Comparing SLI and dyslexia

Developmental language profiles and reading outcomes

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In light of the striking overlap in symptoms, it has been proposed that SLI and dyslexia reflect the same underlying disorder, differing only in severity. An alternative view is that SLI and dyslexia overlap (only) partially, sharing some risk factors, and differing on various others. We will address this debate by presenting results from a longitudinal study of children at familial risk of dyslexia and children with SLI. We focus on two experimental tasks conducted with preschool children, assessing morphosyntactic ability and phonological processing. The performances of each group were compared and related to language and literacy profiles established at age 8. The results agree most with the hypothesis that SLI and dyslexia share risk factors, but are not fully overlapping.

Introduction

When learning to read is unusually hard for a child, despite having no known cognitive, neurological, educational or psychological limitations, a diagnosis of dyslexia is warranted (Snowling 2000). The prototypical symptoms of the disorder, difficulty in acquiring word decoding skills, reading fluency and accuracy, are commonly seen as the result of a phonological processing deficit (de Jong & van der Leij 2003). However, children with dyslexia have been shown to display language difficulties beyond phonological processing (e.g. Rispens & Been 2007; Shankweiler et al. 1995). Indeed, in a study by McArthur, Hogben, Edwards, Heath and Mengler (2000), approximately half of a sample of children with dyslexia met

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the criteria for specific language impairment (SLI), which is defined as a difficulty in acquiring spoken language despite otherwise normal intellectual functioning and hearing and adequate learning environment (Leonard 1998).

Next to this overlap between dyslexia and SLI, children with a *family risk* (henceforth: FR) of dyslexia have been found to display phonological and broader language difficulties (e.g. de Bree, Rispens & Gerrits 2007; Carroll & Snowling 2004; Locke, Hodgson, Macaruso, Roberts, Lambrecht-Smith & Guttentag 1997; Lyytinen, Poikkeus, Laakso, Eklund & Lyytinen 2001; Scarborough 1990; Snowling, Muter & Carroll 2007; van Alphen, de Bree, Gerrits, de Jong, Wilsenach & Wijnen 2004; Wilsenach & Wijnen 2004). Together, these findings imply that the overlap between dyslexia and SLI encompasses a broad range of linguistic difficulties. Understanding the relationship between these two disorders is relevant for both theory and practice. The present study aims to contribute to our knowledge by assessing phonological and morphosyntactic skills in children with a family risk of dyslexia and children with SLI. First, however, literature on language deficits in children with (a family risk of) dyslexia and children with SLI will be discussed, followed by a brief review of models that have been presented to account for the overlap between the two disorders.

Direct comparisons between populations with dyslexia and SLI have burgeoned the last few years. Regarding language difficulties in the two groups, such studies report both similarities and differences (e.g. Catts, Adlof, Hogan & Weismer 2005; Fraser, Goswami & Conti-Ramsden 2010; Kamhi, Catts, Mauer, Apel & Gentry 1988; Larkin & Snowling 2008; Marshall & van der Lely 2009; Marshall, Harcourt-Brown, Ramus & van der Lely 2009; McArthur & Castles 2011; Rispens & Been 2007; Robertson, Joanisse & Ng 2009; Robertson, Joanisse, Desroches & Terry 2013). Generally, performance is ranked such that children with both dyslexia and SLI perform most poorly, followed by children with SLI-only, followed by children with dyslexia only. Phonological processing difficulties have been attested in all three groups, but the extent of such difficulties, and the number of children affected within each group, differ. In some instances, phonological processing difficulties are only present in children with reading impairments, whereas in others all three groups are affected. In a recently published study, Ramus, Marshall, Rosen and Van der Lely (2013) observe that phonological difficulties cannot be attested in a fairly large minority of the children with SLI. Children who meet the diagnostic criteria of both SLI and dyslexia, however, all show a phonological deficit.

With respect to grammatical skills, or, more generally, broader language skills, children diagnosed with SLI are generally more affected than those with reading difficulties only. These findings can thus be matched to the notion of continuity between the disorders. They also call for further research. The studies reported above have been conducted with relatively old children, whereas language impairments arise at an early age and should thus also be studied before literacy skills emerge. This position is endorsed by Bishop, McDonald, Bird and Hayiou-Thomas (2009), who found that phonological processing was generally poor in children with language impairment (LI) at age 4, while at age 9, these difficulties were only attested in those children with LI who also displayed literacy difficulties. Language difficulties thus appear to change over time, possibly in part through interaction with developing literacy skills. Assessment of language skills at a stage prior to literacy instruction is thus needed to attain a more complete picture of the complex developmental relations between language difficulties and reading problems.

To date, few comparisons have been made between FR children and preschool children with SLI, while this is critical for a better understanding of the risk factors that predispose FR and SLI children for literacy and/or language difficulties. The Utrecht dyslexia and language impairment project compared three-to-five-year-old FR children with children with SLI on measures of speech perception and production and grammatical comprehension and production (e.g. de Bree & Kerkhoff 2010; de Bree, Rispens & Gerrits 2007; de Bree & van der Pas 2011; Gerrits & de Bree 2009; van Alphen et al. 2004). Overall, the findings support the idea that a FR of dyslexia coincides with subtle and broad language difficulties, as the FR group has a performance profile intermediate to that of the typically developing children and the children with SLI. The results also suggest that the differences between FR and SLI are not merely quantitative. Error patterns, notably in phonological tasks, differ between these groups, which would suggest that dyslexia and SLI are not the same disorder, differing in severity only, but rather, that both a FR of dyslexia and a diagnosis of SLI are risk factors for literacy difficulties. However, the precursor-consequence relations are not straightforward and may differ between the two groups. As an example, we found that non-word repetition performance as well as speech perception and production at age 4–5 are predictive of literacy outcomes at age 8 for the FR group, but not for the SLI group (de Bree, Wijnen & Gerrits 2010; de Bree, Snowling, Gerrits, van Alphen, van der Leij & Wijnen 2012). The comparisons of children with dyslexia and children with SLI, as well as those comparing FR children and preschool children with SLI thus show that there is evidence for overlap between the disorders, but also for differences between them.

