

## Research Report

# Non-word repetition in adolescents with specific language impairment (SLI)

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### Abstract

**Background:** Non-word repetition (NWR) difficulties are common, but not universal, among children with specific language impairment (SLI). However, older children and adolescents with SLI have rarely been studied. Studies disagree on the relationship between NWR difficulties and difficulties with other areas of language and literacy. There is also no consensus about the underlying reason for the difficulties (some) children with SLI have with NWR. Some scholars argue that difficulties with phonological short-term memory or storage cause NWR and other language difficulties, whereas others argue that difficulties with NWR may be due more to difficulties with phonological representations.

**Aims:** To investigate NWR abilities and their relationship to other language and literacy abilities in a group of older children with SLI and typically developing controls. To investigate the relative effects of increasing phonological complexity and the number of syllables on the ability of the participants to repeat non-words.

**Methods & Procedures:** An NWR test (The Test of Phonological Structure; TOPhS), which systematically varies phonological complexity, was administered to 15 participants with SLI (aged 11–15 years), 30 language and 15 age controls. Standardized language and literacy tests and a specific test of verb agreement and tense marking (Verb Agreement and Tense Test; VATT) were also administered.

**Outcomes & Results:** The participants with SLI showed a bimodal distribution: half achieved age-appropriate NWR, while half scored significantly below language and age controls ( $d > 7$ ). The two groups of participants with SLI (high versus low scorers) only differed in NWR ( $d > 5$ ) and agreement ( $d > 3$ ) and tense marking ( $d > 2.5$ ), not on the standardized language and literacy measures administered. NWR was also highly correlated with verb agreement ( $r = 0.97$ ) and tense marking ( $r = 0.89$ ) among participants with SLI, but not among controls ( $r = 0.16$  and  $0.30$  respectively). Phonological complexity was related to NWR accuracy, particularly among participants with SLI. The number of syllables had no independent effect on NWR performance for any group.

**Conclusions & Implications:** Some children with SLI (who have good NWR) have language difficulties unrelated to any of the factors underlying NWR. Others have a (probably additional) deficit which affects NWR and also leads to greater difficulties with verb agreement and tense marking. The results indicate that difficulties with this particular NWR test are more likely to be due to a deficit with phonology per se, rather than with phonological short-term memory or storage.

**Keywords:** specific language impairment (SLI), adolescents, non-word repetition (NWR), verb agreement and tense marking, phonological complexity.

### What this paper adds

#### *What is already known on this subject*

Many children with SLI find repeating non-words hard. It is unclear (1) whether all children (particularly older children and adolescents) with SLI have NWR difficulties; (2) how these difficulties are related to their general language and literacy difficulties; and (3) what underlies their NWR difficulties.

#### *What this study adds*

It was found that only half of the adolescent participants with SLI had NWR difficulties, despite having severe and persistent difficulties with other areas of language. Thus, difficulties with NWR (or indeed any of the possible factors which underlie NWR difficulties) are unlikely to be the underlying cause of the language impairments of at least half of the participants. Difficulties with NWR were related to difficulties with verb agreement and tense marking, but not to performance on general standardized language or literacy tests. A preliminary analysis of the factors in the non-words that may affect performance suggests that phonological complexity is more strongly related to performance than the number of syllables, particularly among children with SLI. This suggests difficulties with phonological representations are more likely to underlie their NWR difficulties than phonological short-term memory or storage, but this requires further investigation.

### Introduction

Children with specific language impairment (SLI) have difficulties acquiring language despite adequate intelligence, hearing, physical development and exposure to language. When compared with age controls, they score lower on most areas of language (e.g., vocabulary, lexical learning, morphology, syntax, argument structure, text comprehension). However, they also score lower than controls matched on general language abilities in specific areas. The areas of morphosyntax and syntax have been well researched and a general consensus has been reached that (English) children with SLI have particular difficulties with verb tense and agreement, making more errors than language controls (e.g., Leonard *et al.* 1992, Rice *et al.* 1995) as well as a number of areas of syntax (e.g., Bishop 1979, van der Lely 2005). In addition, a key finding over many years is of particular problems with non-word repetition (NWR) (e.g., Briscoe *et al.* 2001, Edwards and Lahey 1998, Farmer 2000, Gallon *et al.* 2007, Gathercole and Baddeley 1990, Montgomery 1995, 2004). The relationship between NWR difficulties and other core deficits is the subject of considerable discussion (Gathercole 2006).

