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Faculty of Medicine

Department of Neurosciences, ExpORL

Exploring literacy development in children with specific language impairment: a prospective longitudinal study

Ellen Vandewalle

Jury:
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Prof. Dr. G. Storms
Prof. Dr. J. Carroll (University of Warwick)
Prof. Dr. M.-A. Schelstraete (Université Catholique de Louvain)

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Voorwoord

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Abstract

Early detection and treatment of dyslexia have attracted much attention in our society. Children with dyslexia experience severe reading and/or spelling problems, which have an influence on their school and career development and their daily life. On the other hand, until now specific language impairment (SLI) is less known by teachers and parents. However, the prevalence of SLI is similar to dyslexia (around 7%). Children with SLI have persistent oral language problems that may be present in different language domains, such as deficits with semantics, morphosyntax, phonology and pragmatics. These children are at high risk to develop dyslexia later on. The overlap between both disorders seems higher than expected, but the amount of the overlap and the causes remain unclear. In daily practice, speech-language therapists have the experience that a number of children with SLI develop dyslexia, but surprisingly also a number of children with SLI do not have problems with word reading and spelling skills. In typically developing children, a number of good predictors for dyslexia have been demonstrated. However, it is unknown whether the same predictors are apparent in children with SLI. It is hard to predict which individual child with SLI is at high risk of developing literacy problems.

The purpose of the present dissertation was to analyze the development of different skills important for literacy development in order to find good predictors for literacy delay in children with SLI. Therefore, a longitudinal study was performed in which children with SLI and children of a control group were followed from the last year of kindergarten until the start of grade 3. A whole range of tests was administered yearly measuring phonological, other oral language and literacy skills. Moreover, temporal auditory processing and speech perception were measured once in grade 1.

For all these skills, a group of children with SLI and literacy delay was compared to a group of children with SLI and normal literacy and to a control group. These group comparisons revealed that both SLI groups had lower scores compared to the control group for phonological awareness and verbal short-term memory: in the SLI group with literacy delay these lower scores remained until grade 3, while in the SLI group with normal literacy the scores were only persistently lower for more demanding phonological awareness and verbal short-term memory tasks. Kindergarten rapid automatized naming scores were lower

for the SLI group with literacy delay compared to the SLI group with normal literacy and to the control group. Moreover, both SLI groups had persistently lower scores on almost all oral language tasks compared to the control group. Only on listening comprehension and storytelling, the children with SLI and normal literacy skills evolved towards the level of the control group, probably as a result of their intact literacy development. Results of auditory tasks showed that the SLI group with literacy delay scored lower than both other groups on speech perception (speech-in-noise and categorical perception), but not on temporal auditory processing tasks (frequency modulation and between-channel gap detection) in grade 1.

These results suggested that kindergarten phonological awareness and verbal short-term memory skills were more related to oral language and that kindergarten rapid automatized naming skills were more associated with literacy. However, these relationships varied over time. Phonological awareness deficits in later grades were more related to dyslexia than to SLI: phonological awareness deficits seemed to be more stable over time across all phonological awareness tasks in children with literacy delay. Moreover, persistent weaknesses in vocabulary, productive morphosyntactic skills and story retelling at least until grade 3 were characteristics for all children with SLI and were not linked to literacy. Additionally, speech perception in grade 1 was more associated with literacy and less with oral language skills alone.

As predictors for literacy delay, kindergarten rapid automatized naming, kindergarten phonological awareness and speech perception in grade 1 turned out to be important. Rapid automatized naming measured in kindergarten was highly correlated to literacy. A combination of kindergarten phonological awareness and rapid automatized naming skills could discriminate children with SLI relatively well in a group with and a group without literacy delay. By including all skills measured in grade 1 into linear regression, third grade reading skills were predicted best by a combination of rapid automatized naming, phonological awareness and speech perception skills. Verbal short-term memory and letter knowledge skills in kindergarten did not turn out to be good predictors for literacy delay in children with SLI.

These results are important for teachers and speech-language therapists to predict which children with SLI have the highest risk to develop literacy problems later on. In the

future, this might help teachers to early recognize problems with the skills that are important for literacy development in children with SLI, to be able to search for adequate pedagogic-didactic methods for each child with a high risk for dyslexia. Moreover, good indicators in kindergarten are important for clinicians to monitor and treat the deficits of the children with SLI with the highest risk for dyslexia at an early age. Further research is still needed to develop, validate and standardize specific tests useful to measure skills that are demonstrated in this research to be important predictors for children with SLI.

Korte inhoud

Vroege opsporing en behandeling van dyslexie krijgen veel aandacht in onze huidige samenleving. Kinderen met dyslexie ondervinden immers ernstige moeilijkheden met lezen en/of spellen, en dat beïnvloedt hun ontwikkeling op school en hun loopbaan, maar ook hun dagelijks leven. Specifieke taalontwikkelingsstoornis (specific language impairment, SLI) is daarentegen tot op de dag van vandaag minder bekend bij leerkrachten en ouders, ook al komt SLI ongeveer even vaak voor als dyslexie (ongeveer 7%). Kinderen met SLI hebben hardnekkige moeilijkheden met mondelinge taal die zich kunnen uiten in diverse taaldomeinen, zoals problemen met semantiek, morfosyntaxis, fonologie en pragmatiek. Deze kinderen lopen een groot risico om later dyslexie te ontwikkelen. De overlap tussen beide stoornissen blijkt groter dan verwacht, maar de mate van overlap en de oorzaken blijven nog onopgehelderd. Logopedisten ondervinden in de dagelijkse praktijk dat een aantal kinderen met SLI later dyslexie ontwikkelt, maar er zijn ook kinderen met SLI die geen moeilijkheden ondervinden met lezen en spellen. Voor kinderen met een normale ontwikkeling zijn er enkele voorspellers van dyslexie bekend. Of diezelfde voorspellers ook bruikbaar zijn voor kinderen met SLI is niet geweten. Het is heel moeilijk om te voorspellen of een kind met SLI al dan niet een risico loopt om later lees- en spellingproblemen te ontwikkelen.

De bedoeling van deze thesis was om de ontwikkeling na te gaan van diverse vaardigheden die belangrijk zijn bij de lees- en spellingontwikkeling om betrouwbare voorspellers te identificeren voor een lees- en spellingachterstand bij kinderen met SLI. Daartoe werd een longitudinaal onderzoek opgezet waarin kinderen met SLI en kinderen van een controlegroep opgevolgd werden vanaf de derde kleuterklas tot het begin van het derde leerjaar. De kinderen werden jaarlijks onderworpen aan verschillende testreeksen, waarbij lezen en spellen, fonologische en andere mondelinge taalvaardigheden nagegaan werden. Bijkomend werden auditieve verwerking en spraakperceptie eenmalig getest in het eerste leerjaar.

Voor al deze vaardigheden werd een groep kinderen met SLI en lees- en spellingachterstand vergeleken met een groep kinderen met SLI en normale lees- en spellingontwikkeling, en met een controlegroep. Deze vergelijkingen tussen de groepen

toonden aan dat beide SLI-groepen lagere resultaten behaalden ten opzichte van de controlegroep voor wat betreft fonologisch bewustzijn en verbaal kortetermijngeheugen: in de SLI-groep met lees- en spellingproblemen bleven deze resultaten laag tot in het derde leerjaar, terwijl in de SLI-groep met normale lees- en spellingontwikkeling de resultaten enkel hardnekkig laag bleven voor meer veeleisende opdrachten van fonologisch bewustzijn en verbaal kortetermijngeheugen. De resultaten voor seriële benoemsnelheid in de kleuterklas waren lager voor de SLI-groep met lees- en spellingachterstand ten opzichte van de SLI groep met normale lees- en spellingontwikkeling en ten opzichte van de controlegroep. Bovendien behaalden beide SLI-groepen aanhoudend lagere resultaten op nagenoeg alle opdrachten van mondelinge taal in vergelijking met de controlegroep. Enkel voor zins- en tekstbegrip en het vertellen van een verhaal evolueerden de kinderen met SLI en normale lees- en spellingontwikkeling naar het niveau van de controlegroep toe, wellicht ten gevolge van hun intacte lees- en spellingontwikkeling. De auditieve taken die afgenomen werden in het eerste leerjaar, toonden aan dat de SLI-groep met lees- en spellingachterstand lagere resultaten behaalde dan beide andere groepen voor spraakperceptie (spraak-in-ruis en categorische perceptie), maar niet voor temporele auditieve verwerkingstaken (frequentiemodulatie en between-channel gap detectie).

Uit deze resultaten konden we afleiden dat de vaardigheden fonologisch bewustzijn en verbaal kortetermijngeheugen in de kleuterklas aan mondelinge taal gerelateerd waren en dat bedrevenheid in seriële benoemsnelheid in de kleuterklas gekoppeld was aan lezen en spellen. Deze verbanden evolueerden doorheen de tijd. Problemen met fonologisch bewustzijn in latere jaren waren eerder gerelateerd aan dyslexie dan aan SLI: de problemen met fonologisch bewustzijn leken stabieler doorheen de tijd in alle opdrachten van fonologisch bewustzijn bij kinderen met vertraagde lees- en spellingontwikkeling. Bovendien waren hardnekkige problemen met woordenschat, productieve morfosyntactische vaardigheden en het kunnen navertellen van een verhaal tenminste tot in het derde leerjaar typerend voor alle kinderen met SLI en hadden deze vaardigheden geen verband met lezen en spellen. Daarnaast was spraakperceptie in het eerste leerjaar veeleer geassocieerd met de lees- en spellingontwikkeling en minder met enkel mondelinge taalvaardigheden.

Als voorspellers van lees- en spellingachterstand bleken seriële benoemsnelheid en fonologisch bewustzijn in de derde kleuterklas en spraakperceptie in het eerste leerjaar

belangrijke vaardigheden. Seriële benoemsnelheid opgemeten in de derde kleuterklas was sterk gecorreleerd met lezen en spellen. Een combinatie van fonologisch bewustzijn en seriële benoemsnelheid in de derde kleuterklas kon kinderen met SLI vrij goed onderscheiden in een groep met en een groep zonder lees- en spellingachterstand. Wanneer alle resultaten van het eerste leerjaar mee opgenomen werden in lineaire regressie werd leesvaardigheid in het derde leerjaar het best voorspeld door een combinatie van seriële benoemsnelheid, fonologisch bewustzijn en spraakperceptie. De vaardigheden verbaal kortetermijngeheugen en letterkennis in de kleuterklas bleken geen goede voorspellers voor lees- en spellingachterstand bij kinderen met SLI.

Deze resultaten zijn belangrijk voor leerkrachten en logopedisten om te voorspellen welke kinderen met SLI de grootste kans hebben om later problemen te ondervinden met lezen en spellen. In de toekomst kan dit leerkrachten helpen om problemen met vaardigheden die belangrijk zijn voor de lees- en spellingontwikkeling bij kinderen met SLI vroegtijdig te herkennen, zodat het mogelijk is adequate pedagogisch-didactische methoden te zoeken voor elk kind met een groot risico op dyslexie. Bovendien zijn goede indicatoren in de kleuterklas belangrijk voor therapeuten om reeds op vroege leeftijd de problemen op te volgen en te behandelen bij de kinderen met SLI met het grootste risico op dyslexie. Bijkomend onderzoek is nog nodig om specifieke tests te ontwikkelen, te valideren en te standaardiseren die nuttig zijn om de vaardigheden op te meten die in dit onderzoek aangetoond werden als belangrijke predictoren bij kinderen met SLI.

Acronyms and abbreviations

C	consonant (used in combination with C and/or V)
CD	compact disc
dB HL	decibel hearing level
dB SNR	decibel signal-to-noise ratio
dB SPL	decibel sound pressure level
ES	effect size
ExpORL	Division of Experimental Otorhinolaryngology
FM	frequency modulation
G	grade (followed by a number)
Hz	Hertz
IQ	intelligence quotient
KG	kindergarten
LD	literacy-delayed
LK	letter knowledge
M	mean
Max	maximum score
Med	median
MLU5	mean length of utterances of the five longest sentences
MMA	Mixed Model Analysis
ms	milliseconds
n	number of participants
NL	normal literacy
p	probability
PA	phonological awareness
RAN	rapid automatized naming
r_S	Spearman's rank correlation coefficient
SD	standard deviation
SLI	specific language impairment
UNESCO	United Nations Educational, Scientific and Cultural Organization

V	vowel (used in combination with C and/or V)
vSTM	verbal short-term memory
yy;mm	notation for age in years and months

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Chapter 1: General introduction

1.1 Motivation for the present research

In recent years, early detection of reading and spelling problems (more specifically dyslexia) and treatment and follow-up of these problems have attracted much attention in our society. Dyslexia can only be reliably diagnosed after at least six months of individualized remedial teaching for reading and spelling problems. Normally, individual remediation only starts when severe reading and spelling problems are observed in class. Most often, children are referred for remediation during the first four years of primary school.

Children with specific language impairment (SLI) experience persistent oral language problems at the level of language production and/or perception, such as deficits in semantics, morphology, syntax, phonology and/or pragmatics. SLI, however, can often be diagnosed earlier than dyslexia, typically in the last years of kindergarten. Although SLI occurs frequently and affects the performance of the children at school, it is until now relatively unknown to teachers in kindergarten, primary and secondary school. Speech-language therapists diagnose and treat these children in their daily practice. It has also been observed that a large number of children with SLI develop dyslexia later on. Although these children have an increased risk, the practical experience of teachers and speech-language therapists shows that a number of these children have a normal literacy development, while other children lag behind. Notwithstanding, it is difficult for both teachers and speech-language therapists to predict which of these children with SLI will develop literacy problems later on. They need better indicators for predicting the literacy development in these children. In typically developing children, a number of good predictors for dyslexia have been demonstrated. However, it is unknown whether the same predictors are appropriate for children with SLI. Although the diagnosis of dyslexia can only be made after sufficient reading and spelling remediation, good indicators in kindergarten are important for speech-language therapists, teachers and parents to monitor and treat the deficits of the children

with the highest risk for dyslexia at an early age. Hence, there is a specific need for early predictors of dyslexia and for a better understanding of which skills influence the development of reading and spelling in children with SLI. The best way to analyze the development of skills is to perform a longitudinal study. As such, the same group of children is observed over an extensive period of time. In order to detect good predictors that are not affected by reading and spelling instruction, the study should already start in kindergarten. Moreover, a longitudinal study can give more insights in a number of open issues related to the overlap between both disorders SLI and dyslexia, i.e. those skills which influence these disorders independently or jointly, and the relationships between these skills.

At present only a limited number of longitudinal SLI studies starting in kindergarten have been reported (e.g., Bishop & Adams, 1990; Bishop & Edmundson, 1987; Snowling, Bishop, & Stothard, 2000; Stothard, Snowling, Bishop, Chipchase, & Kaplan, 1998; Catts, 1993; Catts, Fey, Tomblin, & Zhang, 2002; Catts, Adlof, Hogan, & Weismer, 2005). In order to enable early diagnosis, prevention and intervention, more longitudinal research with an extended set of variables is needed to find reliable preschool predictors for later reading and spelling problems in children with SLI. This doctoral research was focused on these important issues. Through a longitudinal study of a group of children with SLI and a matched control group, relevant skills were measured from the last year of kindergarten (5;5 years) until the start of grade 3 (8;1 years). By performing extensive data-analyses on these measurements, a number of important questions have been answered in this work.

1.2 Specific language impairment and the comorbidity with dyslexia

Specific language impairment (SLI) is defined as a failure in spoken language development occurring despite average or above average nonverbal intelligence, adequate hearing and vision, absence of neurological, physical, emotional or social problems, and adequate opportunity to acquire spoken language skills (McArthur & Bishop, 2001). This disorder affects approximately 7% of the monolingual 5 to 6 year old children (Tomblin et al., 1997). In contrast to a temporary language delay, children with SLI have persistent oral language deficits. It is well known that children with SLI show oral language problems across many different language domains (semantics, morphology, syntax, phonology, and pragmatics) that can be measured through standardized oral language tests (Schwartz,

2009). Deficits in each area can include receptive and/or expressive difficulties (e.g., Bishop & Leonard, 2000; Botting & Conti-Ramsden, 2004). Hence, children with SLI may exhibit varying profiles, arising from different combinations of deficits in these particular areas of language.

Dyslexia is defined as a specific learning disability characterized by severe and persistent difficulties with reading and/or spelling (Gersons-Wolfensberger & Ruijssenaars, 1997; Vellutino, Fletcher, Snowling, & Scanlon, 2004). It has a prevalence of about 5 to 10%. It is generally accepted that dyslexia affects the way in which the brain encodes the phonological features of spoken words. The core deficit is in phonological processing and stems from poorly specified phonological representations (Maillart & Schelstraete, 2004; Snowling, 2000). The impairment in dyslexia does not affect reading directly but affects the development of the spoken language substrate that is critical for learning to read. Therefore, dyslexia has a different manifestation in transparent than in opaque orthographies, and similarly the reading deficit might be almost hidden in children learning to read in logographic scripts. The fact that it has its origins in early spoken language skills is important for early intervention (Snowling, 2000).

Since SLI and dyslexia might have similar underlying problems such as phonological deficits, it is not surprising that both disorders often co-occur. Data on the prevalence of the comorbidity are inconsistent, varying from 12.5 to 85% (for an overview, see McArthur, Hogben, Edwards, Heath, & Mengler, 2000). These different estimates relate to the definitions and criteria used to diagnose SLI and dyslexia, the way of selecting participants and the age of the participants at the time of diagnosis. Catts et al. (2005) used precise selection criteria[1] and observed that 17.0% to 35.8% of the children diagnosed with SLI in kindergarten met various criteria for dyslexia in later grades in a representative sample of

[1] In this study, an extensive procedure was followed in order to analyze the overlap between children with SLI and dyslexia. A representative and balanced population-based sample of schools was selected. The language of all children was screened and a further diagnostic test battery was performed if children failed on the screening test. SLI was identified during the preschool years if children had a score lower than -1.25 SD on at least two out of five language composite scores, had a normal or above normal IQ, normal sensory and socioemotional development and were monolingual English speakers. Dyslexia was diagnosed in second, fourth and eighth grade based on different selection criteria (from a score lower than -1 SD below the mean on a composite score measuring achievement in word-recognition ability alone to the inclusion of different selection criteria for intelligence), which explains the differences in overlap between SLI and dyslexia.

527 children. Because comorbidity of SLI and dyslexia is clearly above chance level, children with SLI seem to have an increased risk to develop dyslexia. On average, children with SLI tend to score significantly poorer on reading and spelling measures than typically developing controls (e.g., Anderson, Brown, & Tallal, 1993; Catts, 1993; Catts, Gillispie, Leonard, Kail, & Miller, 2002; McArthur et al., 2000). Snowling et al. (2000) reported that the number of children with SLI and comorbid dyslexia may increase with age.

The cause of this comorbidity is still under study, but a number of models state that the overlap between both disorders can be explained by problems in the development of phonological skills (Bishop & Snowling, 2004; Catts et al., 2005; Pennington & Bishop, 2009; Scarborough & Dobrich, 1990; Snowling et al., 2000). Phonological skills have been demonstrated in three broad areas (Wagner & Torgesen, 1987): phonological awareness (PA; e.g., Liberman & Shankweiler, 1985; Mann & Liberman, 1984), verbal short-term memory (vSTM; e.g., Catts, 1989; Mann & Liberman, 1984) and retrieval of phonological codes from long-term memory (rapid automatized naming [RAN]; e.g., Bowers & Swanson, 1991). Several prospective longitudinal studies have suggested a causal link between sensitivity to the phonological structure of words and later progress in reading acquisition (e.g., Bradley & Bryant, 1983; Wagner, Torgesen, & Rashotte, 1994), although this relation is probably reciprocal (e.g., Morais, Cary, Alegria, & Bertelson, 1979; Torppa et al., 2007). There is still discussion whether RAN is part of phonology (e.g., Pennington, Cardoso-Martins, Green, & Lefly, 2001; Wagner et al., 1994) or not (e.g., Bowers & Ishaik, 2003; Compton, De Fries, & Olson, 2001; Dencla & Rudel, 1974; Wolf & Bowers, 1999). For a more detailed discussion, see chapter 2, paragraph 2.1.3. The role of PA, vSTM and RAN can change over time and can differ between languages, depending on the transparency of the language (see chapter 3, paragraph 3.1.2 and 3.1.3). The role of RAN for example, is generally larger in transparent languages. Brizzolara et al. (2006) postulated that RAN might represent the main cognitive marker of dyslexia, based on their Italian longitudinal study. More details about the different models are discussed in chapter 3, paragraph 3.1 and the general discussion, paragraph 6.2. At present, the multiple deficits model of Pennington (2006) receives the most support in literature (e.g., Carroll & Myers, 2010). Brizzolara et al. (2011) concluded that there is a complex relationship between oral and written language difficulties which may change at different developmental time points. This complex

relationship cannot be captured by a single deficit model, but can best be conceptualized considering multiple interactions between language skills and literacy abilities. Therefore, more longitudinal studies in different languages are important.

Because most studies analyzing SLI or analyzing dyslexia did not exclude the occurrence of the other disorder, it is difficult to conclude which deficit is linked to which disorder. Therefore, studies comparing a group of children with SLI, a group of children with dyslexia or at risk for dyslexia and a group of children with the combined disorders are highly interesting to relate deficits to one or both disorders (e.g., Bishop & Snowling, 2004; de Bree, Wijnen, & Gerrits, 2010; Larkin & Snowling, 2008). For example, children with language impairment showed poorer phonological memory compared to children with reading impairment (Larkin & Snowling, 2008). Similarly, de Bree et al. (2010) observed poorer nonword repetition in children with SLI compared to children at risk for dyslexia. However, nonword repetition was correlated to literacy for the at-risk group, but not for the SLI-group. Therefore, de Bree et al. argue that SLI and dyslexia are different disorders. Children with language impairment and reading impairment both were impaired for their age at phonetic spelling, but the children with language impairment showed the more severe impairment (Larkin & Snowling, 2008). The different implications are described in the chapters. In the general discussion, a link of our results with a similar longitudinal study analyzing Dutch speaking children at family risk for dyslexia (Boets et al., 2010; Boets et al., 2011) is presented.

Children with SLI often experience expressive phonological impairments or speech sound disorders. It is interesting to study the results of longitudinal studies analyzing this group. Children with expressive phonological impairments often experience difficulties with receptive phonological awareness tasks, regardless whether or not they were accompanied by broader language difficulties (Bird, Bishop, & Freeman, 1995). Therefore, this group is at risk for literacy problems. Moreover, children at risk of reading difficulties because of speech difficulties or because of family risk for dyslexia showed very similar patterns of impairment, i.e. deficits in the development of phonological representations demonstrated by poor input and output speech processing, phonological learning, PA and reading development (Carroll & Snowling, 2004). Bishop and Adams (1990) proposed the ‘critical age hypothesis’, which says that children who have speech difficulties that persist to the point at which they need

to use phonological skills for learning to read, are at high risk for reading problems. As critical age, the time children start school (around 5 years; Bird et al., 1995) and 6;9 years (Nathan, Stackhouse, Goulandris, & Snowling, 2004) were mentioned. Certainly when speech-errors were characterized by non-developmental error processes, the long-term impact on PA, reading accuracy, spelling and reading comprehension was apparent (Leitao & Fletcher, 2004). However, more recent studies (Nathan et al., 2004; Peterson, Pennington, Shriberg, & Boada, 2009) demonstrated that not speech sound disorder persistence or isolated speech problems but oral language problems predicted later literacy. Persistence of speech problems was associated with PA problems and preschool language ability was a unique predictor of PA. PA predicted literacy, but best in combination with other aspects such as syntax and nonverbal IQ (Peterson et al., 2009). The importance of phonological awareness to the literacy development is emphasized in these studies, although this seems to interact with other cognitive factors. Therefore, it is interesting to focus on the development of other oral language skills as well besides phonological awareness to observe the relation with literacy.

1.3 Research objectives

The starting point of this study was the temporal auditory processing deficit theory. This theory states that children with dyslexia experience problems with processing brief and rapidly changing auditory stimuli (Tallal, 1980). In later studies it was demonstrated that auditory deficits in children with dyslexia and children with SLI might not be restricted to brief and rapidly changing auditory stimuli, but might also involve processing slowly varying amplitude and frequency modulated signals (e.g., Talcott & Witton, 2002; Witton, Stein, Stoodley, Rosner, & Talcott, 2002) or amplitude rise times (Goswami et al., 2002). This auditory deficit is hypothesized to interfere with accurate speech perception and the development of well-defined and robust phonological representations, hence resulting in literacy and language difficulties. Based on this theory, we might structure the relationships between the various relevant skills into one diagram (see Figure 1.1). Empirical studies (e.g., Boets et al., 2011; Boets, Wouters, van Wieringen, De Smedt, & Ghesquière, 2008) have confirmed parts of this model.

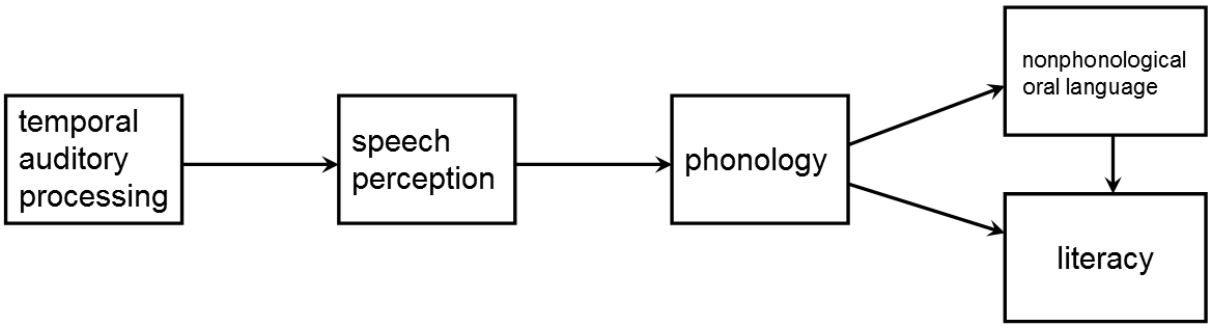


Figure 1.1 Structuring of the relationships between the variables influencing oral language and literacy skills

In this context, it is important to measure basal temporal auditory processing, speech perception and phonological skills. Regarding the specificity of children with SLI, the development of nonphonological productive and receptive oral language aspects such as semantics, morphosyntax and narrative skills are important to study as well. These oral language skills may also have a predictive value in the development of dyslexia (Scarborough, 1998).

The first aim of this project is to compare three groups, i.e. (1) children with SLI and literacy delay, (2) children with SLI and normal literacy, and (3) control children without oral language and articulation problems and with a typical literacy development (further referred to as 'typically developing children' or 'control children'), for the relevant skills, i.e. temporal auditory processing, speech perception, phonological processing and different nonphonological oral language, and literacy skills. Second, the development of phonological processing and other oral language and literacy skills is analyzed in children with SLI with and without literacy delay and typically developing children from the last year of kindergarten until the start of grade 3. Third, the crucial relationships among all skills are studied. Finally, early predictors for literacy skills are derived.

In the different chapters, a number of specific research questions deal with group comparisons, the development, the relations and predictive analyses. A first set of objectives involves *group comparisons*:

- Are there significant differences between the children with SLI and typically developing children for phonological processing (PA, vSTM and RAN) and letter knowledge skills in kindergarten and for literacy (reading and spelling) at the end of grade 1 (see chapter 2)?

In further analyses, three groups of children are compared, i.e. children with SLI and literacy delay, children with SLI and normal literacy and typically developing children. Do the three groups significantly differ for:

- phonological skills (PA, vSTM and RAN) and letter knowledge in kindergarten (see chapter 2) and for phonological skills (PA, vSTM and RAN) in grade 1 and grade 3 (see chapter 3)?
- narrative and other oral language skills beyond phonology (i.e. semantics and morphosyntax) from kindergarten until grade 2 and reading comprehension skills in grade 3 (see chapter 4)?
- temporal auditory processing and speech perception in grade 1 at the start of reading instruction (see chapter 5)?

Second, it is important to study *the development* of phonological skills from kindergarten to grade 3 (see chapter 3) and the development of other oral language skills from kindergarten to grade 2 (see chapter 4) in the three groups. A third set of objectives consists in unraveling *relations*. Are there significant relations between:

- phonological processing (PA, vSTM and RAN) and letter knowledge in kindergarten and reading and spelling in grade 1 in the SLI group and the typically developing children (see chapter 2)?
- low-level temporal auditory processing, speech perception, phonology in grade 1 and oral language, reading and spelling in grade 1 and grade 3 (see chapter 5)?

The fourth objective is to detect *early predictors* for literacy skills:

- Can phonological skills measured in kindergarten discriminate the children with SLI in a group with and a group without high risk for developing literacy problems (see chapter 3)?
- What is the predictive value of low-level temporal auditory processing, speech perception, phonological and other oral language skills in grade 1 for reading in grade 3 (see chapter 5)?

1.4 Methodology

In order to better understand the relationships between the different variables, it was considered important to launch a longitudinal study. This was started up in September

2004 with an extensive study of the literature and a design and planning that included the selection of participants and the different test phases.

1.4.1 Participants

In 2005, 26 children (7 girls and 19 boys) with SLI were selected divided over the whole of Flanders (see Figure 1.2) by contacting speech-language therapists and rehabilitation centers. Children were included in the SLI group when they were born in 2000, attended the last year of regular kindergarten at the start of the study, were monolingual Dutch speakers and had severe and persistent oral language problems for which they received oral language therapy in kindergarten. These oral language problems were determined by a score below percentile 3 on at least one of the subtests of three standardized Dutch language tests before the start of language therapy. Moreover, they all had to score below percentile 10 on at least one of the subtests of these language tests at a second evaluation after the age of 4;4 years. In addition to these language problems, some children had concurrent speech sound problems. Exclusion criteria were lower intelligence (nonverbal, verbal and total intelligence below 85), hearing loss or any other known problem that could explain their language impairment.



Figure 1.2 Geographical spread (white dots) of the matched pairs of participating children all over Flanders

In 2005-2006 for every individual child from the SLI group, the best matching control child was selected based on five criteria: (1) educational environment, i.e. same class, (2) gender, (3) age, (4) nonverbal intelligence, and (5) parental educational level. Nonverbal intelligence was assessed with the Raven Coloured Progressive Matrices (Raven, Court, & Raven, 1984). Parental educational level was obtained by a questionnaire completed by the parents based on the International Standard Classification of Education scale of UNESCO (1997). The parents indicated their highest obtained qualification. The six point scale ranging from no qualification to a qualification of a higher education was transformed into a low (i.e. maximum qualification of third year of secondary school), middle (i.e. maximum qualification of 6th or 7th year of secondary school), or high score (all higher qualifications). Moreover, the control children were monolingual Dutch speakers, had normal hearing and they did not show any speech or language difficulties.

Although initially 26 children with SLI were selected, one child left the study after kindergarten. Moreover, seven children with SLI did not move on to grade 1 of a regular primary school after the last year of kindergarten. Hence, the remaining two groups of 18 matched children that attended grade 1 in a regular primary school were compared in this longitudinal study, as only for these children reading and spelling skills can be compared. In these regular primary schools a similar method to read and spell was used, more or less based on a phonics approach (in Dutch called ‘directe systeemmethode’, in which children start with a small set of words to learn the grapheme-phoneme correspondence rules through analyzing and blending graphemes and phonemes into words).

1.4.2 Design and data collection of the longitudinal study

The administration of the tests was spread over a period of four school years (see Figure 1.3). Each matched pair of children was tested in different individual sessions at the same day in a quiet room at their school under the same circumstances. Oral language, articulation and phonological skills were assessed three times between kindergarten and the start of grade 3. Furthermore, preliminary literacy skills (letter knowledge) were evaluated in the third year of kindergarten along with a phonological test battery. After one and two years of reading and spelling instruction (at the end of grade 1 and at the start of grade 3), literacy tests were administered. Auditory processing and speech perception skills were measured once in grade 1. At the end of 2008, the test phases were completed.

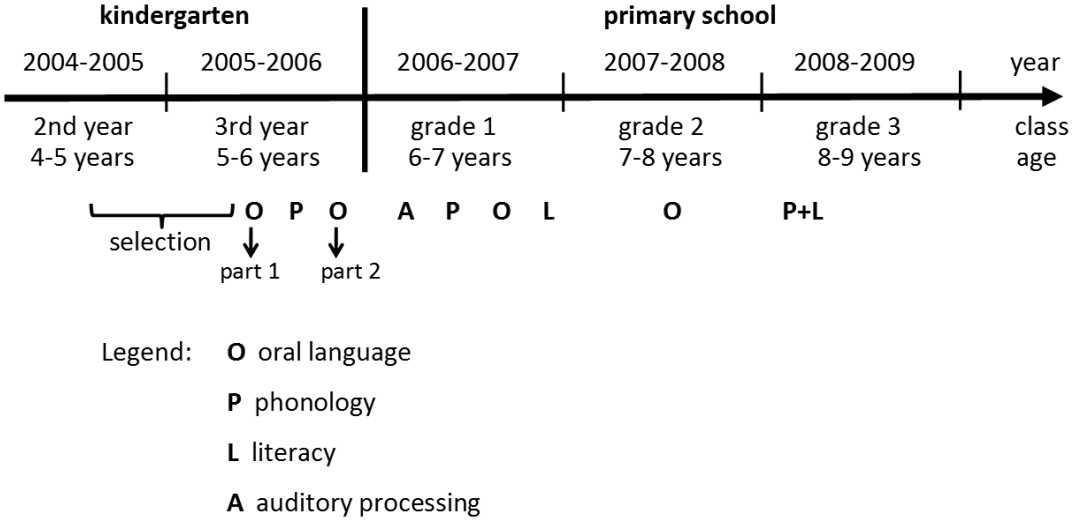


Figure 1.3 Schedule of the selection phase and the different test phases (indicated with letters)

All individual tests of the test batteries were precisely composed and pilot tested before the start of the test phases. Most oral language and articulation tests were selected from Dutch standardized published tests. We selected oral language tests that were infrequently used by speech-language therapists in order to avoid a learning effect in the children with SLI of whom oral language tests have been administered regularly. Since word fluency is not included in these standardized tests, an appropriate additional word fluency test was designed. The phonological tests as well as reading and spelling tests were mainly based on the test battery compiled in the PhD-thesis of Bart Boets (2006). The auditory processing tests were developed at ExpORL (Laneau, Boets, Moonen, van Wieringen, & Wouters, 2005). More details about the occasions of the administration for each test are presented in Table 1.1.

1.5 Thesis outline

After the general introduction, this doctoral thesis consists of four manuscripts that correspond to the chapters 2 to 5. All these chapters are in the format of journal papers. Since different aspects of the same groups of 18 children with SLI and their matched controls were analyzed in each manuscript, this necessarily implies some overlap between the manuscripts, especially with respect to the participant selection and the used measures. Chapter 6 gives overall conclusions, a general discussion and suggestions for further

Table 1.1 Occasions of test administrations

	Kindergarten			Grade 1				Grade 2	Grade 3
		Middle		Start	Middle		End	Middle	Begin
Age (years;months)	**5;5**	**5;7**	**5;9**	**6;3**	**6;7**	**6;8**	**6;10**	**7;6**	**8;1**
Performance IQ	x								
Auditory processing									
FM				x					
BC Gap				x					
Speech perception									
Speech-in-noise				x					
Categorical perception						x			
Oral language									
Productive oral language						x		x	
Productive vocabulary	x					x		x	
Word description			x			x		x	
Word fluency			x			x		x	
Productive morphology	x					x		x	
Receptive oral language						x		x	
Receptive vocabulary			x			x		x	
Sentence comprehension	x					x		x	
Text comprehension			x			x		x	
Narrative skills			x			x		x	
Storytelling			x			x		x	
Story retelling			x			x		x	
Articulation									
Articulation accuracy	x								
Phonology									
PA									
Rhyme production		x							

End rhyme identity	x			
First sound identity	x			
End sound identity	x			
Rhyme categorization		x		
First sound categorization		x		
Auditory analysis		x		
Auditory synthesis		x		
Phoneme deletion		x		x
Spoonerism		x		x
vSTM				
Digit span	x	x		x
Nonword repetition	x	x		x
RAN				
Colors	x	x		x
Objects	x	x		x
Digits	x	x		x
Letters	x	x		x
Literacy				
Reading				
Letter knowledge	x			
One-minute word reading			x	x
Non-word reading			x	x
Word reading accuracy			x	x
Non-word reading accuracy			x	x
Word reading speed			x	x
Non-word reading speed			x	x
Reading comprehension				x
Spelling			x	x

research. In Figure 1.4, an overview of the relationships between the variables analyzed in the different chapters is visually presented.

Chapter 2 presents the results of phonological performance and letter knowledge in kindergarten and literacy skills at the end of grade 1 for the 18 children with SLI and the 18 matched control children and the interrelationships between these skills. The aim of this study is to analyze which children with SLI experience literacy problems at the end of grade 1 and to determine kindergarten predictors for literacy in children with SLI. Therefore, the SLI group is also divided in a group with and without literacy delay based on literacy results at the end of grade 1. The content of this chapter is published in Vandewalle, Boets, Ghesquière and Zink (2010) as a contribution to a special issue on exploring the overlap between dyslexia and SLI: the role of phonology.

While chapter 2 focused on phonological skills in kindergarten, c*hapter 3* investigated the development of phonological skills from the last year of kindergarten until the start of grade 3 in the 18 children with SLI and the 18 control children. In this study, both groups are subdivided into a group with and a group without literacy delay based on a combination of literacy scores at the end of grade 1 and at the beginning of grade 3. The group with SLI and literacy delay (n = 8) is compared to the group with SLI and normal literacy (n = 10) and to the control group with normal literacy (n = 14). Moreover, predictive discriminant analyses were performed to find out which variables could best discriminate children with SLI into a group with and a group without literacy delay. The content of this chapter is described in Vandewalle, Boets, Ghesquière and Zink (in press).