Catts, Adlof, Hogan and Weismer (2005) discussed three models that address the relation between dyslexia and SLI. One model claims that both SLI and dyslexia stem from an underlying phonological processing difficulty, with dyslexia being a milder manifestation of the difficulties shown in SLI. Such a *single source model* (e.g. Tallal et al. 1997) predicts that phonological and grammatical skills are correlated, as poor phonology cascades into poor grammar. The second model holds that both disorders are caused by a phonological processing deficit, but that SLI occurs only if an additional cognitive deficit impacts other areas of language next to phonological processing (*qualitative difference model*, e.g. Bishop & Snowling 2004; *additional deficit model*, Ramus et al. 2013). The third model assumes that the cognitive deficits underlying SLI and dyslexia are different, and that the two can occur in tandem, which results in a behavioral profile with characteristics of both disorders (*comorbidity model*; Catts et al. 2005; *component model*, Ramus et al. 2013).

The models discussed by Catts et al. (2005) each assume a simple and straightforward causal relation between behavioral patterns (symptoms) and underlying cognitive deficits. In contrast, Pennington (2006) argues that neuro-developmental disorders are characterized by multifactorial causation. Each disorder, as defined phenotypically (at the behavioral level), is the outcome of the interplay of multiple risk factors, both at the underlying etiological and cognitive levels. Phenotypical similarity (or co-morbidity) is due to overlap of risk factors. Thus, dyslexia and SLI would both be associated with a specific set of risk factors, but a subset of these factors is likely to be identical for both disorders.

In order to gain more insight into the developmental relations among language skills and literacy skills in dyslexia and SLI, the present prospective, longitudinal study relates the results of preschool tests on inflectional morphology and phonological processing to later literacy and language skills in the same children. The tasks conducted in the preschool phase comprised elicitation of inflectional morphology and phonological error detection (see Methods section below). When the children had been exposed to two years of formal instruction in reading and writing (age ~8), they were invited to return to our lab to take part in an extensive follow-up screening aimed at charting their progress in spelling, tecŠical reading and reading comprehension, as well as general language status. We used the literacy data obtained at age 8 to classify children as normal (i.e., average or better) or poor readers. The classification *poor reader* does not necessarily entail that a child meets all criteria for a diagnosis of dyslexia. Nonetheless, it allows us to explore how early language is related to later literacy, both in SLI and dyslexia.

The data set we present here is fairly small and has various other limitations, as will become clear. Consequently, it cannot be used to test predictions made by the models outlined above. Rather, we will use these models as a starting point for formulating a number of questions on the interrelationships among phonological and broader language skills and their connection to emerging literacy. Our questions are the following: (1) Are SLI and (FR of) dyslexia both associated with phonological processing difficulties, and if so, is there a difference in severity and/or prevalence of these difficulties between the two groups? (2) Given its definition, it is expected that SLI is associated with morphosyntactic difficulty. To what extent is such difficulty associated with FR of dyslexia as well? (3) Is there an implicational relation (dependency) between phonological difficulty and morphosyntactic difficulty? (4) Do the SLI and (FR of) dyslexia groups overlap with regard to phonological skills and morphosyntactic (and other language) skills? (5) How do phonological and other language skills in the two atypical groups relate to their literacy performance?

Methods

Participants

The results presented here were obtained in the context of a longitudinal prospective research program involving children with FR of dyslexia, children with SLI, and a typically developing control group (TD). The children were seen four times over a period of approximately two years (i.e., 6-month intervals), and at each session they took part in various tests and experiments. The FR children had at least one parent with literacy difficulties as indicated by standardized reading and phonological processing measures, including a nonword spelling task, a timed-word and timed-nonword reading task, a non-word repetition task, and a rapid serial naming task. In order for a child to be included in the FR group, the parent had to show poor performance on all the tasks, except on an additional verbal competence task, as this is often a relative strength for highly educated people with dyslexia, in contrast with their reading and spelling abilities. Specifically, performance on the timed-word reading or timed-nonword reading task had to be in the 10th percentile, or in the 25th percentile on both timed reading tasks, and a discrepancy of at least 60% between verbal competence and performance on the timed reading tasks (based on criteria from the Dutch Dyslexia Program; see van Bergen, de Jong, Plakas, Maassen & van der Leij 2012; Koster et al. 2005). The group of FR children did not include children whose parents or siblings had a history of overt oral language impairment.

Children with SLI were recruited through speech therapists and schools for children with severe speech and language difficulties. Prior to the start of the project, they had been diagnosed with SLI after extensive assessment of speech and language abilities by certified speech pathologists. Following common criteria for SLI, all children had to meet the following criteria: normal hearing, absence of neurological difficulties, and normal nonverbal IQ (>75). We only know of one child in this group who had a dyslexic parent.

Typically developing (control) children were recruited through calls in newspapers and magazines. These children were all without literacy or language difficulties and did not have a (family) history of such difficulties, hearing problems, or other developmental difficulties.