A recent meta-analysis of NWR studies including children with SLI (Graf Estes *et al.* 2007) gave a combined effect size of  $d = 1.27$  (ranging from 0.62 to 4.34 in the studies analysed) for the difference between children with SLI and age controls. The effect sizes were not associated with the age of the children being tested, which suggests the magnitude of the deficit in SLI remains relatively stable across ages. Indeed, differences between children with SLI and typically developing (TD) children have been found in older children and adolescents with SLI aged 8–13 years (Munson *et al.* 2005) and 12–19 years (Gallon *et al.* 2007).

### *Variation in NWR performance among children with SLI*

NWR has been proposed as a culturally unbiased clinical marker for SLI which is independent of IQ or social economic status (e.g., Conti-Ramsden *et al.* 2001, Gardner *et al.* 2006). However, several studies have reported an overlap between the scores of children with SLI and those of TD children (Bishop *et al.* 1996, Edwards and Lahey 1998, Gallon *et al.* 2007, Montgomery 1995). This indicates that there are children with SLI who do not have difficulties repeating non-words. Indeed Botting and Conti-Ramsden (2001) reported that 147 out of 200 children with SLI scored below  $-1$  SD for their age on an NWR test. Therefore, by implication, 53 (26.5%) must have scored within or above the normal range. Some recent studies have documented the numbers or percentages of children with language impairments (or at risk of language impairments) who are not impaired on NWR tests. Chiat and Roy (2007) found 25% of their SLI group aged 2;6–4 years scored within the normal range ( $> -1$  SD) on their repetition test which included both words and non-words. Gardner *et al.* (2006) found 59% of children with SLI passed the Grammar and Phonology Screening (GAPS) phonology subtest (using an NWR procedure). Bishop *et al.* (2006) also found that of children who had difficulties marking verb agreement and tense accurately, less than half also had difficulty repeating non-words. These studies, however, only considered children under the age of 12 years. Variation in performance in older children with SLI to the authors' knowledge has not yet been investigated. This is important to study as when children do not show difficulties with NWR, it is unlikely they have ongoing difficulty with any of the lower-level processes involved

in this procedure (e.g., auditory or phonological processing, phonological storage or short-term memory).

One factor that may be related to variation in SLI performance on NWR tasks is the presence or absence of co-occurring dyslexia as children with both SLI and dyslexia perform significantly worse on NWR tasks than children with SLI only (Baird *et al.* 2011, Bishop *et al.* 2009, Catts *et al.* 2005, Rispens and Parigger 2010). Indeed, two of these studies (Bishop *et al.* 2009, Rispens and Parigger 2010) found that the children with SLI only did not differ from TD age controls.

#### *Relationship between NWR and other language and literacy measures*

Correlational evidence of a link between NWR and other language measures in SLI is inconclusive. Some studies have calculated correlations using a combined (SLI and TD) group. This assumes that children with SLI and TD children lie on a continuum. However, children with SLI may have specific difficulties that affect particular language components (e.g., van der Lely 2005). Therefore, grouping them together with TD children may mask potential differences in correlations between the two groups. For those studies that have considered children with SLI separately, NWR has been found to correlate significantly with expressive language as measured on general language tests (e.g., Edwards and Lahey 1998, Montgomery and Windsor 2007). Some studies found significant correlations with sentence comprehension (e.g., Montgomery 1995, Sahlen *et al.* 1999), whereas others did not (e.g., Gallon *et al.* 2007, Montgomery 2004). Botting and Conti-Ramsden (2001) found that NWR predicted all language measures apart from vocabulary. Indeed, significant correlations between NWR and vocabulary are rarely reported for children with SLI (e.g., Farmer 2000, Hansson *et al.* 2004), with more studies finding no significant correlation (e.g., Briscoe *et al.* 2001, Edwards and Lahey 1998, Gallon *et al.* 2007). This is despite such a correlation being found in (generally younger) TD children (e.g., Briscoe *et al.* 2001, Gathercole and Baddeley 1989). The only study to the authors' knowledge reporting correlations between literacy and NWR measures (de Bree *et al.* 2010) found no correlation between these among children with SLI, but did find a correlation among children at risk of dyslexia.

