n=8	0.14 n=17		
4	Rhyme oddity correct (Chapter 7)	0.46 n=7	0.52* n=16	-0.09 n=20	

Note: correlation values are Spearman’s rho. *p<0.05, ** p<0.01

Analyses for the groups separately did not yield significant correlations for the control group. For the SLI group, a significant moderate correlation was found for the rhyme oddity task and the rhyme realisation singular score. The absence of further significant correlations for the control and SLI group could be due to the relatively low number of data points available.

For the at-risk group, however, five out of six correlations were significant. A moderate correlation was found for the speech production task and NWR and the NWR and the rhyme oddity task. Speech production and rhyme oddity, NWR and the rhyme correct score, and the rhyme correct score and the rhyme oddity results showed a weak correlation.

These correlation analyses suggest that there is a relationship between the children performing well or poorly on one task and well or poorly on another. Furthermore, even though the tasks all assess performance on different phonological

levels, they all tap the domain of phonology. Nevertheless, other (non-phonological) skills are most likely involved as well (see also Szenkovits & Ramus 2005). In the rhyme oddity task, for example, a working memory, cognitive, and attention component play a more substantial role than in, for instance, the picture naming task measuring speech production. Picture naming, in its turn, demands access to vocabulary, which is not primary in tasks of non-word repetition. Despite these different task demands, results of the tasks are (partly) related.

The findings summarised and presented above will now be interpreted within the phonological deficit hypothesis of dyslexia and the hypotheses on the relationship between dyslexia and SLI.

8.3 Implications for the hypotheses on dyslexia and SLI

8.3.1 The phonological deficit hypothesis of dyslexia

The results of this thesis were obtained to evaluate the phonological deficit hypothesis of dyslexia. This hypothesis assumes that construction and/or retrieval of phonological representations in children with (a risk of) dyslexia is poor. If this is the case, then the at-risk group should show poorer performance on tasks tapping phonological representation through measures traditionally used in dyslexia research, as well more linguistically-informed tasks. This latter approach allows for systematic investigation of phonology. In other words, it can assess whether at-risk children display difficulties in their language acquisition, what the locus of difficulties is (e.g. with features, phonemes, syllable-structure, word-level), and whether the error patterns resemble those found in typical development.

Generally, the data of both traditional phonological measures used in dyslexia research as well as linguistically-based measures can be accommodated within this hypothesis, as the at-risk group showed significantly poorer performance on most tasks. There were significant differences between the control and at-risk group on measures of speech production for three-and-four-years-olds (Chapter 3), word stress assignment at age three (Chapter 4), and non-word repetition at age four (Chapter 6). Furthermore, in experiments that did not yield significant group differences, a trend of lower performance of the at-risk group was attested: this was the case for the measure of phonological representation in the alternation task, rhyme realisation singular of the plural elicitation task (Chapter 5), and on rhyme sensitivity (Chapter 7). With respect to error analyses, these showed that the control and at-risk groups generally showed similar types of errors.

The findings on phonological acquisition of at-risk children indicated a (subtle) delay with word stress acquisition, metrical structure (weak-syllable truncation was more frequent in children at-risk of dyslexia), acquisition of syllable structure (increased onset consonant cluster avoidance), and phonemes and features (onset dorsal and fricative avoidance), thus spanning many ‘levels’ of representation. It thus seems that acquisition of both the word frame (metrical and syllable structure)

and its content (phonemes, features) were more difficult for the at-risk than the control children. At the same time, it also became evident that some aspects were more difficult to acquire than others. Alternation of the plural was similar for the at-risk and control groups, for example, whereas word stress assignment and speech production was more difficult for the at-risk group. Within tasks, differences were also discernible. Speech production, for example, showed that consonant cluster avoidance occurred much more often than fricative avoidance in the sample of at-risk children (even though the control children showed a much smaller difference between occurrences of these processes). These findings show that the notion of 'a phonological deficit' is too crude, as distinctions can be found for different levels of representations at different ages.

The word stress assignment task was also conducted with children with diagnosed dyslexia (instead of those still only at risk). The results confirmed persistent phonological difficulties in dyslexia, again suggesting a delay in the phonological acquisition of this population. These results can also be incorporated in the phonological deficit hypothesis.

However, the absence of any significant differences whatsoever on the task of speech production at 2;6 were discordant with this hypothesis. Future research with data of more control and at-risk children should be coupled with speech perception data to explore a potential deficit in greater detail. The interpretation proposed here is that expressive differences between the at-risk and control groups can only be discerned once the development of the control group is well underway and more subtle distinctions have to be acquired. This might not yet have been the case for the 2;6-year-old control children.

These findings have thus shown the need to explore the phonological deficit in children with (a risk of) dyslexia by including linguistic assumptions and subsequent research into both segmental as well as suprasegmental abilities. As the findings of the experiments conducted here from three years onwards have found difficulties at all levels assessed, it seems that the phonological deficit ranges from feature to word-level. These results lead to the question whether differences between the at-risk and control children can also be discerned 'higher' up in prosody, such as intonation, in the area of morpho-phonology, and in speech perception. The sub-lexical deficit hypothesis by Ramus (2001) is the only phonological deficit hypothesis to include a linguistic perspective. The present results have shown that such an approach is crucial for further qualification of the phonological deficit and that this hypothesis is more in concordance with observations than the 'traditional' phonological deficit hypothesis

However, it also raises the question which linguistic theory should be applied. The sub-lexical deficit hypothesis, for example, takes a generative grammar as framework. This framework makes a distinction between acquisition of phonological rules and the lexicon. Other theories, such as connectionist models, do

not incorporate these levels, but devote much attention to lexical learning, processing and pattern abstraction. The aim of this thesis was not to evaluate different theories of language learning. The tasks and expectations were geared towards a comparison between at-risk (and SLI) and control children and did not incorporate measures that could decide between models of generative grammar or analogical learning. Future work could undertake a comparison between theories. Such a comparison would be complex, and needs to take phonological regularities, vocabulary, differences between performance on words and non-words, and memory skills, among others, into account.