Measures at preschool age: Inflection and mispronunciation detection

Morphosyntactic ability, i.e., knowledge of verbal inflection and noun pluralization, was assessed when the children were between age 3;3 (years; months) and 3;7. An elicitation task in the format of a standard grammatical closure task (Kirk, McCarthy & Kirk 1968) was used. The child was shown two pictures. The experimenter described the first of these in full, but provided only a partial description of the second picture, omitting the final constituent and thus inviting the child to complete the sentence. One half of the experiment (a block of 10 trials) probed noun pluralization. In these trials, the first picture contained a single exemplar of a referent to be named (e.g. a ball); the second picture contained multiple referents of the same type. The experimenter would describe the first picture, e.g. *Dit is een bal* ('This is a ball'), then proceed to showing the second picture and probe the child by saying (with rising intonation) *En dit zijn twee …?* ('And these are two …?'), upon which the child was expected to say *ballen* ('balls'). The other block of 10 trials probed verb agreement. Two pictures of an animate figure (e.g. a bear) performing different actions were shown. The experimenter described the first action, using a full subject-predicate construction, e.g. *Deze beer loopt* ('This bear walks'). The experimenter then invited the child to complete the description of the action in the second picture by saying (with rising intonation) *En deze beer …?* ('And this bear …? '), upon which the child was expected to pronounce a verb that described the depicted action in the correct morphological form, e.g. 3SG *valt* ('falls'). Proportions of incorrect responses (errors) were calculated, excluding null and irrelevant responses. 85 children completed both blocks of the task (29 TD; 44 FR; 12 SLI).

To assess children's sensitivity to phonological detail in word recognition, a mispronunciation detection task was conducted when the children were 5 years of age (range 5;1–5;4; N = 91: 27 TD; 48 FR; 16 SLI). The task consisted of 12 target words that were presented three times (in a random order): once correctly pronounced, once with a maximal mispronunciation of the initial consonant (target and substitution differing in the place of articulation, manner and voicing, e.g. *pebra* for *zebra*) and once with a minimal mispronunciation (target and substitution phoneme differing only in place of articulation, e.g. *vebra* for *zebra*). All words were bisyllabic with a strong-weak stress pattern. In addition, there were 12 filler words, which were pronounced correctly. Prior to the actual test, children were asked to name pictures that appeared on the screen to familiarize them with the pictures as well as to ensure that they knew the names of the objects presented. Next, there was a training session in which two correctly and two incorrectly pronounced words were presented. Subsequently, the children saw the pictures they had been familiarized with and heard their names pronounced. The participants' task was to push a big red button when a word was pronounced incorrectly. The dependent variable was the proportion of incorrect responses, i.e., misses (missing a mispronunciation) and false alarms (responding to a correctly pronounced item).

It is important to point out that not all children completed both tasks, as children were free to discontinue testing within a session as well as between sessions.

Literacy and language measures at age 8

Four different literacy tasks were presented to the children at age 8: a one-minute word reading task (*EMT*; Brus & Voeten 1972), a two-minute pseudo-word reading task (*Klepel*; Van den Bos, Spelberg, Scheepstra & de Vries 1994), and two spelling tasks, spelling dictation (van den Bosch, Gillijns, Krom, Moelands, Geurts & Verhoeven 1993) and spelling selection, which assesses orthographic knowledge (Horsley, 2005). We also used an instrument that is standardly used in primary schools to determine speed and accuracy in text reading (AVI reading; Visser, van Laarhoven & ten Beek 1996) and a measure of reading comprehension (SBR CITO; Verhoeven 1993). See de Bree et al. (2010 and 2012) for more detailed information.

The language tasks that were included in the battery were a test of receptive vocabulary (Vocabulary CITO; Verhoeven 1996), and the productive morphology and syntactic judgment subtests of the *Taaltests voor Kinderen* (TvK) battery ('Language tests for Children'; van Bon & Hoekstra 1982). To assess phonological processing ability, we used a phoneme deletion task in which both the stimuli and the resulting strings were pseudowords (Messbauer, de Jong, & van der Leij 2002). It should be noted that not all children returned for follow-up testing at age 8.

Results

ANOVAs were conducted to assess group differences. Post hoc tests were Tukeys in case of equal variances and Games Howell in cases of unequal variances.

Preschool morphosyntactic and phonological measures

Inflection experiment

Null responses were tallied as missing data. Inspection of the data (see Table 1) suggested that the numbers of null responses in the noun pluralization condition were not evenly distributed across the participant groups. A one-way ANOVA with number of null responses as dependent variable and group (TD, FR, SLI) as factor returned a significant effect ($F(2, 82) = 4.34$; $p = .001$), with TD < FR < SLI (post-hocs all $p < 0.05$). There was no corresponding effect in the verb agreement condition.

Table 1. Results on the inflection task and mispronunciation detection tasks

Group	Inflection task			Mispronunciation detection
	Null response (Noun condition)*	Null/no verb (Verb condition)	Proportion error (Noun & verb conditions)*	Proportion error*
	M (SD)	M (SD)	M (SD)	M (SD)
TD	0.24 (0.5)	1.34 (1.4)	$0.14\ (0.14)_a$	0.014 (0.03)
FR	1.07 (1.3)	1.5 (1.2)	$0.23\ (0.20)_a$	0.053 (0.05)
SLI	1.25 (2.2)	2.2 (1.9)	$0.37\ (0.31)_a$	0.139 (0.12)

*marks a significant main effect; values with same subscript do not differ on post hoc tests

Discarding null responses, a one-way ANOVA with proportions of errors (see Table 1) as dependent variable and group as factor returned a significant effect ($F(2,82) = 5.29$; $p = .007$; $\eta^2_p = .114$). Although the numerical data show a staircase pattern (TD < FR < SLI), there were no significant differences between the groups in post hoc tests (TD vs. FR children: $p = .073$, TD vs. SLI: $p = .075$, FR vs. SLI: $p = .357$). The poor performance of the SLI children was expected. As regards the FR children, the results are in line with our previous findings: their average performance is intermediate between TD controls and children with SLI.