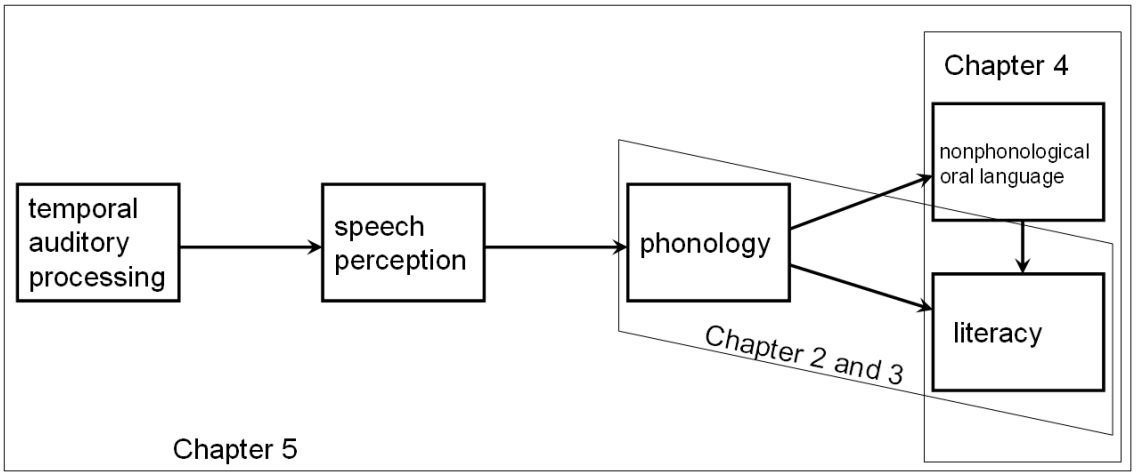


Figure 1.4 The chapters of this doctoral research indicating the studied variables and the analyzed relationships between the variables

In *chapter 4*, the same subdivision of the SLI group and the control group into three groups based on literacy scores at the end of grade 1 and the start of grade 3 is used. Here, we focused on the development of other oral language skills besides phonology (vocabulary, semantics and morphosyntax) and more specifically on narrative skills (pragmatics) from kindergarten to grade 2. We aimed to compare the three groups to observe potential differences in oral language skills before and after the start of reading instruction and to observe the development of storytelling and story retelling. Moreover, differences in reading comprehension at the start of grade 3 are analyzed. The content of this chapter is described in Vandewalle, Boets, Boons, Ghesquière and Zink (submitted).

Chapter 5 compares temporal auditory processing (frequency modulation and between-channel gap detection) and speech perception (speech-in-noise and categorical perception) skills in grade 1 in the same three groups of children. Moreover, these skills were related to phonological skills in grade 1 and oral language and literacy skills in grade 1 and 3. The main objectives of this study were to discover whether temporal auditory processing and speech perception skills are impaired in both SLI groups and whether these skills are linked to phonology, oral language and/or literacy. Moreover, the predictive value of the different skills measured in grade 1 for reading in grade 3 was analyzed with linear regression analyses. The content of this chapter is described in Vandewalle, Boets, Ghesquière and Zink (2012).

In *chapter 6*, we present general conclusions on the results obtained in the current research project and a discussion of important issues of this research. Finally, suggestions for future research are made.

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Chapter 2: Who is at risk for dyslexia? Phonological processing in five to seven-year-old Dutch-speaking children with SLI

The content of this chapter has been described in Vandewalle, E., Boets, B., Ghesquière, P., & Zink, I. (2010). Who is at risk for dyslexia? Phonological processing in five- to seven-year-old Dutch-speaking children with SLI. Scientific Studies of Reading, 14(1), 58-84.

Abstract

A disproportionally high number of children with specific language impairment (SLI) develop dyslexia. Yet it is hard to predict which individual child is at risk. This article presents a longitudinal study of phonological and early literacy development of 18 Dutch-speaking children with SLI, compared to 18 typically developing controls over a period of 2 years. These matched pairs of children were followed from 1 year before until 1 year after the start of formal literacy instruction. Children with SLI had problems with phonological awareness (PA) and verbal short-term memory (vSTM) in kindergarten. PA and vSTM in kindergarten were not good predictors for dyslexia in children with SLI, but rapid automatized naming (RAN) measured in kindergarten was strongly correlated with reading and spelling in both groups. We can infer that only SLI children who additionally obtained lower scores on RAN in kindergarten developed reading and spelling problems at the end of grade 1.

2.1 Introduction

2.1.1 Specific language impairment

Specific language impairment (SLI) is defined as a failure in spoken language development occurring despite average or above-average nonverbal intelligence; adequate hearing and vision; absence of neurological, physical, emotional or social problems; and adequate opportunity to acquire spoken language skills (McArthur & Bishop, 2001). SLI is not a homogeneous disorder, but it includes children with varying profiles, arising from combinations of deficits in particular areas of communication (phonology, morphology, syntax, semantics, and pragmatics). Deficits in each area can include receptive and/or expressive difficulties (e.g., Bishop & Leonard, 2000; Botting & Conti-Ramsden, 2004).

2.1.2 Comorbidity with dyslexia

Dyslexia is frequently comorbid with SLI. Dyslexia is generally defined as a disorder characterized by severe reading and spelling difficulties that are persistent and resistant to the usual didactic measures and remedial efforts. Data on the prevalence of the comorbidity between SLI and dyslexia are inconsistent, varying from 12.5% to 85% (for an overview, see McArthur, Hogben, Edwards, Heath, & Mengler, 2000). These different estimates relate to the definitions and criteria used to diagnose SLI and dyslexia, the way of selecting participants, and the age of the participants at the time of diagnosis. Catts, Adlof, Hogan, and Weismer (2005) used precise selection criteria and found a rather limited but statistically significant overlap (17–36%) between SLI diagnosed in kindergarten and dyslexia in later grades. Because comorbidity of SLI and dyslexia is clearly above chance level, children with SLI seem to have an increased risk to develop dyslexia. On average, children with SLI tend to score significantly poorer on reading and spelling measures than typically developing controls (e.g., Anderson, Brown, & Tallal, 1993; Catts, 1993; Catts, Gillispie, Leonard, Kail, & Miller, 2002; McArthur et al., 2000). Snowling, Bishop, and Stothard (2000) reported that the number of SLI children with comorbid dyslexia may increase with age.

The cause of this comorbidity is still under study, but a number of models posit that the overlap between both disorders can be explained by problems in the development of

phonological skills (Bishop & Snowling, 2004; Catts et al., 2005; Pennington & Bishop, 2009; Scarborough & Dobrich, 1990; Snowling et al., 2000).

2.1.3 Causal theories of dyslexia

Problems with phonology (i.e. the representation and processing of speech sounds) are widely accepted as a cause of dyslexia (for a review, see Snowling, 2000). Phonological deficits have been demonstrated in three broad areas (Wagner & Torgesen, 1987): phonological awareness (PA; e.g., Liberman & Shankweiler, 1985; Mann & Liberman, 1984), verbal short-term memory (vSTM; e.g., Catts, 1989; Mann & Liberman, 1984) and retrieval of phonological codes from long-term memory (rapid automatized naming [RAN]; e.g., Bowers & Swanson, 1991). Several prospective longitudinal studies have suggested a causal link between sensitivity to the phonological structure of words and later progress in reading acquisition (e.g., Bradley & Bryant, 1983; Wagner, Torgesen, & Rashotte, 1994), although this relation is probably reciprocal (e.g., Morais, Cary, Alegria, & Bertelson, 1979; Torppa et al., 2007).

The relation between RAN on one hand and PA and vSTM on the other hand has been subject of an ongoing debate. According to certain authors, slow naming speed reflects a type of problem that is partially distinct from PA but still is connected to a similar underlying deficit, that is, underspecified or immature phonological representations (e.g., Pennington, Cardoso-Martins, Green, & Lefly, 2001; Wagner et al., 1994). According to others (e.g., Bowers & Ishaik, 2003; Compton, De Fries, & Olson, 2001; Wolf & Bowers, 1999) RAN is a unique and independent predictor for dyslexia besides the phonological deficit and can be independently affected and cause dyslexia. If both skills are affected, the child has a so-called double deficit and his or her reading and spelling impairment will be more severe (Wolf & Bowers, 1999).

2.1.4 PA, vSTM, RAN, and their role in reading development in children with SLI

Although many studies have investigated this relation, the precise link between phonological skills and their predictive value for literacy development is not yet clear. It is generally accepted that PA and RAN are *good predictors for reading in typically developing children* (for a review, see Scarborough, 1998; Verhagen, Aarnoutse, & van Leeuwe, 2008; Wolf, Bowers, & Biddle, 2000). PA tends to be more important in the initial phases of reading

development (for word-analytic decoding) and is more correlated with reading accuracy. RAN may be of greater importance in the development of reading fluency (word-holistic recognition) and reading comprehension and is better correlated with reading speed (Elbro & Scarborough, 2004; van den Bos, Ruijssenaars, & Spelberg, 2008; van den Bos, Zijlstra, & Spelberg, 2002). However, other language skills (e.g., general language ability, expressive language, vocabulary) also have a predictive value for dyslexia (Scarborough, 1998).

Although it is not sure whether *these same skills predict dyslexia in children with SLI*, a number of SLI studies do retain the same predictors: PA, RAN, letter knowledge, vocabulary, grammar skills, and nonverbal intelligence (Catts et al., 2002; Elbro & Scarborough, 2004; Scarborough, 1998). Nonverbal intelligence seems to have a protective influence on reading development, as SLI children with high IQ can better compensate for their language problems (Snowling et al., 2000). In Catts's (1993) study, children with speech and/or language problems had significantly lower first- and second-grade reading scores than typically developing controls. For these children, preschool measures of PA and RAN turned out to be better predictors for word recognition in grade 1 and grade 2 than measures of receptive and expressive language ability. de Bree (2007) performed an extensive study on phonological abilities of Dutch-speaking children at various younger ages (1;6 to 5;0 years) and observed that, in comparison with a control group, both children with SLI and children at family risk for dyslexia showed phonological difficulties, but with different error patterns[2].

A number of studies compared child groups that were defined on a basis of presenting oral language and literacy problems: an SLI group with normal literacy (SLI-NL), a literacy-disabled SLI group (SLI-LD), a control group with normal literacy (Control-NL), and a literacy-disabled control group (Control-LD). It is interesting to investigate the potentially different performance of these four groups on tests like PA, vSTM, and RAN, and their relation with reading skills.

[2] For example, for the nonword repetition test, de Bree (2007) observed differences between the error patterns of the at-risk group and the SLI group. Performance of the SLI group was affected more by increasing target length of the nonwords, showed significantly more coda addition and syllable omission, and exhibited both pre- and post-stress syllable substitution, whereas the at-risk (and the control) group mainly applied pre-stress syllable substitution.

On one hand, Catts et al. (2005) observed that the SLI-NL group had no or only a mild deficit in PA and vSTM compared to a control group in grade 4 and 8, whereas the Control-LD group and the SLI-LD group had more problems with PA and vSTM. Based on these results, the authors concluded that problems with PA and vSTM are more closely associated with dyslexia than with SLI. Similar results were obtained by Kelso, Fletcher, and Lee (2007) for SLI children between 7 and 9 years old.

On the other hand, some other studies (Bishop, McDonald, Bird, & Hayiou-Thomas, 2009; Scheltinga, van der Leij, & van Beinum, 2003) found no relation between PA and reading skills in children with SLI. In the study by Bishop et al. (2009), the four groups were compared. At the age of 4 and 6 years, scores for PA and vSTM were not significantly different for the SLI-NL group and the SLI-LD group. Based on this result, the authors concluded that PA and vSTM are associated with oral language problems and are not typical for dyslexia. At the age of 9 years, the SLI-NL group outperformed the SLI-LD group and the control-LD group for RAN, and their scores did not differ significantly from the control-NL group. RAN measured at 9 years was the strongest predictor to divide the SLI children in groups on a basis of literacy achievement. Hence, the authors concluded that RAN is not related to oral language ability, but it is related to reading ability. Apparently, good RAN-skills can be protective for reading development, even when oral language skills are impaired. Unfortunately, in the study by Bishop et al. (2009) RAN was not measured at 4 and 6 years of age, but it was suggested to be a good predictor of early reading difficulties in children with language impairment.

In line with the study by Bishop et al. (2009), Brizzolara et al. (2006) obtained similar results in poor readers with and without a history of language delay. RAN deficits were shared by most dyslexics (with and without a history of language impairment), whereas PA and vSTM problems were mainly associated with a history of language impairment. They concluded that in a language with a regular orthography such as Italian, RAN, and not PA or vSTM, may represent the main cognitive marker of developmental dyslexia. Studies by Raitano, Pennington, Tunick, and Boada (2004) and Tunick (2004) indicate that RAN is relatively spared in children with a speech sound disorder. In these studies good RAN skills seem to protect children with a speech sound disorder and a phonological deficit from developing dyslexia.

2.1.5 Need for more longitudinal research

Thus far it is not clear whether SLI children with normal literacy ability score within normal range for PA and vSTM. Several studies postulate that an isolated PA deficit will not necessarily cause dyslexia in children with SLI. Moreover, the studies by Bishop et al. (2009) and Scheltinga et al. (2003) suggest that PA and vSTM are not related to reading and spelling ability in children with SLI. Therefore, it may be incorrect to assume that literacy predictors for children with SLI are the same as those for the general population. Also the early role of RAN on the reading development of children with SLI has to be further investigated, as good RAN skills are hypothesized to be protective for reading development. In addition, the influence of language transparency (McCardle, Scarborough, & Catts, 2001) is unclear.

At present only a few longitudinal SLI studies started in kindergarten. Yet this is the only way to ensure that the measured phonological and language abilities are not influenced by reading and spelling ability. To enable early diagnosis, prevention, and intervention, more longitudinal research with an extended set of variables is needed to find reliable preschool predictors for later reading and spelling problems in children with SLI.

In the present study, tests of PA, vSTM, RAN, and letter knowledge were assessed in SLI and control children in the last year of kindergarten (KG3), before children received any formal reading and spelling instruction. After 1 year of literacy instruction, at the end of grade 1 (G1), a series of standardized reading and spelling tasks was administered. Groups were compared on the phonological and literacy measures, and the predictive value of the kindergarten measures toward first-grade literacy development was analyzed.

2.2 Method

2.2.1 Participants

This 2-year study pertains to 36 children, aged between 4;9 years and 5;10 years when the first tests were administered: 18 children (3 girls and 15 boys) with SLI (the *SLI group*) and 18 matched typically developing children (3 girls and 15 boys) without language or articulation problems (the *control group*).

All children with SLI were born in 2000, attended the last year of regular kindergarten at the beginning of the study (KG3) and were monolingual Dutch speakers. They had no

mental retardation, hearing loss, or any other known problem that could explain their language impairment. Nonverbal IQ, verbal IQ, or total IQ was above 85 on the Wechsler Preschool and Primary Scale of Intelligence–Revised (Vander Steene & Bos, 1997), on the *Snijders-Oomen Niet-verbale Intelligentietest—Revisie* (Snijders-Oomen Nonverbal Intelligence Test–Revised; Snijders, Tellegen, & Laros, 1988) or on the Colombia Mental Maturity Scale (Burgemeister, Blum, & Lorge, 1972). The SLI group was recruited by open calls toward all speech and language therapists in the Dutch-speaking part of Belgium. All children of the SLI group started language therapy in kindergarten because of severe language problems. At the start of therapy, children scored below percentile 3 on at least one of the subtests of three standardized Dutch language tests: *Reynell Taalontwikkelingsschalen* (Reynell Language Developmental Scales; Schaerlaekens, Zink, & van Ommeslaeghe, 2003), *Taaltests voor Kinderen* (Language Tests for Children; van Bon & Hoekstra, 1982), or *Schlichting Test voor Taalproductie* (Schlichting Test for Language Production; Schlichting, van Eldik, Spelberg, van der Meulen, & van der Meulen, 2003). To ensure the persistence of the language problem, children had to score below percentile 10 on at least one of the subtests of these language tests at a second evaluation after the age of 4;4 years. In addition to these language problems, some children had concurrent articulation problems.

Children in the control group met the same selection criteria, with the restriction that they did not show any speech or language difficulties (as confirmed by their parents and teachers). For every individual child from the SLI group, the best matching control child was selected based on five criteria: (a) educational environment, that is, same class; (b) gender; (c) age; (d) nonverbal intelligence; and (e) parental educational level. Nonverbal intelligence was assessed collectively in the class, using an adapted version of the Raven Coloured Progressive Matrices (Raven, Court, & Raven, 1984) and parental educational level was obtained by a questionnaire completed by the parents. The parents indicated their highest obtained qualification, which was transformed into a low, middle, or high score.

Actually, 26 children with SLI were initially selected, but 1 child left the study after kindergarten because the parents no longer wished to participate, and 7 children did not move on to G1 of a regular primary school after KG3. Three of these 7 children repeated KG3, and 4 moved to a special school for children with language and learning disabilities.

Throughout the article we present only results for the two groups of 18 matched children who attended G1 in a regular primary school, as only for these children reading and spelling skills can be compared and relations between KG3 measures and G1 literacy achievement can be calculated. Moreover, these restricted groups turned out to be better matched than the original groups. In footnote[3] more details about the 7 SLI children not attending G1 after KG3 are presented, and relevant results of the original groups of 26 SLI children and their controls are given in additional footnotes.

Descriptive statistics are displayed in Table 2.1 and Table 2.2.[4] Mixed Model Analyses (MMA) showed that both groups had equivalent age and nonverbal intelligence (see Table 2.1). Fisher's Exact Tests revealed no significant group difference in the distribution of the educational level of the mother, but there was a significant difference in the distribution of the educational level of the father (see Table 2.2). On all productive and receptive oral language measures (for a description of the tests, see the Measures section), the SLI group scored significantly poorer than the control group, even when covariates were taken into account in the MMA (see Table 2.1). For articulation accuracy, control children made few errors (with M = 43.7 close to the maximum score, SD = 0.6), but the SLI group showed a large variation in articulation accuracy (M= 30.9, SD = 12.0).

In G1 oral language skills were reassessed with the same tasks. For all oral language tasks, except sentence and text comprehension, the SLI group again scored significantly lower than the control group. Repeated measures MMA were computed with time (KG3 and G1) as within-subject variable, participant group as between-subject variable and with age,

[3] It is relevant to analyze the seven children with SLI that did not go to G1. Means for nonverbal IQ, oral language, and all phonological tasks were lower for this group compared to the 18 SLI children who went on to G1, but only the differences for nonverbal intelligence, rhyme production, nonword repetition, and the vSTM composite score were significant. The decision to restart KG3 or move to a special school was jointly taken by the parents and teachers at the end of KG3 and depended on different factors, like the presence of emotional problems, doubts about cognitive skills, severe language, phonological and articulation problems, and personal factors. Hence, we can conclude that the 18 children with SLI who attended G1 are a more homogeneous group than the initial group of 26 SLI children. This could be the reason why matching correspondence for the restricted group of 18 pairs of children was better than for the 26 child pairs.

[4] The results of the group comparisons of the 18 pairs of children for the kindergarten data presented in Table 2.1 and Table 2.2 are in line with results of the group comparisons for the original group of 2 × 26 SLI and control children. Only on maternal educational level results were different: The original group of 26 SLI children did differ significantly from their 26 controls (p = .03).

Table 2.1 Characteristics of the participants in KG3: mean (*M*) and standard deviation (*SD*); significance levels (*p*) and effect sizes (*ES*) for the Mixed Model Analysis

		SLI		Control		Group comparisons		Group comparisons	
		n = 18		*n* = 18		with covariates[a]		without covariates	
	Max	*M*	*SD*	*M*	*SD*	*p*	*ES*	*p*	*ES*
Age in months		**63.8**	**2.6**	**64.6**	**3.9**	**-**	**-**	**.39**	**-0.25**
Non-verbal intelligence		**113.6**[b]	**16.0**[b]	**117.2**[b]	**13.9**[b]	**-**	**-**	**.34**	**-0.24**
Oral language productive		**-2.4**	**0.8**	**0.0**	**1.0**	**<.0001**	**-2.05**	**<.0001**	**-2.62**
Productive vocabulary	60	22.7	6.7	33.6	9.1	.005	-1.29	.0002	-1.36
Word description	45	9.6	3.2	17.7	3.5	.0002	-2.25	<.0001	-2.43
Word fluency		4.0	0.5	5.1	1.0	.05	-0.63	.0002	-1.46
Morphology (productive)	24	10.5	3.2	15.3	3.2	.005	-1.22	.0002	-1.49
Oral language receptive		**-2.0**	**1.0**	**0.0**	**1.0**	**.003**	**-1.52**	**<.0001**	**-2.00**
Receptive vocabulary	96	53.6	8.9	67.9	8.5	.008	-1.25	<.0001	-1.64
Sentence comprehension	42	25.6	4.3	31.6	3.4	.02	-1.16	.0001	-1.55
Text comprehension	24	15.2	2.8	19.3	2.8	.02	-1.14	.0004	-1.48

Note. [a] MMA with age, non-verbal IQ and parental educational level as covariates
[b] Transformed scores with population average *M* = 100 and *SD* = 15

Table 2.2 Characteristics of the participants in KG3: distribution of parental educational level in the SLI group and the control group and significance levels (*p*) for Fisher's exact tests

	SLI			**Control**			**Group**
	n = 18			*n* = 18			**comparisons**
Parental educational level	Low	Middle	High	Low	Middle	High	*p*
Maternal educational level	3	11	4	2	5	11	.09
Paternal educational level	2	12	4	0	7	11	.02

Note. KG3 = last year of kindergarten; SLI = specific language impairment.

nonverbal intelligence and parental educational level as covariates. Significant group and time effects were present for all tasks. The Group × Time interaction was only significant for the sentence comprehension task. Because all other interaction terms were nonsignificant, we can conclude that both groups made comparable progress on the oral language tasks. The SLI group went through almost the same evolution as the control group, so there was no recovery or increased delay of their language impairment.

2.2.2 Measures

2.2.2.1 Oral language and articulation abilities

In KG3 and in G1 four tests of productive oral language, three tests of receptive oral language, and an articulation test were administered.

Productive oral language. The productive oral language test battery consisted of a productive vocabulary test from the Taaltoets Allochtone Kinderen (Language Test for Foreign Children; Verhoeven & Vermeer, 1986), a word description test and a productive morphology test (comprising plurals and past participles) from the Taaltoets Alle Kinderen (Language Test for All Children; Verhoeven & Vermeer, 2001), and a newly designed word fluency test. This word fluency test measured the speed at which the child was able to produce words belonging to one semantic category (e.g., beverages, fruit, animals). This test was composed based on the Individuele Taalniveautest voor Kleuters (Individual Language Level Test for Children in Kindergarten; Dudal, 1999) and the subtest Ideeënproductie (Production of Words) of the Revisie Amsterdamse Intelligentie Test (Revised Intelligence Test developed in Amsterdam; Bleichrodt, Drenth, Zaal, & Resing, 1984). The child was given

20 seconds to produce as many words as possible from the given semantic category. The score is then the average of the number of correct responses on all items.

Receptive oral language. The receptive oral language test battery consisted of a receptive vocabulary test, a sentence comprehension, and a text comprehension task from the *Taaltoets Alle Kinderen* (Language Test for All Children; Verhoeven & Vermeer, 2001).

Articulation accuracy. To assess articulation accuracy, two subtests of a Dutch articulation test were administered (Speech Vision, 2000). These subtests measured the pronunciation of two or three consonant clusters in words in initial or final position. The child had to name the different pictures. A cluster was scored incorrect if the child used substitutions or deletions of one or more sounds of the consonant cluster.

2.2.2.2 Phonological abilities

Phonological tests were selected to assess PA, vSTM, and RAN. In the present study, the same phonological tests were used as described in the study by Boets, Wouters, van Wieringen, and Ghesquière (2006).

Phonological awareness. PA was measured in KG3 by a rhyme production task, an end rhyme identity task, a first sound identity task, and an end sound identity task (Boets et al., 2006; de Jong, Seveke, & van Veen, 2000). In the rhyme production task, a one-syllable word and a rhyme word were given to the child, and the child had to name another rhyme word. Each item with a correct rhyme word or nonword produced 1 point. The test started with two practice items and consisted of eight test items gradually getting more difficult[5], which resulted in a maximum score of 8. In the end rhyme identity task a picture of a one-syllable consonant–vowel–consonant (CVC) or CVCC word was shown and named to the child. The child had to indicate out of four alternatives (named and shown on a picture) the word that rhymed (same vowel and end consonant[s]) with the given word. If the child named the correct word or pointed the correct picture, the child received 1 point. The total number of items and the maximum score was 12. In the first sound identity task (respectively, the end sound identity task), again one picture and four alternatives were shown and named to the child. In these two tasks, only CVC words were used. Here, the

[5] The items started with CVC words. The difficulty level was increased by including two sound vowels (e.g., [gauw]) or consonant clusters (e.g., [gracht]).

child had to point or to name the word starting (respectively, ending) with the same beginning (respectively, ending) phoneme. The same scoring system was used with a maximum score of 10 for each task.

Verbal short-term memory. vSTM was assessed by recalling digits in a digit span forward test (Boets et al., 2006) and nonwords in a nonword repetition task (Boets et al., 2006). To standardize assessment, stimuli for both tests were recorded on CD. The digit span forward test produced sequences of digits to the child. The child had to recall the digits in the correct order, starting at a sequence of two digits. After 3 lists of the same length gradually longer sequences are presented, each time increased by one digit. The test ended after three consecutive errors. The test score was the total number of correctly recalled lists (with a maximum of 21). The nonword repetition task (adapted version of Gathercole, Willis, Baddeley, & Emslie, 1994, as described in Boets et al., 2006) consisted of 48 nonwords, increasing from two to five syllables. The child is requested to repeat the nonword. Only completely correctly repeated nonwords are counted, resulting in a maximum score of 48.

Rapid automatized naming. RAN was evaluated by a color-naming and an object-naming task (van den Bos et al., 2002). The child had to name as quickly as possible 50 items, which are taken from five colours in the first test and five pictured objects in the second test. The time to name all symbols was registered. The RAN-score is calculated as the number of symbols named per second. Thus, a higher RAN-score corresponded to a higher naming speed.

2.2.2.3 Literacy

Letter knowledge. To obtain a preliminary assessment of the level of reading development, a letter knowledge task (Boets et al., 2006) was administered in KG3. The 16 most frequently used letters in Dutch books for children (Rolf & Van Rijnsoever, 1984) were shown on two cards. In the productive part, the children were required to name the letters, either by character name or character sound. In the receptive part, the instructor named the character sounds at random and the child had to point to the corresponding printed character. The maximum score for both parts was 16. For the total letter knowledge score, results on both parts were added.

Reading and spelling. To assess literacy skills, six standardized reading tests and a standardized spelling test[6] (Dudal, 2006) were administered at the end of G1 (after receiving 1 year of formal reading instruction). The reading tests consisted of two widely used Dutch reading tests: the one-minute word reading test (Brus & Voeten, 1973) and the nonword reading test (van den Bos, Spelberg, Scheepstra, & de Vries, 1994). These tests respectively measure word reading (number of words increasing in length and read correctly in 1 min) and nonword reading (number of nonwords increasing in length and read correctly in 2 min), but they do not discriminate between reading accuracy and reading speed. To separately measure these aspects, a word reading accuracy test, a nonword reading accuracy test, a word reading speed test, and a nonword reading speed test were administered additionally (Boets, Wouters, van Wieringen, & Ghesquière, 2007). Both word and nonword reading accuracy tests were composed of 40 words (respectively, nonwords) increasing in length. The child had to read the words (respectively, nonwords) as correctly as possible without time restrictions to register a pure reading accuracy score. Both word and nonword reading speed tests were composed of 150 CVC, CV, or VC words (respectively, nonwords) with nonincreasing difficulty level. Children had to read as fast and accurately as possible during 2 min. All correctly read words in 1 min (respectively, nonwords in 2 min) were counted to obtain the score. Because the difficulty level of the words/nonwords is very low, the test measures mainly the speed of reading.

2.2.2.4 Design and procedure

The administration of the tests was spread over a period of 2 years (see Table 2.3). Each pair of matched children from the SLI and control group was tested in a quiet room at their school under the same circumstances and at the same five time points. At each time point, one pair of matched children was tested during one day in three individual sessions of approximately 30 min. Tests were taken at three time points when the children were attending KG3 (before learning to read and write) and at two time points when they were attending G1 (when they started learning to read and write). Data collection was carried out by four trained Master students in Speech-Language Pathology and Audiology.

[6] In the standardized spelling test, children had to spell single words presented in isolation, single words presented in sentence context, and short sentences. The maximum score on the test was 60.

Table 2.3 Overview of the test period and administered tests

Year	Test period	Administered tests
KG3	4th – 7th month	- nonverbal IQ - oral language part 1: productive vocabulary, sentence comprehension, productive morphology - articulation accuracy
	6th – 8th month	- PA - vSTM - RAN - letter knowledge
	8th – 10th month	- oral language part 2: word description, receptive vocabulary, word fluency, text comprehension
G1	8th – 10th month	- oral language (part 1 and 2)
	9th – 10th month	- reading - spelling

Note. KG3 = last year of kindergarten; G1 = grade 1; PA = phonological awareness; vSTM = verbal short-term memory; RAN = rapid automatized naming.

Data were analyzed in a clustered manner, comparing the SLI group with the control group at the level of the matched individuals. MMA (Littell, Stroup, & Freund, 2002; Verbeke & Lesaffre, 1997) was used with pair as a random variable (1–18) and participant group (SLI group vs. control group) as the fixed between-subject variable. Age, nonverbal intelligence, and parental educational level were included as fixed (co)variables. Because the incorporation of covariates might obfuscate some effects, group comparisons without covariates are represented as well. Standardized mean differences were calculated as a measure of effect size for each MMA by dividing the difference between the least-squares means by the pooled standard deviation of the dependent variable for that analysis (Schagen & Elliott, 2004). As described by Cohen (1969), an effect size of 0.2 is considered as small, whereas an effect size of 0.5 is called medium and an effect size of 0.8 is called large. For the nonword repetition test and the verbal short-term memory composite score, a statistical correction for articulation accuracy was applied[7]. For letter knowledge, raw scores were log-transformed prior to MMA in order to obtain a normal distribution.

[7] Articulation accuracy was added as a coviariate in the MMA because it was expected to have an unwanted influence on the nonword repetition results.

Table 2.4 Factor loadings of exploratory factor analysis with varimax rotation of all phonological measures

	Factor 1 vSTM	Factor 2 RAN	Factor 3 PArhyme	Factor 4 PAphoneme
Rhyme production	.10	.01	**.92**	.17
End rhyme identity	.28	.24	**.84**	.11
First sound identity	.56	-.14	.27	**.65**
End sound identity	.12	.04	.13	**.95**
Non-word repetition	**.83**	.20	.25	.20
Digit span	**.87**	.23	.10	.10
RAN colours	.17	**.93**	.07	-.01
RAN objects	.16	**.93**	.13	-.01

Note. n = 36. KG3 = last year of kindergarten; vSTM = verbal short-term memory; RAN = rapid automatized naming; PA = phonological awareness. Bold text indicates the dominant factor scores of the phonological measures used in the composite scores.

Variables that were assumed to measure a common theoretical construct were aggregated into composite scores. For the phonological measures, an exploratory factor analysis with varimax rotation retained four factors based on the Scree test. Factor loadings of all phonological measures are presented in Table 2.4. The first factor had heavy loadings of the nonword repetition task and the digit span and a more modest loading of the first sound identity task. As a consequence, this factor could be reliably labeled as the vSTM factor. The second factor was completely determined by heavy loadings of both the color- and the object-RAN task, and as such could be regarded as the RAN factor. The third factor was completely determined by heavy loadings of the rhyme production task and the end rhyme identity task and hence represents PA at the rhyme level (PArhyme factor). Finally, the first sound identity task and the end sound identity task loaded heavily on the fourth factor, namely, the PAphoneme factor. Consequently, composite scores for PArhyme, PAphoneme, vSTM, and RAN were calculated by computing *z* scores for each task and averaging the scores of the tests that determined the same underlying construct (presented in bold in Table 2.4). In the same way, a composite score for the four expressive oral language tests and a composite score for the three receptive oral language tests were calculated by averaging the *z* scores of the corresponding tests. All composite scores were

further standardized relative to the mean and standard deviation of the control group (with *M* = 0 and *SD* = 1 for the control group).

Spearman correlation coefficients were calculated to analyze relationships between the kindergarten variables and G1 measures. To determine which children have reading and spelling problems at the end of G1, a literacy composite score was calculated averaging the standardized results (relative to normative data) of all reading and spelling tests. A cut-off point of –1 *SD* on this literacy composite score was taken as a criterion to delineate the literacy-delayed group. Another criterion in order to define dyslexia is that the reading and spelling problems have to be persistent and should be didactically resistant (Gersons-Wolfensberger & Ruijssenaars, 1997). This additional criterion could not yet be verified in our study, as children had only 1 year of formal reading instruction. Therefore, we do not call the children scoring below –1 *SD* on the literacy composite score 'dyslexic' or 'literacy-disabled' but 'literacy-delayed' (hence 'LD' stands in the further text for 'literacy-delayed'). The SLI-LD group was compared with the SLI-NL group and the control-NL group using a clustered MMA design with pair as random variable, participant group as fixed between-subject variable and with the same covariates as mentioned above. All post hoc analyses were corrected for multiple comparisons using the Tukey procedure (α = .05).

2.3 Results

Data analyses are presented in function of their relevance to four research questions.

2.3.1 Do children with SLI show more problems with PA, vSTM, RAN, and letter knowledge in KG3 than typically developing children?

Descriptive statistics and MMA test statistics for these KG3 measures are displayed in Table 2.5.[8] MMA significance levels and effect sizes are presented for the group comparisons with and without including covariates age, nonverbal intelligence, and parental educational

[8] The results of the phonological data presented in Table 2.5 are similar to the group comparisons of the original 26 pairs of children. Only on four measures results of the MMA with covariates turned out to be different: The original group of 26 SLI children did differ significantly from their 26 controls on rhyme production (*p* = .007), end rhyme identity (*p* = .03), PArhyme composite score (*p* = .006), and the digit span task (*p* = .005).

Table 2.5 Scores for phonological and letter knowledge abilities in KG3: maximum (*Max*), mean (*M*), and standard deviation (*SD*); significance level (*p*) and effect size (*ES*) for the Mixed Model Analysis

		SLI		**Control**		**Group comparisons**			
		n = 18		*n* = 18		**with covariates**[a]		**without covariates**	
	Max	*M*	*SD*	*M*	*SD*	*p*	*ES*	*p*	*ES*
PArhyme Composite		**-2.0**	**3.0**	**0.0**	**1.0**	**.20**	**-0.47**	**.01**	**-0.88**
Rhyme production	8	6.4	2.3	7.7	0.8	.32	-0.37	.03	-0.70
End rhyme identity	12	7.9	3.6	10.4	1.5	.16	-0.49	.01	-0.89
PAphoneme Composite		**-1.3**	**1.1**	**0.0**	**1.0**	**.03**	**-0.96**	**.002**	**-1.25**
First sound identity	10	4.3	2.2	7.3	2.2	.01	-1.21	.0008	-1.37
End sound identity	10	4.1	2.5	6.1	2.2	.21	-0.50	.02	-0.83
vSTM Composite		**-1.4**	**0.9**	**0.0**	**1.0**	**.04**[b]	**-1.15**[b]	**.0004**	**-1.46**
Non-word repetition	48	10.8	4.6	20.4	6.2	.04[b]	-1.25[b]	<.0001	-1.78
Digit span	21	6.2	1.8	7.8	1.7	.20	-0.51	.01	-0.91
RAN Composite		**-0.5**	**1.1**	**0.0**	**1.0**	**.90**	**-0.05**	**.17**	**-0.48**
RAN colours		0.6	0.2	0.7	0.2	.53	-0.25	.14	-0.52
RAN objects		0.6	0.2	0.7	0.1	.69	0.16	.25	-0.40
Letter knowledge (LK)	**32**	**6.7**	**5.2**	**15.4**	**9.1**	**.02**	**-0.96**	**.0001**	**-1.27**
LK productive	16	2.5	2.9	7.4	5.1	.02	-0.91	.0007	-1.12
LK receptive	16	4.2	2.7	8.1	4.3	.03	-0.85	.0005	-1.19

Note. KG3 = last year of kindergarten; SLI = specific language impairment; PA = phonological awareness; vSTM = verbal short-term memory; RAN = rapid automatized naming.
[a] Mixed Model Analysis with age, nonverbal IQ, and parental educational level as covariates. [b] These values were corrected for articulation accuracy.

level. For PArhyme, PAphoneme, and vSTM tasks, the SLI group scored lower than the control group, but not always significantly when covariates were included. However, if we do not take into account the covariates, all PArhyme, PAphoneme, and vSTM tasks show significant group differences. Effect sizes (see Table 2.5) for PA and vSTM for both group comparisons were almost all medium to large. Remarkable were the large standard deviations for both PArhyme tasks for the SLI group in comparison with the control group and a ceiling effect for the rhyme production task for the control group, which are probably the reasons for the nonsignificant *p* values for the MMA with covariates. For the two RAN

tasks and their composite score, no significant group differences were observed, with very small effect sizes. Similar results were obtained when no covariates were taken into account. For productive and receptive letter knowledge, the SLI group scored significantly lower than the control group with large effect sizes.