A related, residual issue is whether the findings point towards a (phonological) processing limitation or a language acquisition delay. It is, however, difficult to tease these two apart, as a processing component was involved in all experimental tasks presented here. Similarly, all tasks included language-specific stimuli, even the phonological processing measure. Thus, all tasks tapped both processing and language skills. It is evident that the present findings alone cannot contribute to the discussion about a processing or a representation deficit, as both could be affected in the at-risk (and SLI) group and it is likely that the two interact. The phonological deficit hypothesis of dyslexia should thus most preferentially be embedded in a model of language learning that takes both elements into account.

On the assumption that a phonological deficit is a necessary condition for dyslexia to arise, the findings on within-group variability can be couched in the phonological deficit hypothesis. Given that on the basis of the literature, the number of children within the at-risk group expected to be dyslexic is between 30 and 60%, this percentage of children should also display difficulties on the phonological tasks in this thesis. Indeed, between one fifth (word stress assignment) and more than half of the at-risk group (speech production, non-word repetition) performed more than one standard deviation below the control mean. Additionally, data from the toddler group showed that of those children for whom data were available of at least three out of four tasks (speech production, NWR, rhyme oddity, rhyme singular of alternation), 25/49 at-risk children (51%) performed more poorly (>1 standard deviation below the control mean) on at least two of these measures, compared with only 2/21 (10%) control children. This is by and large in line with the phonological deficit hypothesis as well as previous precursor studies of dyslexia.

Finally, the present findings can be accommodated within the viewpoint that dyslexia is a multifactorial trait (Vellutino et al. 2004); in this interpretation there is a gradation of risk for becoming dyslexic resulting from the interaction of the child's particular genetic endowment, environmental factors, such as socio-economic background, but also the orthography that has to be learnt, neurobiological make-up, and cognitive abilities. In this model, the cognitive deficit in phonological processing, which is also on a continuum, constitutes an important risk factor. Skills drawn from, for example within the oral language domain, such as syntax,

semantics, and vocabulary, might protect children from reading failure or might aggravate this risk (e.g. Snowling 2000). Future analyses will further compare the children's performance on the phonological tasks with those on other language skills, such as grammatical morphology (de Jong, Wijnen & de Bree in preparation, Wilsenach 2006) and vocabulary to gain a linguistic profile of each individual child. Such a comparison, related to future reading performance, can be expected to yield further insight into the cognitive risk factors and compensatory strategies of at-risk children.

8.3.2 The single source, comorbidity, and qualitative difference hypotheses of dyslexia and SLI

Data were also collected to assess three hypotheses on the relationship between dyslexia and SLI. In contrast to the single source hypothesis, which purports that the disorders are caused by the same underlying deficit and can thus be seen as one disorder, the comorbidity, and qualitative difference models assume that dyslexia and SLI are distinct. However, whereas the qualitative difference hypothesis assumes that dyslexia and SLI overlap on difficulties with phonology but not on non-phonological measures, the comorbidity hypothesis claims that phonological difficulties only surface in children with dyslexia and not in the children with only SLI.

A direct comparison of the models is hampered by the fact that dyslexia cannot yet be diagnosed in the groups, as the children are too young to read and write. Only once these data have been obtained, can we establish whether those at-risk children performing more poorly than the control group are the dyslexic children. Additionally, only at this stage can it be assessed which SLI children are dyslexic as well as language impaired. This drawback is inherent to the prospective design of the study. However, the at-risk and SLI groups as a whole were expected to perform more poorly than the control group. Within-group variability could furthermore provide insight into the number of children exhibiting phonological difficulties within each group.

The results favour an approach of dyslexia and SLI as distinct disorders. Phonological difficulties were attested in both groups, which would also be in accordance with the single source hypothesis. However, differences between the groups arose on measures outside the phonological domain, such as plural marking (morphosyntax), which was more difficult for the SLI than the at-risk group, and alternation (morpho-phonology), where alternation patterns of the at-risk group resembled those of the control group, and those of the SLI group were reminiscent of younger normally developing children (Chapter 5). Furthermore, differences also surfaced within the phonological domain, for instance in the non-word repetition task (Chapter 6) where error patterns differed between the at-risk and SLI group. The latter groups showed a more severe effect of target length on the correct,

substitution, and omission scores, and more coda omission than the at-risk group, as well as both pre-and post-stress omission, compared with mainly pre-stress substitution of the at-risk group. Similarly, one SLI child displayed unusual errors on the speech production task, including pervasive weak-syllable truncation and consonant cluster omission, whereas none of the at-risk children did so (Chapter 3). Thus, superficially, the at-risk and SLI groups were similar with poorer performance than the control group, but closer inspection disclosed (subtle) qualitative differences between them. The language profiles of both groups seemed to be different.

Recent comparisons on both phonological and grammatical measures have reported similar phonological difficulties for dyslexic and SLI children, but differences between the groups on grammatical measures, in line with the qualitative difference hypothesis. Fraser and Conti-Ramsden (2005), for instance, found poorer phonological (awareness) abilities of (British English) dyslexic and SLI children, but only poorer grammatical skills for the SLI children. Puranik, Lombardino and Altmann (2007) assessed written language in (American English) dyslexic and SLI children and adolescents. They too reported phonological difficulties, such as poorer spelling accuracy, in both groups, but differences between the dyslexic and SLI children on grammatical measures, such as sentence production, which were only partly impaired in the dyslexic group. These studies indicate that the profiles of at-risk/dyslexic and SLI children may differ, with an overlap of poor phonology, but not necessarily poor grammatical ability.

Importantly, however, the present findings also established differences even *within* the phonological domain. These findings are similar to those of Rispens and Been (in press) who found differences on phonological measures of (Dutch) SLI and dyslexic children. Specifically, different error patterns were found on a phoneme deletion task, where both the dyslexic and SLI groups performed more poorly than the control group. Whereas the control and dyslexic groups had most difficulty with phoneme deletion in onset position, the SLI group displayed most difficulty with deletion of final consonants. Furthermore, on a non-word repetition task the SLI group reached the lowest correct scores but also showed a much stronger target length effect than the dyslexic group. Thus, phonology is an overlapping area of difficulty for both groups, but the difficulties may lead to different error patterns. Such findings match those of the present study with different error patterns between the at-risk and SLI groups.