Mispronunciation detection experiment

Table 1 (rightmost column) presents the mean proportions of incorrect responses for the three groups of participants. The staircase pattern (TD < FR < SLI) is supported by the inferential statistics, with a significant main effect of Group ($F(2,88) = 18.33$; $p < .001$; $\eta^2_p = .294$) and significant post hoc test results for the TD – FR contrast ($p = .001$), the TD – SLI contrast ($p = .003$), and the FR – SLI contrast ($p = .035$).

The poor performance of FR children on the phonological judgment task is expected on the basis of the literature. The poorer performance of the children with SLI compared with the FR children is interesting, but we should keep in mind that the FR group is heterogeneous: all children carry a risk, but not all will develop manifest reading difficulties. It remains to be seen if phonological weakness is a specific trait of only those children who will turn out to be poor readers.

Correlations between the phonology and inflection results

56 children took part in both the phonological error detection experiment and the inflection task (20 TD; 30 FR; 6 SLI). For this group of 56, error proportions in the two tasks correlated moderately and significantly ($r = .32$; $p = .017$). Separate analyses for the TD and FR subgroups did not return significant correlations;

the correlation in the SLI group (n = 6) is strong (Spearman's rho = .81; $p = .053$). Obviously, this result should be treated with caution, but it would seem that the overall positive correlation between the two tests is carried by the SLI subgroup.

Literacy outcomes at age 8

At age 8, children were classified as normal or poor readers on the basis of their scores on the norm-referenced tecŠical reading tests EMT (word reading) and Klepel (pseudo-word reading). Children who obtained a score equal to or lower than the population mean minus one standard deviation (i.e., 7 or lower) on at least one of the two tests were labeled *poor readers*; all others were labeled *normal readers*. The number of children who took part in the follow-up procedure at age 8 was 101 (28 controls; 52 FR children; 21 children with SLI). However, not all children completed all tests.

Table 2 shows that the proportion of poor readers in the FR and SLI groups is about 6 times as high as in the TD group. The percentage of poor readers in the FR group matches those found in other Dutch studies (e.g. de Bree et al. 2010; van Bergen et al. 2012) as well as the international literature (e.g. Scarborough 1990; Snowling et al. 2007). The percentage of poor readers in the SLI group is lower than often reported in the literature (e.g. Catts, Hu, Larrivée & Swank 1994; McArthur, Hogben, Edwards, Heath & Mengler 2000, but see Catts et al. 2005).

Table 2. The distribution of normal and poor readers (see main text for criterion) in the typically developing (TD), Family Risk (FR) and SLI groups. Differing subscripts indicate significance by Fisher's Exact test with $p < .05$

	Poor reader	Normal reader	% poor readers
TD	1	27	$4\%_a$
FR	12	40	$23\%_b$
SLI	5	16	$24\%_b$
Total	18	83	18%

In order to validate our poor/normal reader classification, we determined if these two reading status groups differed on measures that are normally associated with tecŠical reading ability (see Table 3). Separate two-way (group by reading status) ANOVAs run on the results of the two spelling tasks, the phonological processing task and the text reading instrument (AVI) returned the same result: there was no significant main effect of group (TD vs. FR vs. SLI), but the effect of reading status was significant. The interaction of group and reading status did not reach significance in any of the tests.

The results of the reading comprehension test (SBR) show a different pattern, however. In addition to a significant effect of reading status (poor readers < normal readers), we obtained a significant effect of group, with post-hoc analyses indicating that particularly the SLI group underperforms in comparison to the TD and FR groups. This shows that the SBR measure picks up on both reading ability and (general) language ability. The conclusion we draw from these results is that the classification of reading status (normal/poor) on the basis of our EMT/Klepel criterion is valid.

Language profiles at age 8

In contrast to the reading-related tests, ANOVAs on each of the three language measures (vocabulary, morphology, syntax) yield significant group effects (see Table 3). The differences between TD children and children with SLI are significant for all three measures. FR children have higher vocabulary and syntax scores than children with SLI, while on the morphology test FR and SLI children do not differ significantly. Moreover, performance on the morphology test is significantly poorer in poor readers than in normal readers, irrespective of group.

The interactions between participant group and reading status are not significant for the morphology and syntax measures, but there is a significant interaction for vocabulary. This appears to be due to the fact that poorly reading FR children have lower vocabulary scores than their normal-reader peers, while the normal and poor readers in the SLI group do not differ in this respect. This interpretation is supported by a separate two-way ANOVA on the data of the FR and SLI groups only, which returned significant main effects (group: $F(1,69) = 6.39$; $p = .014$; reading status: $F(1,69) = 5.43$; $p = .023$) as well as, importantly, a significant interaction ($F(1,69) = 5.1$; $p = .027$).

We cross-correlated the results on all language measures taken at age 8. The results of the phonological processing task (phoneme deletion) are weakly and non-significantly correlated with those of the vocabulary test (N = 99; r = .18; $p = .08$). Phoneme deletion scores and morphology test scores correlate moderately and significantly (N = 97; r = .30; $p = .003$), and a fairly strong correlation is found for the phoneme deletion scores and the syntax test scores (N = 88; r = .46; $p < .001$). None of the other correlations were significant.