2.3.2 Do children with SLI show more reading and spelling problems at the end of G1 than typically developing children?

At the end of G1, reading and spelling skills were assessed. In Table 2.6, maximum scores, means, standard deviations, MMA significance levels, and effect sizes with and without including covariates age, nonverbal intelligence, and parental educational level are given for each test. It is evident that children from the SLI group scored consistently lower on every literacy measure, but none of the group differences was statistically significant when covariates were included. Effect sizes including covariates were very small, both for reading accuracy and reading speed. However, MMA without covariates showed significant group differences and large effect sizes for the word reading accuracy test and spelling test. The mean reading and spelling scores of the control group were comparable to normative data (Boets et al., 2007; Brus & Voeten, 1973; van den Bos et al., 1994) and were almost all situated within 1 *SD* above and below the reference means.

Table 2.6 Scores for literacy at the end of G1: maximum (*Max*), mean (*M*), and standard deviation (*SD*); significance level (*p*) and effect size (*ES*) for the Mixed Model Analysis

		SLI		**Control**		**Group comparisons**			
		n = 18		*n* = 18		**with covariates**[a]		**without covariates**	
	Max	*M*	*SD*	*M*	*SD*	*p*	*ES*	*p*	*ES*
Word reading accuracy	40	17.4	11.0	27.1	12.0	.28	-0.32	.01	-0.83
Non-word reading accuracy	40	10.4	8.8	15.7	11.4	.79	-0.09	.11	-0.52
Word reading speed	150	70.2	33.6	83.2	44.9	.66	0.14	.34	-0.33
Non-word reading speed	150	42.9	23.1	56.3	29.8	.89	0.05	.15	-0.50
One-minute word reading	116	17.3	6.6	23.4	14.3	.87	-0.05	.12	-0.54
Non-word reading	116	16.6	8.5	22.1	11.2	.81	-0.08	.11	-0.55
Spelling	60	44.0	12.3	52.3	6.5	.17	-0.43	.01	-0.85

Note. G1 = grade 1; SLI = specific language impairment.
[a] Mixed Model Analysis with age, nonverbal IQ, and parental educational level as covariates.

2.3.3 What are the relations between KG3 measurements for PA, vSTM, RAN, and letter knowledge, and G1 measurements for reading and spelling skills in children with SLI versus typically developing children?

Spearman correlations between the reading and spelling tests measured at the end of G1 and the (composite) scores of PArhyme, PAphoneme, vSTM, RAN, and letter knowledge measured in KG3 are presented in Table 2.7 and Table 2.8. Because some correlations show remarkable differences for the SLI group and the control group, they are given separately (see Table 2.7 for the control group and Table 2.8 for the SLI group)[9].

For the control group (Table 2.7), RAN and letter knowledge in KG3 are strongly and significantly correlated with all reading and spelling measures (r_S between .53 and .77). RAN has a slightly stronger correlation with both reading speed scores in comparison with both reading accuracy scores. Surprisingly, PArhyme and PAphoneme composite scores showed weak or no correlation with all reading and spelling tests, which were all nonsignificant. For vSTM, correlations with all reading and spelling tests were mild and nonsignificant. Moreover, vSTM is slightly more correlated with both reading accuracy scores in comparison with both reading speed scores.

Table 2.7 Spearman correlations between KG3 phonological and G1 literacy measures for the control group

G1 / KG3	Word reading accuracy	Non-word reading accuracy	Word reading speed	Non-word reading speed	Spelling
PArhyme	-.07	.20	-.16	-.13	.11
PAphoneme	.21	.19	.16	.23	.03
vSTM	.39	.47°	.34	.36	.37
RAN	.53*	.57*	.59**	.64**	.67**
LK	.77***	.61**	.73***	.77***	.66**

Note. n = 18. KG3 = last year of kindergarten; G1 = grade 1; PA = phonological awareness; vSTM = verbal short-term memory; RAN = rapid automatized naming; LK = letter knowledge.
° p < .10; * p < .05; ** p < .01; *** p < .001

[9] However, since the two groups are small, the correlations of the separate groups should be interpreted with caution. As a comparison, in Appendix 2A the correlations of the combined groups are presented.

Table 2.8 Spearman correlations between KG3 phonological and G1 literacy measures for the SLI group

G1 / KG3	Word reading accuracy	Non-word reading accuracy	Word reading speed	Non-word reading speed	Spelling
PArhyme	.24	.15	.13	.14	.43
PAphoneme	-.13	-.29	-.05	-.23	-.05
vSTM	.16	.08	.24	.31	.05
RAN	.72***	.66**	.53*	.62**	.66**
LK	.17	.15	.003	-.18	.25

Note. n = 18. KG3 = last year of kindergarten; G1 = grade 1; PA = phonological awareness; vSTM = verbal short-term memory; RAN = rapid automatized naming; LK = letter knowledge.
$^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$

Similar to the control group, the SLI group (Table 2.8) had strong and significant correlations between the RAN composite score in KG3 and all reading and spelling scores in G1 (r_S between .53 and .72). In contrast with the control group and contrary to the expectations, RAN had for the SLI group slightly stronger correlations with reading accuracy than with reading speed. Moreover, for the SLI group, letter knowledge showed no correlation with reading and spelling scores, in contrast with the strong correlations that were present in the control group. PArhyme, PAphoneme, and vSTM composite scores showed weak or no correlation with all reading and spelling tests, which were all nonsignificant.

2.3.4 Do children with SLI-LD show more problems with PArhyme, PAphoneme, vSTM, RAN, and letter knowledge than SLI-NL children or Control-NL children?

Using a cut-off point of –1 *SD* on the literacy composite score based on reading and spelling scores in G1, 9 of the 18 SLI children were literacy-delayed (SLI-LD group), whereas 4 of the 18 control children were literacy-delayed (control-LD group). In this manner, four groups were obtained: the SLI-NL group (n = 9), the SLI-LD group (n = 9), the control-NL group (n = 14), and the control-LD group (n = 4). Chi-square tests revealed that this group partitioning is close to significance (p = .08). The last group will not be further analyzed because of its small size.

Table 2.9 compares all composite scores measured at KG3 (PArhyme, PAphoneme, vSTM, RAN, letter knowledge, expressive and receptive oral language) for these three groups (SLI-LD, SLI-NL, control-NL). All means and standard deviations shown in Table 2.9 were standardized relative to the mean and standard deviation of the control-NL group (M = 0, SD = 1 for the control-NL group). Effect sizes and significance levels of the group comparisons were presented with and without covariates (age, nonverbal IQ, and parental educational level). Given the rather small sample sizes, it should be noted that the statistical power to discern significant group differences is relatively small.

In KG3, both SLI groups (with and without literacy delay) had low scores for PArhyme, PAphoneme, vSTM, and letter knowledge in comparison with the control-NL group. Most of these group comparisons were significant with large effect sizes when no covariates were taken into account. With covariates, however, fewer significant differences were retained. Remarkably, the SLI-NL group scored even lower than the SLI-LD group for PAphoneme. The scores for the three groups on the RAN tests showed a completely different pattern: the SLI-NL group had similar scores as the control-NL group, but the SLI-LD group scored lower compared to the SLI-NL group and control-NL group. These differences were not significant when covariates were taken into account but were (close to) significant without covariates. The effect sizes for the comparison of the SLI-LD group with the SLI-NL and control-NL groups were large, whereas the effect size for the comparison of the SLI-NL group with the control-NL group was small. For oral language in KG3, the SLI-LD and the SLI-NL group had, as expected, lower scores than the control-NL group and most of these differences were significant. Note that for expressive and receptive oral language the SLI-LD and the SLI-NL group did not differ significantly when covariates were taken into account. However, for expressive oral language, MMA without covariates showed a significantly lower score for the SLI-LD group compared to the SLI-NL group.

Table 2.9 Scores for phonological, letter knowledge, and oral language abilities in KG3: mean (*M*) and standard deviation for the SLI-LD, SLI-NL, and Control-NL group; significance level (*p*) and effect size (*ES*) for the Mixed Model Analysis

	SLI-LD	SLI-NL	Control-NL	Group comparisons with covariates[a]			Group comparisons without covariates		
	(1)	(2)	(3)						
	n = 9	*n* = 9	*n* = 14	1-2	1-3	2-3	1-2	1-3	2-3
	M (SD)	*M (SD)*	*M (SD)*	*ES*	*ES*	*ES*	*ES*	*ES*	*ES*
PArhyme	-2.8 (3.1)	-0.9 (2.3)	0.0 (1.0)	-0.25	-0.81	-0.62	-0.69	-1.30*	-0.50
PAphoneme	-0.9 (1.3)	-1.4 (0.6)	0.0 (1.0)	1.13°	0.09	-1.17*	0.43	-0.83°	-1.54**
vSTM	-1.6 (0.9)	-1.3 (0.9)	0.0 (1.0)	0.53[b]	-0.97[b]	-1.47[b]*	-0.33	-1.61**	-1.32*
$RAN^{Colours+Objects}$	-1.4 (1.4)	-0.3 (0.5)	0.0 (1.0)	-0.56	-0.67	-0.22	-1.05°	-1.20**	-0.34
Letter knowledge	-1.3 (0.7)	-1.3 (0.5)	0.0 (1.0)	0.27	-0.95	-1.19*	-0.19	-1.77**	-1.43**
Expressive Language	-3.0 (0.7)	-2.0 (0.6)	0.0 (1.0)	-0.98	-2.79***	-2.12***	-1.60*	-3.36***	-2.22***
Receptive Language	-1.9 (0.8)	-2.2 (1.2)	0.0 (1.0)	0.93	-1.08	-1.85**	0.36	-1.99***	-2.10***

Note. Tukey correction was used for all pairwise group comparisons. SLI = specific language impairment; SLI-LD = SLI group with literacy delay; SLI-NL = SLI group with normal literacy; Control-NL = control group with normal literacy; PA = phonological awareness; vSTM = verbal short-term memory; RAN = rapid automatized naming.

[a] Mixed model analysis with age, nonverbal IQ, and parental educational level as covariates. [b] These values were corrected for articulation accuracy.

° $p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$

2.4 Discussion

This study focused on the role of preschool phonological skills (PA, vSTM, and RAN) and letter knowledge in the development of reading and spelling problems in children with SLI and allows us to draw some interesting conclusions.

RAN measured in KG3 was highly correlated with reading (both accuracy and speed) and spelling at the end of G1 for children with SLI as well as for typically developing children. Moreover, RAN scores measured in KG3 were lower for the SLI group with literacy delay compared to the SLI group with normal literacy and compared to normal reading controls. Based on these observations, RAN can be regarded as a good preschool predictor for reading and spelling problems at the end of G1 in children with SLI. This was already hypothesized by Bishop et al. (2009) and is empirically confirmed in this study, consistent with the findings of Catts (1993). A slightly stronger correlation between RAN and reading speed compared to reading accuracy could be observed in the control group, but not in the SLI group.

PA (at rhyme and phoneme level) and vSTM scores in KG3 were low for the whole SLI group, not only for the SLI group with literacy delay. These skills did not differentiate the SLI group with literacy delay and the SLI group with normal literacy. Surprisingly, PA and vSTM seem to play a less important role for word reading and spelling development in children with SLI, as PA and vSTM in KG3 did not correlate significantly with reading (both accuracy and speed) and spelling in children with SLI. Part of this phenomenon can be due to the transparent orthography of the language, which is confirmed by a similar lack of correlation between PA scores and reading/spelling scores in the control group. An identical lack of correlation in the SLI group was found in the study by Bishop et al. (2009) and in the study by Scheltinga et al. (2003). Moreover, this result is consistent with the finding of de Bree (2007) for vSTM, but contradicts with the study by Catts (1993). Our results suggest that PA and vSTM in kindergarten do not predict reading and spelling in children with SLI or in children in general, in an orthographically transparent language.

In the control group but not in the SLI group, good letter knowledge in KG3 was associated with better performance for reading and spelling at the end of G1. Hence, letter knowledge does not seem to be a reliable predictor for reading and spelling for children with SLI. This finding is in contrast with the results obtained by Catts et al. (2002). There, letter

knowledge was proposed to be a reliable predictor for children with language impairment beside other predictors.

It is important to observe that these effects for RAN, PA, vSTM, and letter knowledge are not influenced by the severity of the language problems, as the oral language skills in SLI children with and without literacy problems were in general not significantly different (although we have to be careful with this interpretation because of the small sizes of the groups). Looking at expressive and receptive oral language ability, it is interesting to observe that the SLI children with literacy problems generally scored poorer than the SLI normal literacy group on expressive but not on receptive oral language ability.

In summary, not all known predictors for reading and spelling problems in the general population seem to predict reading and spelling problems in children with SLI. In kindergarten, only RAN is able to predict reading and spelling ability at the end of G1 for children with SLI. Not all children with SLI seem to have RAN problems (i.e., 4 of 18 in our study had a score below –1 *SD* in comparison with the control group, all from the SLI-LD group). On the other hand, most children with SLI do have problems with phonological awareness (i.e., 13 of 18 in our study had a score below –1 *SD* on PArhyme and/or PAphoneme, 6 belong to the SLI-LD group) and problems with vSTM (i.e., 12 of 18 in our study, 6 belong to the SLI-LD group). The PA and vSTM problems can be caused by oral language problems as mentioned by Bishop et al. (2009) as all but 1 of the 17 children with PA and/or vSTM problems had an expressive language score lower than –1.6 *SD* in comparison with the control group. Not all children with SLI do have an increased risk for reading and spelling problems in G1. Based on these results, we can infer that only the SLI subgroup with RAN problems on top of PA and vSTM problems will develop reading and spelling problems in G1. In a similar vein, good RAN skills can be seen as a protective factor against the development of reading and spelling deficits (cf. Raitano et al., 2004; Tunick, 2004).

Surprisingly, in our study there was no significant difference in reading (both for speed and accuracy and for words and nonwords) and spelling between the SLI group and the control group at the end of G1 when covariates were taken into account. Moreover, effect sizes were very small and were not larger for reading speed than for reading accuracy as one might have expected for a transparent language. We initially expected a group

difference based on three elements: first, the relatively strong comorbidity between SLI and dyslexia; second, the observation that children with SLI scored significantly lower on most of the tests for PA, vSTM, and letter knowledge in KG3 in comparison with typically developing children; and third, the widely established predictive relationship between PA, letter knowledge, and reading development (e.g., Anderson et al., 1993; Catts, 1993; Catts et al., 2002; McArthur et al., 2000). The fact that PA and vSTM problems in KG3 did not cause literacy problems in G1 in this empirical study is in contradiction with both the Double Deficit Hypothesis and the Single Deficit Hypothesis. Although there is a lack of difference at the level of the group, among the 18 children with SLI 9 had a literacy score lower than 1 *SD* at the end of G1. This prevalence value of 50% is rather high, which is partially due to the mild criterion but is in line with the study of McArthur et al. (2000) where the same cut-off score of –1 *SD* was used. In addition, when no covariates were taken into account in the MMA, a significant group difference was observed for the word reading accuracy task and spelling task. Moreover, reading and spelling was measured in a very early developmental stage where differences may not yet be very pronounced. Indeed, the rate of the comorbidity between SLI and dyslexia is thought to increase over time (Snowling et al., 2000).

Because the empirical data are limited to the Dutch language, one may think that the conclusions about the small role of PA and the important role of RAN in the development of reading in children with SLI may be restricted to transparent languages. Indeed, it is generally acknowledged that in transparent languages such as Dutch, the predictive role of PA may be less pronounced (Elbro & Scarborough, 2004) and RAN can play a more important role (Brizzolara et al., 2006; van den Bos, 1998; Wimmer, 1993). However, as the conclusions of our study are consistent with the conclusions of a study in English, a less transparent language (Bishop et al., 2009), and a study in Italian, an even more transparent language than Dutch (Brizzolara et al., 2006), the results of our study do not seem that language specific.

Although the conclusions of the studies by Catts et al. (2005) and Bishop et al. (2009) may seem contradictory, after precise analysis and comparison with our study, the results can be reconciled by considering the evolution of the variables over time. In kindergarten, grade 1 and grade 2, PA and vSTM skills seem to be weak in all SLI children, also in those with normal reading development, as all three studies observed. In later reading

development measured in grade 4 and grade 8, both PA and vSTM improved for SLI children with normal reading but remained weak in SLI children with dyslexia, as observed in the study by Catts et al. (2005) and in line with some results for vSTM in the study by Bishop et al. (2009) for children at the age of 9. Catts et al. (2005) offered two possible explanations for this time-effect: It may reflect the reciprocal influence of reading on PA or it may indicate that PA deficits are more stable over time in children with dyslexia.

The number of children with SLI and the control group are rather small in this study. However, the selection of both groups was done very carefully and both groups were matched and analyzed while taking into account educational environment (same class), gender, age, nonverbal intelligence and parental educational level. A very important element is that each pair of SLI and control child received exactly the same instruction, which makes the comparisons for reading and spelling ability highly reliable. Moreover, children of both groups were selected spread over the whole Dutch part of Belgium (around 6 million inhabitants) and not only those presented at one rehabilitation center. Most results of both the control and the SLI group are also consistent with literature, indicating that they are representative for both populations.

Two critical elements regarding the group compositions in this study are the persistence of the oral language problems for the SLI children and the representativeness of the control group. Language results of KG3 and G1 showed that the SLI group had very low scores on almost any language aspect compared to the control group. Although the SLI children were initially selected for scoring very low on at least one language aspect, the whole SLI group had significantly lower scores for almost all language aspects, even in G1. The language problems for the SLI group seemed to be persistent, whereas the control group scored within normal ranges for oral language in KG3 and G1. Moreover, repeated measurements showed that the evolution in oral language ability was similar for the SLI group and control group, and the gap between both groups did not narrow despite the oral language therapy that all SLI children received. Therefore, we can conclude that the selection criteria for both groups were appropriate.

We conclude that preschool RAN measures appear to have an important role in predicting the presence of reading and spelling problems among SLI children. Therefore, further research is needed to analyze the underlying cognitive aspects measured by RAN

tests. Previous research has produced a number of possible cognitive aspects as reviewed in Wolf and Bowers (2000), but no decisive conclusions have been reached. Although degraded phonological representations often have been mentioned, more recent studies hypothesize a disturbed access of phonological codes (Ramus & Szenkovits, 2008) or a general deficit in the speed of processing (Catts, Bridges, Little, & Tomblin, 2008). Another open question is whether RAN can be considered as a part of phonology. In this respect, our study demonstrates that RAN has a very different role than PA and vSTM for children with SLI. In this study, only decoding skills and no reading comprehension skills have been measured. Language impairment may have a stronger impact on reading comprehension than on single-word recognition as stated by Catts (1993) and Bishop et al. (2009). It is intended to continue this longitudinal study to find out whether the children with SLI will develop word recognition and spelling problems and/or reading comprehension problems later on and which children with SLI will develop these problems. This study has been performed in Dutch, a transparent language for reading and spelling. Further longitudinal research in other languages and with larger groups starting from kindergarten will also be necessary to generalize these results for all children with SLI.

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Appendix 2A Correlations between phonology and literacy measures for the combined groups

Since the correlations of the SLI and the control group separately (see tables 2.7 and 2.8) were based on small samples, it was worthwhile to investigate the correlations of the combined groups. For PArhyme, PAphoneme, vSTM and RAN, the patterns of both groups were similar and could therefore be combined (see Table 2.10). In view of the larger size of the data set, significant correlations appeared for vSTM and most literacy scores in contrast to the correlations of both groups separately. For RAN, significant correlations with literacy were obtained, comparable to the correlations of both groups separately.

Table 2.10 Spearman correlations between KG3 phonological and G1 literacy measures for the control and SLI group combined

G1 / KG3	Word reading accuracy	Non-word reading accuracy	Word reading speed	Non-word reading speed	Spelling
PArhyme	.25	.29	.04	.10	.41*
PAphoneme	.18	.08	.10	.13	.11
vSTM	.44**	.37*	.31°	.39*	.36*
RAN	.59***	.59***	.57***	.63***	.57***

Note. n = 36. KG3 = last year of kindergarten; G1 = grade 1; PA = phonological awareness; vSTM = verbal short-term memory; RAN = rapid automatized naming; LK = letter knowledge.
° p < .10; * p < .05; ** p < .01; *** p < .001

Chapter 3: Development of phonological processing skills in children with specific language impairment with and without literacy delay: a three-year longitudinal study

The content of this chapter has been described in Vandewalle, E., Boets, B., Ghesquière, P., & Zink, I. (in press). Development of phonological processing skills in children with specific language impairment with and without literacy delay: a three-year longitudinal study. Journal of Speech, Language, and Hearing Research.

Abstract

Purpose: To compare the development of phonological skills in children with SLI with and without literacy delay and to examine whether kindergarten phonological skills could discriminate these two groups.

Method: In a longitudinal study eight children with SLI and literacy delay, 10 children with SLI and normal literacy, and 14 typically developing children were studied from the last year of kindergarten to the start of grade 3. A wide range of phonological tasks (phonological awareness, PA; verbal short-term memory, vSTM; and rapid automatized naming, RAN) were administered yearly.

Results: The SLI group with literacy delay scored significantly lower than the typically developing children on almost all phonological tasks in all grades, while the SLI group with normal literacy scored significantly lower only on demanding PA and vSTM tasks. A combination of kindergarten PA and RAN skills could correctly classify 75% of the children with SLI. By including vSTM, the discriminatory value did not increase.

Conclusions: Children with SLI and normal literacy at age 8;1 years continued to have difficulties with demanding PA and vSTM tasks. Children with SLI and poor PA and RAN in kindergarten were at high risk of developing literacy problems in a transparent orthography.

3.1 Introduction

SLI is defined as an impairment of language comprehension, language production, or both, in the absence of hearing impairment, general developmental delay (i.e., a normal performance IQ), neurological impairment, and autism diagnosis (e.g., Schwartz, 2009). Children with SLI may have deficits in different oral language aspects (phonology, morphology, syntax, semantics and pragmatics). This disorder affects approximately 7% of the monolingual 5 to 6 year old children (Tomblin et al., 1997).

Dyslexia is generally defined as a disorder characterized by severe difficulties in accurate and fluent word reading and spelling that are persistent and resistant to the usual teaching measures and remedial efforts, and has a prevalence of about 5 to 10%. It is widely accepted that the core deficit lies in phonological processing and stems from poorly specified phonological representations (Snowling, 2000).

SLI and dyslexia often co-occur. Data on the prevalence of the comorbidity are inconsistent, varying from 12.5% to 85% (for an overview, see McArthur, Hogben, Edwards, Heath, & Mengler, 2000). These different estimates relate to the definitions and criteria used to diagnose SLI and dyslexia, the way of selecting participants and the age of the participants at the time of diagnosis. Because comorbidity of SLI and dyslexia is clearly above chance level, children with SLI seem to have an increased risk to develop dyslexia. The cause of this comorbidity is still under study. Different models have been proposed to explain the overlap between both disorders. Catts, Adlof, Hogan and Weismer (2005) presented three different models of the relationship between SLI and dyslexia, with a phonological processing deficit causing dyslexia. In a first one-dimensional model, SLI is a severe form of dyslexia, caused by a more severe phonological deficit. This model did not get much support because in this model all children with SLI are supposed to have literacy difficulties. In a second two-dimensional model, the same phonological deficit causes SLI and dyslexia (Bishop & Snowling, 2004), but in SLI other nonphonological deficits cause additional problems in the development of oral language. In a third model, SLI and dyslexia are distinct developmental disorders with different cognitive deficits and different manifestations and the overlap is due to comorbidity. The data of the study by Catts et al. (2005) fitted best this model because in their study, it was observed that a deficit in phonological processing was

closely associated with dyslexia but not with SLI when it occurred in the absence of dyslexia and the overlap between SLI and dyslexia was relatively small. In contrast to the previous one- and two-dimensional models, a fourth model, described by Pennington (2006), takes multiple deficits into account. In this model, developmental disorders such as SLI and dyslexia are the result of multiple deficits. Comorbidity between disorders occurs because one or more of these deficits is shared. Carroll and Myers (2010) observed that both family history of dyslexia and receiving speech-language therapy were independent risk factors in predicting reading difficulties. Their results fitted most closely to this multiple deficits model of Pennington (2006). They argued that SLI and dyslexia both have shared difficulties in phonological processing combined with other disorder-specific deficits. For SLI, the disorder-specific deficits might be difficulties in semantic and syntactic aspects of language. For dyslexia on the other hand, visual-verbal association difficulties such as problems with rapid automatized naming might be a disorder-specific risk factor. SLI and dyslexia are thus separable but linked disorders. They share some risk factors and deficits, but each has additional specific deficits.

3.1.1 Phonological processing

Phonological processing is used for a wide range of skills (Siegel, 2003; Uppstad & Tonnessen, 2007). It involves the representation, manipulation, short-term storage and retrieval of speech sounds (Snowling, 2000; Wagner & Torgesen, 1987). Three interrelated but distinctive phonological components can be distinguished: (1) *phonological awareness* (PA) or the conscious sensitivity to the sound structure of language, which is assessed by a wide variety of tasks that measure the ability to distinguish and manipulate syllables or phonemes (Yopp, 1988), such as phoneme deletion or spoonerism tasks; (2) *verbal short-term memory* (vSTM) or the ability to shortly maintain auditory information, usually assessed by digit span or nonword repetition tasks; (3) *lexical access* or the retrieval of lexical sound-based representations from long-term memory, which is measured by rapid automatized naming tasks (RAN) such as letter or colour naming. The performance on each of these three components is assumed to be determined by the quality, specificity or distinctness of underlying phonological representations (Elbro, 1996; Snowling, 2000; Wagner, Torgesen, & Rashotte, 1994), although this remains a debated issue (Bowers & Ishaik, 2003). There is an extensive discussion whether PA, vSTM and RAN are partially distinct cognitive skills that

jointly tap a similar underlying skill called ‘phonology’ (Pennington, Cardoso-Martins, Green, & Lefly, 2001; Pennington & Lefly, 2001; Wagner et al., 1994) or whether RAN has an independent status.

Within the phonological awareness component, tasks may encompass different subskills that may be linked in different ways to the acquisition of reading and spelling skills (Treiman & Zukowski, 1996). The use of such a wide variety of tasks makes interpretation, consolidation and comparison of research findings difficult (Yopp, 1988). Performance varies with the cognitive demands of the task. Complex tasks, which require more steps to completion and which place a greater burden on memory, tend to be harder than simple tasks. Performance also depends on the linguistic level that is tapped by the task. This linguistic level is determined by the size of the shared unit (Brady, Fowler, Stone, & Winbury, 1994; Walley, Smith, & Jusczyck, 1986). For example, syllables are more accessible than rhymes/onsets and rhymes/onsets are more accessible than phonemes. However, also the linguistic status of the unit determines the difficulty level (Treiman & Zukowski, 1996). It is for instance easier to detect a shared consonant when it constitutes an individual onset than when this consonant is part of a cluster onset. There exists controversy whether the different levels of phonological awareness represent one general ability or several distinct abilities. Based on the results of four independent studies, Anthony and Lonigan (2004) concluded that sensitivity to these various linguistic units can be best conceptualized by one general underlying phonological ability.

3.1.2 The link between phonological processing and reading development

Several prospective longitudinal studies have suggested a causal and reciprocal link between sensitivity to the phonological structure of words and progress in reading acquisition (e.g., Bentin & Leshem, 1993; Wagner et al., 1994). It is generally accepted that PA and RAN are good predictors for reading in typically developing children (for a review, see Scarborough, 1998). This relationship between phonological abilities and reading achievement also depends on the level of reading proficiency and the phase of reading acquisition (de Jong & van der Leij, 1999). In general, PA tends to be more important in the initial phases of reading development and is more strongly related to reading accuracy. RAN is of greater importance in the later development of reading fluency and reading comprehension and relates more to reading speed (e.g., van den Bos, Ruijssenaars, &

Spelberg, 2008; Verhagen, Aarnoutse, & van Leeuwe, 2008). Individual differences in non-alphanumeric RAN, PA, and letter knowledge measured before reading instruction, are strong, independent predictors of subsequent reading achievement (Lerväg & Hulme, 2009). After the onset of reading instruction, alphanumeric RAN predicts further reading development better than non-alphanumeric RAN (Lerväg & Hulme, 2009).

In children with dyslexia, persistent deficits have been shown in PA, vSTM and RAN (e.g., Boets et al., 2010). In the double deficit hypothesis, RAN is considered as a unique and independent predictor for dyslexia besides the PA deficit (e.g., Bowers & Ishaik, 2003; Wolf & Bowers, 1999). This hypothesis predicts that if both PA and RAN skills are affected, the child has a double deficit and his or her reading and spelling impairment will be more severe. Although it is not clear whether similar impairments predict reading and spelling problems in children with SLI, a number of SLI studies did retain the same predictors, such as PA and RAN (Catts, Gillispie, Leonard, Kail, & Miller, 2002; Elbro & Scarborough, 2004; Scarborough, 1998).

Differences in languages, and especially differences in the transparency of the orthography, can influence the rate and pattern of development of phonological processing and literacy skills. Both oral and written language input play a role in raising children's phonological awareness. In a language with a relatively transparent orthography, metaphonological abilities (i.e., PA) tend to develop more quickly than in languages with less transparent orthographies (Caravolas & Bruck, 1993). Moreover, RAN skills assessed in kindergarten might be a more important predictor for reading development than PA and vSTM, especially for the development of reading fluency which is the main deficit in dyslexic children in a transparent language (de Jong & van der Leij, 1999; Wimmer, Mayringer, & Landerl, 2000). Brizzolara et al. (2006) suggested that impairments in RAN may represent the main cognitive marker of developmental dyslexia in a transparent language.

3.1.3 Development of phonological processing in children with SLI

The developmental trajectories of the different phonological components have rarely been reported in children with SLI. In the following we present an overview of cross-sectional and longitudinal studies dealing with the development of phonological processing in children with SLI.

3.1.3.1 Phonological awareness

Treiman and Zukowski (1996) mentioned that different aspects of PA develop at different phases. In typical development, children initially learn to segment speech into words. This is followed by the ability to divide words into syllables. Then they gain the aptitude to divide syllables into intra-syllabic components, and finally intra-syllabic units into phonemes. The developmental trend that segmentation at syllable level is easier than segmentation at intra-syllabic level which on its turn is easier than segmentation at phoneme level was observed in a cross-sectional study of Thatcher (2010) in 15 typically developing children. However, this trend could not be confirmed in 15 children with SLI from preschool (4;7 years), over kindergarten (6;1 years) to first grade (7;5 years). The children with SLI exhibited no significant improvement in their abilities to segment at the various levels. This might be explained by generally decreased PA abilities in children with SLI. In contrast to the PA development in phases in typically developing children, several studies did not find a staged progression of PA from syllables to rhymes to phonemes to be universal. Children can detect similar- and dissimilar-sounding words before they can manipulate sounds within the words, and children can generally blend phonological information before they can segment phonological information of the same linguistic complexity (Anthony, Lonigan, Driscoll, Phillips, & Burgess, 2003). Moreover, children refine phonological awareness skills they have already acquired while they are learning new phonological awareness skills (Anthony et al., 2003), contrary to a strict stage theory of development. Moreover, there are a number of oral and written language effects playing a role on the development of PA (for an overview, see Anthony and Francis, 2005). A more specific study for Dutch language by Geudens and Sandra (2003) revealed the important role of phonetic factors in the segmentation of syllables (e.g., segmenting VC-syllables was easier for prereaders and first grade readers than segmenting CV-syllables).

Early PA deficits are present in young children with SLI with and without later dyslexia (i.e., at 4 and 6 years old and in grade 2) (Bishop, McDonald, Bird, & Hayiou-Thomas, 2009; Catts et al., 2005), but they resolve over time (i.e., in grade 4 and 8) in those children who develop normal reading skills (Catts et al., 2005). Whereas Bishop et al. (2009) suggested that PA is related to oral language development, Catts et al. (2005) concluded that PA processing is specifically related to reading development. Catts et al. suggested that this

time-effect may either reflect the reciprocal relation of reading and PA or it may indicate that PA deficits are more stable over time in children with dyslexia.

3.1.3.2 Verbal short-term memory

Children with SLI frequently experience vSTM problems, especially problems with nonword repetition, and these problems seem to be persistent (Conti-Ramsden & Durkin, 2007). Nonword repetition skills have been claimed to be a reliable marker of SLI (Gathercole, Willis, Baddeley, & Emslie, 1994). These skills are impaired in 4 to 6 year old children with SLI with and without later dyslexia (Bishop et al., 2009; de Bree, Wijnen, & Gerrits, 2010), but they improve in children with SLI and normal literacy in grade 2 or later (Bishop et al., 2009; Catts et al., 2005; Rispens & Parriger, 2010). In kindergarten, vSTM seems to be more related to oral language ability. However, after 6 years of age, vSTM may be more related to literacy development than to oral language development (Catts et al., 2005; Rispens & Parriger, 2010) and hence, the nonword repetition test may no longer be a valid marker for SLI in general after 6 years of age. It is still debated whether the vSTM problems of individuals with SLI do resolve in later grades. In the studies of Rispens and Parriger (2010) and Bishop et al. (2009), no significant differences in vSTM were observed between the normal reading SLI group and typically developing children at respectively 8;3 and 9;0 years. However, other studies suggest that children with SLI and normal literacy might still show mild vSTM problems (Catts et al., 2005), even until 11 years of age (Conti-Ramsden & Durkin, 2007). It remains unclear whether the observed differences in nonword repetition skill between the SLI groups with and without literacy impairment are a consequence or a precursor of differences in literacy ability. In most abovementioned studies, group differences were explained as a consequence of differences in reading ability, although this unidirectional influence was only proven by Conti-Ramsden and Durkin (2007) and Nation and Hulme (2011). Moreover, in this last study, nonword repetition was not a longitudinal predictor of the growth in reading.

3.1.3.3 Rapid automatized naming

RAN skills seem to correlate with reading and not with oral language ability (Bishop et al., 2009; Brizzolara et al., 2006). Indeed, Bishop et al. (2009) observed that RAN skills measured at 9 years were impaired in children with SLI and literacy problems, but were

equivalent to typically developing children in children with SLI and normal literacy. In line with these findings, Brizzolara et al. (2006) observed that RAN deficits were present in most individuals with dyslexia, not merely in those with a history of language impairment. Moreover, RAN measured at 9 years was the strongest predictor to differentiate a group of children with SLI in a group with and a group without dyslexia (Bishop et al., 2009).

3.1.4 Present study

There is a lack of longitudinal studies examining all three phonological components (i.e., PA, VSTM and RAN) in children with SLI with and without literacy delay and typically developing controls at multiple time points before and after the start of formal reading instruction. Developmental trajectories of the different phonological components have rarely been reported for children with SLI. The present study examined phonological processing in children with SLI with and without literacy problems and matched controls from the last year of kindergarten until the start of grade 3. Children in this study spoke Dutch, a language with a relatively transparent orthography. A first account of this study (Vandewalle, Boets, Ghesquière, & Zink, 2010) was restricted to phonological data in kindergarten and literacy skills in grade 1. Here, it was observed that in kindergarten, children with SLI showed impairments in PA and vSTM but not in RAN. Only children with SLI and literacy delay at the end of grade 1 scored poorer on RAN in kindergarten. RAN in kindergarten was highly correlated to literacy skills at the end of grade 1 and therefore RAN seemed to be a good predictor for literacy skills in children with SLI. In the present study, participant groups were defined by combining literacy status in first and third grade (literacy-delayed versus normal literacy ability) with the clinical status of SLI. The study comprised three groups: (1) children with SLI and literacy delay, (2) children with SLI and normal literacy, and (3) typically developing control children. We aimed to investigate in which phonological skills (PA, vSTM and RAN) the three groups of children differed over the three-year period from kindergarten to third grade and how the different phonological skills developed over this period. Moreover, we wanted to examine whether phonological skills measured in kindergarten could discriminate the children with SLI in a group with and a group without high risk for developing literacy problems.

3.2 Method

3.2.1 Participants

Eighteen children (three girls and 15 boys) with a formal SLI diagnosis participated in the study. All children were born in 2000, attended the last year of regular kindergarten at the start of the study, were monolingual Dutch speakers, and had severe and persistent oral language problems for which they already received oral language therapy in kindergarten. Oral language problems were determined by a score below percentile 3 before the start of language therapy on at least one of the subtests of three standardized Dutch language tests: *Reynell Taalontwikkelingsschalen* [Reynell Language Developmental Scales] (Schaerlaekens, Zink, & van Ommeslaeghe, 2003), *Taaltests voor Kinderen* [Language Tests for Children] (van Bon & Hoekstra, 1982) or *Schlichting Test voor Taalproductie* [Schlichting Test for Language Production] (Schlichting, van Eldik, Spelberg, van der Meulen, & van der Meulen, 2003). At a second evaluation after the age of 4;4 years, they all had to score below percentile 10 on at least one of the subtests of these language tests to ensure the persistency of the language problems. In addition to these language problems, some children had concurrent articulation problems. Exclusion criteria were low intelligence (non-verbal, verbal and total IQ below 85), hearing loss or any other known problem (e.g., neurological disorder) that could explain their language impairment.

For every individual child of the SLI group, the best matching control child was selected based on five criteria: (1) educational environment (i.e., same class), (2) gender, (3) age, (4) non-verbal intelligence, and (5) parental educational level. We followed an elimination procedure to detect the best matching child. Firstly, parents of all children from the same class and the same gender as the child with SLI were requested to grant parental consent and to complete a questionnaire. Secondly, all bilingual children and all children with speech, language or hearing difficulties mentioned by the teacher or parents were omitted. Thirdly, non-verbal intelligence was assessed with the Raven Coloured Progressive Matrices (Raven, Court, & Raven, 1984). Based on age, non-verbal intelligence and parental educational level (International Standard Classification of Education scale, UNESCO, 1997) and in this order of importance, the best matching control child was selected.

Although initially 26 children with SLI were selected, only 18 are included in the present report because one child left the study after kindergarten and seven children did not move on to grade 1 of a regular primary school after the last year of kindergarten. Hence, only the data of the 18 children with SLI and their 18 matched controls attending regular primary school were further analyzed in this study.