The fact that a substantial number of children with SLI in the present thesis showed phonological difficulties seems difficult to align with the comorbidity hypothesis. This hypothesis anticipates that only those children with SLI who are also dyslexic will display phonological difficulties. On the speech production task (Chapter 3), eight out of ten SLI children were poor performers and on the non-word repetition measure (Chapter 6), excepting one child, all 22 SLI children belonged to

the ‘poorly’ performing group. It seems unlikely that more than 80% of the SLI sample would continue to become dyslexic, as the literature expects between 40-60% to do so. Thus, the pervasive phonological difficulties in the SLI group seem to rule out the comorbidity hypothesis. A definite answer can be provided once literacy skills develop and can be tested.

Instead, these findings support the qualitative difference hypothesis that proposes that SLI and dyslexia are distinct disorders but both show difficulties in the phonological domain. Furthermore, the results provide an extension of this model, as qualitative differences surfaced within the phonological domain. Thus, it is likely that other (cognitive and linguistic) factors impact on the phonological deficit. In other words, both dyslexia and SLI could (partly) be characterised by phonological difficulties, but the phonological impairments derive from (a mixture of) different causes. Such an interpretation has previously been proposed by Joanisse et al (2000). They assessed speech perception (categorical perception), phonology (phonemic awareness), and morphology (plural noun and past tense verb marking) in a group of eight-and-nine-year-old dyslexic children. On the basis of these results, the dyslexic group was divided in subgroups of phonological dyslexics, language-impaired dyslexics, and delay-type dyslexics. Whereas both the phonological and language-impaired dyslexics performed similarly on phonemic awareness and non-word reading, performance was different on the other measures. The language-impaired dyslexics showed difficulties with speech perception and morphology, but the phonological dyslexics did not. Thus, although the language-impaired and phonological dyslexic groups exhibited similar deficits in phonology and reading, their causes may differ. The ensuing phonological deficit then partly overlaps, but also shows differences.

An additional advantage of the qualitative difference hypothesis is that it can subsume views of dyslexia and SLI as multirisk disorders (see Bishop & Snowling 2004). As indicated in 8.3.1. above, dyslexia has been interpreted as a disorder with multiple interacting risk factors on genetic, environmental, neurobiological, and cognitive levels. A similar model has also been proposed for SLI (see Bishop 2001). Interpretation of both disorders as multifactorial with risk and compensatory (or protective) factors can further account for the heterogeneity within both disorders. Both disorders can be qualified by poor phonological abilities, but both are also dependent on other risk factors. This model relates coherently to neurobiological and genetic findings of research into dyslexia and SLI (see Bishop & Snowling 2004 for an overview).

8.4 Clinical implications

A number of findings of this dissertation might be relevant for clinical practice. Importantly, the results have established that phonological difficulties are present in children at-risk of dyslexia (and children with SLI), further underscoring the

linguistic basis of dyslexia. The non-word repetition task proved to be an especially powerful measure for language impairment as well as screening potential true at-risk children. After standardisation research of this measure, it might be used in clinical practice (Gerrits in preparation).

The findings have further shown that the phonological deficit of dyslexia extends beyond traditional measures of phonological processing and awareness. Thus, training of language-specific sounds and patterns could assist not only children with SLI, but also children at-risk of dyslexia. Intervention can start prior to reading instruction. Furthermore, it could exceed the segmental level, as realisation of suprasegmental structures such as word stress, rhythmical patterns, and consonant clusters also differed between the at-risk and control group.

The findings suggest that dyslexia and SLI are separate disorders, with overlapping phonological difficulties. Nevertheless, qualitative differences arose within the phonological domain. This suggests that speech and language therapy would be beneficial for both groups, but different nuances in treatment might be required for the groups.

At a methodological level, it was found that for speech production, percentages of phonemes correct and phonological mean length of utterances yielded similar results and were highly correlated with each other. This implies that selection of either of these measures for assessment might suffice.

8.5 Suggestions for further research

Due to time-constraints, literacy results and speech perception data are not part of this thesis. Future research will have to establish whether the (future) dyslexic children in the at-risk group were those labelled as ‘poor performers’ on the phonological tasks in the current investigation. This information will contribute to further interpretation of the phonological deficit hypothesis of dyslexia, as well as more definitively decide between the comorbidity and qualitative difference hypotheses of dyslexia and SLI.

Additionally, the notion of a phonological deficit in dyslexia, as well as phonological difficulties in dyslexia and SLI should ideally be assessed through both perception and production studies. This dissertation focused on phonological production. Perception studies with these same children have shown that phonemic mispronunciations (e.g. *zebra* ‘zebra’ presented as *vebra*) were harder to detect for five-year-old at-risk and SLI children than the control group (van Alphen et al. 2004) and that categorical perception of /p/ and /k/ was more difficult for three-and-four-year-old at-risk and SLI children (Gerrits 2003). Some comparisons between perception and production data have been made. Inspection of the categorisation task and the speech production measure at three years of age, for example, revealed a substantial overlap of at-risk, and to a lesser extent, SLI children, performing poorly on both tasks (Gerrits & de Bree in preparation). Furthermore, preliminary

investigation into the role of metrical stress in comprehension and production of three-year-old at-risk children suggests that the at-risk group showed more difficulty with both tasks (van Alphen, de Bree, Fikkert & Wijnen submitted) Additionally, with respect to the at-risk group, data on phoneme mismatches in word recognition with two-year-olds are pending (van Alphen, Fikkert & Wijnen in preparation). Once these have been obtained, a comparison between ‘poor performers’ on the perception and production task can be made.