Table 3. Results on language, reading, spelling and phonological processing tests as obtained in the follow-up procedure at age 8. Subscripts indicate which group scores are significantly different ($p = .05$ or better) in pairwise post-hoc tests (Tukey or Games-Howell; only if corresponding F-value is significant: * $p < .05$; ** $p < .01$; *** $p < .001$)

Domain	Test	Reading status subgroups	TD		FR children		SLI children		Group	Reading status	Interaction
			M (SD)	N	M (SD)	N	M (SD)	N	F, η^2_p	F, η^2_p	F
TecŠical reading	EMT (real words)	all	11.82 (2.5)	28	10.27 (3.1)	52	10.05 (3.43)	21	2.94	.058	
	Klepel (pseudowords)	all	11.43 (2.46)	28	9.96 (3.17)	52	10.24 (3.6)	21	2.1	.128	
Spelling	Spelling / dictation	all	126.9 (8.89)	28	118.9 (10.62)	51	116.9 (9.98)	21	1.49	9.08** $\eta^2_p = .088$	.104
		Normal reader	127.2 (8.88)	27	121.2 (7.94)	40	120.1 (9.41)	16			
		Poor reader	118 (–)	1	110.4 (14.74)	11	107 (2)	5			
	Spelling / selection	all	54.2 (8.37)	27	45.3 (10.28)	44	42.6 (12.76)	19	1.8	15.54*** $\eta^2_p = .157$	.018
		Normal reader	54.7 (8.1)	26	47.1 (9.22)	39	46.1 (9.87)	15			
		Poor reader	41 (–)	1	31.4 (7.54)	5	31.6 (8.71)	4			
Phonological processing	Phoneme deletion	all	19.9 (4.45)	28	15.9 (6.49)	51	14.1 (5.63)	20	1.24	8.25** $\eta^2_p = .082$	.018
		Normal reader	20.2 (4.37)	27	17.2 (5.83)	40	15.7 (4.8)	15			
		Poor reader	14 (–)	1	11.3 (6.92)	11	9.2 (5.45)	5			
Reading comprehension	Reading comprehension (SBR)	all	106.5_A (5.16)	27	104.2_B (5.48)	46	99.2_{AB} (4.03)	20	3.53* $\eta^2_p = .075$	7.81** $\eta^2_p = .082$	
		Normal reader	106.7 (5.14)	26	105.2 (5.07)	39	100 (3.83)	16			
		Poor reader	101 (–)	1	98.4 (4.08)	7	96 (3.56)	4			

Table 3. (*continued*)

Domain	Test	Reading status subgroups	TD		FR children		SLI children		Group	Reading status	Interaction
			M (SD)	N	M (SD)	N	M (SD)	N	F, η^2_p	F, η^2_p	F
Text reading	Text reading level (AVI)	all	7.38 (1.44)	26	5.5 (2.27)	44	5.33 (2.44)	21	1.96	21.59*** $\eta^2_p = .203$	.284
		Normal reader	7.48 (1.39)	25	6.17 (1.82)	35	6.25 (1.98)	16			
		Poor reader	5 (–)	1	2.89 (1.97)	9	2.4 (0.89)	5			
Language	Vocabulary	All	46.8_{AB} (2.64)	28	44.8_{AC} (3.36)	52	40.9_{BC} (4.85)	21	8.03** $\eta^2_p = .145$	.458	4.27* $\eta^2_p = .082$
		Normal reader	46.7 (2.66)	27	45.9 (2.36)	40	40.9 (5.07)	16			
		Poor reader	49 (–)	1	41.1 (3.58)	12	40.8 (4.6)	5			
	TvK Morphology (norm score)	all	7.14_{AB} (1.23)	27	5.68_{A} (1.58)	51	4.86_{B} (1.56)	21	3.39* $\eta^2_p = .068$	3.97* $\eta^2_p = .041$	.598
		Normal reader	7.17 (1.24)	26	6.04 (1.48)	40	5.1 (1.59)	16			
		Poor reader	6.3 (–)	1	4.35 (1.22)	11	4.3 (1.42)	5			
	TvK syntax (norm score)	all	6.55_{A} (1.44)	25	5.76_{B} (1.86)	44	4.34_{AB} (1.59)	20	3.31* $\eta^2_p = .074$	.391	.247
		Normal reader	6.56 (1.47)	24	5.96 (1.76)	34	4.37 (1.76)	16			
		Poor reader	6.3 (–)	1	5.07 (2.11)	10	4.23 (0.79)	4			

Preschool language related to literacy and language at age 8

The performance levels of the three groups of participants in the two preschool tests showed a staircase pattern. In this section we want to establish if reading status as determined at age 8 can be linked to preschool task performance and whether poor performance on either task is a precursor to later reading difficulty. However, as pointed out earlier, not all children who took part in the preschool tests could be included in the follow-up at age 8. Consequently, we will first have to establish if the children who were included in the follow-up are representative of the full sample as regards the preschool (phonological and morphosyntactic) data. Of the 101 children who participated in the follow-up procedure, 62 also contributed to the data set of the inflection task (at age 3.5). The proportions of total error on this task for this group of 62 children were 0.149 for the TD controls, 0.213 for the FR children and 0.418 for the children with SLI. For 72 of the 101 children who took part in the follow-up phonological error detection data (age 5) are available. The average proportions of errors are 0.019 for the TD children, 0.048 for the FR children and 0.167 for the children with SLI. There are differences of up to 20% between the average scores of the full sample and those of the subset of children who returned for the follow-up. Nonetheless, the overall pattern (TD < FR < SLI) is the same for the total group and the subset that seen at age 8.