Both the SLI group and the control group were divided into two subgroups based on word reading and spelling achievement in first and third grade. In Flanders, children start literacy instruction at school in grade 1 at the age of 6. All children scoring 1 *SD* below the mean of a normative reference group on a standardized word reading (van den Bos, Spelberg, Scheepstra, & De Vries, 1994) and/or spelling test (Dudal, 2006), in both first and third grade were classified as 'literacy-delayed'. This criterion took into account both the severity and the persistence of a child's literacy problem. By applying this criterion, we identified eight children with literacy delay in the SLI group and four children in the control group. In the following analyses only three groups of children are compared: (1) children with SLI and literacy delay (SLI-LD; $n = 8$), (2) children with SLI and normal literacy (SLI-NL; $n = 10$), and (3) control children with normal literacy (Control-NL; $n = 14$).

Descriptive statistics and Mixed Model Analyses (MMA) of word reading and spelling skills at the end of grade 1 and at the beginning of grade 3 are presented in Table 3.1. As defined, the SLI-LD group scored lower than the SLI-NL group and the Control-NL group on word reading and spelling with large effect sizes. However, these group differences were not always significant, especially for word reading. MMA group comparisons for age and nonverbal intelligence showed that the three groups had equivalent age ($F(1,29) = 0.10$; $p = .90$) and did not differ significantly on non-verbal intelligence ($F(2,29) = 2.67$; $p = .09$) (see Table 3.1). In contrast, a Fisher's Exact Test revealed significant group differences for educational level of the mother ($p = .03$; Fisher's Exact Test). In the SLI-LD group, three mothers had a low, four a middle and one a high educational level. In contrast, the SLI-NL group counted zero mothers with low, seven with middle and three with high educational level. The Control-NL group counted respectively one, four and nine mothers with low, middle and high educational level. Because of these differences, maternal educational level was controlled for in all group comparisons.

Table 3.1 Characteristics of the participants: mean (*M*) and standard deviation (*SD*); effect size (*ES*)

	SLI-LD (1)		SLI-NL (2)		Control-NL (3)		Group comparisons		
	n = 8		*n* = 10		*n* = 14		1-2	1-3	2-3
	M	*SD*	*M*	*SD*	*M*	*SD*	*ES*	*ES*	*ES*
KINDERGARTEN									
Age (months)	64.1	1.6	63.5	3.2	63.9	3.4	0.24	0.09	-0.11
Non-verbal intelligence[a]	108.2	14.2	118.0	16.7	122.4	11.2	-0.63	-1.15	-0.32
GRADE 1									
Word reading[a,b]	91.3	7.9	100.5	6.9	107.9	15.0	-0.79	-0.79	-0.37
Spelling[a,b]	74.3	8.8	92.4	10.3	100.3	14.0	-1.59	-1.90**	-0.65
GRADE 3									
Word reading[a,b]	78.1	19.3	102.0	11.8	107.9	14.4	-1.20	-1.45*	-0.36
Spelling[a,b]	67.1	10.7	92.1	12.6	107.3	14.5	-1.82*	-2.51***	-0.86

Note. [a] Transformed scores with population average $M = 100$ and $SD = 15$; [b] MMA with maternal educational level as covariate; * $p < .05$; ** $p < .01$; *** $p < .001$

3.2.2 Measures

3.2.2.1 Phonological abilities

A number of PA and RAN tests used in this study were similar to the phonological awareness and naming speed tests of the Phonological Assessment Battery (PhAB; Frederickson, Frith, & Reason, 1997; Wheldall & Pogorzelski, 2003). For each of the experimental non-standardized tests, Cronbach's alpha was calculated and added as a measure of internal consistency (see Table 3.2).

3.2.2.1.1 Phonological awareness (PA)

The phonological awareness test battery was based on previous research (Boets et al., 2010; Boets, Wouters, van Wieringen, & Ghesquière, 2006; de Jong, Seveke, & van Veen, 2000) and consisted of a series of tasks that were designed to meet the rapidly changing level of phonological performance in children starting to read and write. Each task was preceded by two practice items to familiarize children with the task requirements. For each correct answer, one point was assigned.

Rhyme production task. In this task, a one-syllable word and an exemplary rhyming word were given and the child had to produce another rhyming word or nonword. The test consisted of eight items gradually getting more difficult.

Identity tasks. Three identity tasks were administered. In the end rhyme identity task a picture of a one-syllable consonant-vowel-consonant (CVC) or CVCC word was shown and named to the child, and the child had to select from four alternatives (named and shown on a picture) the word that had the same end rhyme as the given word. The total number of items was 12. The same format was used for the first sound identity task and the end sound identity task, where the child had to select from four alternatives the word that respectively started or ended with the same sound (a single consonant) as a given word. The total number of items on each test was 10.

Categorization tasks. In the first sound categorization and the rhyme categorization task each item consisted of three monosyllabic words presented twice from a CD with an inter-stimulus interval of one second. The child was asked to name the two words that had the same first sound or the same end rhyme, respectively. The first sound categorization

task had 15 items. Eight items consisted of words that started with a single consonant; seven items involved words that began with a consonant cluster. The rhyme categorization task consisted of 20 items of varying difficulty level (by using diphthongs or by manipulating the phonological similarity with the distracter item).

Auditory analysis and synthesis. The auditory analysis and synthesis task were part of a standardized Dutch test battery to measure phonology and reading (Drie-Minuten-Toets; Verhoeven, 1995). In the analysis task, the child had to analyze a word into phonemes. In the synthesis task, the child had to aggregate the individual phonemes (presented auditory on a CD with an interval of one second between the phonemes) to reconstruct the word. For both tasks, the one-syllable words of the 20 items increased in length and difficulty level, with more consonant clusters in the items at the end of the task.

Phoneme deletion. The phoneme deletion task consisted of 28 one-syllable nonwords that were presented twice from a CD (an adaptation of de Jong & van der Leij, 2003). The child was asked to delete a given phoneme of the nonword. In all items, the first or second consonant of a consonant cluster in the start or end position had to be deleted (e.g., BIJLF without /f/ becomes BIJL). For the first 10 items, the deletion of the phoneme resulted in an existing word. For the next 18 items, the residual phonological string remained meaningless after phoneme deletion. The maximum score on the test was 28. In grade 1, the task was terminated after 20 items because of the high complexity of the last items.

Spoonerism. The spoonerism task consisted of three sets of 10 items. For all sets, the first five items resulted in the disclosure of existing words, and the remaining five items yielded nonwords. In the first set, the child was required to replace the onset (consonant or consonant cluster) of a word with another consonant (cluster) in order to create a new word or nonword (e.g., KAT with /m/ becomes MAT). In the second and third set, two one-syllable words were given and the child was instructed to swap their consonant onset in order to produce two new words or nonwords (e.g., MUS-KAT becomes KUS-MAT). In the second set, words started with a single consonant; in the third set, words started with a consonant cluster. Each correctly produced word and nonword was rewarded with one point, with a maximum score of 50 on the whole test. Every child completed all items of the first set. The second and third sets were discontinued after four consecutive errors (0/2 for an item). The

third set was only presented to those children who obtained a score equal to or above 6/20 on the second set.

3.2.2.1.2 Verbal short-term memory (vSTM)

Verbal short-term memory was assessed by a digit span forward task and a nonword repetition task (Boets et al., 2006).

Digit span forward. In this task, the child had to correctly recall a sequence of digits presented from a CD. Testing started with a sequence of two digits. After presenting three trials of the same list length, the sequence was increased by one digit. The test ended after three consecutive errors. The test score was the total number of correctly recalled lists.

Nonword repetition. In this task (adapted version of Gathercole et al., 1994), as described in Boets et al. (2006), the child had to repeat a nonword presented from a CD. The difficulty level of the 48 nonwords increased gradually from two to five syllables, with half of the items in each category containing consonant clusters in different medial positions. Only completely correctly repeated nonwords were rewarded with one point.

3.2.2.1.3 Rapid automatized naming (RAN)

Lexical access was evaluated with four classic rapid automatized naming tasks, which involved the naming of highly familiar colours, objects, digits and letters (van den Bos, Zijlstra, & Spelberg, 2002). Each task involved the presentation of a card of five different stimuli randomly arranged in five columns of 10 stimuli, with each stimulus appearing 10 times. The participant was instructed to serially name the stimuli on the card as quickly and accurately as possible. The time to complete the card was recorded for each task. Colour naming comprised the colours black, blue, red, yellow and green, which were represented by small rectangles. Object naming involved the naming of five high-frequent, one-syllable words: boom (‘tree’), eend (‘duck’), stoel (‘chair’), schaar (‘scissors’) and fiets (‘bicycle’). Digit naming involved the digits 2, 4, 8, 5 and 9. Letter naming involved the naming of the lowercase letters d, o, a, s and p. The RAN-score was calculated as the number of symbols named per second.

3.2.2.2 Literacy skills

3.2.2.2.1 Reading

The One-Minute Reading test (van den Bos et al., 1994) was administered both in grade 1 and grade 3 as a standardized measure of single word identification. This test combined speed and accuracy into one index score. The child had to read a list of words of increasing difficulty (with increasing number of syllables and consonant clusters) as correctly and quickly as possible. The score on the test was the number of words read correctly within one minute. For diagnostic purposes, this score was transformed to an age-adjusted standard score relative to population average.

3.2.2.2.2 Spelling

Spelling was evaluated by a standardized spelling achievement test (Dudal, 2006). Grade-appropriate versions of the test were used in first and third grade measuring spelling features increasing in difficulty level. In grade 1, children had to spell single words presented in isolation, single words presented in sentence context, and short sentences. The maximum score on the test was 60. In grade 3, children had to spell words in sentences with a maximum score of 30. For diagnostic purposes this score was transformed to an age-adjusted standard score relative to population average.

3.2.3 Design and procedure

The administration of the tests was spread over a period of three years. Phonological skills were measured at three time points, that is in the middle of the last year of kindergarten (mean age = 5;7 years), in the middle of grade 1 (mean age = 6;7 years) and at the beginning of grade 3 (mean age = 8;1 years). In kindergarten, four PA tasks were administered, that is rhyme production, end rhyme identity, first sound identity and end sound identity. In grade 1, children performed six more difficult PA tasks, that is rhyme and first sound categorization, auditory analysis and synthesis, phoneme deletion and spoonerism. In grade 3, the children performed the same phoneme deletion and spoonerism task again. To measure vSTM, the digit span and nonword repetition task were administered at the three time points. RAN was assessed with the colour and object naming tasks in kindergarten. In grade 1 and grade 3, the RAN tasks comprised colour, object, digit and letter

naming. Literacy skills were measured after one year of literacy instruction at the end of grade 1 (mean age = 6;10 years) and after two years of literacy instruction at the beginning of grade 3 (mean age = 8;1 years) by the same word reading test and a grade-appropriate version of the spelling test. Each matched pair of children from the SLI and control group was tested in a quiet room at their school under identical circumstances and when feasible on the same day. All tests were administered individually, only the tests for non-verbal intelligence and spelling were administered individually in small groups. Data collection was carried out by trained students in speech-language therapy.

Groups were compared using MMA with pair as a random variable and participant group (SLI-LD, SLI-NL and Control-NL) as the fixed between-subject variable. Maternal educational level was included as fixed covariate. To investigate developmental trends, repeated measures MMA were calculated with time (kindergarten, grade 1 and grade 2) as within-subject variable, participant group (SLI-LD, SLI-NL and Control-NL) as between-subjects variable and with maternal educational level as covariate. Post hoc analyses were corrected for multiple comparisons using the Tukey procedure, and standardized mean differences were calculated as a measure of effect size by dividing the difference between the least-squares means by the pooled standard deviation. As described by Welkowitz, Ewen and Cohen (1988), an effect size of 0.2 was considered as small, whereas an effect size of 0.5 was called medium and an effect size of 0.8 is called large. Given the rather small sample sizes, it should be noted that the statistical power to discern significant group differences was relatively small. Often, there were large and potentially meaningful effect sizes with a large power, but these did not reach significance. Therefore, we also analyzed the effect sizes for the interpretation of the results.

Variables that were assumed to measure a common theoretical construct were aggregated into composite scores in order to give a quick overview of developmental trends. Based on a series of principal component analyses in previous research (Boets et al., 2010), we could conclude that the phonological battery indeed represented the well-known three-dimensional phonological structure. Composite scores for PA, vSTM and RAN were calculated by computing *z*-scores for each task (relative to the mean and standard deviation of the Control-NL group) and averaging the scores of the tests that constituted the same underlying construct. All composite scores at all time-points were further standardized

relative to the mean and standard deviation of the Control-NL group. In this manner, the Control-NL group had a mean of 0 and *SD* of 1 at each time point.

Predictive discriminant analyses were used to determine how well the phonological measures discriminated between the children with SLI and literacy delay and the children with SLI and normal literacy (cf., Bedore & Leonard, 1998; Plante & Vance, 1994). Discriminant analyses and cross validation were applied to the three kindergarten composite scores. Discriminant analysis generates a discriminant criterion that maximizes the distance between the groups. Cross validation uses the discriminant criterion to assess the error rate for the discriminant function by comparing each observation to the remaining data set and calculating the probability that it belongs to either of the groups.

3.3 Results

We analyzed the development of the phonological skills (PA, vSTM and RAN) for the three groups (SLI-LD, SLI-NL and Control-NL group) over the three-year period from kindergarten to third grade. Descriptive statistics and MMA group comparisons are presented in Table 3.2.

The composite scores for PA at the three time points revealed a significantly lower score for the SLI-LD group compared to the Control-NL group with large effect sizes. When comparing the composite scores for the SLI-NL group with the two other groups, we observed that the SLI-NL group scored in between the SLI-LD and the Control-NL group. There was a large and significant group difference between the SLI-NL and Control-NL group for the PA composite scores, except in kindergarten. Comparisons between the SLI-NL and SLI-LD groups revealed medium to large but no significant effect sizes. At the level of the individual PA tasks, the SLI-NL group scored either similar stto the SLI-LD group or scored in between the SLI-LD group and the Control-NL group. It is notable that the standard deviation for most PA tasks in kindergarten was much larger for both SLI groups in comparison with the Control-NL group. To investigate developmental trends, repeated measures mixed models were calculated for each task that was assessed at multiple time points. The three groups made comparable development from grade 1 to grade 3 for the phoneme deletion and spoonerism task. There was a main effect of group (for the two tasks, respectively

Table 3.2 Phonological measures for the three participant groups: mean (*M*) and standard deviation (*SD*); effect size (*ES*)

			SLI-LD (1) *n* = 8		SLI-NL (2) *n* = 10		Control-NL (3) *n* = 14		Group comparisons[b] 1-2	1-3	2-3
	α^a	*Max*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*ES*	*ES*	*ES*
KINDERGARTEN											
PA composite			**-5.1**	**4.2**	**-2.6**	**3.5**	**0.0**	**1.0**	**-0.53**	**-1.67***	**-0.97**
Rhyme production	.88	8	5.9	2.5	6.9	2.1	7.8	0.6	-0.25	-0.97	-0.66
End rhyme identity	.69	12	6.0	3.7	9.4	3.0	10.7	1.3	-0.79	-1.76*	-0.76
First sound identity	.59	10	4.0	2.3	4.6	2.2	7.6	2.2	-0.22	-1.44*	-1.23*
End sound identity	.63	10	4.0	3.2	4.2	2.0	6.1	2.3	-0.25	-0.66	-0.51
vSTM composite			**-1.8**	**1.1**	**-1.7**	**0.8**	**0.0**	**1.0**	**0.31**	**-1.38***	**-1.87*****
Digit span		21	6.1	2.0	6.3	1.8	8.1	1.7	0.23	-0.90	-1.18*
Nonword repetition	.84	48	10.3	6.1	11.2	3.2	22.2	5.9	0.35	-1.57**	-2.21***
RAN composite			**-1.67**	**1.40**	**-0.42**	**0.93**	**0.00**	**1.00**	**-0.79**	**-1.05**	**-0.30**
Colours (items/s)		-	0.50	0.17	0.67	0.12	0.76	0.16	-0.82	-1.18*	-0.51
Objects (items/s)		-	0.51	0.22	0.68	0.16	0.72	0.13	-0.70	-0.85	-0.09
GRADE 1											
PA composite			**-2.7**	**0.9**	**-1.3**	**0.7**	**0.0**	**1.0**	**-1.32**	**-2.51*****	**-1.60****
Rhyme categorization	.69	20	7.1	4.4	10.5	4.0	13.3	3.0	-0.48	-1.42*	-0.88
First sound categorization	.71	15	7.3	2.1	9.1	1.8	11.5	3.3	-0.89	-1.14*	-0.58
Auditory analysis	.88	20	8.3	3.0	14.4	4.0	17.1	3.3	-1.44*	-2.75***	-1.01
Auditory synthesis	.72	20	7.3	2.6	11.2	3.1	15.1	3.5	-1.05	-2.29***	-1.28*
Phoneme deletion	.84	20	3.8	1.8	6.7	4.1	12.1	5.1	-0.81	-2.07**	-1.29**
Spoonerism	.91	50	7.5	6.2	12.3	8.0	24.5	11.5	-0.27	-1.33*	-1.10*

vSTM composite			**-2.2**	**1.5**	**-1.9**	**1.1**	**0.0**	**1.0**	**0.14**	**-1.56****	**-1.96*****
Digit span		21	6.8	2.3	7.7	1.7	9.3	1.2	-0.11	-1.20	-1.23
Nonword repetition	.79	48	13.9	4.9	13.0	4.7	23.5	5.3	0.54	-1.68**	-2.23***
RAN composite			**-0.84**	**1.20**	**-0.27**	**0.83**	**0.00**	**1.00**	**-0.48**	**-0.50**	**-0.06**
Colours (items/s)		-	0.80	0.20	0.85	0.15	0.98	0.23	-0.03	-0.44	-0.46
Objects (items/s)		-	0.74	0.23	0.89	0.20	0.90	0.21	-0.69	-0.45	0.25
Digits (items/s)		-	1.06	0.26	1.13	0.21	1.28	0.26	-0.16	-0.56	-0.44
Letters (items/s)		-	1.10	0.36	1.28	0.26	1.19	0.26	-0.42	-0.15	0.32
GRADE 3											
PA composite			**-3.2**	**1.5**	**-1.7**	**1.5**	**0.0**	**1.0**	**-0.74**	**-2.14****	**-1.21***
Phoneme deletion	.92	28	10.3	7.2	17.5	7.1	23.1	4.0	-0.84	-2.09**	-0.95
Spoonerism	.92	50	16.9	10.1	24.0	10.3	37.9	8.4	-0.44	-1.78**	-1.25*
vSTM composite			**-2.0**	**1.4**	**-1.2**	**1.1**	**0.0**	**1.0**	**-0.33**	**-1.36***	**-1.10**
Digit span		21	8.6	2.4	9.5	1.4	10.2	1.3	-0.17	-0.59	-0.53
Nonword repetition	.79	48	17.6	4.4	21.2	5.4	28.5	4.7	-0.49	-2.09**	-1.44**
RAN composite			**-2.02**	**1.50**	**-1.08**	**1.30**	**0.00**	**1.00**	**-0.48**	**-1.40***	**-0.88**
Colours (items/s)		-	0.86	0.20	0.99	0.15	1.16	0.18	-0.55	-1.46*	-1.08
Objects (items/s)		-	0.84	0.20	0.95	0.22	1.06	0.12	-0.36	-1.02	-0.50
Digits (items/s)		-	1.42	0.33	1.60	0.36	1.81	0.19	-0.31	-1.19	-0.69
Letters (items/s)		-	1.29	0.39	1.49	1.17	1.71	0.38	-0.58	-0.99	-0.69

Note. [a] Cronbach's α; [b] MMA with maternal educational level as covariate; * $p < .05$; ** $p < .01$; *** $p < .001$

F(2,27) = 12.60; *p* = .0001 and *F*(2,27) = 8.89; *p* = .001) and a main effect of time (respectively *F*(1,29) = 62.70; *p* < .0001 and *F*(1,29) =45.60; *p* < .0001), but no significant group by time interaction (respectively *F*(2,29) = 1.36; *p* = .27 and *F*(2,29) = 0.46; *p* = .63).

At every time point, the composite scores for *vSTM* revealed significantly lower scores for both SLI groups compared to the Control-NL group, whereas there was neither significant group difference nor a substantial effect size between both SLI groups. It is evident that nonword repetition is much more sensitive to differentiate the SLI groups from the Control-NL group than digit span. Nonword repetition was consistently and significantly impaired in both SLI groups. For digit span, the group difference was smaller and not always significant, although effect sizes revealed a similar pattern. Considering the development of vSTM, the three groups made comparable progress from kindergarten to grade 3. For digit span and nonword repetition there was a main effect of group (respectively *F*(2,27) = 3.35; *p* = .05 and *F*(2,27) = 15.55; *p* = <.0001) and a main effect of time (respectively *F*(2,58) = 60.60; *p* < .0001 and *F*(2,58) = 61.11; *p* < .0001), but no significant group by time interaction (respectively *F*(4,58) = 1.63; *p* = .18 and *F*(4,58) = 2.13; *p* = .09).

In kindergarten, *RAN* scores differentiated between the SLI-LD group and the Control-NL group and also between the two SLI groups. Although the effect sizes were substantial, the group difference was only significant on the colour naming task between the SLI-LD group and the Control-NL group. Effect sizes of the group comparisons were smaller in grade 1. In grade 3, there was a substantial difference between children of the SLI-LD group and the Control-NL group with large effect sizes, in particular for the colour naming task. On the other RAN tasks, the group difference did not reach significance level. Repeated measures MMA only showed a main effect of group (*F*(2,27) = 3.28; *p* = .05) on the RAN colour naming task. For all RAN tasks there was a main effect of time (RAN colours: F(2,58) = 79.69; *p* < .0001; RAN objects: F(2,58) = 79.75; *p* < .0001; RAN digits: F(1,29) = 142.36; *p* < .0001; RAN letters: F(1,29) = 33.65; *p* < .0001). The group by time interaction was only significant for the RAN letter naming task (*F*(2,29) = 4.62; *p* = .02).

We can summarize that for all phonological abilities children of the three groups made significant progress from kindergarten to grade 3. The rate of development was similar across the groups for PA and vSTM. For RAN, however, the Control-NL group made more

Table 3.3 Percentages and total number of children with SLI correctly classified in the cross-validation analyses into a group of children with delayed versus normal literacy delay based on phonological composite scores in kindergarten.

	SLI and literacy delay	**SLI and normal literacy**
	n = 8	*n* = 10
PA + vSTM + RAN	75%	80%
PA + vSTM	38%	70%
PA + RAN	75%	80%
vSTM + RAN	63%	90%
PA	63%	80%
vSTM	25%	30%
RAN	63%	80%

progress on the RAN letter naming task compared to the two SLI groups. Group comparisons revealed that for PA, in general, the SLI-LD group scored significantly lower than the Control-NL group. The SLI-NL group scored in between the SLI-LD and Control-NL group (i.e., somewhat better than the SLI-LD group and in half of the tests significantly poorer than the Control-NL group). For vSTM, both SLI groups did not differ from each other and scored lower than the Control-NL group. For RAN, the SLI-LD group scored somewhat lower than the SLI-NL group and substantially lower than the Control-NL group in kindergarten.

Predictive discriminant analyses were calculated to analyze the predictive value of each of the three kindergarten phonological components for distinguishing between children with SLI that would develop normal versus delayed literacy skills. The percentage and actual number of cases that were correctly classified in the cross-validation analyses are summarized in Table 3.3. A combination of the three phonological composite scores PA, vSTM and RAN resulted in a sensitivity of 75% for the SLI group with literacy delay (6 of the 8 children with literacy delay were detected) and a specificity of 80% for the SLI group with normal literacy (8 of the 10 children without literacy delay were correctly classified). A combination of the PA and RAN composite variables produced the same classification results. Hence, vSTM did not bring any additional discriminatory value. When only PA or only RAN was used, similar specificity but lower sensitivity was observed. VSTM as a single classification variable had a very low sensitivity and specificity. Interestingly, when

implementing discriminant analyses on single tests instead of composite variables, a well-selected combination of one kindergarten PA variable (end rhyme identity task) and one kindergarten RAN variable (RAN test for objects) could achieve the same results as the combination of the PA and RAN composite variables.

3.4 Discussion

Based on this three-year longitudinal study of phonological processing in children with SLI and literacy delay, children with SLI and normal literacy and typically developing children, several conclusions about the development of PA, vSTM and RAN and their predictive value for literacy delay could be drawn.

First, our results suggested that children with SLI and literacy delay showed extensive and persistent PA problems, at least until grade 3. On almost every PA task across the three time points, the SLI-LD group scored significantly poorer than the Control-NL group. In comparison, children with SLI and normal literacy showed milder PA problems, at least until grade 3. They mainly struggled with higher-order linguistic, more demanding or less familiar PA tasks[10]. On easier tasks (i.e., lower linguistic level and more familiar tasks), like rhyming in the last year of kindergarten (Stanovich, 1988; Yopp, 1988) and first sound categorization in grade 1, children with SLI and normal literacy obtained scores close to those of typically developing children. On more demanding tasks (i.e., more difficult, higher linguistic level and less familiar tasks), both SLI groups had difficulties compared to typically developing children. In the last year of kindergarten, a task at phoneme level was very difficult and not often trained. On the first sound identity task, for instance, the two SLI groups scored significantly lower in kindergarten compared to the control group. In grade 1, phoneme deletion (see also Stanovich, 1988; Yopp, 1988) and spoonerism were difficult and unfamiliar tasks. Accordingly, the two SLI groups scored significantly lower on these tasks than the control group, while there was no significant difference between both SLI groups. In grade 3, the phoneme deletion task became somewhat less demanding (see also Durgunoglu & Öney, 1999) and at this moment, the SLI-NL group did no longer differ significantly from the

[10] More demanding tasks are considered to be tasks that involve higher mental manipulations at a high linguistic level (phonemes), as was also observed in dyslexic children by de Jong and van der Leij (2003). This is considered to be the most likely explanation for the observed group differences of the SLI-NL group compared to the two other groups.

Control-NL group. In contrast, the spoonerism task was still difficult in grade 3 as was reflected in the lower scores for both SLI groups in comparison with the Control-NL group. Additionally, for some tasks there might have been a ceiling effect for the Control-NL and SLI-NL group, prohibiting these groups to obtain higher scores. This phenomenon was potentially apparent in the rhyme production and end rhyme identity task in kindergarten. This might have been the reason for the absence of significant group differences for these tasks between the SLI-LD group and the two other groups.

The observation that in kindergarten both the children with SLI with and without later literacy delay had PA problems confirmed our previous findings (Vandewalle et al., 2010) and kindergarten data of larger studies (Bishop et al., 2009; Catts et al., 2005). In the study by Catts et al. (2005) PA skills (measured by a phoneme deletion task) improved in grade 4 and grade 8 in children with SLI and normal reading. This was in accordance with our observation that for phoneme deletion children with SLI and normal literacy did not anymore score significantly lower than the Control-NL group in grade 3. We could support the conclusion of Catts et al. (2005) that PA deficits in later grades were more related to dyslexia than to SLI: PA deficits seemed to be more stable over time across all PA tasks in children with literacy delay.

The observation that children with SLI and normal literacy skills showed remaining PA problems with more demanding PA tasks in the first three grades of primary school suggested that they still seemed to be at risk for developing literacy problems. Therefore, the risk for dyslexia in children with SLI seemed to be continuous rather than discrete, comparable to the family risk for dyslexia (Boets et al., 2010; Pennington & Lefly, 2001; Snowling, Gallagher, & Frith, 2003).

Landerl and Wimmer (2000) warned that some PA tasks, such as spoonerism, place a large burden on working memory skills, and thus were not a pure measure of PA. Because children with SLI typically have persistent working memory problems (Conti-Ramsden & Durkin, 2007), this could be an alternative explanation for the PA problems in children with SLI. Indeed, for spoonerism all children with SLI had significantly more problems in comparison to typically developing children. However, this alternative explanation did not hold for all our results. We also measured other PA tasks requiring working memory skills, such as rhyme and first sound categorization in grade 1, in which the children had to

remember three words and then had to decide whether the words rhymed or had the same first sound. Yet, in spite of the heavy working memory load, children with SLI and normal literacy did not fail on these tasks.

Second, with regard to vSTM, we could infer that vSTM problems, as measured by more demanding tasks such as nonword repetition[11], seemed to persist in all children with SLI, at least until grade 3. Both the SLI group with normal and delayed literacy achievement scored significantly lower than controls on nonword repetition from kindergarten until grade 3. Furthermore, both SLI groups did not differ significantly from each other. Persistent vSTM problems in children with SLI were also observed by Conti-Ramsden and Durkin (2007). Moreover, the lack of significant differences between both SLI groups corroborated the findings of Bishop et al. (2009) and de Bree et al. (2010), in four-year-old and six-year-old children, respectively, but was in contrast with studies at older ages (Bishop et al., 2009; Catts et al., 2005; Rispens & Parriger, 2010). Our observation that children with SLI and normal literacy still scored significantly lower for nonword repetition than the typically developing group until grade 3, was in accordance with the study of Catts et al. (2005), but contradicted the studies of Rispens and Parriger (2010) and Bishop et al. (2009). Thus, at least until grade 3, our results did not support the suggestion that nonword repetition problems disappeared in children with SLI and normal literacy. In addition to the age of the children, the difficulty of the nonword repetition task, as determined by the syllable length (Dollaghan & Campbell, 1998), the number of items with consonant clusters (Rispens & Parriger, 2010) and the position of the consonant cluster (Marshall & van der Lely, 2009) could be a differentiating factor between the results of the studies. In the studies of Bishop et al. (2009), Conti-Ramsden and Durkin (2007) and in our study, half of the items contained consonant clusters (see Gathercole et al., 1994). In contrast, the items in the studies of Catts et al. (2005), de Bree et al. (2010) and Rispens and Parriger (2010) did not contain consonant

[11] The nonword repetition task is assumed to be more demanding than the digit span task. Since neither the nonwords nor the constituent syllables of the nonwords used in the nonword repetition task correspond to existing words, the use of long-term memory representations to support the recall of the nonwords is prevented (see Gathercole, 1999). As such, the nonword repetition task provides a more sensitive measure of phonological short-term memory than traditional digit or word span tasks – according to the Baddeley and Hitch multicomponent model of working memory (see Baddeley & Logie, 1999). However, Snowling, Chiat and Hulme (1991) argue that in the nonword repetition task, other processes are involved as well (e.g., perceptual skills, phonological segmentation, assembly of articulatory instructions, execution of speech motor programs) which are no measures of short-term memory, but make the task more demanding as well.

clusters. We could infer that nonword repetition skills improved in children with SLI and normal literacy as could be observed from the studies using a nonword repetition task without consonant clusters. However, we observed in our study that at least mild vSTM problems remained in children with SLI and normal literacy in comparison to typically developing children when more sensitive and complex tasks were used, such as a nonword repetition task with consonant clusters. The reason why our results for nonword repetition did still differ from those of Bishop et al. (2009) might have been the small difference in age and in the received literacy instruction.

We must warn that articulation errors (often apparent in children with SLI) might have an influence on nonword repetition scores, especially when clusters had to be repeated. However, articulation errors were less frequent in children in grade 3 and even after statistical correction for articulation accuracy in our study, all group differences remained.

In summary, combining our results and those of other studies, the conclusions for PA and vSTM for children with SLI were similar: children with SLI and literacy delay seemed to have persistent PA and vSTM problems on all tasks at least until grade 3, whereas children with SLI and normal literacy only showed persistent PA and vSTM problems on the more demanding tasks.

Third, we could observe that the SLI-LD group had in general lower RAN scores in kindergarten compared to the SLI-NL group and the Control-NL group, as was also mentioned in Vandewalle et al. (2010). This suggested that RAN in kindergarten might have been a good predictor for later literacy delay. With respect to the development of RAN skills, the substantial effect sizes between the two SLI groups observed in kindergarten disappeared in grade 1 and 3. Hence, the predictive value of RAN might have decreased over the years.

A fourth conclusion dealt with the discriminative value of phonological skills in kindergarten as predictors for literacy delay in first and third grade. It appeared that a combination of PA and RAN skills discriminated relatively well between the presence versus absence of later reading and spelling problems in children with SLI. Linear discriminant analyses and cross validation on the PA and RAN composite scores resulted in a sensitivity of

75% and specificity of 80%. These sensitivity and specificity were rather weak for a formal diagnosis (Plante & Vance, 1994), but the analyses might be meaningful in highlighting the differences between the two SLI groups in kindergarten. Moreover, these might be useful as predictors for literacy delay in kindergarten in order to start monitoring and training the children with the highest risk before the start of literacy instruction. It was not surprising that the end rhyme identity task and the RAN objects task resulted in the same discriminative value as the composite scores. Group comparisons revealed moderate to strong effect sizes for these tasks between both SLI groups. Both tasks were less challenging for children in kindergarten and therefore might have discriminated better between subgroups of children with SLI. A word of caution about the nature of literacy delay might be appropriate here, given that variation in literacy skills lies on a continuum rather than being clustered in two clearly distinguishable subgroups. Correlations in our previous report (Vandewalle et al., 2010) suggested that RAN but not PA scores in kindergarten were good predictors for literacy achievement in children with SLI at the end of grade 1. The discriminant analyses of our present study however demonstrated that a combination of PA and RAN scores had the best predictive value. Only PA skills or only RAN skills did not have a similar sensitivity to detect children with SLI and literacy delay. This was in accordance with the double deficit hypothesis: PA problems, RAN problems or a combination of PA and RAN problems could cause literacy problems (Wolf & Bowers, 1999).

Fifth, the lack of significant differences between the SLI-LD and SLI-NL groups on all but one phonological test was quite surprising. Although the effect sizes for a number of other tasks were medium to large, but not significant, one might wonder what actually might have been driving the group difference in literacy skills. In a study of Wimmer et al. (2000) it was observed that in the context of a regular orthography and a synthetic phonics teaching approach, a PA deficit had no negative influence on reading of nonwords and phonetic spelling until grade 3. However, children with a RAN deficit or a double deficit did have reading problems, more specifically reading fluency problems. In our study, the children with SLI and normal literacy tended not to have marked RAN problems (effect sizes between the SLI-NL group and Control-NL group for RAN were typically small to moderate) and had mild PA deficits. This might explain why these children did not experience severe literacy problems at least until grade 3 in a language with a regular orthography. It would be

interesting to observe whether these children will later on develop problems with word reading, spelling and/or reading comprehension.

Sixth, two surprising phenomena regarding the reading and spelling scores should be mentioned. First, the differences between the SLI-LD group and the two normal literacy groups were not significant for all reading and spelling measures, although the groups were divided based on a combination of these scores. Possible explanations might be the lower discriminatory value of the one minute word reading test in grade 1 because of the relatively high difficulty level of the task and the fact that in a more transparent orthography children experience fewer problems with word reading at the start of reading instruction (Wimmer et al., 2000). Second, the effect sizes between the SLI-NL and Control-NL group were moderate to large for spelling scores. These differences were caused by an average score higher than the normative reference group for the Control-NL group and lower than this normative reference group for the SLI-NL group. Moreover, it is important to notice that for each task, effect sizes were larger between the SLI-LD group and the two normal literacy groups than between the SLI-NL and Control-NL group.

Finally, some limitations of the present study should be discussed. First, the sample sizes of the three groups of children were small. Therefore, group comparisons could not easily reach significance level and interpretations of group differences should have been made with caution. Second, the SLI criterion to score persistently low on only one language aspect might not have been very selective. Hence, one should be careful in generalizing our findings to a population of children with more severely impaired oral language skills. However, the whole SLI group had significantly lower scores than the control group for almost all language aspects in kindergarten, grade 1 and grade 3, despite the oral language therapy they all received in kindergarten (Vandewalle, Boets, Boons, Ghesquière, & Zink, submitted; Vandewalle et al., 2010). Third, it is not clear how the oral language therapy that these children with SLI typically had for two years, might have affected our results. Fourth, the literacy criterion of 1 *SD* below the norm group might have been rather lenient, but the persistency of the reading or spelling problems was confirmed by the criterion that children had to fail on literacy in both grade 1 and grade 3. Moreover, literacy was measured relatively early and in a transparent language, so a milder criterion could be justified. However, we have to be careful in generalizing our results for children with literacy delay to

the dyslexic population as we do not know which children of our study will receive the diagnosis of dyslexia later on. Fifth, within this study, we did not analyze the direction of the relations between phonology and literacy, so we could not make conclusions about their causal relationships.

Further research with a longer follow-up is needed in order to observe whether the PA and vSTM difficulties in children with SLI and normal literacy would disappear in later grades (as was observed in the study of Catts et al., 2005) or would cause permanent problems on the more demanding tasks. There is a strong need for a precise inventory of the different PA tasks with their underlying cognitive skill, their difficulty level and their role in the literacy development in typically developing children and in specific populations such as children with SLI. Based on the observation that the performance of the SLI group with normal literacy had no problems with less demanding and more familiar tasks, a training study of PA skills might be set up in kindergarten in order to detect children with SLI at risk for dyslexia at an early age. We expect that the children whose PA skills improve by this training will not develop literacy problems, while the children who show less improvement have an increased risk to develop dyslexia later on. Additionally, the development of RAN skills in children with SLI over a longer period and the combined predictive value of PA and RAN for the development of literacy skills are topics that need further investigation. More longitudinal studies on large groups of children with SLI with and without literacy delay in transparent and non-transparent languages starting from kindergarten are necessary to generalize the conclusions of this study to all children with SLI.

3.5 Acknowledgments

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Chapter 4: Oral language and narrative skills in children with specific language impairment with and without literacy delay: a three-year longitudinal study

The content of this chapter is described in Vandewalle, E., Boets, B., Ghesquière, P., & Zink, I. (submitted). Oral language and narrative skills in children with specific language impairment with and without literacy delay: a three-year longitudinal study. In revision for Research in Developmental Disabilities.