Next to relating these literacy and perception findings to the data of this thesis, at least five avenues of research can be proposed to further explore the phonological deficit. One area that deserves more attention, for example, is (word) stress acquisition. A word stress delay was attested for at-risk and dyslexic children. This raises the question whether acquisition of higher-level stress, such as phrasal stress, or morphologically-influenced stress assignment, such as stress in derived words, are also delayed. Such experiments can provide further insight on the locus of phonological deficit in children with (a risk of) dyslexia. Related, a cross-linguistic comparison of stress acquisition of at-risk children between languages with varying stress systems would lead to new perspectives on the phonological deficit. A possible comparison would be of at-risk children learning a language with fixed stress, such as French (final) and Finnish (initial), a language with predominantly lexical stress, such as Russian, and a language with a combination of lexical and rule-based stress, such as Dutch. On the basis of the present findings, it would be expected that regular stress (rule-based stress and stress in fixed position) should not be difficult to acquire, whereas lexically learned stress might be more problematic. Such a comparison could shed light on the role of phonological regularities, lexical learning, and (phoneme) segmentation in stress acquisition and could yield further insight into the nature of the phonological deficit.

Secondly, it was found that phonological difficulties did not impact on the production of voicing alternations of the plural, but it would be interesting to investigate whether this is the case for a more productive morpho-phonological process, such as selection of the *–s* or *–en* nominal plural suffix. Selection of this plural suffix is guided by phonological criteria such as rhythmic patterns of the stem ant the sonority slope of its final rhyme (van Wijk 2007). Related, it will be interesting to see whether orthographic abilities impact on production of the voicing alternation of the plural.

Thirdly, the experiments here have generally focused on word and non-word realisations, whereas the question arises whether differences also occur in conversational speech. Assessment of conversational speech could further investigate skills such as co-articulation and intonation of at-risk and control children.

Fourthly, next to assessment of phonological skills in older children, it can also be determined whether phonology in even younger at-risk children shows traces of a

deficit. Not only can this assist in interpreting the absence of differences between the two-and-a-half-year-old at-risk and control children, it can also present information on the earliest signs of the phonological deficit. A study by Molfese (2000), for example, showed that auditory ERPs recorded within 36 hours of birth successfully discriminated at well above chance levels the reading performance of these same children eight years later.

Finally, it will be interesting to establish whether the phonological skills assessed here are also problematic for older dyslexics. The phonological deficit hypothesis would predict that this is still the case. Indeed, preliminary findings on the word stress task with dyslexic children have shown that difficulties are still present. Pursuing similar research with adolescents with dyslexia, who may have compensated for their reading deficits to a larger degree, would be informative in measuring the persistence of a phonological deficit and its relation to other reading and writing-related skills. Additionally, performance could be compared with SLI-only, as well as SLI+dyslexic children to shed further light on the relationship between the two disorders. In short, the phonological deficit of dyslexia deserves (even) further exploration.

8.6 Conclusions

There are two key messages of this thesis. First, the investigation of phonological development of children at-risk of dyslexia has established a phonological deficit from an early age onwards in children at-risk of dyslexia. The present findings suggest a delay in acquisition and specify the phonological deficit of dyslexia, which is necessary to understand dyslexia further. Specifically, the results imply that speech production, word stress production, and non-word repetition are potential linguistic precursors of dyslexia.

Secondly, despite the apparent overlap of a phonological deficit in both children at-risk of dyslexia and children with SLI, the two groups should not be collapsed into one, as error patterns of the groups differ. The findings support an approach of dyslexia and SLI as distinct disorders. These findings are best subsumed in the qualitative difference hypothesis of dyslexia and SLI.

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Samenvatting

Dyslexie is een stoornis die gekenmerkt wordt door aanhoudende problemen met het aanleren en het accuraat en/of vlot toepassen van het lezen en/of het spellen op woordniveau. Ondanks normale intelligentie en neurosensorische vermogens en adequaat onderwijs, houden dyslectici leesproblemen. Recent onderzoek toont aan dat 3,6% van de basisschoolkinderen in Nederland als dyslectisch kan worden aangemerkt (Blomert 2003). Bovendien heeft onderzoek aangetoond dat kinderen met tenminste één dyslectische ouder een verhoogd risico lopen zelf ook dyslectisch te zijn. Tussen de 30 en 60% van deze risicokinderen is dyslectisch. De taalontwikkeling van deze kinderen verloopt anders dan die van normaal ontwikkelende kinderen. Verder onderzoek naar de taalontwikkeling van (Nederlandse) risicokinderen is van belang om dyslexie nauwkeuriger te kunnen definiëren en om mogelijke vroege voorspellers van dyslexie te kunnen vinden.

Het project 'Early language development in specific language impairment and dyslexia: A prospective and comparative study' bestond uit vier deelprojecten (spraakperceptie en woordherkenning, fonologische vaardigheden, morfosyntactische ontwikkeling en syntactische verwerking). In het project werd een tweeledig onderzoek verricht. In de eerste plaats werd de hypothese getoetst dat kinderen met een familiaal risico voor dyslexie taalproblemen hebben. Ten tweede werd onderzocht of deze mogelijke taalproblemen lijken op die van kinderen met specifieke taalontwikkelingsstoornissen (SLI, specific language impairment). SLI is een taalontwikkelingsstoornis die ontstaat ondanks normale intelligentie en neurosensorische vermogens. Ongeveer de helft van kinderen met SLI heeft leesproblemen op school. Terwijl kinderen met dyslexie opvallen door hun lees- en spellingsproblemen en vaak een voorgeschiedenis van taalproblemen hebben, worden kinderen met SLI op jonge leeftijd gediagnosticeerd met taalproblemen en vertonen op schoolgaande leeftijd vaak lees- en spellingsproblemen. Bij zowel kinderen met (een risico voor) dyslexie als kinderen met een taalstoornis komen dus taal- en leesproblemen voor. De vraag is in hoeverre dyslexie en SLI dezelfde aandoeningen zijn.