For verb agreement and tense marking, one study reported weak, but non-significant correlations with NWR within their SLI group (Norbury *et al.* 2001), while others reported significant correlations (Bishop *et al.* 2006, Thordardottir 2008). Formation of the regular past tense and also third-person singular agreement usually results in a consonant cluster, and

Marshall and van der Lely (2007) found that children with SLI (but not TD children) were less likely to produce past tense forms that require a word-final cluster (a phonologically more complex structure) than those which do not. Thus, phonological abilities can impact on verb agreement and tense marking. Phonological abilities are also likely to impact on NWR performance and at least some of the variation in NWR in SLI discussed above could be due to variation in phonological abilities. Thus, a correlation would be predicted between a past tense and agreement test requiring clusters and an NWR test including clusters in children with SLI, because of the impact of phonological abilities on both tasks. However, if some children with SLI do not have difficulties with NWR, as suggested by previous studies, they presumably do not have phonological difficulties (or difficulties with any of the other processes underlying NWR). Then, the question remains whether they would have difficulties with verb agreement and tense marking, as such difficulties have been suggested as a marker for SLI (e.g., Rice and Wexler 1996). Although phonology may have an impact on this area, knowledge of syntactic and morphological rules and the ability to apply them are also required and may remain impaired in all children with SLI, even in those whose phonological abilities may be relatively unimpaired.

#### *Factors underlying difficulties with NWR*

The underlying causes of the difficulties many children with SLI have with NWR and the extent to which these cause difficulties with other areas of language have been the subject of considerable debate (see Gathercole 2006 and associated commentaries). Part of the reason for this lack of agreement is that NWR is a complex task that involves several cognitive processes (Snowling *et al.* 1991), any of which could underlie difficulties with the task. Different NWR tasks are designed to test different properties of non-words. Gathercole and Baddeley's (1990) Children's Non-word Repetition (CNRep) test aimed to test phonological short-term memory and therefore varies the length of non-words in order to analyse the effect of length on performance. Dollaghan and Campbell's (1998) Nonword Repetition Test (NRT) also varies length, but it was designed to minimize complexity so excludes clusters and late-acquired consonants. In contrast, Edwards and Lahey (1998) manipulated the phonological complexity of their non-words and carried out detailed error analyses to rule out difficulties with discrimination or planning and executing a response. In this study we used the Test of Phonological Structure (TOPhS; van der Lely and Harris 1999) that systematically manipulates prosodic-phonological complexity rather than length, thus aiming

to test phonological representations themselves rather than the associated processes of phonological short-term memory or storage.

Previous studies have mainly examined the effect of length (usually measured in the number of syllables) and phonological complexity. Findings of a length effect have been used to support theories implicating phonological short-term memory (Gathercole and Baddeley 1990) or storage (Gathercole 2006) and findings of a phonological complexity effect to support theories implicating phonology and phonological representations (Chiat 2001, Edwards and Lahey 1998, Gallon *et al.* 2007, Marshall and van der Lely 2009). Most studies that considered word length found performance decreased with increasing word length for all children, but particularly those with SLI (e.g., Bishop *et al.* 1996, Dollaghan and Campbell 1998). In individual studies, differences between children with SLI and TD children at shorter word lengths were often not significant but when combined in a meta-analysis, Graf Estes *et al.* (2007) found children with SLI were impaired at all word lengths, but effect size magnitudes increased with word length. Thus, while phonological short-term memory or storage could be involved, impairment on even short non-words implicates other mechanisms or processes.

One difficulty with analyses of length effects is that in many NWR tests (especially the CNRep) length is conflated with other factors such as phonological complexity (longer words often have more complex stress patterns, or 'metrical structure'), phonotactic probabilities and possibly also word-likeness (which is itself related to phonotactic probability; Munson *et al.* 2005). Munson *et al.* (2005) found a main effect of length using non-words containing either three or four syllables. But when they carried out a regression analysis including word-likeness and phonotactic probability, length did not predict a significant proportion of the variance, unlike the other two factors.

Several studies have considered the impact of phonological complexity in terms of the presence or absence of consonant clusters. All have found that non-words involving consonant clusters are harder to repeat, but some have found this affects both children with SLI and TD children equally (Edwards and Lahey 1998, Gathercole and Baddeley 1990), while others have found a complexity by group interaction where children with SLI were more affected by the addition of consonant clusters than TD children not only in general (Archibald and Gathercole 2006, Bishop *et al.* 1996, Briscoe *et al.* 2001) but also even on monosyllabic non-words (Gallon *et al.* 2007).

Another aspect of phonological complexity concerns words' metrical structure (i.e., stress patterns). Investigations of metrical structure have revealed that both young TD children and young children with SLI omit more

syllables if they are unstressed and if they are in a pre-stress rather than a post-stress position (Chiat and Roy 2007). Omission of syllables is less frequent in older children with SLI (Gallon *et al.* 2007, Marshall and van der Lely 2009), but these studies found metrical structure still impacts on the ability of children with SLI and those with dyslexia (but not TD children; Marshall and van der Lely 2009) to repeat non-words.