Abstract

Purpose: To compare the development of oral language and more specifically narrative skills (storytelling and story retelling) in children with specific language impairment (SLI) with and without literacy delay.

Method: This longitudinal study followed 18 children with SLI and 18 matched controls from the last year of kindergarten (mean age = 5;5 years) until the beginning of grade 3 (mean age = 8;1 years). Oral language tests measuring vocabulary, morphology, sentence and text comprehension and narrative skills were administered yearly. Based on first and third grade reading and spelling achievement, both groups were divided into a group with and a group without literacy problems.

Results: The children with SLI and literacy delay had persistent oral language problems across all assessed language domains. The children with SLI and normal literacy skills scored also persistently low on vocabulary, morphology and story retelling skills. Only on listening comprehension and storytelling, they evolved towards the level of the control group.

Conclusions: Oral language skills in children with SLI and normal literacy skills remained in general poor, despite their intact literacy development during the first years of literacy instruction. Only for listening comprehension and storytelling, they improved, probably as a result of more print exposure.

4.1 Introduction

While it is well established that there is a considerable comorbidity between specific language impairment (SLI) and dyslexia (e.g., Catts, Adlof, Hogan, & Weismer, 2005; McArthur, Hogben, Edwards, Heath, & Mengler, 2000; Snowling, Bishop, & Stothard, 2000), the underlying causes for this comorbidity remain unclear. Phonological impairments are widely studied as a potential cause for dyslexia and its comorbidity with SLI. In contrast, other language skills such as vocabulary, morphology, syntax and narrative skills, and their role in the overlap between SLI and dyslexia have been studied less frequently.

4.1.1 Narrative skills

Telling a story involves a number of higher-level language and cognitive skills. All language components come together to form a cohesive, well-formulated, meaningful story (Seiger-Gardner, 2009). The analysis of narratives provides information about grammatical skills and the ability of children to formulate sentences, to use cohesive devices relating meanings across sentences, and to organize the story content in a meaningful way.

It has been observed that typically developing children are generally able to comprehend and retell stories by the age of six years (Merritt & Liles, 1987). By the age of seven, stories with multiple episodes begin to emerge, and by age nine or ten children use considerable detail and complete their episodes (for an overview, see Crais & Lorch, 1994). As children mature, the number of complete episodes consisting of initiating events, attempts and consequences increases with age (Muñoz, Gillam, Peña, & Gulley-Faehnle, 2003).

There are different elicitation methods to evaluate narrative skills (for a review, see Liles, 1993). Two frequently used methods are story generation tasks (e.g., Frog, where are you? Mayer, 1969), in which children are instructed to compose stories from sequencing cards or wordless books, and story retelling tasks (e.g., the Bus Story Test; Renfrew, 1997), in which children listen to stories narrated by the experimenter and are asked to retell the stories back to the experimenter (Seiger-Gardner, 2009). Story retelling tasks result in longer stories with more story grammar components and complete episode structures than story generation tasks (Merritt & Liles, 1989; Westerveld & Gillon, 2010). Story retelling is more

clinically useful with older children (9 to 11 years old) for the assessment of the global organization of content than story generation. In contrast, a story generation task allows the speaker to access a larger range of structural variation and content. It is also more exigent than retelling and generally offers a better indication of vocabulary ability or potential word-finding difficulties. Additionally, it is more representative of spontaneous communication, reflects more accurately the pragmatic characteristics of the narrative and the subject is less influenced by the context because no story was told in advance to the child (Liles, 1993). However, Merritt and Liles (1989) concluded that story retelling and story generation are both effective measures of narrative ability that both activate a cognitive organization consistent with story schema. McCabe, Bliss, Barra and Bennett (2008) compared a fictional story generation task based on pictures (Frog, where are you?) with personal narratives without pictures in 7 to 9;9 year old children with language impairment. They observed a significant longer story in the fictional generation task than in the personal narrative. However, more personal narratives met minimal narrative criteria. In the fictional generation task, the children often treated the pictures in isolation from each other rather than a series of events. Hence, the use of pictures might have a negative influence on narrative criteria.

Assessment of narrative skills offers a rich source of information about the higher-level language abilities of young children (Paul & Smith, 1993). Liles, Duffy, Merritt and Purcell (1995) demonstrated that a large range of narrative production variables could be reliably represented by two dominant factors: a factor measuring global organization of content (i.e., episode structure), currently assigned as *macrostructure*, and a factor measuring within- and across-sentence structure (i.e., grammatical sentence structure, within subordinate clause productivity, and textual cohesion), also called *microstructure*. In contrast, a study of Westerveld and Gillon (2010) demonstrated that microstructure measures of oral narrative performance did not represent a single construct. Mean length of utterance in morphemes and grammatical accuracy loaded on different factors. Therefore, it is important to analyze oral narratives on a range of measures.

4.1.2 Oral language and narrative skills in children with SLI

It is well known that children with SLI show oral language problems across many different language domains (lexical and semantic, morphological, syntactic, phonological, and pragmatic deficits) that can be measured through standardized oral language tests

(Schwartz, 2009). As a result, children with SLI may have difficulties with the linguistic abilities necessary to narrate stories.

A number of *cross-sectional studies* demonstrated a poorer *macrostructure* in the stories of children with (a history of) SLI compared to typically developing children. For instance, they obtain a lower information score (4 years) (Paul & Smith, 1993), fewer complete story episodes and more incomplete episodes (9 - 11;4 years) (Merritt & Liles, 1987), a lower narrative stage (6 - 7 years) (Paul, Hernandez, Taylor, & Johnson, 1996) and a lower macrostructure composite score (8 - 9 years) (Manhardt & Rescorla, 2002). Soodla and Kikas (2010) observed that SLI and control children between 6 and 8 years were equally capable to produce structurally complete stories (no group difference for the presence of the story grammar components such as setting, initiating events, internal response), but the SLI group scored significantly lower for the quantity of story information units (i.e., the amount of relevant information included in the story) in comparison to typically developing children. Also the *microstructure* of stories is poorer in children with SLI in comparison with typically developing children, as evidenced by fewer sentences (7;6 - 10;6 years) (Liles, 1985), fewer main and subordinate clauses (9 - 11;4 years) (Merritt & Liles, 1987), fewer complete cohesive ties (4, 6 and 7;6 – 10;6 years) (Liles, 1985; Paul et al., 1996; Paul & Smith, 1993), fewer complex sentences and more tense errors (6 - 10 years) (Norbury & Bishop, 2003), a lower mean length of utterances (4 – 12 years) (Kit-Sum To, Stokes, Cheung, & T'sou, 2010; Paul & Smith, 1993), a lower syntax composite score (8 and 9 years) (Manhardt & Rescorla, 2002), referential problems and the use of less sophisticated vocabulary (4;10 - 12;01 years) (Kit-Sum To et al., 2010), and a smaller number of different word roots (4 - 6 years) (Paul et al., 1996; Paul & Smith, 1993).

Although several studies observed group differences on both macro- and microstructure qualities while comparing children with SLI and typically developing controls, Norbury and Bishop (2003) observed no group differences for the macrostructure of stories of children between 6 and 10 years old performing a telling task. In this regard, Liles et al. (1995) observed that the macrostructure factor did not distinguish children with SLI from typically developing children after microstructure was accounted for. In contrast, Manhardt and Rescorla (2002) demonstrated that late talking children did show weaknesses in macrostructure skills independent of the variance accounted for by their weaker general

language abilities. It is still a matter of debate whether the macrostructure ability is independently disabled in children with SLI. In contrast, microstructure abilities seem to be more systematically disabled in children with SLI and the constituting variables are more effective in distinguishing children with and without SLI. Kit-Sum To et al. (2010) demonstrated that syntactic complexity, measured by the mean length of utterances, was the single best predictor to differentiate between children with and without SLI.

The observed problems with macrostructure narrative ability in children with SLI do not result from difficulties perceiving the characters' mental state (Befi-Lopes, Bento, & Perissinoto, 2008; Norbury & Bishop, 2003) or from a poorer understanding of the factual details of the retold stories (Merritt & Liles, 1987), because children with SLI did not differ from typically developing children on these aspects. However, they did differ in their comprehension of relationships linking the critical parts of the stories together (Merritt & Liles, 1987).

Several studies observed deficits on narrative abilities in children with SLI on both story generation and story retelling tasks (e.g., Befi-Lopes et al., 2008). Merritt and Liles (1989) mention a strong overall homogeneity between story generation and story retelling, although for some aspects only group differences in a retelling and not in a generation task were observed and vice versa. For example in this study of Merritt and Liles, the children with SLI produced a similar number of main clauses as children with normal language in the story generation task, but fewer main clauses when retelling a story.

Moreover, there are inconsistencies across studies concerning the number of utterances, the number of words (for an overview, see Crais & Lorch, 1994) and the mean length of utterances over the ages in children with SLI. In early preschool years, children with SLI have a lower mean length of utterances compared to typically developing children (e.g., Paul & Smith, 1993). However, from the late preschool years onwards, results of different studies are contradictory. Paul et al. (1996) observed no group differences at 6, 7 and 8 years, while Kit-Sum To et al. (2010) did observe significant group differences in children between 4;10 to 12;01 years.

Crais and Lorch (1994) suggested that these conflicting findings are caused by differences in the type of task applied, in motivation of the children, in subject selection and

in method of transcription and analysis (e.g., whether or not repetitions were included in the analyses). In general, it can be concluded that certainly the narrative microstructure is poorer in stories of children with SLI as compared to typically developing children. In addition, the narrative macrostructure may be impaired too, probably as a secondary effect because of problems with the microstructure or with the comprehension of relationships in the stories.

Only few *longitudinal studies* investigated the development of narrative abilities in children with SLI. In a study of Paul et al. (1996), children with language impairment and controls performed a narrative task yearly from kindergarten to grade 2. At each time point, the children were repartitioned into three groups: a group with a past history of expressive language delay, a group with persistent expressive language delay and a typically developing group. Results demonstrated that in kindergarten, typically developing children scored significantly higher than both language delayed groups on lexical diversity and narrative stage and they had a higher proportion of complete cohesive ties than the children with persistent expressive language delay. There were no significant differences for the information score and the mean length of utterances. Group differences for macro- and microstructure narrative scores were more pronounced in kindergarten than in grade 2. The authors hence stated that problems with narrative skills tend to disappear in children with a history of expressive language delay. However, the narrative deficits disappear at a slower rate than the expressive syntactic deficits. At earlier ages, children with a history of language impairment have a deficit in many oral language aspects. When children mature, fewer oral language aspects are impaired.

In another longitudinal study (Fey, Catts, Proctor-Williams, Tomblin, & Zhang, 2004) different conclusions were drawn. Children were divided into four groups based on kindergarten language and intelligence scores, that is a typically developing group, an SLI group, a group with nonspecific language impairment and a group with low nonverbal IQ. The children performed a narrative task in grade 2 and 4. The stories of the typically developing group had higher micro- and macrostructure narrative scores (more different words, more grammatical complexity, fewer errors and more overall quality) than both language impaired groups at either grade. Moreover, children with language impairment (specific and nonspecific) were divided by the end of grade 2 in a group with and without

language impairment at that moment measured using a standardized language test. The group without language impairment in grade 2 also appeared to have recovered in storytelling abilities at that point comparable to the study of Paul et al. (1996). However, by the fourth grade, the study of Fey et al. demonstrated that the stories of these children were less like the typically developing children and more like those of children with persistent language impairment. Therefore, the authors argued that the narrative deficits do not disappear but rather increase from the second to the fourth grade in children with a history of language impairment. Moreover, they warned that children with typical language had reached a ceiling in grade 2 on the measure of episode structure in the study of Paul et al.

In a study of Finestack, Fey and Catts (2006), pronominal reference skills were analyzed in these same four groups from grade 2 to grade 4. The children with SLI could not be differentiated from typically developing children based on the rate of pronominal referencing. Moreover, this rate of pronominal referencing did not significantly increase from grade 2 to grade 4 in children with SLI, which was comparable to typically developing children. However, in a similar study of Strong and Shaver (1991) concerning all types of cohesion, the opposite was observed for both observations.

To summarize, narrative tasks are more sensitive to persistent oral language problems than other standardized oral language tests. They have a good sensitivity to detect oral language difficulties (Kit-Sum To et al., 2010; Pankratz, Plante, Vance, & Insalaco, 2007) and can therefore play a significant role in the evaluation of children with developmental language impairment (Fey et al., 2004). They may also constitute a reliable indicator of future language and literacy performance in children with SLI (Bishop & Edmundson, 1987; Pankratz et al., 2007; Stothard, Snowling, Bishop, Chipchase, & Kaplan, 1998). Yet, the specificity of these narrative tasks seems to be rather poor (Kit-Sum To et al., 2010; Pankratz et al., 2007). Even typically developing children show a wide variation in narrative performance (measured through a telling task) between 6 and 10 years (Norbury & Bishop, 2003). A possible solution is the combination of a narrative task with other language measures to identify language disorders in school-age children (Kit-Sum To et al., 2010). Redmond, Thompson and Goldstein (2011) observed a high diagnostic accuracy in discriminating children with SLI from typically developing children when a combined

measure comprising story understanding, macrostructure and microstructure narrative ability was used.

4.1.3 Links with reading comprehension and accuracy

Reading comprehension is a complex cognitive linguistic process that involves multiple levels of processing, particularly when texts become longer. All components of language (phonology, morphology, syntax, semantics, discourse structure, and pragmatics) are involved, as well as attention, executive function, and memory skills (Hook & Haynes, 2009). Different studies have shown that oral language (receptive vocabulary, listening comprehension, expressive vocabulary, text comprehension and semantic skills) at the age of eight predict future reading comprehension in typically developing children (Nation & Snowling, 2004; Spear-Swerling, 2006). In children with SLI, sentence comprehension and the information score of the Bus Story Test at seven years were good predictors of reading comprehension at 11 years (Botting, Simkin, & Conti-Ramsden, 2006). Also in children with reading disabilities, the predictive value of storytelling for reading comprehension was frequently demonstrated (Feagans & Appelbaum, 1986; Gilmore, Klecan-Aker, & Owen, 1999). In general, narrative skills might be more important predictors for reading comprehension than traditional language skills such as vocabulary and syntax (Feagans & Appelbaum, 1986).

Surprisingly, in some studies, not only reading comprehension, but also word reading accuracy could be predicted by nonphonological oral language skills. Nation and Snowling (2004) showed that expressive vocabulary, text comprehension and semantic skills at eight years predicted reading accuracy at the age of 13 in typically developing children. In a similar vein, Botting et al. (2006) showed that sentence comprehension at seven years uniquely predicted reading accuracy at the age of 11 in children with SLI, even after controlling for early single word reading level at 7 years. Also Westerveld, Gillon and Moran (2008) demonstrated that children with problems on word reading, listening comprehension and reading comprehension had a lower performance on narrative comprehension, narrative macrostructure, grammatical complexity and semantic diversity in comparison to typically developing children. Compared to reading-matched controls, they had significantly lower scores on narrative comprehension, suggesting a specific oral narrative comprehension deficit. In a study of Gillam and Carlile (1997), children with SLI and control children matched

on the basis of single-word reading had to read and retell stories one grade level above their reading level. Remarkably, results showed that story retellings in the two groups were similar in terms of percentages of recalled vocabulary, story elements, and problem-resolution pairs, suggesting that the level of reading is associated with the narrative level. However, holistic analysis showed that fewer retellings in the SLI group were complete, and more of their retellings were confusing. Based on these studies, we can conclude that there is a link between oral language ability (including narrative skills) and reading accuracy and comprehension.

4.1.4 Present study

Previous studies have shown that children with SLI exhibit problems with narrative skills. Yet, since most of these studies have a cross-sectional design, little is known about the development of these abilities. Narrative skills are closely related to reading comprehension and reading accuracy. Together with other oral language skills, these skills can play a role in the overlap between SLI and dyslexia, which is of special interest in our study. In the present longitudinal study we compare three groups of children on various oral language and narrative skills: a group with SLI and literacy delay, a group with SLI and normal literacy and a typically developing group. Oral language measures were assessed in kindergarten, grade 1 and grade 2, literacy skills were evaluated in grade 1 and grade 3 and reading comprehension skills were measured in grade 3. In two previous reports (Vandewalle, Boets, Ghesquière, & Zink, 2010; Vandewalle, Boets, Ghesquière, & Zink, in press), we described the development of phonological and literacy skills, and the interrelation between these abilities. The present study focuses on narrative and other oral language skills beyond phonology (i.e., vocabulary, morphology and syntax), and reading comprehension skills in these same groups of children.

4.2 Method

4.2.1 Participants

Eighteen children (three girls and 15 boys) with SLI participated in the study. All children were born in 2000, attended the last year of regular kindergarten at the start of the study, were monolingual Dutch speakers, had severe and persistent oral language problems

and received language therapy. Oral language problems were determined by a score below percentile 3 before the start of language therapy and a score below percentile 10 after 4;4 years of age on at least one subtest of three standardized Dutch language tests: *Reynell Taalontwikkelingsschalen* [Reynell Developmental Language Scales] (Schaerlaekens, Zink, & van Ommeslaeghe, 2003), *Taaltests voor Kinderen* [Language Tests for Children] (van Bon & Hoekstra, 1982) or *Schlichting Test voor Taalproductie* [Schlichting Test for Language Production] (Schlichting, van Eldik, Spelberg, van der Meulen, & van der Meulen, 2003). In addition to these language problems, some children had concurrent articulation problems. Exclusion criteria were low intelligence (non-verbal, verbal and total IQ below 85), hearing loss and any other known problem (e.g., neurological disorder) that could explain their language impairment.

For every individual child of the SLI group, the best matching control child was selected based on five criteria: (1) educational environment, i.e., same class, (2) gender, (3) age, (4) non-verbal intelligence, and (5) parental educational level. Non-verbal intelligence was assessed collectively in the class with an adapted version of the Raven Coloured Progressive Matrices (Raven, Court, & Raven, 1984) and parental educational level was obtained by a questionnaire completed by the parents (based on the International Standard Classification of Education scale, UNESCO, 1997). All control children were monolingual Dutch speakers, had normal hearing and did not show any speech or language difficulties as confirmed by their parents and teachers.

Initially 26 children with SLI were selected, but only 18 children are included in the present report because one child left the study after kindergarten and seven children did not move on to grade 1 of a regular primary school after the last year of kindergarten. Consequently, the eight corresponding control children were also left out of the present report.

Both the SLI group (n = 18) and the control group (n = 18) were divided into two subgroups based on word reading and spelling achievement. The ‘literacy-delayed’ group comprised all children scoring 1 *SD* below population mean on a standardized word reading (van den Bos, Spelberg, Scheepstra, & De Vries, 1994) or spelling test (Dudal, 2006), in both first and third grade. This criterion took into account both the severity and the persistence of a child’s literacy problem. By applying this criterion, we identified eight children with literacy

delay in the SLI group and four children in the control group. In the following analyses only three groups of children will be compared: (1) children with SLI and literacy delay (SLI-LD; *n* = 8), (2) children with SLI and normal literacy (SLI-NL; *n* = 10), and (3) control children with normal literacy (Control-NL; *n* = 14).

Mixed Model Analyses showed that the three groups had equivalent age (*p* = .90) and did not differ significantly on non-verbal intelligence (*p* = .09). In contrast, Fisher Exact Test revealed significant group differences for educational level of the mother (*p* = .03). Therefore, in all group comparisons, we will control for maternal educational level as this can have an influence on language and reading comprehension skills. A more detailed description of the three groups can be found in Vandewalle et al. (in press).

4.2.2 Measures

4.2.2.1 Oral language skills

The oral language test battery included tests that have not been used in the selection procedure or diagnostic assessment to avoid learning effect.

Vocabulary. Vocabulary was measured through three different tests. In the productive vocabulary test from the *Taaltoets Allochtone Kinderen* [Language test for foreign children] (Verhoeven & Vermeer, 1986) the child had to name the correct word depicted by a picture. The receptive vocabulary test and the word description test from the *Taaltoets Alle Kinderen* [Language test for all children] (Verhoeven & Vermeer, 2001) measured respectively whether the child could assign the correct picture to a given word (out of four alternatives) and could describe the word by giving a definition or a correct example.

Word fluency. To measure word fluency a newly designed test was administered. This word fluency test measured the number of words belonging to one semantic category (e.g., beverages, fruit, animals) that the child was able to produce in 20 seconds (Vandewalle et al., 2010).

Productive morphology. Morphology was measured through a productive morphological test from the *Taaltoets Alle Kinderen* [Language test for all children] (Verhoeven & Vermeer, 2001): the child had to make 12 plurals and 12 past participles, both regular as well as irregular forms.

Sentence listening comprehension. This was measured through the sentence comprehension test from the *Taaltoets Alle Kinderen* [Language test for all children] (Verhoeven & Vermeer, 2001). In this task, the child had to depict the picture that represents the sentence read by the instructor out of three alternatives.

Text listening comprehension. This receptive task is also a part of the *Taaltoets Alle Kinderen* [Language test for all children] (Verhoeven & Vermeer, 2001). Different oral language skills had to be combined to perform this task. Six short stories were told to the child and immediately after each story, four questions were asked. Each correct answer resulted in one point.

4.2.2.2 Narrative skills

Story retelling. A Dutch translation (Jansonius-Schultheiss, Borgers, De Bruin, & Stumpel, 2007) of the Bus Story Test from the Renfrew Language Scales (Renfrew, 1997) was presented to the child and was accompanied with twelve pictures. Immediately after listening to the story, the child had to retell the story as accurately as possible while looking at the pictures. This story was mainly told in the past tense with long sentences and a lot of subordinate clauses which make the morphology and syntax of the story complex.

Storytelling. This storytelling task is part of the *Taaltoets Alle Kinderen* [Language test for all children] (Verhoeven & Vermeer, 2001). The child first had to look at eight pictures representing one sequence of events of a story. Then the child had to give his/her own interpretation of the story by telling the story while looking at the pictures.

Scoring of the story(re)telling. Firstly, all stories were transcribed literally. Afterwards different types of scores were awarded to each transcription. The *information score* was calculated as described in the manuals of both tasks. For the Bus Story Test, this score indicates the number of relevant pieces of information the child included in the story. Two points were given for each item that Renfrew designated as ‘essential’ and one point for each item designated as ‘subsidiary’. For each element, the reference to the subject had to be correct too. If not, one point was subtracted from the information score. In the storytelling task, nine information elements and seven relations between different elements were scored by one point each. Furthermore, the transcribed stories were divided into utterances as described in the manual of the Bus Story Test. A new utterance was identified

after a coordinating conjunction (e.g., and, or, but), unless there was a coreferential subject deletion in the second clause. The *mean length of the five longest correct utterances (MLU5)* and the *mean length of all utterances* were calculated for each story. All utterances with syntactic errors in the sentence construction (e.g., incomplete sentences, wrong ordering of words) were excluded from these scores. Finally, different *syntactic and morphological measures* were calculated based on both stories: the total number of all correct and incorrect utterances, all words, the proportion of sentences with syntactic errors, the proportion verbs with a disagreement between subject and verb, the proportion errors in the used definite articles and the proportion errors in verb conjugations. In Dutch language, male and female words have the definite article /de/ and neuter words have the definite article /het/. In early language development, children often switch both articles. Moreover, since the Bus Story Test was told with a lot of subordinate clauses and mainly in the past tense, the proportion of subordinate clauses and the proportion verbs in the past tense were calculated as well.

4.2.2.3 Literacy skills

Reading. The One-Minute Reading test (van den Bos et al., 1994) was used as a standardized measure of single word identification. This test combines speed and accuracy into one index score. The child had to read a list of words of increasing difficulty as correctly and quickly as possible. The score on the test is the number of words read correctly within one minute. For diagnostic purposes, this score was transformed to an age-adjusted standard score relative to population average.

Spelling. Spelling was evaluated by a standardized spelling achievement test (Dudal, 2006). Children had to spell single words presented in isolation, single words presented in sentence context, and short sentences. The maximum score on the test was 60. For diagnostic purposes this score was transformed to an age-adjusted standard score relative to population average. Grade-appropriate versions of the test were used in first and third grade.

Reading comprehension. The reading comprehension task is part of the Dutch reading comprehension test for children at the end of grade 2 (Krom, van Berkel, & Jongen, 2006). After four practice items, the child had to read one story with four sentences in a wrong

order and the child had to encircle the first sentence of the story. Afterwards, the child had to read silently seven short texts and immediately after reading each text, the child had to encircle the correct answer for multiple choice questions with four alternatives. Only the number of correct answers is counted.

4.2.3 Design and procedure

The administration of the tests was spread over a period of three years (see Table 4.1). Each matched pair of children from the SLI and control group was tested in a quiet room at their school under identical circumstances and in the same period. All tests were administered individually, only the tests for spelling and reading comprehension were administered collectively. Data collection was carried out by trained Master students in Speech-Language Pathology and Audiology. The data of one control child on the Bus Story retelling Test and one child with SLI on the telling task in kindergarten were removed because of their unreliable performance. Moreover, the reading level of one child with SLI was too low to administer the reading comprehension task. Hence, for these three tasks, the measurements of one child are missing.

Groups were compared using Mixed Model Analyses (MMA) with pair as a random variable and participant group (SLI-LD, SLI-NL and Control-NL group) as the fixed between-subject variable. Maternal educational level was included as fixed covariable. To investigate developmental trends, repeated measures MMA were calculated with time (kindergarten, grade 1 and grade 2) as within-subject variable, participant group as between-subjects variable and maternal educational level as covariate. Post hoc analyses were corrected for multiple comparisons using the Tukey procedure, and standardized mean differences were calculated as a measure of effect size by dividing the difference between the least-squares means by the pooled standard deviation. Given the rather small sample sizes, the statistical power to reveal significant group differences is relatively small and interpretation of the results should also be guided by inspection of these effect sizes. Kruskal Wallis nonparametric ANOVA was used to compare the three groups on the non-normally distributed proportion scores. The Bonferroni procedure for multiple comparisons was used for the post hoc analyses of the Kruskal Wallis tests by using an adjusted significance level.

Table 4.1 Occasions of test administrations

	Kindergarten		**Grade 1**	**Grade 1**	**Grade 2**	**Grade 3**
	Middle		**Middle**	**End**	**Middle**	**Begin**
	5;5 years	5;9 years	6;8 years	6;10 years	7;6 years	8;1 years
Oral language skills						
Productive vocabulary	x		x		x	
Word description		x	x		x	
Word fluency		x	x		x	
Productive morphology	x		x		x	
Receptive vocabulary		x	x		x	
Sentence comprehension	x		x		x	
Text comprehension		x	x		x	
Narrative skills		x	x		x	
Literacy						
Word reading				x		x
Spelling				x		x
Reading comprehension						x

4.2.4 Reliability

Master students in Speech-Language Pathology and Audiology were intensively trained before administering the tests, performing the transcriptions and scoring all items based on clearly specified coding rules. The same person did the coding of all narrative tests of all children administered in the same grade to avoid effects within a grade. To check the quality and consistency of scoring over the years, results on all items were individually verified by the first author, who has extended experience with these tasks. Moreover, 25% randomly selected items of the information score of the retelling task in grade 1 and 2 were independently rescored, which resulted in a strong inter-rater reliability (r_S = .98).

Moreover, in a pilot study, the inter-rater reliability between 3 students Speech-Language Pathology was compared for the retelling task. After a training, they independently transcribed the stories and calculated the information score and the mean length of the five longest sentences of 12 randomly selected children (9 typically developing

children and 3 children with a cochlear implant). Spearman correlations revealed again a strong inter-rater reliability for the information score (r_S = .94) and an acceptable inter-rater reliabiltity for the mean length of the five longest sentences (r_S = .75).

4.3 Results

4.3.1 Development of oral language skills

The development of the different language skills (i.e. productive and receptive vocabulary, word description, word fluency, morphology, sentence and text listening comprehension) is depicted in Table 4.2 and Figure 4.1. Repeated measures MMA showed main effects of group (*p*s ≤ .0001) and grade (*p*s ≤ .0004) for all tasks, but no group by grade interactions (*p*s ≥ .09), except for the sentence listening comprehension (*p* = .005) and text listening comprehension task (*p* = .003). Both SLI groups scored significantly lower than the Control-NL group on all tasks in all grades, except for the sentence listening comprehension task in grade 1 and the text listening comprehension task in grade 1 and 2, where there were no significant differences between the SLI-NL group and the Control-NL group. There were no significant differences between both SLI groups on any of the oral language tasks across the three years, except for text listening comprehension in grade 1 and 2. It is remarkable that the SLI-NL group evolved towards the Control-NL group in grade 1 and grade 2 for text listening comprehension, while scores of the SLI-LD group remained significantly lower. A similar pattern was apparent for sentence listening comprehension from kindergarten to grade 1.

Table 4.2 Oral language measures for the three participant groups: maximum (*Max*), mean (*M*) and standard deviation (*SD*); effect size (*ES*)

			SLI-LD (1) $n = 8$		SLI-NL (2) $n = 10$		Control-NL (3) $n = 14$		Group comparisons[a] 1-2	1-3	2-3
	Max		*M*	*SD*	*M*	*SD*	*M*	*SD*	*ES*	*ES*	*ES*
Productive vocabulary	60	KG	19.6	5.0	25.2	7.1	34.1	7.8	-1.16	-2.38***	-1.23*
		G1	31.1	3.2	32.6	4.7	41.9	2.9	-0.19	-3.33***	-2.48***
		G2	35.3	1.5	37.2	5.0	43.1	3.1	-0.57	-3.04***	-1.46**
Receptive vocabulary	96	KG	56.4	5.4	51.4	10.6	68.9	7.6	0.70	-1.57*	-1.90***
		G1	64.3	7.1	65.0	7.0	76.5	5.0	-0.27	-2.06**	-1.71**
		G2	69.8	4.7	70.7	5.1	80.7	5.4	-0.10	-1.70**	-1.56**
Word description	45	KG	8.5	3.4	10.4	2.3	17.5	3.1	-0.79	-2.80***	-2.51***
		G1	12.9	4.0	12.9	3.0	20.7	4.0	0.05	-1.86**	-2.10***
		G2	10.8	3.1	15.9	5.9	22.7	4.2	-0.98	-3.13***	-1.47**
Word fluency	-	KG	3.8	0.7	4.1	0.3	5.3	0.8	-0.40	-1.85**	-1.84**
		G1	4.5	0.7	5.2	1.0	6.0	0.6	-0.73	-2.70***	-1.25*
		G2	5.1	0.9	5.6	0.5	6.5	0.7	-0.69	-1.71**	-1.32*
Productive morphology	24	KG	9.4	3.6	11.4	2.7	15.6	3.4	-0.22	-1.37*	-1.29*
		G1	13.0	3.9	15.6	2.4	19.4	2.0	-0.50	-1.83**	-1.66*
		G2	15.6	3.1	18.3	2.9	22.1	2.0	-0.78	-2.29***	-1.31*
Sentence listening comprehension	42	KG	26.3	3.4	25.0	5.1	32.5	2.8	0.35	-2.03***	-1.97*
		G1	30.0	3.9	33.0	3.3	35.1	2.3	-0.99	-1.93**	-0.78
		G2	34.0	2.1	34.4	2.5	38.0	1.5	-0.46	-2.60***	-1.74**
Text listening comprehension	24	KG	14.6	2.3	15.6	3.2	19.4	2.5	-0.55	-2.05**	-1.20*
		G1	14.0	4.6	19.1	1.4	19.9	1.8	-2.02***	-2.16***	-0.09
		G2	15.5	2.9	20.1	2.4	20.1	2.4	-2.11***	-1.94**	0.20

Note. [a] MMA with maternal educational level as covariate; * $p < .05$; ** $p < .01$; *** $p < .001$
KG = kindergarten; G = grade

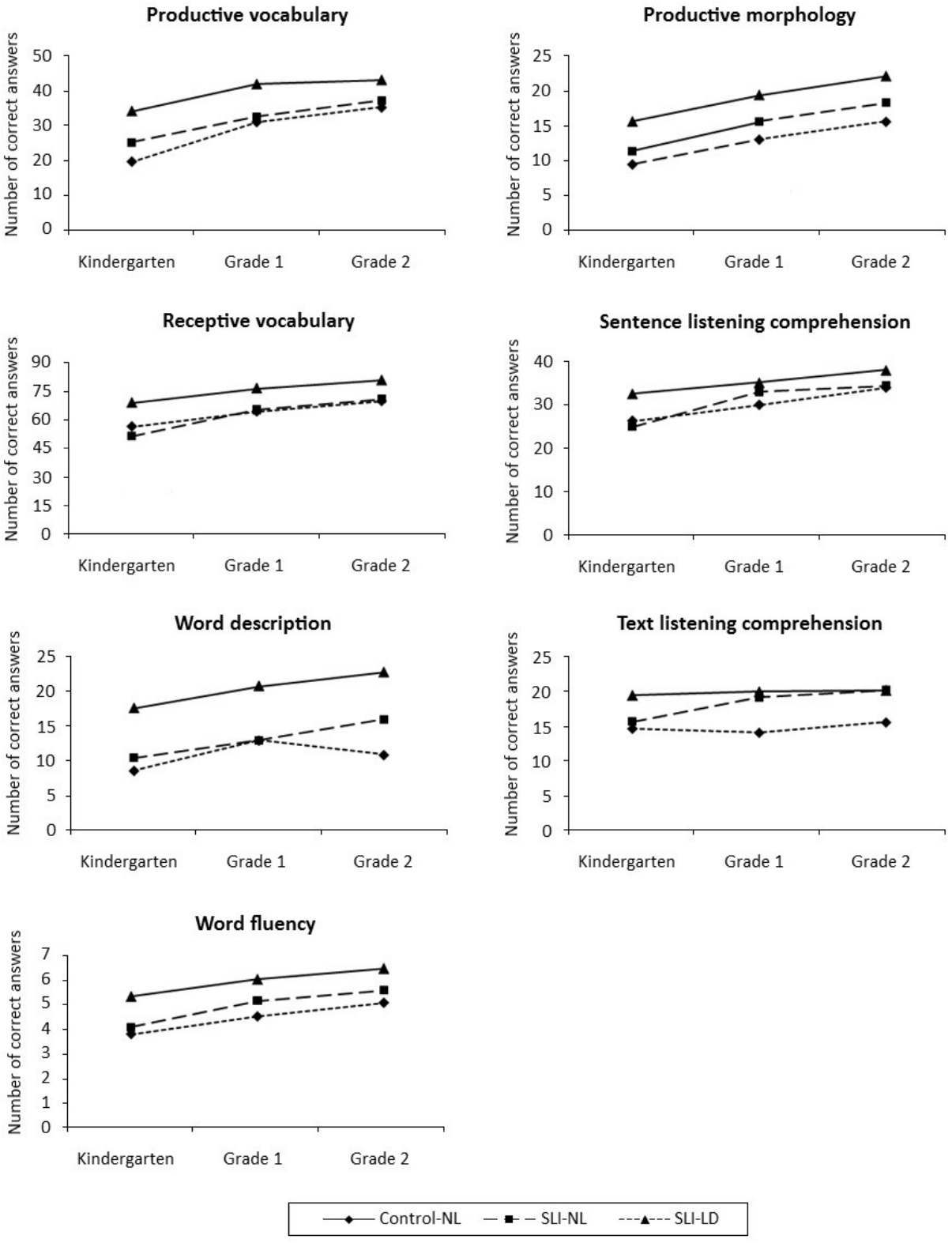


Figure 4.1 Development of oral language measures for the SLI-LD, SLI-NL and control-NL group. Arrows designate significant group differences ($p < .05$)

4.3.2 Development of narrative skills

The development of the information score and MLU5 on the story retelling and storytelling tasks can be observed in Table 4.3 and Figure 4.2. Repeated measures MMA showed main effects of group ($p \leq .0008$) and grade ($p < .005$) for the information score and MLU5 for the retelling and the telling task, but no significant interaction effects ($p \geq .60$).

In general, the SLI-LD group scored significantly lower than the Control-NL group across almost all grades. However, the SLI-NL group showed a differential pattern on both narrative tasks. On the story retelling task, the SLI-NL group scored rather similar to the SLI-LD group and significantly lower than the Control-NL group. In contrast, on the storytelling task, the SLI-NL group scored in between the Control-NL and the SLI-LD group, and did not differ from these two groups in kindergarten. Moreover, across time the SLI-NL group evolved in the direction of the Control-NL group on the storytelling task, while the SLI-LD group continued lagging behind. Group differences on the mean length of all utterances index and MLU5 were very similar for both the retelling and telling task. Hence, only MLU5 scores were presented.