Deze dissertatie: achtergrond en onderzoeksvragen

Het onderzoek waarover in dit proefschrift wordt gerapporteerd richtte zich op fonologische vaardigheden. Ten eerste werd een mogelijke fonologische stoornis in kinderen met een risico voor dyslexie bestudeerd. Een belangrijke hypothese in de literatuur is dat dyslexie door een fonologisch tekort veroorzaakt wordt. Er zijn verschillende versies van deze *fonologische tekorthypothese*, maar de algemene aanname is dat dyslectici moeite hebben met het construeren, vasthouden en ophalen

van fonologische representaties. Als dit zo is, dan kan verwacht worden dat fonologische verwerving van kinderen met een risico voor dyslexie moeizamer verloopt dan die van normaal ontwikkelende kinderen. Deze verwachting is nog nauwelijks getoetst; onderzoek naar fonologische vaardigheden is voornamelijk beperkt gebleven tot fonologische verwerking en fonologisch bewustzijn en spraakwaarneming. Fonologie en fonologische verwerving zijn nauwelijks bestudeerd. Met andere woorden, de hypothese van een fonologisch tekort is over het algemeen niet linguïstisch geïnformeerd. De enige uitzondering hierop is de sublexicale tekorthypothese (Ramus 2001). Deze hypothese gaat er expliciet vanuit dat problemen met de verwerving van fonologische structuren en patronen moeilijker zullen zijn voor kinderen met (een risico voor) dyslexie. De sublexicale tekorthypothese incorporeert bovendien een taalverwervingsmechanisme en geeft daarmee aan verder te kijken dan de andere fonologische tekortmodellen.

Om de reikwijdte van een fonologisch tekort vast te stellen besloeg dit fonologische deelproject onderzoek naar de verwerving van spraakproductie, woordklemtoon, en het morfofonologische proces van stemalternantie van meervouden bij risicokinderen. Daarnaast werden fonologische maten die vaak in dyslexie-onderzoek gebruikt worden, fonologische verwerking en fonologisch bewustzijn, bij de kinderen afgenomen. De bevindingen dragen bij aan de interpretatie van de fonologische tekorthypothese van dyslexie.

Het tweede doel van dit project was de vergelijking tussen mogelijke fonologische problemen van risicokinderen en die van kinderen met een specifieke taalontwikkelingsstoornis. De bevinding dat beide stoornissen gepaard gaan met spraak-, taal-, en leesproblemen, heeft geleid tot de vraag of dyslexie en SLI veroorzaakt worden door eenzelfde onderliggende stoornis, bijvoorbeeld in de linguïstische component fonologie. Over de relatie tussen dyslexie en SLI zijn in de literatuur drie modellen geformuleerd. Twee modellen nemen aan dat de kern van zowel dyslexie als SLI ligt in fonologische tekorten. Het eerste model stelt dat er een continuüm is tussen vroege spraak-taalproblemen en fonologisch gebaseerde leesproblemen. Dyslexie en SLI zijn in dit model dus kwalitatief hetzelfde. De factor leeftijd bepaalt of een kind als taalgestoord of dyslectisch aangemerkt wordt; jonge, voorschoolse kinderen vertonen een taalstoornis, terwijl op schoolgaande leeftijd de lees- en spellingsproblemen het duidelijkst aanwezig zijn. In deze hypothese vervaagt de grens tussen dyslexie en SLI en is er hoogstens een verschil in gradatie tussen SLI en dyslexie zichtbaar. De SLI kinderen laten slechtere spraak-taalprestaties zien dan de dyslectische kinderen. Deze aannames worden bevestigd als zowel de risico- en taalgestoorde kinderen problemen vertonen op fonologische maten, en de SLI kinderen in grotere mate dan de risicokinderen. Kwalitatieve verschillen tussen de groepen, bijvoorbeeld in foutenpatronen, worden niet verwacht.

Naast deze *enkele oorzaakhypothese* neemt ook *de kwalitatieve verschillenhypothese* aan dat fonologische tekorten een kernkenmerk zijn van dyslexie als SLI. In tegenstelling tot de enkele oorzaakhypothese gaat de kwalitatieve verschillenhypothese er vanuit dat dyslexie en SLI aparte aandoeningen zijn. Een fonologisch tekort is een gezamenlijk onderliggende risicofactor, maar bij SLI kinderen vormen bijvoorbeeld vocabulaire en morfosyntactische problemen een grotere risicofactor dan bij dyslectische kinderen. Deze hypothese veronderstelt dat naast kwantitatieve verschillen ook kwalitatieve verschillen tussen de groepen voorkomen. Binnen het domein van de fonologie zou deze hypothese bevestigd kunnen worden als groepsverschillen op zowel kwantitatieve als kwalitatieve analyses gevonden zouden worden.

Een derde model, *de comorbiditeitshypothese*, stelt dat fonologische problemen alleen een rol spelen bij dyslexie, niet bij SLI. Alleen SLI kinderen met zowel dyslexie als SLI vertonen dus fonologische problemen, kinderen met alleen SLI niet. Net als de kwalitatieve verschillenhypothese postuleert deze hypothese ook dat dyslexie en SLI kwalitatief niet hetzelfde zijn en dus beschouwd moeten worden als aparte aandoeningen. De verwachting van deze hypothese is dat er zowel kwantitatieve als kwalitatieve verschillen tussen de groepen voorkomen. Bovendien zal een beperkt deel van de SLI kinderen fonologische moeilijkheden laten zien, namelijk degenen die dyslectisch zijn (tussen de 40 en 60% van de SLI kinderen). Het is belangrijk op te merken dat tot op heden niet vastgesteld kon worden welke (risico, SLI en controle) kinderen dyslectisch zijn. Dit is immers pas mogelijk als de kinderen leesinstructie hebben gekregen. Met andere woorden, de vergelijking tussen de risico- en SLI kinderen geeft dus een indicatie over de haalbaarheid van de modellen; zekerheid kan pas worden verschaft als de kinderen leren lezen en schrijven. De kwalitatieve en kwantitatieve vergelijkingen die zijn gemaakt in dit proefschrift met betrekking tot fonologische vaardigheden van risicokinderen en kinderen met SLI kunnen bijdragen aan de discussie over de relatie tussen dyslexie en SLI.

In dit proefschrift werden aan de hand van verschillende experimenten twee vragen getoetst: 1) zijn fonologische problemen aanwezig bij kinderen met een familiair risico voor dyslexie? En 2) zijn deze problemen gelijk aan die van kinderen met een taalontwikkelingsstoornis?

Subjectselectie van de groepen werd beschreven in hoofdstuk 2. De bevindingen van de experimenten, weergegeven in hoofdstuk 3 tot en met 7, worden hieronder per hoofdstuk samengevat.