### Summary

NWR has been proposed as a possible clinical marker of SLI, but variability in performance has been reported for younger children with SLI. Only one study (Gallon *et al.* 2007) has included adolescents with SLI and thus the degree of variability in this age group is uncertain. We therefore investigated the NWR abilities of older children with SLI comparing them with both age and language controls, extending Gallon *et al.*'s (2007) study where they used several groups of language controls but not age controls.

NWR has been found to be related to other language measures in SLI, but this is not universal. We therefore investigated correlations between NWR and a range of general language and literacy measures and also a specific measure tapping verb agreement and tense marking, within both children with SLI and TD children. We predicted that the children with SLI would have particular difficulties with verb agreement and tense marking, as this has also been proposed as a clinical marker for SLI (e.g., Rice and Wexler 1996). However, as Marshall and van der Lely (2007) pointed out, phonological complexity impacts on past tense and agreement. Therefore, this predicts that there is likely to be a significant correlation between the children's performance on verb agreement and tense marking and NWR (using the TOPhS) as both involve complex phonology (consonant clusters).

Furthermore, while there is a general consensus that NWR is constrained by multiple processes, the relative importance of these processes, particularly as concerns the poor NWR of children with SLI is still the topic of much debate (see Gathercole 2006 and associated commentaries). Many researchers view poor phonological short-term memory or storage as the root cause, while others propose difficulties forming phonological representations could underlie poor NWR performance. We will investigate this using the TOPhS whose stimuli vary in both complexity and length. These variables are correlated, but not perfectly. We are therefore able to perform a preliminary analysis by items to determine whether length and/or phonological complexity make an independent contribution to the variance in TOPhS scores.

*Aims of the study*

The aims of the study were as follows:

- To evaluate Gallon *et al.*'s (2007) finding that older children and adolescents with SLI have more difficulties with NWR than TD children and investigate the variation in NWR performance among this older SLI group.
- To examine correlations between NWR performance on the TOPhS and other language and literacy measures in children with SLI and TD children separately.
- To investigate the relative contributions of length and phonological complexity to the ability of children with SLI and TD children to repeat non-words accurately.

**Methods***Participants*

Fifteen participants with persisting SLI (mean age = 13;1 years, range = 11;0–14;11), 30 language controls (mean age = 8;5, range = 5;4–12;2) and 15 age controls (mean age = 13;1, range = 11;3–14;10) participated. The participants with SLI all attended a specialist school in the UK for children with primary language impairments. All children in the school who were aged between 11 and 15 and met the following criteria were recruited: (1) receptive and expressive language difficulties (at least  $-1.5$  SD below the mean) as measured on the Clinical Evaluation of Language Fundamentals—3 (CELF-3 UK; Semel *et al.* 1995), (2) typical non-verbal performance abilities (not more than  $-1$  SD below the mean) on the mean of Matrices and Pattern Construction from the British Ability Scales II (BAS-II; Elliot *et al.* 1996), (3) intelligible spontaneous speech, (4) no hearing impairment, neurological dysfunction, structural abnormalities or diagnosis of autism or Asperger's syndrome, and (5) written consent given by the parents.

The participants with SLI were also tested on the Wechsler Objective Reading Dimensions (WORD; Rust *et al.* 1993). As a group they scored on average in the impaired range on Reading Accuracy (mean SS = 72) and Spelling Accuracy (mean SS = 75). At an individual level, three participants scored within the normal range on both Reading and Spelling Accuracy. All the others scored more than 1.5 SD below the mean on Reading Accuracy, although two of these scored within the normal range on Spelling Accuracy. Thus, for only three of the participants with SLI could dyslexia be ruled out.

The TD controls were recruited from six mainstream schools in the same geographical region as the SLI school. None had identified special educational needs

or English as an additional language. They scored above  $-1$  SD on both performance IQ (mean of Matrices and Pattern Construction from the BAS-II) and language abilities. Language was tested using the Formulated Sentences subtest of the CELF-3 (which requires participants to create sentences including particular words), the British Picture Vocabulary Scale—II (BPVS-II, a multiple-choice vocabulary comprehension test; Dunn *et al.* 1997) and the Test of Reception of Grammar (TROG; a multiple-choice sentence comprehension test; Bishop 1989). Each language control child was individually matched to a child with SLI on the basis of performance IQ (within 1 SD) and either the BPVS (15 'BPVS controls': raw score within 3 points) or the TROG (15 'TROG controls': matched on exact raw score). They were also required to score within the normal range for their age (i.e., not more than 1 SD above or below the mean) on the test with which they were matched to the participants with SLI. The age controls were individually matched to the participants with SLI by age (within 3 months) and also scored within the normal range (within 1 SD of the mean) on the BAS-II (performance IQ).<sup>1</sup> The scores for the four groups on the matching criteria are shown in table 1.