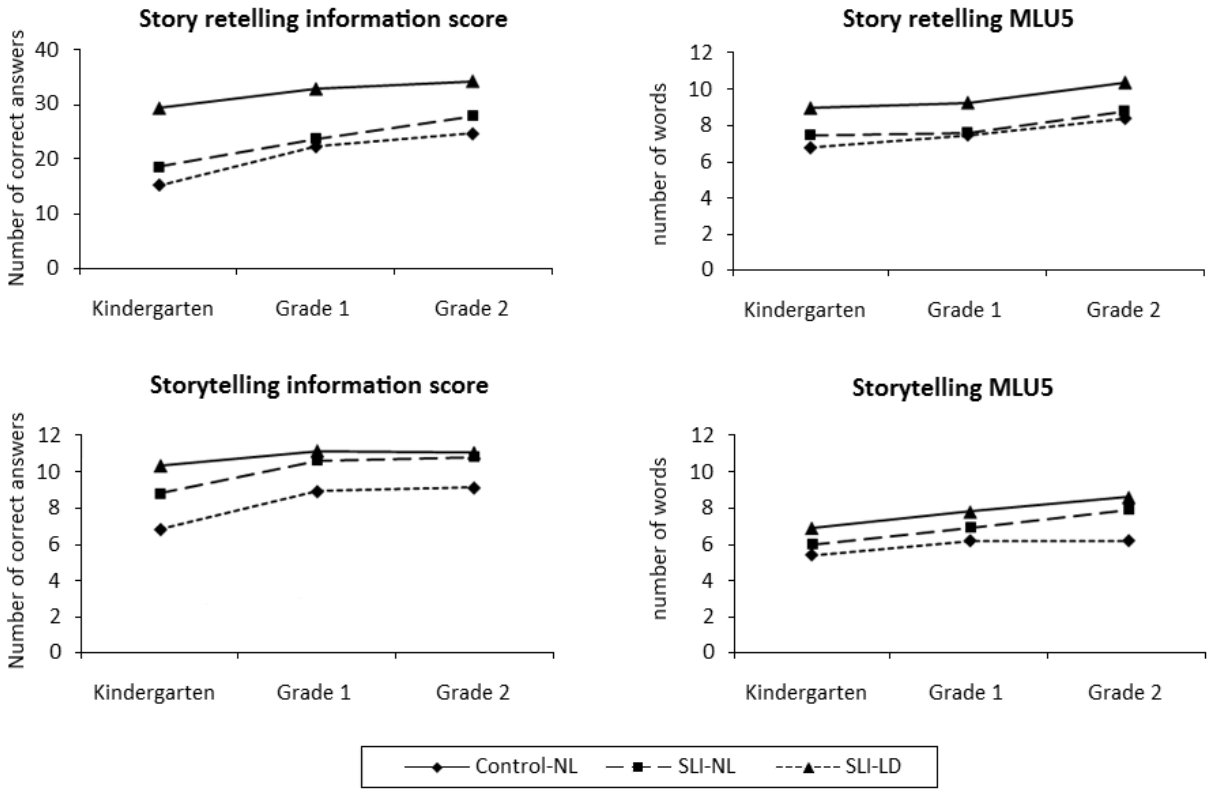


Figure 4.2 Development of narrative measures for the SLI-LD, SLI-NL and control-NL group. Arrows designate significant group differences ($p < .05$)

Table 4.3 Narrative and literacy measures for the three participant groups: maximum (*Max*), mean (*M*) and standard deviation (*SD*); effect size (*ES*)

			SLI-LD (1) *n* = 8		SLI-NL (2) *n* = 10		Control-NL (3) *n* = 14		Group comparisons[a] 1-2	1-3	2-3
	Max		*M*	*SD*	*M*	*SD*	*M*	*SD*	*ES*	*ES*	*ES*
Story retelling											
Information score	53	KG	15.3	3.7	18.7	7.6	29.4	8.0	-0.79	-2.24**	-1.32*
		G1	22.4	7.0	23.8	7.2	32.9	6.0	-0.29	-1.71*	-1.35*
		G2	24.8	5.5	27.9	7.5	34.3	4.6	-0.49	-1.91*	-1.03*
MLU5	-	KG	6.8	0.8	7.5	0.8	9.0	1.7	-0.87	-1.40*	-0.94
		G1	7.5	1.8	7.6	1.6	9.3	1.6	-0.10	-1.25**	-1.18**
		G2	8.4	0.7	8.8	2.0	10.4	1.4	-0.45	-2.01*	-1.02*
Storytelling											
Information score	16	KG	6.8	1.4	8.8	2.3	10.3	1.8	-1.11	-2.51**	-0.95
		G1	8.9	2.8	10.6	1.8	11.1	1.9	-1.24*	-1.35*	-0.12
		G2	9.1	3.1	10.8	1.9	11.0	2.4	-0.40	-0.59	-0.25
MLU5	-	KG	5.4	0.6	6.0	1.4	6.9	1.3	-0.82	-1.24	-0.50
		G1	6.2	1.2	6.9	1.7	7.8	1.9	-0.58	-1.60*	-0.69
		G2	6.2	1.0	7.9	1.4	8.6	1.6	-1.30	-1.71**	-0.49
Word reading[b]	-	G1	91.3	7.9	100.5	6.9	107.9	15.0	-0.79	-0.79	-0.37
		G3	78.1	19.3	102.0	11.8	107.9	14.4	-1.2	-1.45*	-0.36
Spelling[b]	-	G1	74.3	8.8	92.4	10.3	100.3	14.0	-1.59	-1.90**	-0.65
		G3	67.1	10.7	92.1	12.6	107.3	14.5	-1.82*	-2.51***	-0.86
Reading comprehension	25	G3	7.9	2.2	13.5	3.7	16.9	3.8	-1.80*	-2.39***	-0.60

Note. [a]MMA with maternal educational level as covariate; [b]standard scores with mean = 100, SD = 15; *p < .05, ** p < .01, *** p < .001

In the retelling task, the children were implicitly encouraged to make longer sentences as the story was told in long sentences. This resulted in a significantly higher MLU5 on the retelling task as compared to the telling task over the three groups and years (*p*s < .0001).

Repeated measures MMA showed that there were no group differences in the number of sentences used (correct and incorrect) in the retelling (*p* = .09) and the telling task (*p* = .52). The average number of words that were used in the retelling and telling task did differ between the three groups for both tasks (*p*s < .04): the two SLI groups used significantly fewer words than the Control-NL group. Kruskal Wallis tests revealed also that the SLI-LD group made significantly more errors in sentence constructions (e.g., incomplete sentences, wrong ordering of words) than the Control-NL group on the retelling task in grade 1 and on the telling task in each of the three grades (see Appendix 4A).

Different morphological skills were scored for the three groups as well (see Appendix 4A). The SLI-LD group made significantly more errors in verb conjugations than the Control-NL group on the retelling task in grade 2. In other grades and on the telling task, there were no significant differences between the three groups. For subject-verb agreement, Kruskal Wallis tests showed that the SLI-LD group made significantly more errors than the Control-NL group on both the retelling and the telling task in kindergarten. In grade 1, both SLI groups made more subject-verb agreement errors than the Control-NL group on both tasks. In grade 2, no group differences were retained. Although hardly any errors in the use of definite articles were made in any of the groups, children of the SLI-LD group made significantly more errors than children of the Control-NL group on the retelling task in grade 2. Kruskal Wallis test showed that children in the SLI-LD group used significantly fewer subordinate clauses than the Control-NL group in the retelling task in all grades. There was a large variability within the SLI-NL group in grade 1 and 2. On the telling task, however, no group differences were retained in the number of subordinate clauses. Analyzing the use of the past tense in the retelling task, Kruskal Wallis tests revealed that both SLI groups used the past tense less frequently in kindergarten compared to the Control-NL group. In grade 1, the SLI-NL group still used the past tense less frequently than the Control-NL group. However, in grade 2, the SLI-NL group evolved towards the level of the Control-NL group, whereas the SLI-LD group made significantly more errors than the Control-NL group.

4.3.3 Reading comprehension skills

Reading comprehension was only measured in grade 2. Table 4.3 shows that the SLI-LD group scored significantly poorer than the SLI-NL and the Control-NL group. The SLI-NL group had similar scores as the Control-NL group.

4.4 Discussion

From our study we can conclude that *children with SLI and literacy delay* showed persistent language problems across all the assessed language domains: vocabulary, morphology, syntax and narrative skills (storytelling and retelling). They experienced productive as well as receptive oral language problems from kindergarten until at least grade 2. Hence, in spite of the fact that all children with SLI had started oral language therapy in kindergarten, they did not show any recovery of their language problems. Our observation that children with SLI and literacy delay (and to a minor extent also those with normal literacy development) showed persistent narrative problems until grade 2, contrasts with the findings of Paul et al. (1996) but confirms the conclusions of Fey et al. (2004). We observed that these children made more errors than control children in sentence construction, verb conjugation, subject-verb agreement and the use of definite articles. In the Bus Story retelling Test, they used subordinate clauses and the past tense less frequently. These observations are in accordance with other studies (Liles et al., 1995; Merritt & Liles, 1987; Norbury & Bishop, 2003), although we did not observe any group difference in the number of sentences used in the narrative tasks (in contrast to the study of Liles, 1985). In accordance with other studies (Bishop & Adams, 1990; Conti-Ramsden, Botting, Simkin, & Knox, 2001), the children with SLI and literacy delay also showed problems with reading comprehension in the beginning of grade 3.

The c*hildren with SLI and normal literacy* also scored persistently low from kindergarten till grade 2 on vocabulary, morphology and story retelling skills. However, for some oral language tasks, this group caught up with the control group.

First, for text listening comprehension and partly for sentence listening comprehension, the children with SLI and normal literacy evolved towards the control group while the SLI group with literacy delay continued lagging behind. In these tasks, children had to combine different receptive oral language skills in order to complete the task.

Surprisingly, the children with SLI and normal literacy experienced problems with the isolated skills (e.g., receptive vocabulary), but not in combining the skills in an integrated manner to comprehend a sentence or text. Because most improvement was accomplished from kindergarten to grade 1, we postulate that this improvement might have been provoked by the exposure to written text during literacy instruction. The SLI group with normal literacy received more from print exposure as a result of their better reading than the SLI group with literacy delay.

Second, on storytelling, the SLI group with normal literacy had in general better scores than the SLI group with literacy delay, both on the information score and on the mean length of the five longest sentences. Already in kindergarten, this group performed at a similar level as the control group, which suggests that this good performance level resulted from spontaneous development or compensation. Certainly, it could not be the effect of literacy instruction or print exposure because formal literacy instruction started one year later. In grades 1 and 2, the group evolved further towards the control group. Remarkably, both on the information score (measuring the content – an aspect of narrative macrostructure) and on the mean length of the five longest sentences (measuring the linguistic form – an aspect of narrative microstructure) group differences showed a similar pattern (see Figure 4.2). However, there was an effect of the kind of task, i.e. telling versus retelling. The SLI group with normal literacy scored consistently poorer on story retelling (both content and linguistic form) compared to the control group, but scored nearly identically to the control group for storytelling (both content and linguistic form). An effect of task was also observed by Merritt and Liles (1987), but not by Befi-Lopes et al. (2008). Storytelling is a complex task in which different oral language skills have to be combined. Therefore, we expected that the deficits would have been more persistent compared to those for the individual language skills (Paul et al., 1996), but this was not the case. Another influencing effect might be the use of pictures. McCabe et al. (2008) observed that a lot of children with language impairment treated the pictures in isolation from each other rather than a series of events. In contrast, personal narratives (without presenting pictures) were often more coherent stories. In our study, pictures were used in both tasks, but we suppose that this effect was larger in the storytelling than in the story retelling task because in the storytelling task, the children could only get information based on the pictures. However,

this effect did not seem to cause more differentiation between the three groups. Another potential explanation of the larger group differences in the retelling task might be the fact that control children benefit more from the told story (the auditive information) in contrast to the two SLI groups. However, based on the improved scores for listening comprehension in the SLI-NL group in grades 1 and 2, we would expect improved retelling scores in this group as well, which was not the case. The different pattern of performance on story retelling versus storytelling might have been provoked by the fact that children could freely choose the difficulty level of expression (e.g., the length of the sentences) in the storytelling task. In contrast, the difficulty level was somehow imposed in the retelling task, where children were implicitly encouraged to make longer and more complex sentences. This was evidenced by the observation that children produced shorter sentences in the telling task as compared to the retelling task. As a consequence, these shorter and easier sentences and stories in the telling task might have been less sensitive to differentiate between the groups.

There is a narrow link between oral language and reading comprehension skills, which is also evidenced by several studies showing that a high proportion of children with SLI develop reading comprehension problems (Bishop & Adams, 1990; Conti-Ramsden et al., 2001). Hence we expected the entire SLI group to be at risk for reading comprehension problems. However, we observed that only the SLI group with literacy delay developed reading comprehension problems in grade 3, whereas the SLI group with normal literacy did not present reading comprehension problems despite their oral language problems. This pattern of findings suggests that reading comprehension performance at this age was mainly determined by word reading skills and not by oral language skills. It should be noted that the texts of this particular reading comprehension task were short and easy. Possibly at a later age when texts become longer and use more complex language, the SLI group with normal literacy may develop reading comprehension problems as a consequence of their remaining oral language problems.

To investigate developmental trends in longitudinal studies, it is important to compare scores for the same tests measured at different time instants, as was done in this study for the narrative and other oral language skills. However, then the scores might be influenced by unwanted learning effects of the specific task. In order to minimize these

learning effects, in our study the interval between the consecutive test administrations was kept large (i.e., yearly).

More longitudinal studies with larger groups, in different languages, spanning a longer period and using a wider range of oral language and narrative measures are needed. In particular, a more extensive comparison of children with SLI with and without literacy delay is desirable to generalize our results. Because a good narrative ability involves many different skills such as working memory, vocabulary, pragmatic skill, and meta-linguistic knowledge (Botting, 2010), further research is needed to analyze the underlying mechanisms that play a role in the development of narrative skills in both SLI groups. Early diagnosis and effective therapy will ultimately be based on a solid understanding of the underlying relations over time.

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Appendix 4A Median (Med) and range of percentages of different scores in the storytelling and story retelling task for the three participant groups

		Story retelling task			Storytelling task		
		SLI-LD	SLI-NL	Control-NL	SLI-LD	SLI-NL	Control-NL
		n = 8	*n* = 10	*n* = 14	*n* = 8	*n* = 10	*n* = 14
		Med (Range)	*Med (Range)*	*Med (Range)*	*Med (Range)*	*Med (Range)*	*Med (Range)*
% erroneous sentences	KG	14 (5-36)	10 (0-36)	7 (0-31)	23 (9-50)$_{a}$	10 (0-40)$_{ab}$	11 (0-18)$_{b}$
	G1	20 (5-72)$_{a}$	16 (0-45)$_{ab}$	5 (0-24)$_{b}$	26 (9-42)$_{a}$	13 (0-42)$_{ab}$	4 (0-25)$_{b}$
	G2	21 (0-31)	6 (0-21)	5 (0-20)	18 (0-44)$_{a}$	9 (0-25)$_{ab}$	0 (0-30)$_{b}$
% errors in verb conjugations	KG	6 (0-14)	4 (0-14)	4 (0-24)	0 (0-0)	0 (0-11)	0 (0-20)
	G1	7 (0-58)	5 (0-13)	2 (0-14)	3 (0-20)	0 (0-5)	0 (0-18)
	G2	7 (0-29)$_{a}$	7 (0-16)$_{ab}$	4 (0-16)$_{b}$	11 (0-36)	7 (0-12)	0 (0-18)
% wrong subject-verb agreement	KG	6 (0-18)$_{a}$	6 (0-20)$_{ab}$	0 (0-31)$_{b}$	13 (0-43)$_{a}$	8 (0-33)$_{ab}$	0 (0-10)$_{b}$
	G1	2 (0-16)$_{a}$	0 (0-7)$_{a}$	0 (0-0)$_{b}$	10 (0-31)$_{a}$	5 (0-20)$_{a}$	0 (0-9)$_{b}$
	G2	0 (0-11)	0 (0-4)	0 (0-4)	0 (0-7)	4 (0-13)	0 (0-9)
% wrong articles	KG	0 (0-0)	0 (0-13)	0 (0-6)	0 (0-40)	8 (0-67)	0 (0-33)
	G1	0 (0-6)	0 (0-10)	0 (0-0)	0 (0-50)	0 (0-29)	0 (0-13)
	G2	3 (0-8)$_{a}$	0 (0-10)$_{ab}$	0 (0-0)$_{b}$	0 (0-17)	0 (0-17)	0 (0-0)
% subordinate clauses	KG	0 (0-22)$_{a}$	5 (0-13)$_{ab}$	13 (0-35)$_{b}$	0 (0-0)	0 (0-9)	3 (0-13)
	G1	6 (0-14)$_{a}$	5 (0-33)$_{ab}$	15 (0-29)$_{b}$	0 (0-13)	0 (0-10)	0 (0-9)
	G2	6 (0-16)$_{a}$	8 (0-35)$_{ab}$	22 (00-54)$_{b}$	0 (0-11)	0 (0-33)	3 (0-25)
% past tense	KG	40 (12-76)$_{a}$	61 (14-86)$_{a}$	85 (52-100)$_{b}$			
	G1	75 (16-95)$_{ab}$	73 (14-100)$_{a}$	90 (50-96)$_{b}$			
	G2	64 (21-83)$_{a}$	83 (44-94)$_{ab}$	87 (74-96)$_{b}$			

Note. Different subscripts designate significant differences ($p < .017$) using Kruskal Wallis tests with Bonferroni correction

Chapter 5: Auditory processing and speech perception in children with specific language impairment: relations with oral language and literacy skills

The content of this chapter is described in Vandewalle, E., Boets, B., Ghesquière, P., & Zink, I. (2012). Auditory processing and speech perception in children with specific language impairment: relations with oral language and literacy skills. Research in Developmental Disabilities, 33, 635-644.

Abstract

This longitudinal study investigated temporal auditory processing (frequency modulation and between-channel gap detection) and speech perception (speech-in-noise and categorical perception) in three groups of 6;3 to 6;8-year-old children attending grade 1: (1) children with specific language impairment (SLI) and literacy delay (*n* = 8), (2) children with SLI and normal literacy (*n* = 10) and (3) typically developing children (*n* = 14). Moreover, the relations between these auditory processing and speech perception skills and oral language and literacy skills in grade 1 and grade 3 were analyzed. Results showed that the SLI group with literacy delay scored significantly lower than both other groups on speech perception, but not on temporal auditory processing. Both normal reading groups did not differ in terms of speech perception or auditory processing. Speech perception was significantly related to reading and spelling in grade 1 and 3 and had a unique predictive contribution to reading growth in grade 3, even after controlling reading level, phonological ability, auditory processing and oral language skills in grade 1. These findings indicated that speech perception also had a unique direct impact upon reading development and not only through its relation with phonological awareness. Moreover, speech perception seemed to be more associated with the development of literacy skills and less with oral language ability.

5.1 Introduction

SLI is defined as an impairment of spoken language comprehension, production, or both, in the absence of hearing impairment, general developmental delay (i.e., a normal performance IQ), neurological impairment, and autism diagnosis (e.g., Schwartz, 2009). Children with SLI may present deficits in different oral language aspects (phonology, morphology, syntax, semantics and pragmatics), thereby making it a rather heterogeneous group. The etiology of SLI is still hotly debated, ranging from nonlinguistic deficits in auditory perception to high-level deficits in grammar (linguistic deficit) (Joanisse & Seidenberg, 1998). Developmental dyslexia is a disorder characterized by severe reading and spelling difficulties that are persistent and resistant to the usual didactic measures and remedial efforts (Gersons-Wolfensberger & Ruijssenaars, 1997; Vellutino, Fletcher, Snowling, & Scanlon, 2004). Problems with phonology are widely accepted as a cause of dyslexia (Snowling, 2000). These phonological problems are possibly rooted in an underlying temporal auditory processing deficit, but the prevailing empirical evidence is mixed (e.g., McArthur & Bishop, 2001). SLI and dyslexia often co-occur; a significant number of children with SLI develops dyslexia (Catts, Adlof, Hogan, & Weismer, 2005; McArthur, Hogben, Edwards, Heath, & Mengler, 2000). One explanation entails that both disorders share a same underlying cause, such as a basic deficit in temporal auditory processing (Tallal, 1980). This auditory deficit is hypothesized to interfere with accurate speech perception and the development of well-defined and robust phonological representations, hence resulting in literacy and language difficulties.

The evidence for an auditory processing deficit in dyslexia was recently reviewed by Hämäläinen, Salminen, and Läppanen (in press). Individuals with dyslexia tend to present problems processing short and rapidly presented acoustic stimuli (e.g., Farmer & Klein, 1995; McArthur & Bishop, 2001). Other studies have also shown impairments processing slowly varying amplitude and frequency modulated signals (e.g., Talcott & Witton, 2002; Witton, Stein, Stoodley, Rosner, & Talcott, 2002) or amplitude rise times (Goswami et al., 2002). These auditory processing problems have been hypothesised to affect the accurate detection of the acoustical changes in speech (i.e. the rapidly varying fine time structure and the slowly varying speech envelope, respectively), which is evidenced by the high prevalence

of speech perception problems in individuals with dyslexia (for reviews, see Boets, Ghesquière, van Wieringen, & Wouters, 2007; Vandermosten et al., 2010).

Similar phenomena have been observed in children with SLI. These children too seem to experience problems processing rapid and briefly presented acoustic stimuli (e.g., Tallal, 1999) or durational and amplitude envelope cues (e.g., Corriveau, Pasquini, & Goswami, 2007). Moreover, speech perception problems have also often been reported in children with SLI, such as phonetic features extraction, especially voicing (Ziegler, Pech-Georgel, George, Alario, & Lorenzi, 2005), speech perception in various conditions with and without noise (e.g., Ziegler et al., 2005; Ziegler, Pech-Georgel, George, & Lorenzi, 2011) and categorical perception (e.g., Robertson, Joanisse, Desroches, & Ng, 2009).

However, results of studies measuring auditory processing and speech perception in SLI and/or dyslexia are not unequivocal. A number of studies observed no auditory processing problems in children with SLI and/or dyslexia (e.g., Marshall, Ramus, & van der Lely, 2011) or suggested that the problems would only encompass speech perception and not the perception of non-speech stimuli (Bishop, Adams, Nation, & Rosen, 2005). Moreover, there is a lot of individual variation in the auditory processing abilities of populations with SLI and dyslexia, and impaired performance is usually only observed in a relatively small proportion of them (Bishop & McArthur, 2005; McArthur & Bishop, 2001). Against this background, Rosen (2003) concluded that auditory deficits do not appear to be causally related to language disorders, but only occur in association with them. Overall, a consensus concerning the causal role of auditory processing deficits in SLI and dyslexia has not yet been reached.

Besides the question whether auditory processing and speech perception problems are present in children with SLI and/or dyslexia, and to which extent these exist, one might wonder whether they are more tightly related to oral language impairment (SLI) or to literacy impairment (dyslexia) or to a combination of both. In this regard the study of Gerrits and de Bree (2009) where 3-year old children with SLI as well as a relatively pure group 3-year olds at risk for dyslexia showed speech perception problems, seems to suggest that speech perception problems are a hallmark of both SLI and dyslexia. A number of studies in school-aged children, however, suggest that auditory temporal processing (Heath, Hogben, & Clark, 1999) and speech perception (Joanisse, Manis, Keating, & Seidenberg, 2000;

Robertson et al., 2009) are rather linked to oral language ability because problems in auditory processing and speech perception were only apparent in children with SLI or with a combination of SLI and dyslexia and not in children with pure dyslexia. Moreover, Robertson et al. (2009) observed a significant relation between receptive language ability and speech perception and only a weak relation between reading ability and speech perception. Similarly, Bishop et al. (2005) observed only a weak relation between speech-in-noise performance and literacy ability in 9 to 12 year old children with SLI. Additionally, Benasich and Tallal (2002) reported that early deficits in rapid auditory processing in 3-years old children with SLI precede and predict subsequent oral language delays. Quite the opposite, some other studies suggest that auditory processing problems are linked to reading impairment and not to oral language impairment. Indeed, Fraser, Goswami and Conti-Ramsden (2010) observed poorer auditory rise time detection in a dyslexia-only group as well as in a comorbid SLI/dyslexia group, but not in an SLI-only group. These authors also observed that auditory rise time processing was related to reading but not to oral language ability. In a similar vein, McArthur and Bishop (2004) discovered that the SLI-subgroup with deficits in frequency discrimination showed poorer nonword reading. In conclusion, it remains unclear whether and to what extent auditory processing and speech perception problems are associated with language problems, literacy problems or a combination of both.

Another point of discussion is whether auditory and speech perception problems have a direct influence on oral language and/or reading ability (e.g., Boets et al., 2011), or only indirectly through phonology (e.g., Fraser et al., 2010). Also, the relation of auditory processing and speech perception with phonology is not clear. Robertson et al. (2009), for instance, observed no significant correlation between speech perception and phonological awareness, whereas Fraser et al. (2010) observed that auditory rise time processing was uniquely associated with phonological awareness. Results of the study of Joanisse et al. (2000) indicated that not all phonological impairments are caused by speech perception deficits.

Most studies investigated either children with SLI or children with dyslexia, but not a group with the combined disorders. Moreover, there is a lack of studies analyzing the broader range of skills, including auditory processing, speech perception, phonology, literacy

and oral language ability, in the same group of participants. The present study aims to fill in this gap by investigating this full range of skills in children with SLI and normal literacy development, in children with comorbid SLI and literacy delay and in matched typically developing controls.

This study fits within a longitudinal research project where children with SLI with and without literacy delay and matched controls were followed from kindergarten to grade 3. The phonological development of these groups of children has been described in two previous reports (Vandewalle, Boets, Ghesquière, & Zink, 2010; Vandewalle, Boets, Ghesquière, & Zink, in press). There, it was concluded that children with SLI and literacy delay showed persistent problems with phonological awareness (PA) and verbal short-term memory (vSTM) on a whole range of tasks at least until grade 3, whereas children with SLI and normal literacy only showed persistent problems on the more demanding phonological tasks. Moreover, a combination of PA and rapid automatized naming (RAN) skills discriminated relatively well between the presence versus absence of later reading and spelling problems in children with SLI. In the present study, we examined three different hypotheses: (1) Does the SLI group with literacy delay score significantly lower for temporal auditory processing and speech perception in grade 1 compared to the SLI group with normal literacy and compared to the control group with normal literacy at the start of reading instruction?; (2) Are there significant correlations between low-level temporal auditory processing, speech perception, PA, vSTM and RAN in grade 1 and oral language, reading and spelling in grade 1 and grade 3? Moreover, can these correlations clarify the remaining ambiguities regarding the direct or indirect, via PA, influence of auditory processing and speech perception on literacy and/or on oral language?; (3) Do low-level temporal auditory processing and speech perception contribute significantly besides PA, vSTM, RAN, other oral language and reading skills in grade 1 to the prediction of reading in grade 3?

5.2 Method

5.2.1 Participants

Eighteen children (three girls and 15 boys) with SLI participated in the study. All children were born in 2000, attended the last year of regular kindergarten at the start of the

study, were monolingual Dutch speakers, had severe and persistent oral language problems and received language therapy. Oral language problems were defined by a score below percentile 3 before the start of language therapy and a score below percentile 10 after 4;4 years of age on at least one subtest of three standardized Dutch language tests: *Reynell Taalontwikkelingsschalen* [Reynell Developmental Language Scales] (Schaerlaekens, Zink, & van Ommeslaeghe, 2003), *Taaltests voor Kinderen* [Language Tests for Children] (van Bon & Hoekstra, 1982) or *Schlichting Test voor Taalproductie* [Schlichting Test for Language Production] (Schlichting, van Eldik, Spelberg, van der Meulen, & van der Meulen, 2003). In addition to these language problems, some children had concurrent articulation problems. Exclusion criteria were low intelligence (non-verbal, verbal and total IQ below 85), hearing loss and any other known problem (e.g., neurological disorder) that could explain their language impairment.

For every individual child of the SLI group, the best matching control child was selected based on five criteria: (1) educational environment, i.e., same class, (2) gender, (3) age, (4) non-verbal intelligence, and (5) parental educational level. Non-verbal intelligence was assessed with a Dutch version of the Raven Coloured Progressive Matrices (Raven, Court, & Raven, 1984) and parental educational level was obtained by a questionnaire completed by the parents (based on the International Standard Classification of Education scale, UNESCO, 1997). All control children were monolingual Dutch speakers, had normal hearing and did not show any speech or language difficulties as confirmed by their parents and teachers.

Although initially 26 children with SLI were selected, only 18 are included in the present report because one child left the study after kindergarten and seven children did not move on to grade 1 of a regular primary school after the last year of kindergarten. Hence, only the data of the remaining 18 children with SLI and their 18 matched controls are further analyzed in this study, as only for these children literacy skills can be reliably compared.

Both the SLI group (n = 18) and the control group (n = 18) were divided into two subgroups based on word reading and spelling achievement. The ‘literacy-delayed’ group comprised all children scoring 1 *SD* below population mean on a standardized word reading (van den Bos, Spelberg, Scheepstra, & De Vries, 1994) or spelling test (Dudal, 2006), in both first and third grade. This criterion took into account both the severity and the persistence of

a child's literacy problem. We refer to these children as literacy-delayed because a persistent score of 1 SD below population mean is too lenient for a formal diagnosis of dyslexia, although most of these children will probably receive the diagnosis later on. By applying this criterion, we identified eight children with literacy delay in the SLI group and four children in the control group. For the purpose of this paper we will compare three groups of children: (1) children with SLI and literacy delay (SLI-LD; $n = 8$), (2) children with SLI and normal literacy (SLI-NL; $n = 10$), and (3) control children with normal literacy (Control-NL; $n = 14$).

Mixed Model Analyses showed that the three groups did not differ in age ($p = .90$) and non-verbal intelligence ($p = .09$) (see Table 5.1). As defined, the SLI-LD group scored significantly lower than both other groups on most of the standardized word reading and spelling tests in grade 1 and 3, whereas the control-NL and the SLI-NL group mostly did not differ significantly from each other. Further details about the participants and the selection procedure are described in Vandewalle et al. (2010) and Vandewalle et al. (in press).

Table 5.1 Characteristics of the participant groups: SLI-LD, SLI-NL and control-NL group

	SLI-LD		**SLI-NL**		**Control-NL**	
	n = 8		*n* = 10		*n* = 14	
	M	*SD*	*M*	*SD*	*M*	*SD*
SELECTION DATA IN KINDERGARTEN						
Non-verbal intelligence[1]	108.2	14.2	118.0	16.7	122.4	11.2
GRADE 1						
Age (months)	74.1	1.6	73.5	3.2	73.9	3.4
Word reading[1]	91.3_a	7.9	100.5_{ab}	6.9	107.9_b	15.0
Spelling[1]	74.3_a	8.8	92.4_b	10.3	100.3_b	14.0
GRADE 3						
Word reading[1]	78.1_a	19.3	102.0_b	11.8	107.9_b	14.4
Spelling[1]	67.1_a	10.7	92.1_b	12.6	107.3_c	14.5

Note. [1] Transformed scores with population average $M = 100$ and $SD = 15$; Significant group differences are indicated by different subscripts ($p < .05$, Tukey correction)

5.2.2 Measures

5.2.2.1 Low-level auditory processing

Frequency modulation (FM) detection. In this psychophysical threshold test, the child had to detect the presence or absence of a 2 Hz sinusoidal frequency modulation of a 1000 Hz carrier tone. The modulation depth decreased with a factor of 1.2 from 100 to 11 Hz and a step size of 1 Hz from 11 Hz on. The threshold was defined as the minimum depth of frequency deviation required to detect the modulation.

Between-channel gap-detection test (gap). This gap-detection task was designed to probe the auditory mechanisms involved in voice-onset-time processing (cfr. Phillips, Taylor, Hall, Carr, & Mossop, 1997). Children had to detect the presence or absence of a silent interval (gap) in between two one-octave band noise stimuli centered around 1000 and 4000 Hz. The gap duration decreased with a factor of 1.2 from 358 ms to 6.5 ms and with a fixed step size of 0.4 ms from 6.5 ms to 0.1 ms. The threshold was defined as the minimum gap length of the silent interval that could still be detected.

Test procedure for the auditory processing tasks. Thresholds were estimated using a three-interval forced-choice oddity paradigm embedded within an interactive computer game (Laneau, Boets, Moonen, van Wieringen, & Wouters, 2005). Stimuli were presented monaurally at 70 dB SPL with an interstimulus interval of 400 ms. The depth of modulation and the length of the gap were adjusted adaptively using a two-down, one-up rule, which targets the threshold corresponding to 70.7% correct responses. In both tests a threshold run was terminated after eight reversals. Thresholds were calculated by the geometric mean of the values of the last four reversals. For each participant, three thresholds were determined for FM-detection and four thresholds were determined for gap-detection (because this last test is more difficult and requires more practice). The average of the best and second best threshold was used as an indicator of auditory sensitivity. More details about the description of the stimuli, procedure and equipment can be found in Boets, Wouters, van Wieringen, & Ghesquière (2006).

5.2.2.2 Speech perception tests

Speech-in-noise perception task. Seven lists of ten high-frequent monosyllabic words (Wouters, Damman, & Bosman, 1994) were presented monaurally together with a

continuous stationary speech noise with an identical spectrum as the average spectrum of the word lists. The speech noise was presented at 70 dB SPL and the two word lists were presented at -1, -4 and -7 dB SNR each. Before administration of the six test lists, one practice list was presented at +4 dB SNR. The child had to repeat the words as accurately as possible, resulting in a percentage correct word score for every list. A speech perception composite score was calculated by averaging z-scores (relative to the mean and standard deviation of the Control-NL group) for the three SNR-levels. This composite score was then again standardized relative to the Control-NL group. To estimate the speech reception threshold (SRT: the signal level required for 50 percent correct responses), for every subject a logistic function was fitted to the data (cfr. Boets et al., 2007).

Categorical perception task. The test used a ten-point speech continuum ranging from /bAk/ to /dAk/ (i.e. the Dutch word for 'basket' and 'roof'). The stimuli were based on natural speech and are produced by linearly interpolating the second formant (F_2) from /b/ to /d/ (van Beinum, Schwippert, Been, van Leeuwen, & Kuijpers, 2005). The child had to identify the stimuli as /bAk/ or /dAk/ by making a two-alternative forced choice. Each of the 10 stimuli was presented 12 times in a random order without feedback. The child was instructed to repeat the perceived word and point to the corresponding picture on a computer screen. Before test administration, each of the two endpoint stimuli was presented five times with feedback. For each stimulus, the percentage /dAk/-answers was registered (for details, see Boets et al., 2007). The parameter of interest in this test was the slope of the identification curve at the category boundary. A high slope value indicates a small uncertainty range and suggests a highly consistent ability to categorize sounds, whereas a low slope value indicates a large range of uncertainty and suggests difficulties in identifying the sounds. Because some participants failed to reliably perceive /bAk/ at the endpoint of the continuum it was not allowed to fit a logistic function to the data to estimate the Point of Subjective Equivalence (PSE, i.e. the stimulus value corresponding to 50% /bAk/ and 50% /dAk/ responses) and the slope in this PSE. Alternatively, a range parameter was calculated as the difference between the average percentage correct answers for the three most extreme /dAk/ stimuli (i.e. stimulus 8, 9 and 10) and for the three most extreme /bAk/ stimuli (i.e. stimulus 1, 2 and 3). A higher value on this range parameter is indicative of a more reliable categorical perception.

5.2.2.3 Phonological abilities

For a more detailed description of the phonological test battery we refer to Vandewalle et al. (in press).

Phonological Awareness (PA). The PA test battery was based on previous research (Boets, De Smedt, Cleuren, Vandewalle, Wouters, & Ghesquière, 2010; Vandewalle et al., in press) and consisted of six tasks: first sound and rhyme categorization, auditory analysis and synthesis, phoneme deletion and spoonerism.

Verbal short-term memory (vSTM). Verbal short-term memory was assessed by a digit span forward task and a nonword repetition task (as described in Boets et al., 2010).

Rapid Automatized Naming (RAN). Lexical access was evaluated with four classic rapid automatized naming tasks, which involved the naming of highly familiar colours, objects, digits and letters (van den Bos, Zijlstra, & Spelberg, 2002).

Based on a series of principal component analyses in previous research (Boets et al., 2010), we could conclude that the phonological battery represents the well-known three-dimensional phonological structure. Composite scores for PA, vSTM and RAN were calculated by computing *z*-scores for each task (relative to the mean and standard deviation of the Control-NL group) and averaging these scores.

5.2.2.4 Literacy

Reading. Six standardized reading tests were administered: two widely used standardized reading tests, i.e. the one-minute word reading test and the nonword reading test, both combining speed and accuracy in a single index (van den Bos et al., 1994), a word and a nonword reading accuracy test and a word and a nonword reading speed test (Boets et al., 2010). A composite score of all reading tests was calculated by computing *z*-scores for each task (relative to the mean and standard deviation of the Control-NL group) and averaging these scores.

Spelling. Spelling was evaluated by a standardized spelling achievement test (Dudal, 2006). Grade-appropriate versions of the test were used in first and third grade.

5.2.2.5 Oral language

In order to avoid learning effects, the selected oral language tests were different from those used in the diagnostic assessment.

Productive oral language. The productive oral language test battery consisted of a productive vocabulary test from the *Taaltoets Allochtone Kinderen* [Language test for foreign children] (Verhoeven & Vermeer, 1986), a word description test and a productive morphology test (comprising plurals and past participles) from the *Taaltoets Alle Kinderen* [Language test for all children] (Verhoeven & Vermeer, 2001) and a newly designed word fluency test. This word fluency test measured the number of words belonging to one semantic category (e.g., beverages, fruit, animals) that the child was able to produce in 20 seconds (see Vandewalle et al., 2010). A composite score was calculated as the mean of the z-scores of all productive oral language tests (relative to the mean and standard deviation of the Control-NL group).

Receptive oral language. The receptive oral language test battery comprised the receptive vocabulary test, the sentence comprehension test and the text comprehension task from the *Taaltoets Alle Kinderen* [Language test for all children] (Verhoeven & Vermeer, 2001). Again, a composite score was calculated as the mean of the z-scores of all receptive oral language tests (relative to the mean and standard deviation of the Control-NL group).

5.2.3 Design and procedure

The FM and gap detection tests and the speech-in noise perception test were administered at the beginning of grade 1 (mean age = 6;3 years). Phonological skills (PA, vSTM and RAN) (mean age = 6;7 years) and categorical perception (mean age = 6;8 years) were measured around the middle of grade 1. Oral language skills were measured twice, i.e. once in the middle of grade 1 (mean age = 6;8 years) and again in the middle of grade 2 (mean age = 7;6 years) by the same tests. Literacy skills were administered after one year of literacy instruction at the end of grade 1 (mean age = 6;10 years) and after two years of literacy instruction at the beginning of grade 3 (mean age = 8;1 years) by the same word reading tests and a grade-appropriate version of the spelling test. Each matched pair of children from the SLI and control group was tested in a quiet room at their school under identical circumstances and when feasible at the same day. All tests were administered

individually, only the spelling test was administered in small groups. Data collection was carried out by trained students in speech and language therapy.