Samenvatting van de resultaten per hoofdstuk

Dan volgt nu een samenvatting van de belangrijkste resultaten per hoofdstuk. In *hoofdstuk drie* werd *spraakproductie* van risicokinderen bestudeerd aan de hand van resultaten op een plaatjesbenoemingstaak. In een eerste studie werden de data van

tweejarige risico- en controlekinderen vergeleken en in een tweede studie werd een vergelijking gemaakt tussen de resultaten van drie- en vier jarige risico, SLI en controlekinderen. Hoewel er geen kwalitatieve en kwantitatieve verschillen werden gevonden tussen de risico- en de controlegroep in de eerste studie, waren verschillen duidelijk zichtbaar bij de drie- en vierjarigen. De risicogroep presteerde op de kwantitatieve maten percentages fonemen correct (PPC) en fonologische gemiddelde uitingslengte (PMLU) tussen de controle en SLI groep in. Ook werden verschillen gevonden op de kwalitatieve maten truncatie (bijvoorbeeld *ballon* gerealiseerd als *bon*), onset consonantcluster- (*bloem* als *boem*), dorsaal,- (*kip* als *tip*) en fricatiefvermijding (*fiets* als *piets*).

De resultaten geven aan dat er sprake is van tenminste een milde stoornis op het gebied van verwerving van spraakproductie bij de risicokinderen. Bovendien presteerde meer dan de helft van de risicogroep relatief slechter dan de controlegroep. Dit toont aan dat problemen in een groot aantal van de risicokinderen aanwezig zijn.

Zowel de risico- als SLI kinderen lieten fonologische problemen zien, maar de risicogroep in mindere mate dan de kinderen met SLI. Het soort fonologische simplificaties dat voorkwam in beide groepen was over het algemeen hetzelfde en suggereert een vertraging in fonologische verwerving. De meerderheid van de kinderen met SLI vertoonde problemen op deze taak.

Klemtoontoekenning door driejarige risico- en controlekinderen werd onderzocht in *hoofdstuk vier*. In een experiment werden de kinderen gevraagd nonsenswoorden zoals *kákot* en *sotá* te herhalen met klemtoonpatronen die verschilden in regelmatigheid, variërend van heel regelmatig tot (hoogst) onregelmatig tot verboden. De regelmatige klemtoonpatronen waren het makkelijkst om goed te herhalen voor zowel de risico- als de controlekinderen en de hoogst onregelmatige en verboden klemtoonpatronen waren het moeilijkst. De risicokinderen hadden echter meer moeite met de herhaling van hoogst onregelmatige en verboden klemtoonpatronen dan de controlekinderen. Ze haalden bovendien een lager foneempercentage correct. Deze resultaten suggereren een vertraging in verwerving van woordklemtoon van de risicogroep. Ongeveer een vijfde van de risicokinderen liet sterke problemen zien vergeleken met de controlegroep. Er werd ook een relatie gevonden tussen de regelmatigheid van het klemtoonpatroon en het foneempercentage correct: hoe regelmatiger het klemtoonpatroon, hoe hoger het percentage fonemen correct.

Deze klemtoontoekenningstaak werd ook voorgelegd aan een groep acht- en negenjarige dyslectische en controlekinderen. In dit experiment waren ook verschillen zichtbaar tussen de dyslectische kinderen en de controlegroep, met name op de realisatie van hoogst onregelmatige en verboden klemtoonpatronen. Bovendien had meer dan een derde van de dyslectische kinderen beduidend meer

moeite met de taak dan de controlegroep. De foneempercentages correct van de groep dyslectische kinderen waren lager dan die van de controlekinderen. De bevindingen van studie 1 en 2 samen geven aan dat woordklemtoon een persistent probleem is in dyslexie.

Hoofdstuk vijf draaide om de vraag of de mogelijke zwakkere fonologische representaties van vijfjarige risicokinderen zouden leiden tot problemen met de verwerving van het morfofonologische proces van *stemalternantie in het meervoud* (vergelijk pet ~ petten, uitspraak [pɛt̠] ~ [pɛt̠ən] met bed-bedden, uitspraak [bɛt̠] ~ [bɛd̠ən]). Een vergelijking tussen risico, SLI en controlekinderen werd gemaakt op een *wug*–taak, waarin kinderen de meervouden van woorden en nonsenswoorden (bijvoorbeeld *flant* als *flanten* of *flanden*) moesten maken. Alternantie, een maat van fonologische representatie, meervoudsvorming, evenals het maken van het stemcontrast (/t/~/d/) werden in dit hoofdstuk vergeleken tussen de drie groepen.

Alternantie in alledrie de groepen was infrequent. Het alternantiepatroon van de SLI groep verschilde van dat van de risico- en controlegroep en deed denken aan dat van jongere kinderen. Als maat van fonologische representaties werd de rijmrealisatie van de enkelvouden van de (non-)woorden genomen. Er werd geen significant verschil gevonden tussen de groepen op deze maat. Bovendien waren de resultaten van de fonologische maat niet gecorreleerd aan alternantiegedrag. De kwaliteit van de fonologische representatie bepaalde dus niet of er alternantie voorkwam.

De studie liet verschillen zien tussen de controle- en risicogroep aan de ene kant en de SLI groep aan de andere kant. De SLI groep liet een ander alternantiepatroon zien, had meer moeite met het maken van meervouden en realiseerde het stemcontrast anders. Hun gedrag lijkt op dat van jongere normaal ontwikkelende kinderen.

In *hoofdstuk zes* werd verslag gedaan van een vergelijking tussen vierjarige risico-, controle- en SLI kinderen op een taak van *fonologische verwerking*. De risico- en SLI groep vertoonden beduidend lagere resultaten dan de controlegroep op een nonsenswoordrepetitietaak met doelvormen als *soteif* en *topeusiwoem*. Bovendien behaalde meer dan de helft van de risicokinderen (56%) en bijna alle SLI kinderen (95%) aanzienlijk lagere scores dan de controlegroep. Deze resultaten tonen aan dat problemen met herhaling van nonsenswoorden kenmerkend zijn voor beide groepen. Er werden verschillende foutenpatronen tussen de risico- en SLI groep gevonden. De scores van de SLI groep, bijvoorbeeld, werden meer door toenemende lengte van het doelwoord beïnvloed dan die van de controle- en risicogroep. De SLI groep liet ook meer coda-additie (bijvoorbeeld ji'nus als ji'nust̠) en syllable-omissie (bijvoorbeeld ji'nus als nus) zien. Deze groep vertoonde ook vervanging van hele lettergrepen voor en na de hoofdklemtoon, terwijl de controle- en risicogroepen

voornamelijk lettergreepsubstitutie lieten zien als de lettergreep voor de hoofdklemtoon stond.