Inflection task results and reading status

The mean proportions of errors in the inflection task, broken down over group (TD, FR, SLI) and reading status (normal, poor) are presented in Table 4. In view of the low numbers of participants classified as *poor reader* in the TD and SLI groups (one in both), we refrained from running a full factorial ANOVA. Instead, we re-assigned the participants to one of four groups: TD (n = 22), FR / normal readers (n = 25); FR / poor readers (n = 8) and SLI (n = 7). A one-way ANOVA with proportion of errors as dependent variable and *new group* as a single factor returned a significant effect ($F(3, 58) = 3.01$; $p = .037$; $\eta^2_p = .135$), but there were no significant group differences on post hoc tests. Our tentative interpretation of these results is that while group membership makes a difference with regard to performance on the inflection task, reading status does not. This is corroborated by the absence of significant correlations between tecŠical reading scores (the sums of EMT and Klepel norm scores) and proportion of errors in the inflection task for the total sample of children as well as for the subset of FR children (all: r = .146; $p = .26$; FR children: r = .139; $p = .44$).

Table 4. Proportions of error in the inflection and phonological error detection tasks, broken down by group (typically developing – TD; family risk – FR; SLI) and reading status (normal, poor) as determined at age 8

Group	Reading status	Inflection task		Phon error detection task	
		N	M (SD)	N	M (SD)
TD	Normal	21	0.15 (0.16)	21	0.019 (0.039)
	Poor	1	0.1 (–)	0	–
FR	Normal	25	0.21 (0.22)	30	0.038 (0.043)
	Poor	8	0.24 (0.13)	9	0.080 (0.056)
SLI	Normal	6	0.47 (0.36)	8	0.174 (0.097)
	Poor	1	0.11 (–)	4	0.153 (0.190)

Phonological error detection and reading status

The rightmost column of Table 4 shows the proportions of errors in the phonological error detection experiment, broken down over group and reading status. A two-way ANOVA with proportion of errors as dependent variable and Group and Reading Status as factors returned a significant effect of Group ($F(2,67) = 16.62$; $p < .001$; $\eta^2_p = .332$) but not of Reading Status ($F(1,67) = 0.21$) or of the interaction ($F(1,67) = 1.81$; $p = .18$). Post hocs for group showed that TD and FR children made significantly fewer errors than children with SLI ($p < .001$). The difference between the TD and FR children was not significant.[1]

Similarly to what we described in the previous section, we regrouped the participants into four new categories: TD (n = 21), FR/normal readers (n = 30), FR/poor readers (n = 9), and children with SLI (n = 12). An ANOVA with *new group* as factor returned a significant effect ($F(3,68) = 15{,}21$; $p < .001$; $\eta^2_p = .402$). Post-hoc tests indicate significant differences between TD and FR/poor readers ($p = .05$), TD and children with SLI ($p = .009$), and FR/normal readers and children with SLI ($p = .022$). The difference between FR/normal readers and FR/poor readers was not significant ($p = .22$), nor was the difference between FR/poor readers and children with SLI ($p = .19$). The correlation between tecŠical reading scores (summed EMT and Klepel norm scores) and proportion of errors in the phonological error detection task was of medium magnitude and significant in the subset of FR children ($r = -0.32$, $p = .05$). A weak and non-significant correlation was obtained for the total sample ($r = -0.18$, $p = .13$). These results suggest that deficient phonological processing is related to poor reading in family risk children only.

1. The same analysis was also run without the TD data. The outcomes are similar to those reported: a significant effect of group (FR vs SLI), no significant effect of reading status and no significant interaction.

Case series analysis

In the previous section we used averaged group data to explore the interrelationships among phonological processing, other language skills, and reading status. However, group data do not tell us much about specific associations or dissociations within individuals. If we want to shed more light on the relation between SLI and dyslexia in the light of the various models introduced earlier, it is exactly these intra-individual patterns that we need to look at. The co-occurrence or non-co-occurrence of difficulties in tecŠical reading, phonological processing and morpho-syntax/non-phonological language ability is of primary importance. We address this issue by individually categorizing FR and SLI children as *normal* or *poor* on measures that reflect these domains. As pointed out above, tecŠical reading status is indexed by performance on the word and pseudo-word decoding tests (EMT and Klepel, respectively). Indicative of phonological processing capacity are performance on the error detection task conducted at age 5 and phoneme deletion performance at age 8. For non-phonological language ability, we look at the inflection task (age 3) as well as the language proficiency measures (vocabulary, morphology, syntax) obtained at age 8. For each of these tests, *poor* performance is defined as having a score at 1SD or more below the relevant mean. With regard to the language measures taken at age 8, a child was classified as *poor* if at least one of the three tests yielded a poor score. The data set used here comprised only the children for whom we were able to obtain tecŠical reading (EMT / Klepel) scores at age 8 and who had taken part in the phonological error detection experiment or the inflection test (or both) in their preschool years. Table 5 gives a summary of the results.

Table 5. Summaries of case series data

	FR / normal reader	**FR / poor reader**	**SLI / normal reader**	**SLI / poor reader**
Poor phonological error detection (age 5)	12/30 (40%)	6/9 (67%)	8/8 (100%)	2/4 (50%)
Poor phoneme deletion performance (age 8)	13/36 (36%)	7/11 (63%)	6/10 (60%)	3/4 (75%)
Poor Inflection (age 3)	7/25 (28%)	3/8 (37%)	4/6 (67%)	0/1 (0%)
Poor language tests (age 8)	3/36 (8%)	5/11 (45%)	6/10 (60%)	2/4 (50%)

The case series data suggest that phonological difficulties are a risk factor in the FR group, as a substantial number (but not all) of FR/poor readers as well as FR/normal readers perform poorly on these measures at both age 5 and age 8. Similarly, poor phonological processing seems to be an important characteristic of the SLI group (both normal and poor readers), at both time points.