Groups were compared using Mixed Model Analyses (MMA) with pair as a random variable and participant group (SLI-LD, SLI-NL and Control-NL) as the fixed between-subjects variable. For the speech-in-noise perception task (respectively the categorical perception task), repeated measures MMA were calculated with SNR at -1, -4 and -7 dB SNR (respectively stimulus step 1 to 10) as within-subject variable and participant group (SLI-LD, SLI-NL and Control-NL) as between-subjects variable. Post hoc analyses were corrected for multiple comparisons using the Tukey procedure. Spearman correlations and linear regressions were calculated, comparable to Boets et al. (2011). The scores on FM and gap detection were multiplied by -1 to obtain a positive definite correlation matrix. Prior to analyses, scores on the FM and gap task were $\log_{10}$-transformed to obtain normally-distributed variables.

Prior to administering any auditory psychophysical test all children performed a standard audiometric pure tone detection task assessing hearing level at 500, 1000 and 2000 Hz. All but four children obtained average thresholds (Pure Tone Average PTA-index) below 25 dB HL. For these four children the amplitude of the auditory and speech stimuli was proportionally increased. Detailed inspection of their test results did not show any anomalies. Mixed Model Analyses revealed no significant group differences on the PTA-index (p = .70).

5.3 Results

5.3.1 Group comparisons

Results of the comparisons between the SLI-LD, SLI-NL and Control-NL group are presented in Table 5.2. There were no significant group differences on the auditory measures FM- and gap-detection. Among the eight children in the SLI-LD group two children scored much higher on both temporal tasks. The other six children covered the whole range of values from low to high scores. Results of the speech-in-noise perception data are depicted in Figure 5.1a. Table 5.2 shows the means and standard deviations for the

Table 5.2 Auditory and speech perception measures for the three participant groups: mean (*M*) and standard deviation (*SD*)

	SLI-LD (*n* = 8)		**SLI-NL** (*n* = 10)		**Control-NL** (*n* = 14)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Auditory measures						
FM average (Hz)	7.8	6.8	5.5	2.6	4.3	2.3
gap average (ms)	110.1	86.9	68.9	35.9	58.4	25.9
Speech-in-noise						
COMPOSITE	-1.03_{a}	0.63	0.12_{b}	1.07	0.00_{ab}	1.00
SRT (dB SNR)	-0.27_{a}	0.55	-1.41_{ab}	1.15	-1.44_{b}	1.02
Categorical perception						
range parameter (%)	35_{a}	35	85_{b}	24	78_{b}	21

Note. Significant group differences are indicated by different subscripts ($p < .05$, Tukey correction)

composite score of the SNR's and for the estimated SRT's. Repeated measures MMA revealed a main effect of group ($p = .03$). Post hoc tests showed significantly lower scores for the SLI-LD group compared to the SLI-NL group ($p = .04$) and the Control-NL group ($p = .03$). Additionally, there was a main effect of SNR ($p < .0001$), i.e. a lower SNR resulted in fewer correct answers. There was no interaction effect between group and SNR (p = .40). We can conclude that the three groups have comparable speech-in-noise perception curves, but the curve of the SLI-LD group is shifted to a higher SNR in comparison with the two other groups. This was confirmed by the results on the estimated speech-reception threshold (SRT): the SLI-LD group scored significantly poorer than the Control-NL group, and marginally significantly poorer than the SLI-NL group.

Figure 5.1b displays the curves of the categorical perception task for the three participant groups. Repeated measures MMA revealed a main effect of group ($p < .0001$), a main effect of stimulus ($p < .0001$), and a significant group by stimulus interaction (p < .0001). Post hoc tests showed significantly lower scores for the SLI-LD group compared to the Control-NL group ($p = .03$), but no significant differences between the other groups. The significant group by stimulus interaction indicates that the slopes differ between the groups. Yet, not for all children the steepness of this slope could be estimated by fitting a logistic

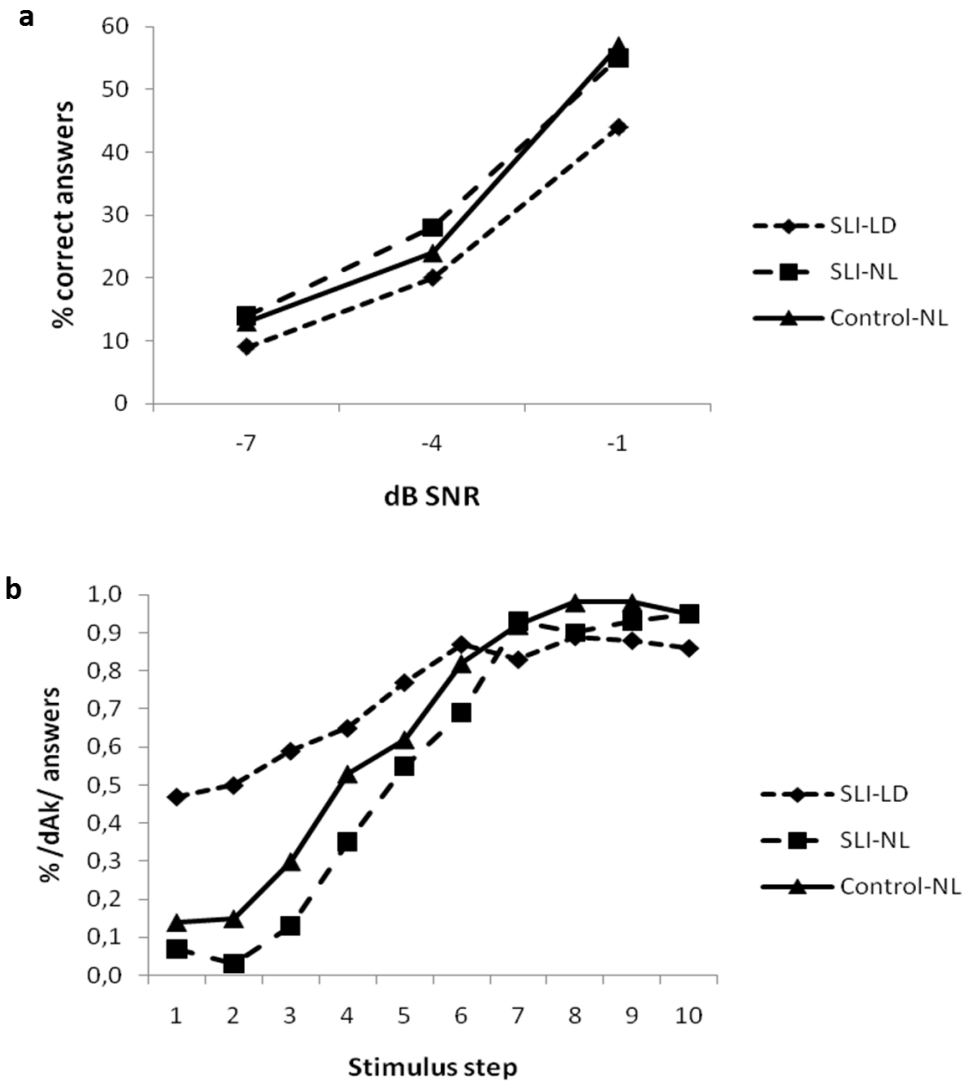


Figure 5.1 (a) Speech-in-noise perception in grade 1: mean scores for the three participant groups relating the proportion of correctly perceived words to the signal-to-noise ratio (SNR); (b) categorical perception in grade 1: mean scores for the three participant groups relating the proportion perceived /dAk/-answers to the stimulus steps

function to the data because two children of the SLI-LD group and one child from the SLI-NL group scored randomly on all items, and four children of the SLI-LD group and one child of the Control-NL group did not obtain a score below 35%, even not for stimuli 1 and 2, which implies that they perceived these endpoint /bAk/ stimuli as /dAk/ in more than 65% of the cases. Determining the Point of Subjective Equivalence and slope for these children was therefore unwarranted. It should be noted that these unreliable data were mainly present in the SLI-LD group and were almost absent in the other two groups. As an alternative index of the individual robustness of categorization of the speech tokens the range between stimuli 8+9+10 and 1+2+3 was calculated instead. Group comparisons for this range parameter

revealed that the SLI-LD group had a significantly lower mean range than the SLI-NL group (p = .004) and the Control-NL group (p = .008).

5.3.2 Auditory processing and speech perception in relation with phonology, oral language, reading and spelling

Table 5.3 presents for the three groups together Spearman correlations between phonology (a composite score for PA, vSTM and RAN), auditory processing (a composite score of FM and gap) and speech perception (a composite score of speech-in-noise and categorical perception) in grade 1, productive and receptive oral language in grade 1 and grade 2, and reading and spelling in grade 1 and grade 3. For the auditory processing tasks, we only observed significant correlations with PA (r = .36) and vSTM (r = .52). Remarkably, there were no significant correlations between auditory processing and speech perception, reading and spelling skills and only close to significant correlations with oral language. Speech perception on the other hand correlated significantly with PA (r = .36), oral language in grade 1 (r = .36), reading and spelling in grade 1 and 3 (r varying from .39 to .51). As expected, PA, vSTM and RAN had significant correlations with all reading and most spelling scores in grade 1 and grade 3 (r varying between .30 and .64), but even more strongly with productive and receptive oral language (r varying between .40 and .76).

5.3.3 Prediction of reading and spelling in grade 3

Based on previous research (e.g., Boets et al., 2011), we anticipated that phonology (PA, vSTM and RAN), temporal auditory processing (FM- and gap-detection), and speech perception (speech-in-noise and categorical perception) might contribute to predicting reading and spelling ability across the three groups[12]. Two sets of simultaneous regression analyses were calculated to predict reading in grade 3, one without an autoregressive effect (see Table 5.4, Model 1) and one with the reading composite score at the end of grade 1 included as an autoregressor (see Table 5.4, Model 2). Without inclusion of the autoregressor all variables explained 66% of the total variance. Both RAN and speech

[12] Because multiple regression including seven variables might not be appropriate for this sample size of 36, regression analyses were calculated involving the three and four variables that revealed important group differences. This led to models 3 and 4, described in Appendix 5A.

Table 5.3 Spearman correlations for the three groups (n = 32) between phonological, auditory and speech perception skills in grade 1, productive and receptive language ability in grade 1 and grade 2, and reading and spelling ability in grade 1 and 3

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
1. AUDITORY PROCESSING		.01	.36*	.52**	.16	.32°	.34°	.08	.15	.15	.20
2. SPEECH PERCEPTION			.36*	.16	.34°	.36*	.28	.45**	.47**	.39*	.51**
3. PHONOLOGICAL AWARENESS				.70***	.29	.76***	.73***	.58***	.64***	.57***	.64***
4. VERBAL SHORT-TERM MEMORY					.37*	.67***	.59***	.38*	.30°	.45*	.51**
5. RAPID AUTOMATIZED NAMING						.40*	.42*	.61***	.60***	.55**	.40*
6. ORAL LANGUAGE Grade 1							.93***	.47**	.55**	.49**	.62***
7. ORAL LANGUAGE Grade 2								.57***	.57***	.56**	.61***
8. READING Grade 1									.73***	.83***	.66***
9. Spelling Grade 1										.54**	.60***
10. READING Grade 3											.75***
11. Spelling Grade 3											

Note. $^{\circ}p < .10$; $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$

Table 5.4 Unique variance (R^2) in reading achievement at the start of grade 3 explained by individual differences in phonological awareness (PA), verbal short-term memory (vSTM), rapid automatized naming (RAN), auditory processing, speech perception and oral language in grade 1

	3rd grade reading	
	Model 1	**Model 2**
READING grade 1 (autoregressor)	-	.12**
PA	.02	.00
vSTM	.00	.01
RAN	.10*	.00
AUDITORY PROCESSING	.02	.02
SPEECH PERCEPTION	.07*	.05*
ORAL LANGUAGE	.00	.00
Total R^2	.66	.78

Note. * $p < .05$; ** $p < .01$

perception in grade 1 had a unique contribution to reading ability at the beginning of grade 3. It is remarkable that the other variables (such as PA and oral language) did not significantly contributed to reading ability. After including reading at the end of grade 1 as autoregressor, 78% of the variance in reading ability in grade 3 could be explained. Besides the autoregressor only speech perception in grade 1 uniquely contributed to growth in reading ability in grade 3.

5.4 Discussion

In this study we investigated temporal auditory processing and speech perception and the relation with phonology, oral language and reading development in children with SLI with and without literacy delay and a control group. To summarize, our results demonstrated that in grade 1, the SLI group with literacy delay scored significantly lower compared to children with SLI and normal literacy and also compared to typically developing children on speech perception, but not on non-speech temporal auditory processing. Children with SLI and normal literacy did not differ from typically developing children in speech perception and temporal auditory processing. Temporal auditory processing (FM- and gap-detection) was not correlated to oral language and literacy, but speech perception

had significant, low correlations with PA and oral language in grade 1 and moderate correlations with reading and spelling in grade 1 and 3. A combination of RAN and speech perception turned out to be the best predictors of reading in grade 3. After including reading at the end of grade 1, only speech perception abilities significantly added to the prediction.

Our observations about the children with SLI and literacy delay (i.e., significantly poorer scores on speech-in-noise perception and categorical perception in grade 1 compared to both other groups but no lower scores on low-level auditory temporal processing), are in accordance with the results by Bishop et al. (2005). They observed normal perception of transient nonspeech stimuli and a small but significant difference on the speech-in-noise task in children with SLI. However, a subsample of our children with SLI and literacy delay did have problems with temporal auditory processing. This large within-group variability was also observed by Heath et al. (1999). Yet, contrary to the study of Heath et al. (1999), we did not observe general low-level temporal auditory processing problems in the SLI group with literacy delay. This does not exclude that other low-level auditory tasks may reveal problems in this group, as observed by Fraser et al. (2010) for auditory rise time detection and by McArthur and Bishop (2004) for frequency discrimination.

Our second observation that children with SLI and normal literacy did not differ from typically developing children in speech perception and non-speech temporal auditory processing, implies that speech perception is associated with the development of literacy skills and not with oral language ability.

The correlations revealed that the auditory processing tasks (FM- and gap-detection) did correlate significantly with PA and vSTM, but not with oral language and literacy. Similarly, Fraser et al. (2010) observed a significant correlation of auditory rise time processing with PA, but not with oral language. However, in their study auditory rise time was correlated with reading and not with vSTM. Speech perception in our study had significant, low correlations with PA and oral language in grade 1 and moderate correlations with reading and spelling in grade 1 and 3. On the contrary, Robertson et al. (2009) observed a more dominant association of speech perception with receptive language and at best a weak relation with reading ability. In our study, PA and RAN had moderate and significant correlations with reading and spelling skills in grade 1 and 3, and PA had a high correlation with oral language skills in grade 1 and 3 (even higher than with literacy skills). This

correlational study similarly suggests that speech perception is more related to the development of literacy skills and less to oral language ability.

Based on the group comparisons and correlations, we might conclude that speech perception deficits are associated with reading impairment or with the combination of reading and oral language impairments, but not with specific language impairment itself. A number of other studies also tried to pinpoint whether variation or impairments in auditory processing and speech perception are rather related to oral language ability or to reading ability. Results of the studies of Fraser et al. (2010) and McArthur and Bishop (2004) suggest that auditory processing (i.e. amplitude rise time sensitivity and frequency discrimination, respectively) is specifically related to reading and not to oral language ability. Other findings, however, suggested that temporal auditory processing (Heath et al., 1999) and speech perception (Robertson et al., 2009) are linked to oral language ability. In this regard, Robertson et al. (2009) observed speech perception problems in children with SLI but not in children with pure dyslexia. Unfortunately, their number of the children with SLI and dyslexia was too small to compare the results with. Instead, the authors analyzed the SLI-only group and observed similar results as in the full SLI group (with and without dyslexia). Therefore, it was concluded that speech perception deficits are more closely associated with atypical language development and not with atypical reading development. The differential results with our study might be due to differences in participant characteristics, such as age (6-7 years versus 10 years) and the applied selection criteria for SLI (children with receptive and/or productive language problems versus children with deficits in receptive grammatical comprehension), as well as to task-characteristics. Indeed, the categorical perception tasks in the study of Robertson et al. (2009) were administered with and without background noise, and only in the categorical perception task with noise significant poorer performance was observed in children with SLI as compared to children with dyslexia and typically developing controls. It is not unconceivable that also in our sample of children with SLI and normal literacy categorical perception problems would emerge if background noise is added to the task. This raises the possibility that children with SLI and normal literacy development are only impaired in the most demanding and sensitive categorical perception tasks (i.e. with background noise) (as explained by Robertson et al., 2009), whereas children with SLI and literacy delay present a more general speech perception impairment which can be revealed

through less demanding speech-in-noise and categorical perception tasks as in our study. In this regard, it has indeed been reported that speech perception in optimal listening conditions tends to reach ceiling rather quickly in the course of language development (Bernstein & Stark, 1985). If indeed children with SLI and literacy delay have more persistent speech perception problems compared to children with SLI and normal literacy, speech perception would be more linked to literacy skills or to the combination of literacy and oral language skills, but not to the oral language ability only.

Linear regression analyses (without inclusion of an autoregressor) showed that a combination of RAN and speech perception predicted 66% of the variance of reading in grade 3. After including reading at the end of grade 1, 78% of the variance of reading in grade 3 could be explained and only speech perception abilities significantly added to the prediction. Based on these results, we can hypothesize that temporal auditory processing did not play a role in the development of literacy impairment in children with SLI, but speech-perception problems may play an important mediating role. Given the correlational nature of the study, we cannot draw conclusions about causality, but the significant correlations of speech perception and PA in grade 1 with reading and spelling in grade 3 suggest at least a directional influence of speech perception and phonology on later reading and spelling ability. Moreover, speech perception uniquely predicted *growth* in reading ability, even after controlling for previous reading skills. These results imply that speech perception has a unique impact on reading development besides the indirect influence of speech perception on reading via PA. These findings are in line with results of Boets et al. (2011) in preschool children at risk for dyslexia and controls, although they observed a significant predictive association of both FM sensitivity and speech perception towards reading development. In grade 1, Boets et al. (2011) observed that the association between FM sensitivity, speech perception and reading development was fully mediated by PA.

Results of our study suggest that speech perception and PA are at least partially independent language abilities, which independently influence literacy development. The SLI group with normal literacy had poorer scores on PA compared to the control group, whereas the SLI group with literacy delay had poorer scores on both PA and speech perception skills. This perspective fits well with the multiple dimension approach of developmental disorders proposed by Pennington (2006). Pennington postulates that both SLI and dyslexia involve

difficulties in phonological processing combined with other disorder-specific deficits. Although they share some risk factors and deficits, each of the disorders also has additional specific deficits.

This study revealed the specific impact of speech perception problems on the development of literacy problems in children with SLI. However, further validation of these findings is certainly needed given the small sample size. Further longitudinal studies from kindergarten on in transparent and non-transparent languages are necessary to unravel the complex and potentially causal relations between auditory processing, speech perception, phonology, literacy and oral language ability.

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Appendix 5A Unique variance in reading achievement using multiple regression with three and four variables

Because multiple regression including seven variables might not be appropriate for this sample size of 36, additional regression analyses were calculated. Among the seven variables, the three variables that revealed important group differences (PA, RAN and speech perception) were selected with and without the autoregressor (reading in grade 1). Unique variances in reading achievement explained by these variables were presented in models 3 and 4 (see Table 5.5). Most results confirmed those obtained in model 1 and 2, presented in Table 5.4. The only difference in model 3 compared to model 1 was that PA additionally had a significant contribution besides RAN and speech perception.

Table 5.5 Unique variance (R^2) in reading achievement at the start of grade 3 explained by individual differences in phonological awareness (PA), rapid automatized naming (RAN) and speech perception in grade 1

	3rd grade reading	
	Model 3	**Model 4**
READING grade 1 (autoregressor)	-	.09**
PA	.09*	.01
RAN	.13**	.02
SPEECH PERCEPTION	.08*	.05*
Total R^2	.63	.71

Note. * $p < .05$; ** $p < .01$

Chapter 6: General conclusions, discussions and future research directions

6.1 General conclusions

This doctoral research project aimed at investigating the literacy development of children with SLI. By means of a longitudinal study, we studied important factors influencing this development. The study was conducted in Dutch speaking children in Flanders from the last year of kindergarten until the start of grade 3. Based on this longitudinal study, we can draw a number of conclusions related to group comparisons, the predictive value of different variables for literacy in children with SLI and common and distinctive features of SLI and dyslexia.

During the selection phase, an SLI group and a control group were selected. Two groups of 18 children could be monitored over the entire period of the study. Based on the reading and spelling scores at the end of grade 1 and the beginning of grade 3, we partitioned the SLI group and the control group into a group with literacy delay and a group without literacy delay. A child belonged to the literacy-delayed group when he/she scored 1 SD below the mean of a normative reference group on reading or spelling in grade 1 as well as in grade 3. An overall table of individual composite scores of the three groups of 8, 10 and 14 children is presented as Appendix 6A. *Group comparisons* between the SLI group with literacy delay (SLI-LD), the SLI group with normal literacy (SLI-NL) and the control group with normal literacy (Control-NL) revealed different patterns for the development of the various skills. An overview of the scores and development for the different skills in the two SLI groups compared to the Control-NL group are presented in Table 6.1. The SLI-LD group scored significantly lower than the control-NL group on almost all PA and vSTM tasks in all grades. The SLI-NL group, on the other hand, scored significantly and persistently lower than the Control-NL group only on the more demanding PA and vSTM tasks until grade 3 (see chapter 3). Kindergarten rapid automatized naming scores were lower for the SLI-LD group

Table 6.1 Overview of the group comparisons for the two SLI groups compared to the Control-NL group

	SLI-LD	**SLI-NL**
Temporal auditory processing	adequate score in grade 1 (some children lower score)	adequate score in grade 1
Speech perception	low score	adequate score
PA and vSTM	low score	low score; improvement for easier tasks
RAN	lower score in kindergarten	adequate score in kindergarten
Nonphonological oral language		
- vocabulary	low score	low score
- productive morphosyntax	low score	low score
- listening comprehension	low score	improvement towards grade 3
- story retelling	low score	low score
- storytelling	low score	adequate score
Letter knowledge	low score in kindergarten	low score in kindergarten

compared to the SLI-NL group and to the control group (see chapter 2 and 3). Moreover, both SLI groups had persistently lower scores on almost all oral language tasks besides phonology. Only on listening comprehension and storytelling, the children with SLI and normal literacy skills evolved towards the level of the control group, probably as a result of their intact literacy development (see chapter 4). Results on auditory processing tests showed that the SLI-LD group scored significantly lower than both other groups on speech perception (speech-in-noise and categorical perception), but not on temporal auditory processing tasks (FM and gap detection) in grade 1 (see chapter 5).

Another important research question of this project was to analyze which children with SLI have a high risk for developing dyslexia. Using Spearman correlations, predictive discriminant analyses and linear regression, good *predictors of literacy skills* up to grade 3 could be derived from the measurements. In chapter 2, it was surprising that PA, vSTM and letter knowledge skills in kindergarten did not correlate with literacy at the end of grade 1 in

children with SLI, but RAN measured in kindergarten was strongly correlated with reading and spelling in both the SLI group and the control group. Based on literacy data up to grade 3 in chapter 3, linear predictive discriminant analyses revealed that a combination of kindergarten PA and RAN skills could divide children with SLI relatively well into a group with and a group without literacy delay. By including auditory processing and speech perception scores (chapter 5), linear regression analyses showed that third grade reading skills were best predicted by a combination of PA, RAN and speech perception skills measured in grade 1. In summary, gradually stronger conclusions for predicting literacy scores can be drawn. If only one single test can be administered in kindergarten in children with SLI, RAN should be used for predicting literacy. We can infer that children with SLI who additionally had low scores on RAN in kindergarten developed reading and spelling problems at the end of grade 1 and at the start of grade 3. When PA can be scored on top of RAN in kindergarten, children with SLI could be discriminated even more clearly into a group with and a group without later literacy delay. Thus, children with SLI and poor RAN and PA performance in kindergarten seem to be at high risk for developing literacy problems. Based on measurements in grade 1, a combination of PA, RAN and speech perception was the best predictor for reading performance at the start of grade 3. Clearly at grade 1, speech perception had a better predictive value than PA, and appeared to have a unique influence on third grade reading that does not operate via PA. We expect that children with literacy delay might receive the diagnosis of dyslexia later on and therefore, we conjecture that good predictors of literacy delay are also good predictors for dyslexia.

These findings provide useful information for teachers and speech-language therapists on those skills which have the best predictive value for literacy development in children with SLI. This is important to be able to predict which children with SLI have the highest risk of developing literacy problems later on. Teachers in the last year of kindergarten train preliminary literacy skills to make the children ready for the start of literacy instruction. These teachers and the teachers of the first years of primary school have to recognize early problems with the skills that are important for literacy development. This allows them to be able to search for adequate pedagogic-didactic methods for each child with a high risk for dyslexia and, if necessary, to refer the children in a timely manner for personalized support by clinicians. Although a diagnosis of dyslexia can only be made by

clinicians after sufficiently long reading and spelling instruction, good indicators in kindergarten and the first years of primary school are important for clinicians to monitor and treat the deficits of the children with the highest risk for dyslexia at an early age.

A third set of conclusions clarifies *the common and the distinctive features of SLI and dyslexia*. In chapter 2, our study has shown that kindergarten PA and vSTM skills are more related to oral language and that kindergarten RAN skills are more related to literacy. Analyses of the development of these phonological skills in chapter 3 revealed that these relationships vary over time. Here we support the conclusion of Catts, Adlof, Hogan, & Weismer (2005) that PA deficits in later grades are more related to dyslexia than to SLI: PA deficits seem to be more stable over time across all PA tasks in children with literacy delay. Moreover, persistent weaknesses in semantic and productive morphosyntactic skills and story retelling at least up to grade 3 are characteristics of all children with SLI and are not linked to literacy. Additionally, speech perception in grade 1 was more associated with literacy (or the combination of literacy and oral language), and less with oral language alone (see chapter 5).

In summary, our longitudinal study has clarified the development and interrelations of different skills in children with SLI over the period from kindergarten to grade 3 (see Figure 6.1). This figure is based on our empirical results from group comparisons, correlations and predictive analyses and, as such, cannot give causal explanations. After the selection of the children with SLI, deficits in receptive and productive semantic (e.g. vocabulary), receptive and productive morphosyntactic, demanding verbal short-term memory and phonological awareness skills were observed in the whole group of children with SLI in kindergarten. A number of children with SLI experienced additionally speech perception problems in grade 1. Moreover, many of these variables were interrelated in grade 1, as shown by the arcs in the figure. Most of the observed deficits persisted until grade 2 or 3. The whole group of children with SLI continued to have problems with receptive and productive semantics, productive morphosyntax, demanding verbal short-term memory and demanding phonological awareness. Children with overall phonological awareness deficits in grade 3, lower speech perception in grade 1 and/or low kindergarten rapid automatized naming scores had the highest risk for a comorbid literacy delay.

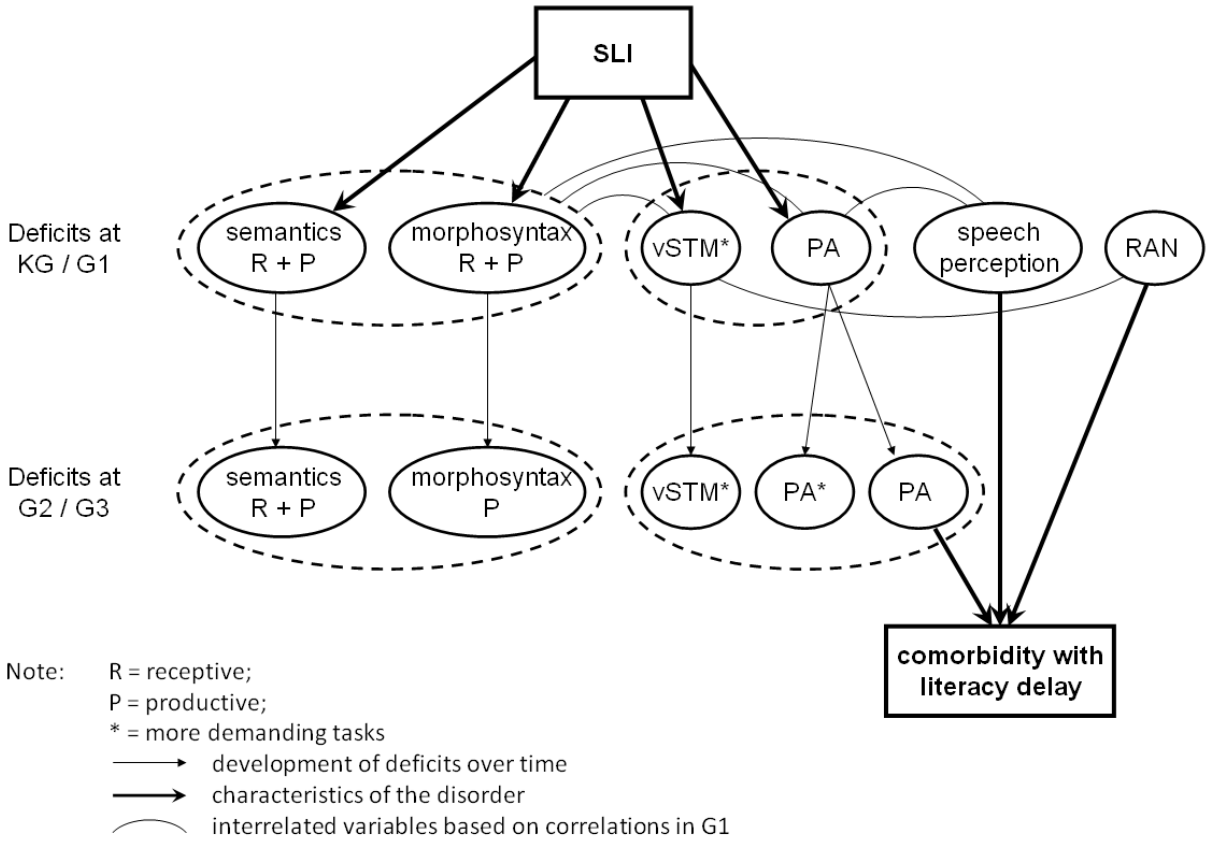


Figure 6.1 Development of the characteristics for children with SLI from kindergarten to grade 3 based on our longitudinal study and their relation with literacy delay

Important relations between the composite scores of different variables are visually presented in scatter plots in Appendix 6B.

6.2 Discussions

Some *important issues and limitations* of this doctoral research study should be highlighted. First of all, the number of children in the different groups is relatively small, despite the fact that we selected children with SLI from the entire Dutch part of Belgium (Flanders). The main reason for this limited number is that we only selected children with SLI who attended the last year of regular kindergarten at the start of the study and we followed only those children who attended regular primary school after the last year of kindergarten in order to be able to compare these children with a control group who received the same instruction at school. In Flanders, children with very severe oral language problems most often are referred to schools for special education (called 'language classes'). This implies that children with the most severe forms of SLI were not included in this study, so that our

results cannot be generalized to this subgroup. Despite this restriction, the pairwise selection of the children with SLI and the matched control children was done very carefully. A very important element is that each pair of child with SLI and control child received exactly the same instruction during the first years of the study, which makes the comparisons for reading and spelling ability and related skills highly reliable. In all data-analyses, the selected pairs were included as clusters. Because of the small group numbers, only statistical methods that were appropriate for small groups could be used. Since a significance level of .05 or lower is not often reached for small data sets, effect sizes were also interpreted. Despite the restricted statistical methods and the fact that children with the most severe forms of SLI were not included, our results revealed several remarkable group differences that are important for children with SLI attending regular school. Secondly, the study has been performed in Dutch, a language with a relatively transparent orthography. Hence, not all results might be transferred to less transparent languages. For example, it is known that in transparent languages, the role of PA is smaller and RAN is more important in the development of reading in children with SLI (Brizzolara et al., 2006; de Jong & van der Leij, 1999; Elbro & Scarborough, 2004; van den Bos, 1998; Wimmer, 1993; Wimmer, Mayringer, & Landerl, 2000). Thirdly, in the scope of this study, we could not analyze the direction of the relations between the variables, so we cannot draw conclusions about their causal relationships.

As a second important item, we discuss the selection criteria for SLI and for literacy delay. The *SLI criterion* to score persistently low on only one language aspect is less restrictive than many other studies that require a low score on two language aspects. The criterion to score lower than percentile 3 on at least two language aspects resulted in a too small number of children to follow, so a less restrictive criterion had to be chosen. However, our criterion was still selective (a score lower than Pc 3 on one language aspect before the start of language therapy) and language problems were persistent (a score lower than Pc 10 on one language aspect after the age of 4;4 years). Moreover, the whole SLI group had significantly lower scores compared to the control group on almost all language aspects in kindergarten, grade 1 and grade 3, despite the less restrictive criterion and the oral language therapy they all received in kindergarten (see chapter 2 and 4). On the other hand the *literacy criterion* of 1 *SD* below the mean of a norm group may have been rather lenient.

Therefore, we called this group ‘literacy-delayed’ and not ‘dyslexic’. The persistency of the reading or spelling problems was confirmed by the criterion that children had to fail on literacy in both grade 1 and grade 3. Moreover, literacy was measured relatively early and in a transparent language, where a phonological awareness deficit has little influence on nonword reading at the start of literacy instruction (Wimmer et al., 2000). Therefore, a milder criterion is justified.

A third item of discussion is the *composition of the test battery*. In fact, the choice, design, implementation and planning of the different tests were fixed at the start of the longitudinal study. For the composition of the test battery, several criteria were used, i.e. (1) feasibility for the researchers to administer and for the children to perform the tests, (2) reliable and valuable tests and preferably standardized tests available in Dutch, (3) reported experiences with these and similar tests as described in literature, (4) age range in which the tasks are considered to be reliable and valuable, (5) preferably the same tests during the whole longitudinal study to measure developmental effects (although learning effects should be avoided) and (6) a broad coverage of tests measuring different relevant skills. The overall practical experience with the test battery was positive, but some difficulties occurred. Some tasks were difficult to administer to children with SLI because of the speech sound problems of some of these children. For example it was sometimes difficult to repeat and score nonwords with consonant clusters in the nonword repetition task. Also tasks requiring a repetition of words such as some PA tasks in grade 1 and grade 3 and the speech-in-noise task were more difficult to score. The effect of pronunciation errors was eliminated manually as much as possible. These problems could be avoided in the future by using pictures as much as possible instead of requesting to repeat the correct answer. In fact, in kindergarten, when the pronunciation problems were more severe in the children with SLI, most tasks were based on pictures. Another difficulty is that children with SLI typically have persistent working memory problems (Conti-Ramsden & Durkin, 2007), which may negatively affect the scores on other tests that do not intend to measure vSTM but that place a large burden on working memory skills. For example, in some PA tasks measured in grade 1 several words were presented orally and the child had to manipulate these words. Again, this problem can be avoided by using tests with pictures as was done in this study in kindergarten. Also the auditory processing tasks (FM and gap detection) were quite

demanding on memory. Our results indeed confirmed moderate correlations with vSTM, but this can additionally be caused by a known correlation between auditory processing and working memory (Downie, Jakobson, Frisk, & Ushycky, 2002), suggesting that some common factor (perhaps underlying neurophysiological disruption) could be affecting both auditory processing and vSTM. In order to eliminate the role of memory in our data, group comparisons have also been statistically analyzed with vSTM as a covariate. However, results similarly showed no significant group differences and hence are not reported in detail. Moreover, as almost all children were able to perform the tasks at the easy starting level which were as demanding on memory as at a more difficult level, we can conclude that the FM and gap detection task were not purely measuring memory. Basic auditory processing deficits might also become more pronounced when the working memory load of the auditory task is increased (Stark & Tallal, 1988). In our data, the lack of correlation between auditory processing and speech perception is also remarkable. This seems a clear indication that the two sets of tasks were measuring different skills. Additionally, as was mentioned in footnote 11 of chapter 3, the nonword repetition task might not be a pure measure of verbal short-term memory, because other processes are involved as well (e.g., perceptual skills, phonological segmentation, assembly of articulatory instructions, execution of speech motor programs) (Snowling, Chiat & Hulme, 1991). We might therefore conclude that the PA and vSTM tasks administered in our study were intertwined. As it is also known that PA and vSTM are highly correlated variables probably resulting from an inefficiency in the formation of phonological representations (Elbro, 1996), we jointly discussed the similar results of PA and vSTM in our study. Finally, a new hypothesis regarding the auditory processing deficit as presented by Goswami et al. (2002) recently gained more support in literature (Fraser, Goswami, & Conti-Ramsden, 2010; Goswami et al., 2010). According to this hypothesis, children with dyslexia experience problems in detecting the speech envelope rise time and changes in syllable and phoneme duration. This may require appropriate tests to be included in the basal auditory processing part of the test battery, eventually instead of the FM and gap detection tasks.

Fourth, the timing of this longitudinal study was important. In retrospect, it was a good choice to start our longitudinal study already in kindergarten. Useful predictors for literacy are best measured before the start of reading and spelling instruction in order to

avoid an influence of literacy development on these predictors. On the other hand, tests administered early in kindergarten may not be useful as predictors because the necessary preparatory skills for reading and spelling might not have sufficiently developed and their variability among children can be larger. Therefore, the *final year of kindergarten* is considered to be an appropriate time to start the longitudinal study. Unfortunately, auditory processing and speech perception skills were not measured in kindergarten for practical reasons. It was decided to measure these skills as soon as possible in grade 1 when children only had received limited literacy instruction.