Het laatste experimentele hoofdstuk, *hoofdstuk zeven*, deed verslag van een rijm *oddity* taak voorgelegd aan vijfjarige risico-, SLI en controlekinderen. Ze moesten aangeven welk woord uit een reeks niet rijmde op de andere woorden, bijvoorbeeld *jurk* in de reeks ‘plant-mand-want-jurk’.

In tegenstelling tot de verwachtingen werden geen significante groepsverschillen gevonden op deze maat van *fonologisch bewustzijn*, maar het resultatenpatroon ging wel in de verwachtte richting, met de hoogste correctscore voor de controlegroep en de laagste voor de SLI groep. De resultaten van ongeveer eenderde van de risico- en SLI groep waren meer dan een standaarddeviatie lager dan die van de controlegroep. Het foutenpatroon voor de drie groepen was hetzelfde; de kinderen hadden de meeste moeite met het vinden van een *odd-one-out* die alleen verschilde in de finale consonant en minder met veranderingen van het hele rijm of de klinker. De prominentie van de verandering in de odd-one-out beïnvloedde dus de prestatie op de oddity taak. De positie van de odd-one-out bleek ook een (onwelkom) effect op de correctscore te hebben.

Interpretatie van de bevindingen: het fonologische tekort in dyslexie

De resultaten van de experimenten laten een zelfde soort patroon zien (*hoofdstuk acht*): de risicokinderen en de SLI kinderen, daar waar deze laatste groep in de vergelijking werd meegenomen, hadden meer moeite met fonologische taken dan de controlegroep. Dit patroon werd over het algemeen gevonden op zowel taken die vaak gebruikt worden in dyslexie-onderzoek (fonologische verwerking en fonologisch bewustzijn) als de linguïstisch-gebaseerde taken (spraakproductie, klemtoontoekenning, en alternantie van het meervoud).

De bevindingen wijzen naar een fonologisch tekort voor de risicogroep als geheel. Dit tekort lijkt gekenmerkt te worden door een vertraging in de fonologische ontwikkeling. De risicokinderen lieten (subtiele) vertraging zien in klemtoonverwerving, verwerving van metrische structuur (meer truncatie in de controle- dan de risicogroep), verwerving van syllabestructuur (meer onset clustervermijding) en vertoonden meer foneem- en kenmerkvermijding (onset dorsaal- en fricatiefvermijding). Het fonologische tekort is dus zichtbaar op meerdere fonologische niveaus, zowel op het niveau van het woordskelet (metrische- en syllabestructuur) als de inhoud (fonemen en kenmerken). Tegelijkertijd werd duidelijk dat sommige aspecten moeilijker waren dan anderen. In tegenstelling tot spraakproductie en klemtoontoekenning, bleek de verwerving van alternantie van het meervoud bijvoorbeeld gelijk te zijn voor de risico- en controlegroep. Binnen de taken waren ook verschillen zichtbaar: de spraakproductietaak liet bijvoorbeeld zien dat consonant clustervermijding veel vaker voorkwam dan fricatiefvermijding. Deze

resultaten laten dus zien dat het concept van een 'fonologisch tekort' te weinig specifiek is, omdat onderscheid gemaakt kan worden tussen verschillende fonologische niveaus en fonologische vaardigheden op verschillende leeftijden.

De bevinding dat woordklemtoonverwerving van dyslectische kinderen (in plaats van risicokinderen) ook vertraagd was, vormt bewijs voor aanhoudende fonologische problemen in dyslectische populaties. De resultaten van dit experiment kunnen ingelijfd worden in de fonologisch tekorthypothese.

Deze dissertatie toont aan dat het fonologische tekort in kinderen met (een risico) voor dyslexie uitgebreid dient te worden door linguïstische aannames toe te voegen en onderzoek op meerdere fonologische niveaus uit te voeren. De verwerving van fonologische regels en patronen verdienen dus zeker de aandacht in dyslexie-onderzoek. De hypothese moet niet alleen gebaseerd zijn op psychologische maten van fonologie, zoals fonologische verwerking en fonologisch bewustzijn, maar dient ook een linguïstische invalshoek te incorporeren. Een dergelijke aanpak staat een systematische studie van de hypothese toe.

Toekomstig onderzoek zal moeten aantonen of de risicokinderen die slechter presteerden dan de controlegroep op deze experimentele taken ook daadwerkelijk de 'echte' risicokinderen zijn, dat wil zeggen, de risicokinderen die dyslectisch worden. Gemiddeld behaalden tussen een vijfde en meer dan de helft van de risicokinderen lagere scores op de fonologische taken dan het gemiddelde van de controlegroep. Dit getal komt overeen met het percentage kinderen dat op basis van de literatuur uiteindelijk dyslectisch zal worden (tussen de 30 en 60%). Op het moment dat leesvaardigheid van de risicokinderen vergeleken kan worden met de experimentele resultaten, kan de relatie tussen fonologische verwerving en dyslexie direct getoetst worden.

Inmiddels is wél duidelijk dat fonologische problemen aanwezig zijn in de risicogroep, een uitkomst die past binnen de interpretatie dat dyslexie een aandoening is met veel risicofactoren, waaronder genetische aanleg, omgevingsfactoren, zoals de thuissituatie en de te leren orthografie, neurobiologische structuur en cognitieve vaardigheden. In dit model vormen fonologische problemen een belangrijke cognitieve risicofactor. Compensatie of verslechtering kan ontstaan via andere vaardigheden, bijvoorbeeld binnen het taaldomein, zoals uit syntaxis, semantiek of vocabulaire.