The picture of the FR groups for the (non-phonological) language measures is different to that of phonology. At age 3, about one-third of the FR children scores poorly on the inflection task and in the FR children who were classified as a poor reader at age 8, this proportion is slightly higher than in the normal readers. The language data obtained at age 8 suggest that a large minority of poorly reading FR children have (non-phonological) language difficulties. Possibly, this is a consequence of poor reading, rather than a cause. In the sample of children with SLI, a small majority (~57%) scores poorly on the language tasks, and there is no apparent relation to reading status.

In view of the models presented earlier, it is useful to explore if there is an implicational relation between phonological processing difficulty and poor language performance. For this purpose, we looked at FR children for whom data of both *preschool* phonological processing and inflection production experiments are available (see Table 6, panel a). Twenty-four of such cases were found, 15 of which scored poorly in the inflection test. Ten of these 15 have normal scores on the phonology test; the remaining 5 are classified as poor. These figures do not support an implicational relation between phonological processing and morpho-syntactic skill.

Table 6. Breakdown of FR cases over reading status, performance on phonological processing tasks, and non-phonological language tasks

(a) Preschool	**Poor readers**			**Normal readers**		
	Phonology poor	**Phonology normal**	**Total**	**Phonology poor**	**Phonology normal**	**Total**
Morphosyntax poor	3	–	3	2	10	12
Morphosyntax normal	1	1	2	4	3	7
Total	4	1	**5**	6	13	**19**

(b) Age 8	**Poor readers**			**Normal readers**		
	Phonology poor	**Phonology normal**	**Total**	**Phonology poor**	**Phonology normal**	**Total**
Language poor	3	2	5	2	–	2
Language normal	3	2	5	11	23	34
Total	6	4	**10**	13	23	**36**

At age 8, we have relevant and complete data of 46 FR children. Seven out of this group are classified as poor with regard to language (vocabulary, morphology, syntax); phonology is classified as poor in 5 of these 7 cases. There are 39 children with normal language scores; 14 of these have poor phonological processing. Again, these figures do not seem to agree with an implicational relation between phonology and non-phonological language skills.

In the (small) sample of SLI children, the pattern of results is slightly different. Four out of 5 children score poorly in the inflection task at age 3, and all four of them also performed poorly in the phonological task. The remaining child had good scores on both phonological error detection and inflection. The data obtained at age 8 are similar to those of the FR children: there is no systematic association between poor language scores and poor phonological processing.

Discussion

We set out to chart the differences and commonalities with regard to language abilities and literacy skills in children with (a familial risk) of dyslexia and children with SLI. Previous studies have argued that SLI and (FR of) dyslexia show marked phenotypical similarities. Our results were gathered in an attempt to replicate these earlier observations and to contribute to the theoretical discussion concerning the relation between SLI and dyslexia. In the light of the models that have been proposed to account for the overlap between SLI and dyslexia, we formulated a number of questions, addressing the presence of phonological and other (oral) language difficulties (specifically morphosyntactic) in children with SLI and (FR of) dyslexia, and the degree of overlap between the two groups with regard to such difficulties. Furthermore, we were interested to see if phonological difficulties and other language difficulties are implicationally related, and we wanted to know if the severity and prevalence of phonological and other oral language difficulties are related to later literacy difficulties.

Before we go on to discuss our results in the light of our research questions, two general observations need to be made. First, the data reported here clearly replicate the 'staircase pattern' we found in earlier studies (e.g. van Alphen et al. 2004). In the preschool (preliterate) stage, children with SLI perform most poorly, and children with a FR of dyslexia show a performance level intermediate between those of TD controls and children with SLI. This was attested in the phonological error detection data as well as the inflection task results. At age 8 a similar, a statistically reliable staircase pattern was found as well for vocabulary, morphology and syntax. In the phonological processing data obtained at this age the pattern is numerically present, but not statistically reliable. Taken together, these results suggest that, on the one hand, dyslexia involves more than a phonological processing deficit, and, on the other, SLI involves more than a morphosyntactic deficit.

A second general observation is that reading and spelling difficulties at age 8 can be associated with both a family risk of dyslexia and SLI. We noted, however, that the percentages of children classified as poor readers are relatively low, despite our fairly lenient criterion. Reading comprehension is (on average) more deficient in the SLI group than in the FR group, which is supportive of the notion that in children with SLI, but not in children with dyslexia, reading performance is affected by limitations in language understanding.

Phonological processing difficulty is expected in children with a FR of dyslexia, specifically in those children who manifest literacy difficulties after some years of formal instruction. On average, FR children performed more poorly on the preschool phonological task, as expected, but at the same time we noted in our case series analysis that not all FR children (viz. 48%) could be considered as poor performers. A similar finding was reported by Ramus et al. (2013). However, phonological processing performance in FR children at age 5 appears associated with their reading status at age 8 – poor phonological performance predicts poor literacy skills for the majority of cases.

Interestingly, children with SLI are on average poorer in phonological processing at age 5 than FR children. The results of the case series analysis confirms this picture: 83% of the children with SLI are classified as poor performers in the phonological error detection task at age 5, vs. 48% in the FR children. The difference between the groups is persistent: At age 8, 69% of SLI children were classified as poor performers on the phoneme deletion task, vs. 43% of the FR children.