As a fifth item, we discuss the different *data-analyses*. Over the various chapters, group comparisons based on Mixed Model Analyses were performed by incorporating different covariates. In chapter 2, the MMA analyses included all covariates, i.e. age, non-verbal intelligence and parental educational level. Since this collection of covariates is extensive, additionally results of MMA without any covariates were presented as well. In chapters 3 and 4 we decided to incorporate only maternal educational level as there were no significant differences for age and non-verbal intelligence between the groups. In chapter 5, no covariates were incorporated in the MMA because educational level was supposed to have less influence on auditory processing and speech perception skills and we did not want to exclude the potential genetic factors of the parents.

In order to find reliable *predictors* for literacy we performed Spearman correlations (see chapter 2 and 5), predictive discriminant analyses (see chapter 3) and linear regression (see chapter 5). While predictive discriminant analysis provides a classification in discrete sets (SLI-LD versus SLI-NL), the other two analyses give continuous estimates of the prediction. Because the risk for dyslexia in children with SLI seems to be continuous rather than discrete, comparable to the family risk for dyslexia (Boets et al., 2010; Pennington, Cardoso-Martins, Green, & Lefly, 2001; Snowling, Gallagher, & Frith, 2003), a continous estimate seems to be more in line with literature and our expectations. However, for diagnostic purposes a classification is needed and in that case discriminant analyses are more appropriate.

A next point of discussion is the *underlying model explaining the overlap between SLI and dyslexia*. As described in chapter 3, in the literature four different models were presented. Catts et al. (2005) mentioned three different models of the relationship between

SLI and dyslexia, with a phonological processing deficit causing dyslexia. In a first one-dimensional model, SLI is a severe form of dyslexia, caused by a more severe phonological deficit. In a study of Larkin and Snowling (2008) a subgroup of children with language impairment had poorer phonological skills than predicted from receptive vocabulary, which supports the severity hypothesis. However, this model did not get much support because in this model all children with SLI are supposed to have literacy difficulties. Our empirical data did not support this model as only 8 of the 18 children with SLI had a lower literacy score (1 SD below the normative mean of reading or spelling in grade 1 and grade 3). In a second two-dimensional model, Bishop and Snowling (2004) explained that the same phonological deficit causes SLI and dyslexia. This part of the model is not in line with our study since the children with SLI and literacy delay showed more persistent phonological awareness deficits than the SLI group without literacy delay. Bishop and Snowling also explained that in children with SLI other nonphonological deficits cause additional problems in the development of oral language. This hypothesis seems consistent with our study, where several nonphonological (semantic and productive morphosyntactic) deficits were persistent in children with SLI until grade 3 which hinder the oral language development. In the study of Larkin and Snowling (2008), another subgroup of children with language impairment had concurrent impairments in vocabulary and phonological skills, in line with this two-dimensional model. In a third model, SLI and dyslexia are distinct developmental disorders with different cognitive deficits and different manifestations and the overlap is due to comorbidity. The data of the study by Catts et al. (2005) fitted best this model because in their study, it was observed that a deficit in phonological processing was closely associated with dyslexia but not with SLI when it occurred in the absence of dyslexia and the overlap between SLI and dyslexia was relatively small. With our empirical study, we could endorse that overall PA problems were more persistent in children with literacy delay and improved for less demanding tasks in children with SLI only. However, linking SLI and dyslexia to different cognitive deficits and explaining the overlap only by comorbidity, does not seem to fit our data as we observed overlapping risk factors for both disorders and a larger overlap than would be expected based on comorbidity only. In contrast to the previous one- and two-dimensional models based on phonological deficits only, a fourth model, described by Pennington (2006), takes multiple deficits into account. In this model, developmental disorders are the result of multiple deficits. Comorbidity between disorders occurs because

one or more of these deficits are shared. Our data and the results of our study give most support to this multiple deficits model described by Pennington (2006) and further specified in terms of the comorbidity between SLI and dyslexia in the empirical study of Carroll and Myers (2010). In this study, it was argued that SLI and dyslexia both have shared difficulties in phonological processing combined with other disorder-specific deficits. Also in our study, phonological awareness deficits were to a certain extent a shared risk factor for children with SLI with and without literacy delay. Indeed in kindergarten, it was a shared risk factor, but in primary school only for the group of children with SLI and literacy delay were these problems more persistent. Hence, this risk factor became disorder-specific for literacy delay after kindergarten. In the study of Carroll and Myers (2010), disorder-specific deficits for SLI might be difficulties in semantic and syntactic aspects of language. In our study, indeed these semantic and productive morphosyntactic deficits seemed to be disorder-specific for SLI. For dyslexia on the other hand, Carroll and Myers mentioned visual-verbal association difficulties such as slower rapid automatized naming as a potential disorder-specific risk factor. Our study confirmed that slower rapid automatized naming in kindergarten was a specific risk factor and a good predictor for literacy delay in children with SLI. Another specific risk factor for literacy delay might be speech perception problems. We support the conclusion of Carroll and Myers that SLI and dyslexia are thus separable but linked disorders. They share some risk factors and deficits, but each has additional specific deficits. Although this model fitted the best with our results, many interrelations between the different characterizing skills exist, also between the shared and the disorder-specific risk factors, which makes the model more complex. Examples of such interrelations are those between speech perception and phonological awareness and between phonological awareness and other oral language skills (see Figure 6.1).

As a *final point of discussion*, we can situate our findings in the context of the temporal auditory processing deficit theory (see Figure 1.1 in the Introduction), mentioned as the starting point of our study. In Figure 6.2, we present the adapted model based on the results of our study. Our results of the FM and gap detection tasks could not confirm that temporal auditory processing deficits are the underlying problem of the speech perception problems. The other links between the variables that are demonstrated in our study through

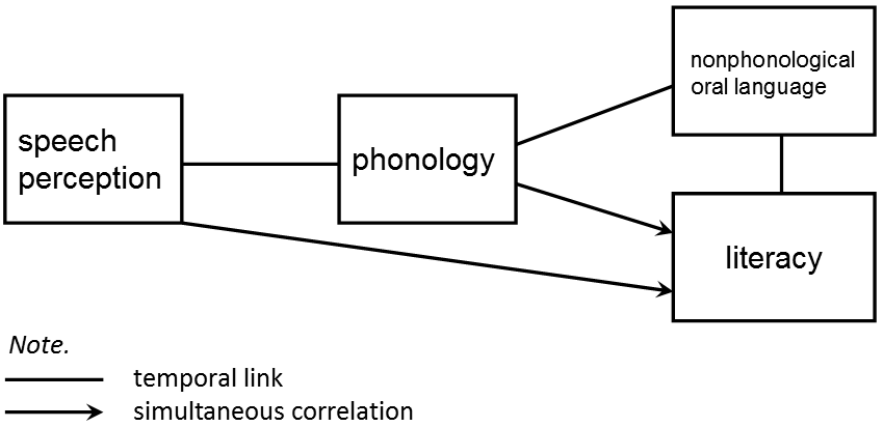


Figure 6.2 Diagram based on the temporal auditory processing deficit theory that could be confirmed by our longitudinal study

simultaneous correlations (represented by undirected lines) and predictors over time (represented by arrows), are consistent with the original model of Figure 1.1. A remarkable addition to the model is a direct link between speech perception and literacy.

It is interesting to bring our results in relation to previous studies analyzing these variables in children with dyslexia. In the studies of Boets et al. (2010) and Boets et al. (2011) the same test battery to measure auditory processing (FM and gap detection tasks), speech perception, phonological awareness, verbal short-term memory, rapid automatized naming and literacy was applied to a different group of children, i.e. children at family risk for dyslexia over the same age period. In these studies, except for vocabulary, no other nonphonological oral language tasks were measured. Our study differs in the fact that we concentrated on children with SLI. Results by Boets et al. (2010) and Boets et al. (2011) confirmed the temporal auditory processing deficit theory and model presented in Figure 1.1 (except for nonphonological oral language that was not measured). Most of the results for the children with dyslexia in these studies were similar to the results of the children with SLI and literacy delay in our study. However, in contrast to our study, Boets et al. (2011) observed for temporal auditory processing a lower score for FM detection compared to a control group and FM sensitivity in kindergarten uniquely contributed to growth in reading ability, even after controlling for phonological awareness. This implies that there seemed to be a direct link between temporal auditory processing and literacy in kindergarten. A direct link between speech perception and literacy was also observed in kindergarten to predict reading in grade 1 but not in grade 1 to predict reading in grade 3, whereas in our study (see Model 3 and 4 in Appendix 5A) this direct link was observed in grade 1 to predict reading in

grade 3. Comparable to the results in our study for children with SLI and dyslexia, the children with dyslexia in the study of Boets et al. (2010) had persistent deficits for the three phonological aspects, i.e. phonological awareness, verbal short-term memory and rapid automatized naming.

6.3 Suggestions for further research

The previous discussions already hinted several suggestions for further research.

First of all, it would be interesting if the results could be confirmed for a larger number of participants if possible (probably by selecting several cohorts of children over a number of years).

Because children with the most severe forms of SLI could not be included in our study, it would be interesting to study this group separately in special education schools. The set-up of this kind of study would be different. A comparison with a typically developing group would be impossible, because children in schools for special education receive different didactical instruction at different time instants in comparison with the education in regular schools. The SLI group with and without literacy delay could be compared in the same 'language classes'. It would be difficult to combine groups of different classes because didactical methods and time planning might differ a lot in schools for special education as well.

Further research with a longer follow-up is also needed in order to observe whether the difficulties in children with SLI and normal literacy will disappear in later grades, as was already observed for PA and vSTM by Catts et al. (2005), or cause more permanent problems. Whereas our study mainly involved word decoding and basic spelling skills, further studies can also include the development of higher level literacy skills such as reading comprehension at later ages. Language impairment may have a stronger impact on reading comprehension than on single-word recognition as stated by Catts (1993) and Bishop, McDonals, Bird, and Hayiou-Thomas (2009).

There are also several suggestions for the design and administration of the test battery. It is definitely important to have a broad spectrum of tests measuring different skills, as was done in this study. More specifically tests to detect the speech envelope rise

time can be included in order to reveal potentially basal auditory processing deficits in children with SLI with or without dyslexia (in contrast to FM and gap detection). There is still a need for a precise inventory of the different tasks with their different difficulty levels and their underlying cognitive skills. Moreover, it is important to analyze the role of these different tasks during the literacy development in typically developing children and in specific populations such as children with SLI and/or dyslexia.

Some studies compare the SLI groups not only with a control group with normal literacy but also with a group of children with dyslexia only. This would be interesting for extending our study, since it might reveal phenomena that are specific for dyslexia and not for the combination of dyslexia and SLI.

Another open question is whether RAN can be considered as a part of phonology (e.g., Pennington et al., 2001; Wolf & Bowers, 1999). In this respect, our study demonstrates that RAN has a very different role than PA and vSTM for children with SLI, but more extensive research is needed to elucidate their distinctive features.

Moreover, our study was restricted to a language with a relatively transparent orthography. Thus, our findings might be generalized to other transparent orthographies, but for non-transparent languages the generalization of our results is not straightforward and thus more research is needed.

The comorbidity with different speech sound disorders (e.g., articulation errors, phonological output problems, verbal dyspraxia), their severity and role in the development of literacy problems in children with SLI can be analyzed in more detail. Also the influence of other frequently comorbid disorders such as attention deficits and autism has to be studied in detail.

The mapping of activations and dysfunctions in different brain areas using brain imaging techniques may give more insight into the differential diagnosis between SLI and dyslexia and their overlap, in the same way as is done for the differential diagnosis between SLI and autism (Verhoeven et al., 2011). In this study by Verhoeven et al., a number of children with SLI that were selected in our longitudinal study was compared with a group of children with the diagnosis autism. It would be interesting to compare also the subgroups of

children with SLI with and without literacy delay and the control group to discover potential differences in brain functioning specifically linked to SLI or dyslexia.

Finally, there are a number of research questions related to the field studies in class rooms and speech-language therapy. First, there is a need for validation and optimization of the tests measuring the skills that were demonstrated as good predictors for literacy in children with SLI in the third year of kindergarten. Second, once good tests have been validated, their adequate use to give advice on the need for different suitable pedagogic-didactic methods and/or on appropriate therapy has to be studied. In this respect, it is important to firstly evaluate different pedagogic-didactic methods and the effectiveness of therapy methods. In this way, children with SLI can optimally benefit from early literacy instruction and can be guided efficiently during their school years.

6.4 References

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Appendix 6A Individual data of the composite scores standardized relative to the mean and standard deviation of the control-NL group from kindergarten to grade 3

					KG	KG	KG	KG	KG	KG	KG	KG	KG	KG	KG	KG
code	group	lit. group	pair	gender	age	perf. IQ	lang. P	lang. R	art. acc.	story ret. SL	story ret. inf.	storyt. SL	storyt. inf.	PA	vSTM	RAN	LK
1	0	2	1	1	62	110	-3,79	-1,19	-24,99	-1,39	-1,92	-0,68	-0,16	-7,96	-0,65	-1,60	-2,57
2	1	3	1	1	60	105	-0,95	-1,97	-1,52	-0,45	-1,05	1,31	-1,85	-0,64	-0,11	0,77	-1,02
3	0	1	2	0	64	110	-3,31	-2,29	-10,06	-0,57	-2,17	-0,68	-1,29	-4,37	-1,03	-0,77	-1,23
4	1	3	2	0	65	114	-1,16	-1,48	0,61	1,08	-0,30	1,46	0,97	0,70	0,66	0,63	1,17
5	0	1	3	0	64	109	-5,10	-2,43	-88,98	-1,74	-1,92	-1,44	-2,42	-3,64	-3,02	-2,23	0,50
6	0	2	4	1	68	102	-3,93	-3,48	-27,12	-1,39	-2,79	-0,68	0,97	-1,11	-2,20	-0,71	-2,12
7	1	3	4	1	66	117	-0,34	0,19	0,61	0,25	0,08	-0,37	1,53	0,39	-0,51	-0,95	0,07
8	0	2	5	0	65	101	-5,04	-3,99	-5,79	-0,22	-1,92	1,00	-2,98	-1,46	-1,28	1,84	-1,23
9	1	3	5	0	64	108	0,90	-0,35	0,61	-0,57	0,70	-0,37	0,97	-0,33	-0,07	-0,98	-0,03
10	0	1	6	0	65	112,5	-6,33	-1,20	0,61	-1,16	-1,67	-1,29	-1,29	-1,15	-1,48	-2,92	-1,76
11	1	3	6	0	65	128,5	1,36	1,35	0,61	2,37	1,57	0,09	-0,16	0,30	0,95	2,43	0,65
12	0	2	7	0	63	122	-3,79	-4,90	-48,45	-1,27	-1,92	/	/	-9,86	-2,10	-0,54	0,17
13	1	3	7	0	61	128,5	-0,42	0,78	0,61	0,37	-0,55	-1,75	-1,85	-0,83	0,81	0,29	1,17
14	0	1	8	0	62	108	-3,97	-2,68	-35,65	-1,04	-2,04	-1,59	-0,73	-4,25	-0,40	0,87	-4,30
15	0	2	9	0	62	89,5	-3,69	-2,07	-50,58	-0,22	0,08	0,39	0,97	-1,88	0,04	-0,10	-2,57
16	0	2	10	0	60	138	-2,01	-0,58	-46,32	-0,57	-0,42	-0,52	-1,85	0,15	-1,66	-0,77	-0,52
17	1	3	10	0	64	126,5	1,51	1,17	0,61	-0,22	1,82	0,70	0,40	1,06	1,96	-1,35	-0,84
18	0	1	11	1	65	90	-4,80	-1,69	-42,05	-1,86	-2,42	-0,37	-2,42	0,38	-0,65	-3,23	-0,67
19	1	3	11	1	57	105	-0,70	-0,24	-1,52	-0,92	0,58	-1,29	-0,16	0,64	-1,33	0,10	0,17
20	0	2	12	0	61	128,5	-3,35	-2,00	-1,52	-0,45	-0,67	-0,07	-1,29	0,87	-2,00	-1,02	-2,12
21	1	3	12	0	61	126,5	0,34	-0,82	0,61	-0,22	-0,17	0,39	-0,16	-2,04	-1,77	-0,90	-0,26
22	0	2	13	0	70	120	-1,26	-1,18	0,61	-0,92	-0,55	-1,29	-0,73	-1,06	-2,34	0,16	-1,76
23	1	3	13	0	68	128,5	0,60	1,17	-1,52	-0,22	-0,80	-0,37	-0,73	-1,29	-1,18	0,27	0,34
24	0	1	14	0	67	101	-4,97	-3,70	-3,66	-1,63	-1,30	-1,44	-2,98	-12,00	-2,78	-0,91	-3,21
25	1	3	14	0	69	118,5	0,16	-0,12	-1,52	0,61	-0,05	0,09	0,40	0,88	0,76	-0,55	-2,57
26	0	1	15	0	63	97	-2,72	-1,89	-56,98	-1,39	-1,54	-1,44	-2,42	-6,10	-3,36	-2,85	-2,57
27	1	3	15	0	63	138	1,16	-0,03	0,61	-0,33	-0,05	0,55	-0,16	1,41	0,12	0,92	1,12
28	0	1	16	0	63	138	-4,00	-2,90	-42,05	-0,80	-1,05	-0,68	-2,42	-9,92	-2,00	-1,34	-1,76
29	1	3	16	0	68	138	-1,02	-0,46	0,61	-1,74	-1,79	1,00	0,97	-0,79	-0,12	-0,52	0,17
30	0	2	17	0	62	131	-3,14	-3,17	-5,79	-1,39	-2,29	-1,90	-1,85	-1,01	-2,34	-0,91	-1,76
31	0	2	18	0	62	138	-2,92	-3,78	-1,52	-1,04	-0,92	-0,37	-0,73	-2,32	-2,34	-0,55	-1,02
32	1	3	18	0	63	131	-1,46	0,81	0,61	/	/	-1,44	-0,16	0,55	-0,17	-0,16	-0,14

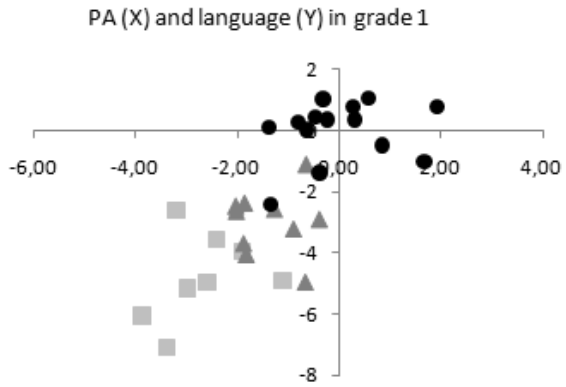
	G1	G1	G1	G1	G1	G1	G1	G1	G1	G1	G1	G1	G1
code	aud. proc.	speech perc.	lang. P	lang. R	story ret. SL	story ret. inf.	storyt. SL	storyt. inf.	PA	vSTM	RAN	reading	spelling
1	0,80	1,23	-5,91	0,16	-2,02	-2,48	-1,44	-0,56	-0,89	-0,51	-0,99	-1,41	-1,66
2	-0,06	1,65	-1,54	-2,67	-0,08	-0,48	0,59	-0,56	-1,34	-0,66	0,32	-0,97	0,44
3	1,48	-0,16	-3,52	-2,77	-0,08	0,19	-0,88	-2,14	-2,41	-1,72	1,02	-0,37	-1,31
4	0,46	-0,54	-1,11	-0,66	0,29	-0,48	0,22	-1,09	1,67	0,60	0,73	0,99	0,96
5	1,54	-3,30	-7,17	-3,49	-2,39	-3,14	-1,81	1,02	-3,88	-3,67	-1,13	-1,95	-2,53
6	1,33	0,01	-3,15	-3,35	-2,15	-2,98	-1,62	-2,14	-1,88	-3,02	-0,69	0,06	0,78
7	-0,01	-0,35	0,48	0,30	1,02	0,86	-0,15	1,02	-0,46	0,17	-0,32	-0,62	0,09
8	0,76	-0,68	-2,26	-2,07	-0,08	-1,81	-2,18	-0,04	-2,04	-0,83	1,05	-1,56	-0,26
9	-0,76	-1,25	0,71	0,68	0,89	-0,48	-0,70	-0,04	0,27	-0,55	-0,57	-1,09	0,26
10	3,20	-0,80	-5,13	-3,53	-0,44	-1,64	-2,18	-1,62	-1,12	-1,91	-1,86	-1,93	-1,13
11	-0,63	0,02	1,94	-0,11	0,65	-0,14	-0,15	-1,09	-0,32	0,82	2,56	1,02	0,78
12	0,53	2,06	-5,71	-3,07	-0,69	-2,64	0,41	0,49	-0,66	-2,88	-0,88	0,17	0,44
13	0,96	-1,27	0,02	-0,86	0,29	0,02	0,22	1,54	0,84	-0,72	0,26	1,49	0,78
14	-0,40	-2,93	-3,80	-3,15	-1,29	-1,48	-0,33	-0,04	-1,90	-0,15	0,71	-0,62	-1,31
15	0,28	0,93	-3,95	-0,62	0,65	-0,64	1,70	-1,09	-1,27	-0,42	1,18	0,58	-0,78
16	-0,27	-0,28	-5,48	-1,72	-2,15	-0,64	0,59	0,49	-1,83	-2,94	-0,55	-0,18	-0,09
17	-0,37	0,60	0,70	0,71	-0,93	-0,98	2,26	0,49	1,92	1,50	-0,74	0,00	-0,09
18	-0,77	-1,87	-5,21	-3,49	-2,15	-2,98	-2,55	-1,62	-2,59	-0,93	-2,17	-2,09	-7,41
19	0,48	0,13	-0,73	0,74	-0,56	1,52	-0,52	-0,04	-0,65	-0,98	-1,22	-1,08	-1,48
20	-1,08	-1,05	-3,28	-1,84	-0,08	-0,48	0,78	-0,56	-0,38	-1,40	-0,82	-1,41	-1,31
21	2,65	1,08	0,39	-0,19	1,75	1,02	0,22	1,54	-1,39	-2,09	-0,24	1,17	-0,44
22	2,46	0,88	-1,37	-0,56	-0,93	0,19	-1,07	1,02	-0,64	-1,30	0,31	-0,70	-0,96
23	-0,39	1,08	-0,25	0,86	0,41	0,36	-1,07	-0,04	-0,23	-0,57	0,62	-0,53	0,78
24	0,18	-1,57	-4,45	-7,93	-2,27	-2,81	-2,55	-3,72	-3,38	-2,19	-1,66	-1,76	-3,40
25	-0,80	-0,28	0,41	0,09	-0,69	0,69	-0,52	0,49	-0,81	0,50	-1,09	-1,60	-2,18
26	5,22	-4,34	-3,85	-0,78	0,41	-0,81	-1,81	-1,09	-3,20	-4,82	-1,35	-2,21	-6,19
27	-1,61	0,84	0,64	1,25	0,29	0,69	1,70	0,49	0,57	-0,08	0,74	0,88	0,96
28	0,35	-2,92	-7,07	-2,04	-0,69	-1,31	0,59	-0,04	-2,98	-2,34	-0,25	-1,50	-2,18
29	0,31	-1,79	-1,75	-0,67	-1,90	-0,14	-1,07	-1,09	-0,39	1,50	-1,05	0,22	-1,31
30	-0,22	0,31	-3,56	-1,11	-1,78	-2,98	-2,73	-0,56	-2,03	-2,94	-0,33	-0,59	-0,78
31	1,57	-0,07	-2,71	-1,48	-1,42	-0,64	-2,55	0,49	-1,86	-2,41	-0,98	-0,82	0,26
32	-0,23	0,06	0,09	0,53	-1,42	-2,48	-1,07	-1,62	0,32	0,56	0,00	0,11	0,44

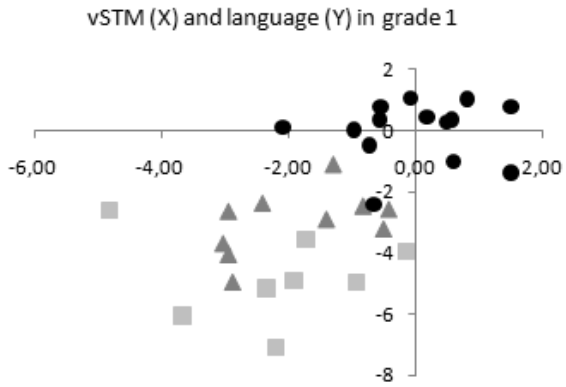
	G2	G2	G2	G2	G2	G2	G3	G3	G3	G3	G3	G3
code	lang. P	lang. R	story ret. SL	story ret. inf.	storyt. SL	storyt. inf.	PA	vSTM	RAN	reading	spelling	reading comp.
1	-5,01	-2,60	-1,73	-2,23	-0,25	-0,85	-1,25	-0,20	-1,18	-1,60	0,59	-1,04
2	-0,96	-2,48	0,42	-0,50	-1,02	0,42	-0,57	0,28	1,95	-0,45	0,30	-1,30
3	-2,08	-3,66	-1,73	-3,53	-1,02	0,00	-2,60	-1,23	0,20	-1,24	-2,07	-2,88
4	0,19	0,26	1,42	-1,58	0,40	-1,70	0,67	0,99	-1,11	0,37	1,48	-1,04
5	-5,01	-2,49	-1,15	-2,45	-1,79	-0,42	-4,14	-3,11	-3,47	-3,98	-5,04	-1,83
6	-3,28	-2,72	-2,87	-2,01	-1,28	0,00	-0,41	-1,97	-1,90	0,19	0,89	0,81
7	1,10	-0,80	-1,30	-1,36	2,07	-0,42	-0,82	0,40	-0,71	-1,27	-1,48	0,02
8	-3,49	-1,81	-3,02	-2,66	-1,28	-0,85	-2,20	-0,20	2,17	-1,49	-1,78	-2,62
9	-0,50	0,34	-0,01	0,59	-0,25	0,00	-1,13	-1,73	-0,92	-1,83	-1,48	-2,35
10	-5,48	-3,47	-2,01	-2,45	-1,15	1,27	-3,54	-2,52	-3,31	-3,66	-5,04	-3,15
11	1,77	0,25	-0,44	1,67	0,27	-0,42	-0,30	0,09	1,29	1,51	0,30	0,81
12	-4,60	-3,25	-2,16	-3,10	-0,12	-0,42	-1,87	-2,45	-1,42	-0,23	-2,96	-1,04
13	0,47	-0,83	-0,15	0,15	0,40	1,27	0,53	-0,08	-0,07	1,03	0,89	0,81
14	-3,67	-2,11	-0,87	-0,50	-1,02	-0,42	-0,55	0,90	-0,24	0,23	-2,07	-2,62
15	-2,86	-0,87	-1,30	-1,58	-1,15	0,00	-0,72	0,83	-0,43	0,66	-1,19	-1,30
16	-2,04	-0,06	0,42	2,32	0,78	-0,85	0,34	-2,38	-1,92	-0,18	-1,19	0,55
17	1,45	0,43	-1,58	0,59	0,65	-0,85	1,15	2,33	-0,60	-0,77	-1,19	0,02
18	-3,70	-3,32	-1,73	-2,66	-1,28	-2,12	-4,69	-1,04	-3,12	-4,79	-5,93	-2,09
19	-1,08	0,05	-1,30	-1,58	-1,54	-1,70	0,14	-0,63	0,08	0,45	1,19	1,07
20	-1,71	-1,78	0,85	-0,28	1,43	-0,42	-1,11	-0,27	-1,63	-0,25	-1,78	-0,77
21	-0,47	1,77	1,71	0,37	1,17	1,27	-0,01	-0,27	-1,04	1,30	0,30	1,34
22	-0,89	-1,03	0,99	-0,71	-0,51	1,27	-1,66	-1,18	-0,65	-0,13	-1,78	-1,56
23	0,96	0,49	1,13	0,15	-0,64	0,42	-2,51	-1,42	0,75	-0,87	-0,59	0,28
24	-5,02	-4,47	-2,30	-3,31	-0,89	-1,27	-2,67	-2,87	-2,42	-3,81	-4,45	-1,56
25	-1,17	0,63	0,28	-0,71	0,27	-0,42	0,34	0,21	0,63	-0,44	-0,59	0,02
26	-4,51	-0,44	-1,01	-0,93	-2,57	-2,97	-5,09	-3,47	-3,01	-8,16	-6,52	/
27	-0,09	0,77	0,13	0,59	-0,89	0,85	0,95	0,16	0,56	0,89	1,19	0,55
28	-4,85	-2,00	-1,01	-0,71	-2,44	-0,42	-2,01	-2,52	-0,81	-2,47	-4,74	-2,62
29	-0,95	-0,87	0,28	0,59	0,40	1,27	0,62	-0,77	-1,38	0,28	-0,59	0,02
30	-3,33	-1,75	-1,30	-2,88	-1,15	0,00	-3,12	-1,73	-1,28	-2,39	-1,48	-1,04
31	0,09	-1,95	-1,15	-0,71	-0,76	1,27	-4,83	-2,26	-2,59	-2,18	-2,96	-1,04
32	-0,72	-0,02	-0,58	1,02	-1,28	0,00	0,94	0,45	0,57	-0,20	0,30	-0,24

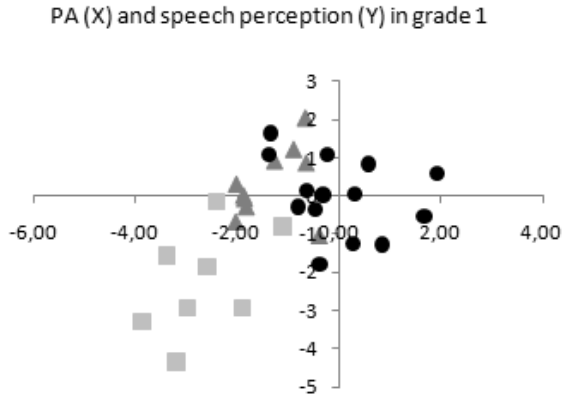
Legend.

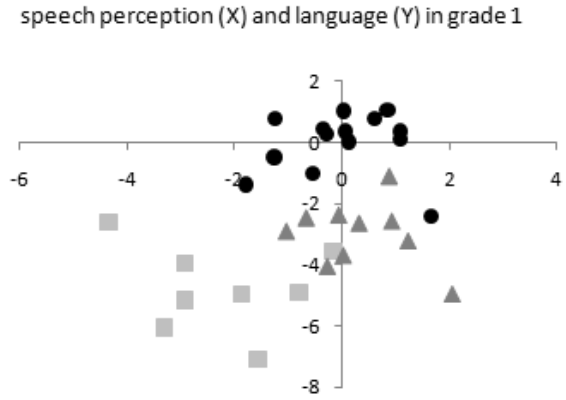
code	number corresponding with a person
group	0 = SLI-group; 1 = control group
lit. group	literacy group: 1 = SLI group with literacy delay; 2 = SLI group with normal literacy; 3 = control group with normal literacy
pair	same numbers correspond to the selected pairs
gender	0 = male; 1 = female
age	age in months at the start of the longitudinal study
perf. IQ	standard score of performance IQ measured in kindergarten (M = 100; SD = 15)
aud. proc.	auditory processing
speech perc.	speech perception
lang. P	productive language
lang. R	receptive language
art. acc.	articulation accuracy
story ret. SL	mean length of the five longest correct sentences of the story retelling task
story ret. inf.	information score of the story retelling task
storyt. SL	mean length of the five longest correct sentences of the storytelling task
storyt. inf.	information score of the storytelling task
reading comp.	reading comprehension
/	unreliable score

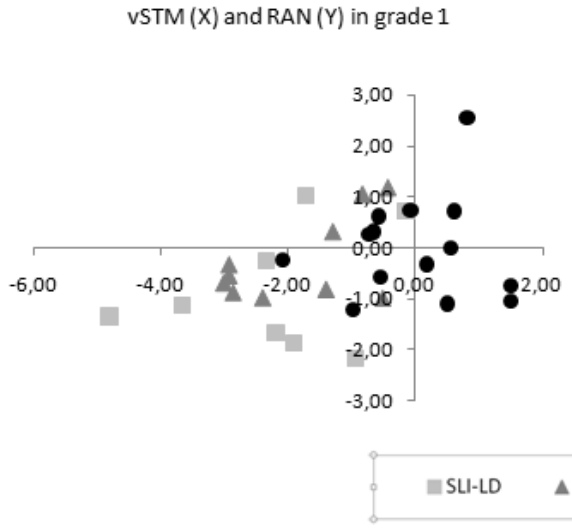
Appendix 6B Scatter plots representing relations between composite scores of variables



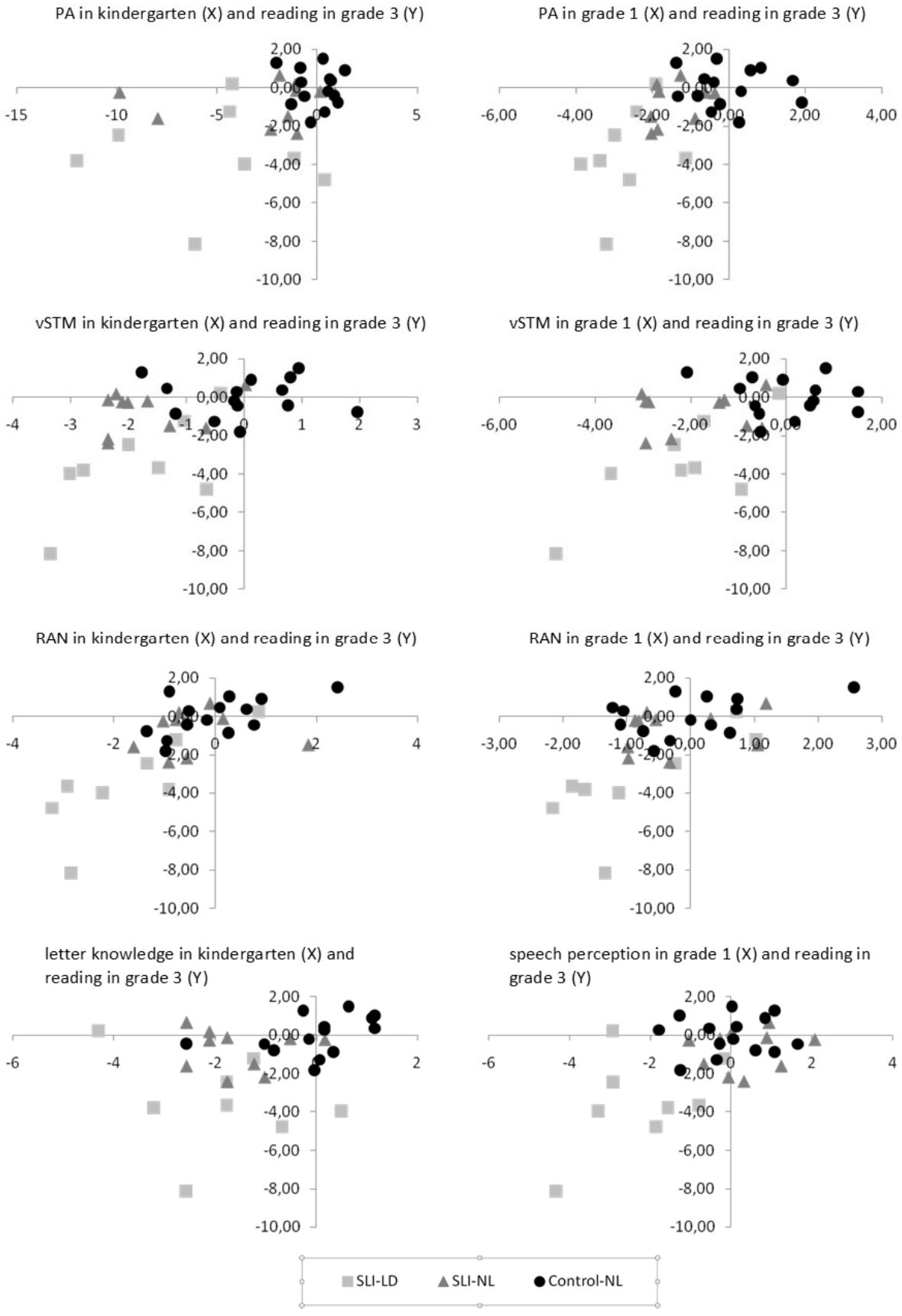











PA in kindergarten (X) and reading in grade 3 (Y)
PA in grade 1 (X) and reading in grade 3 (Y)
vSTM in kindergarten (X) and reading in grade 3 (Y)
vSTM in grade 1 (X) and reading in grade 3 (Y)
RAN in kindergarten (X) and reading in grade 3 (Y)
RAN in grade 1 (X) and reading in grade 3 (Y)
letter knowledge in kindergarten (X) and reading in grade 3 (Y)
speech perception in grade 1 (X) and reading in grade 3 (Y)
SLI-LD
SLI-NL
Control-NL

List of publications

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Vandewalle, E., Boets, B., Ghesquière, P., & Zink, I. (in press). Development of phonological processing skills in children with specific language impairment with and without literacy delay: a three-year longitudinal study. *Journal of Speech, Language and Hearing Research*.

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Curriculum vitae

Ellen Vandewalle was born in Leuven, Belgium in 1981. After her secondary education at Heilig-Hartinstituut in Leuven (1999), she obtained her Master's degree in Speech-Language Pathology and Audiology cum laude from Katholieke Universiteit Leuven, Belgium, in 2003. Her master thesis concerned the development of tests particularly dedicated to the professionel speaking and singing voice. In 2004 she completed the academic teacher's education at the same university. After first experiences as a speech-language therapist in a private practice with emphasis on stuttering and in a school for special education, she started her PhD at the Laboratory for Experimental Otorhinolaryngology at KU Leuven under supervision of Prof. dr. Inge Zink and Prof. dr. Pol Ghesquière. She combined her research work with teaching activities in the Speech-Language Pathology and Audiology education at KU Leuven. Besides, she regularly gives workshops to school teachers on the correct use of the professional voice. Since 2011 she combines a job as research coordinator at CODE at Lessius Antwerpen with teaching activities in the education for primary school teachers at Katholieke Hogeschool Leuven.