Interpretatie van de bevindingen: de relatie tussen dyslexie en SLI

Daarnaast kunnen de bevindingen in dit onderzoek inzicht geven in de drie hypothesen die geformuleerd zijn over de relatie tussen dyslexie en SLI, de enkele oorzaak, de comorbiditeits- en de kwalitatieve verschillenhypothese. Ook al kunnen deze modellen pas met grotere zekerheid getoetst worden op het moment dat de leesvaardigheid van de kinderen bekend is en vastgesteld kan worden welke risico-

en SLI kinderen dyslectisch zijn, toch kan er al een eerste evaluatie gemaakt worden.

De resultaten pleiten voor een benadering van dyslexie en SLI als verschillende aandoeningen. In beide groepen werden fonologische problemen aangetoond. Dit kan ook verklaard worden door de enkele oorzaakhypothese, waarin enkel kwantitatieve verschillen verwacht worden. Echter, zowel binnen als buiten het fonologische domein werden verschillen tussen de groepen gevonden. Meervoudsvorming, een morfosyntactische vaardigheid, bijvoorbeeld, was moeilijker voor de risico dan de SLI groep. De SLI groep liet ook een ander alternantiepatroon zien, een morfofonologisch proces, dan de controle- en risicogroepen. Binnen het fonologische domein werden bovendien ook kwalitatieve verschillen gevonden, bijvoorbeeld in de foutenpatronen van de nonsenswoordherhalingstaak (hoofdstuk 6). Tevens vertoonde een SLI kind op de spraakproductietaak (hoofdstuk 3) ongebruikelijke simplificatieprocessen, zoals sterke en zwakke syllabetruncatie en consonant clusteromissie (in plaats van reductie). Geen van de risicokinderen produceerde uitingen met zulke ongebruikelijke processen. Deze kwalitatieve verschillen passen niet bij de interpretatie dat dyslexie en SLI dezelfde aandoeningen zijn. Oppervlakkig gezien zijn de fonologische problemen van de twee groepen hetzelfde, maar een meer nauwkeurige inspectie laat verschillen zien.

Kwalitatieve verschillen tussen risico- en SLI groepen zijn recentelijk ook door andere studies gerapporteerd. Deze studies laten voornamelijk zien dat verschillen tussen de groepen voorkomen op morfosyntactische maten. Deze dissertatie toont echter aan dat er ook binnen de fonologie al verschillen tussen de groepen optreden.

De uitkomst dat een substantieel aantal SLI kinderen in dit proefschrift fonologische problemen liet zien, lijkt moeilijk te verbinden met de comorbiditeitshypothese. Deze hypothese voorspelt dat alleen de kinderen met een taalstoornis die dyslectisch zijn fonologische tekorten zullen vertonen. De nonsenswoordherhalingstaak (hoofdstuk 6) liet echter zien dat op één na alle SLI kinderen een zwakke score behaalden. De taak die keek naar spraakproductie vond ook dat meer dan 80% van de SLI kinderen als zwak aangemerkt konden worden. Het is onwaarschijnlijk dat 95% van de SLI groep dyslectisch zal worden. Op basis van eerder onderzoek kan aangenomen worden dat ongeveer 40 tot 60% van kinderen met een taalstoornis dyslectisch wordt. De duidelijk aanwezige fonologische problemen in een groot aantal SLI kinderen sluit wellicht de comorbiditeitshypothese uit.

De resultaten lijken de kwalitatieve verschillenhypothese te ondersteunen. Dit model stelt dat SLI en dyslexie verschillende aandoeningen zijn, maar dat beide gekenmerkt worden door problemen in het fonologische domein. De resultaten geven ook aan dat dit model uitgebreid kan worden, omdat er verschillen binnen de fonologische vaardigheden naar voren kwamen. Dit suggereert dat andere (cognitieve en linguïstische) factoren invloed hebben op het fonologisch tekort.

Een bijkomend voordeel van de kwalitatieve verschillenhypothese is dat de visies dat dyslexie en SLI multi-risk stoornissen zijn, hierin opgenomen worden. Zowel dyslexie als SLI zijn aandoeningen met een veelvoud aan risicofactoren, op genetisch-, omgevings-, neurobiologisch-, en cognitief niveau. Deze interpretatie kan de heterogeniteit van beide groepen verklaren. Beide aandoeningen worden gekenmerkt door zwakke fonologische vaardigheden, maar zijn ook afhankelijk van andere risicofactoren.

Conclusie

Tot besluit kan worden gesteld dat de boodschap van dit proefschrift tweeledig is. Ten eerste heeft het onderzoek een fonologisch tekort aangetoond bij jonge kinderen met een risico voor dyslexie. De resultaten doen vermoeden dat er sprake is van vertraging in de fonologische verwerving. De bevindingen suggereren dat spraakproductie, klemtoontoekenning en fonologische verwerking mogelijke voorlopers en voorspellers zijn van dyslexie. De resultaten pleiten voor verfijning en linguïstische benadering van de fonologische tekorthypothese om meer inzicht te krijgen in dyslexie.

Ten tweede heeft de vergelijking tussen kinderen met een risico voor dyslexie en kinderen met een taalstoornis uitgewezen dat dyslexie en SLI vooralsnog als verschillende aandoeningen gezien dienen te worden. In beide groepen zijn fonologische tekorten aangetoond, maar de foutenpatronen van de twee groepen zijn verschillend. Deze bevindingen sluiten het best aan bij de kwalitatieve verschillenhypothese.

Curriculum Vitae

Elise de Bree was born on 20 December 1976 in Amersfoort, The Netherlands. After obtaining her VWO (Year 12) diploma from the O.S.G. Huizermaat (Huizen), she read English Language and Literature at the University of Utrecht from 1995 to 2000. During her studies, she spent one year at the University of Adelaide (Australia). From 2001 to 2006 she was employed as a PhD student at the Utrecht Institute of Linguistics OTS. This thesis is the result of the research she carried out during that period. Elise is currently involved as a postdoc researcher in the project 'Category formation in phonology and grammar: Distributional learning in children with and without a developmental language delay'.