Phonological processing performance at age 5 (the error detection task) was shown to have some degree of predictive value with respect to later reading in the FR children. It is remarkable, however, that a large majority of children with SLI, irrespective of their reading status, were poor performers in the phonological error detection task (age 5), and that their performance on this task was not correlated with later reading status. Thus, it seems justifiable to conclude that phonological processing difficulty in children with SLI is unrelated to later reading skill, while it is in FR children. This finding is in agreement with observations we made in previous studies (de Bree et al. 2010, 2012). This might indicate that the phonological difficulties in children with SLI and FR are qualitatively different, as suggested by Ramus et al. (2013).

As expected, children with SLI in our sample had marked difficulty with the morphological inflection task at age 3; the average performance level was below that of TD children and children with a family risk of dyslexia. The average performance level of children with a family risk is better than that of the children with SLI, and lower than that of the TD children. At age 8, the average language scores of the children with SLI are still the lowest of the three groups. It appears that the variability is high, however, in both non-typical groups, and this is confirmed by the case series data. Fifty-seven percent of the children with SLI and 30% of the FR children were classified as poor performers in the inflection task at age 3. At age 8, 57% of the children with SLI performed poorly performing on the language tasks, vs. 17% of the FR children. Thus, a FR of dyslexia – particularly also when associated with poor literacy skills – is not fully dissociated from non-phonological language difficulties. What is furthermore remarkable about these results is that they suggest that not *all* children diagnosed with SLI have grammatical difficulties. It is conceivable that this reflects the heterogeneity of the SLI group – some of the children perhaps did not fall within the 'grammatical SLI' subtype (Van der Lely & Marshall 2011). On the other hand, it is also conceivable that some of the children have been misdiagnosed, and were in fact language-delayed, rather than disordered.

Nonetheless, the data suggest that developmental trajectories are different for SLI and FR of dyslexia. Difficulty in grammar is generally persistent in the SLI group (as would be expected), while the pattern in children with a FR of dyslexia is more complex. These children have better vocabulary and syntax at age 8 than children with SLI, whereas their performance on the morphology test does not differ significantly from the SLI group. In combination with the results of the inflection task obtained at age three, this suggests that morphological ability is persistently weak in FR. Morphology is also the only language measure at age 8 that shows an effect of reading status. Thus, it seems as if poor morphological ability is connected to reading difficulty (see Vogel 1974). We can speculate that the connection is an indirect one, mediated by phonology, in line with proposals done by Joanisse, Manis, Keating and Seidenberg (2000) and Rispens (2004), among others. Thus, poor phonological skills would on the one hand cascade into poor morphology, and on the other hamper the development of literacy skills. However, this scenario would predict that preschool phonology scores are predictive of inflection performance, which we did not observe (see also Robertson et al. 2013). An alternative account for the weak morphology – poor literacy association at age 8 is that a morphological deficit is a *result* of limited reading experience. This interpretation would seem to agree with the observation that there is virtually no (statistical) connection between morphosyntactic skills probed at age 3 and later reading status. However, we cannot resolve this issue on the basis of our data and further research is clearly warranted.

On a more general note, the developmental relation between phonological difficulty and difficulties in other, non-phonological language domains needs further scrutiny. We found positive correlations between phonological processing performance and non-phonological language performance, but the case series data did not show a clear implicational relation between poor phonological processing and poor non-phonological language skills. This would seem to agree with proposals to the effect that phonological and non-phonological deficits are separate and independent causal factors in language and literacy-related developmental disorders (Bishop & Snowling 2004; Ramus et al. 2013).

In summary, the results we reported here are consistent with earlier studies that show a close phenotypical resemblance of SLI and (FR of) dyslexia. Children with (FR of) dyslexia not only have a deficiency in phonological processing, but also in non-phonological aspects of language, notably morphology and morphosyntax. Children diagnosed with SLI show a language profile in which phonological difficulties are prominent, next to the expected morphosyntactic problems. Moreover, a large proportion of children with SLI go on to develop literacy problems, similar in degree and quality to those seen in dyslexics. By and large, these observations would seem to be sympathetic to an account that considers the two conditions as points on a continuum, differing only in severity. However, closer scrutiny the performance patterns in our sample suggests otherwise. Our data – both the group averages and the case series – strongly suggest that the interrelations between various language and literacy skills are quantitatively and qualitatively different in the two groups of non-typical children. This outcome is not easy to match with any of the models on the relation between SLI and dyslexia sketched by Catts et al. (2005). On the other hand, our results may well be in line with a multifactorial account, in which SLI and dyslexia share certain risk factors and differ on others (Pennington 2006; Pennington & Bishop 2009). What we cannot do on the basis of the results presented here, however, is to indicate what exactly the nature of those shared and non-shared risk factors is.

In part, this is due to limitations of our data and analyses. The data set presented here is small, and, more importantly, incomplete, in the sense that not all tests and experimental tasks have been administered to all participants. Furthermore, the phonological and other language skills that we speak about entail much more than what the simple procedures we employed probed. Another point is that our classifications are partially uncertain, both with regard to reading status and language impairment. We cannot be sure that the children we labeled *poor readers* are, in fact, dyslexics. Neither can we be sure that the children in the SLI group all have persistent full-blown language impairment. Finally, in connection to the previous point, it is more than likely that our groups are not only heterogeneous (primarily as a result of the indeterminacy of our inclusion criteria and cut-off points), but also heterogeneous to different degrees. It can be expected that children selected on the basis of family risk represent a broader range of interindividual difference than children who have been selected on the basis of a clinical criterion (our SLI group; see Carroll & Myers 2010). This can and should be addressed in future research, for instance by including a group of children at familial risk of SLI. We are confident that including children at familial risk – as we did in the current study for dyslexia – is a valuable addition to longitudinal designs aiming to elucidate the interrelationships and developmental trajectories of language and literacy-related developmental disorders.

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