In order to validate the matching procedures, the groups were compared on age and raw scores of the language tests used for matching. We found a significant effect of age,  $F(3,56) = 51.18$ ,  $p < 0.001$ ,  $\eta^2 = 0.73$ , where the participants with SLI did not differ from the Age controls,  $p = 1.0$ ,  $d = 0.004$ , but differed significantly from both TROG,  $p < 0.001$ ,  $d = 3.35$ , and BPVS controls,  $p < 0.001$ ,  $d = 3.03$ . The latter two groups did not differ from each other,  $p = 1.0$ ,  $d = 0.3$ , but did differ from the Age controls (TROG:  $p < 0.001$ ,  $d = 3.34$ ; BPVS:  $p < 0.001$ ,  $d = 3.03$ ).

The four groups differed significantly on the BPVS raw score,  $F(3,56) = 18.874$ ,  $p < 0.001$ ,  $\eta^2 = 0.50$ . Post-hoc tests showed the participants with SLI did not differ from either their BPVS,  $p = 1.0$ ,  $d = 0.01$ , or TROG controls,  $p = 1.0$ ,  $d = 0.28$ , but scored significantly lower than their Age controls,  $p < 0.001$ ,  $d = 2.13$ , as did both the TROG,  $p < 0.001$ ,  $d = 2.41$ , and BPVS controls,  $p < 0.001$ ,  $d = 2.15$ , who did not differ from each other,  $p = 1.0$ ,  $d = 0.27$ .

The four groups also differed significantly on the TROG raw score,  $\chi^2(3) = 23.46$ ,  $p < 0.001$ .<sup>2</sup> Post-hoc tests showed the participants with SLI did not differ from either their TROG,  $W = 232.5$ ,  $n_1 = 15$ ,  $n_2 = 15$ ,  $p = 1.0$ , or BPVS controls,  $W = 74.5$ ,  $n_1 = 15$ ,  $n_2 = 15$ ,  $p = 0.11$ , but did differ from their Age controls,  $W = 130$ ,  $n_1 = 15$ ,  $n_2 = 15$ ,  $p < 0.001$ . The TROG controls differed from the Age controls,  $W = 130$ ,  $n_1 = 15$ ,  $n_2 = 15$ ,  $p < 0.001$ , whereas the BPVS controls did not,  $W = 185.9$ ,  $n_1 = 15$ ,  $n_2 = 15$ ,  $p = 0.05$  (Bonferroni corrected  $\alpha = 0.008$ ). Again, the TROG

Table 1. Mean (SD) and ranges on matching criteria.

	SLI	TROG controls	BPVS controls	Age controls
TROG	15.40 (2.32)	15.40 (2.32)	17.00 (1.69)	18.33 (0.90)
Range	9 to 18	9 to 18	15 to 19	17 to 20
BPVS	91.07 (14.24)	87.00 (16.17)	90.87 (13.84)	121.87 (13.45)
Range	63 to 115	58 to 120	65 to 112	99 to 149
BAS	-0.04 (0.82)	0.33 (0.60)	0.53 (0.68)	0.06 (0.66)
Range	-0.95 to 1.55	-0.60 to 1.25	-0.55 to 1.95	-1.15 to 1.60
Age	13;1 (1;3)	8;3 (1;8)	8;8 (1;6)	13;1 (1;3)
Range	11;0 to 14;11	5;4 to 11;3	5;10 to 12;2	11;3 to 14;10

Note: Raw scores are given for BPVS and TROG, z-scores for BAS, and years; months for age.

and BPVS controls did not differ significantly from each other,  $W = 194.5$ ,  $n_1 = 15$ ,  $n_2 = 15$ ,  $p = 0.11$ .

Thus, in summary, the Age controls had higher BPVS and TROG raw scores than the participants with SLI and the language controls. The two language control (TROG and BPVS) groups did not differ significantly from each other on the language tests or age. The relationship between the SLI group and the BPVS versus TROG controls was also the same. For these reasons, the TROG and BPVS control groups were merged to form a larger 'language control group'. This group consisted of 30 children, 15 matched to the SLI group on the TROG and 15 on the BPVS.

### Non-standardized assessments

#### Non-word repetition: Test of Phonological Structure (TOPhS; van der Lely and Harris 1999)

The TOPhS consists of 96 non-words, which are derived from four basic non-words / $\text{dep}\partial$ /, / $\text{ptf}\text{f}\text{f}$ /, / $\text{ket}\partial$ /, / $\text{fip}\partial$ / with the simplest stress pattern (Strong Weak, SW) and no consonant clusters, thus fitting the template CVCV. The 24 non-words based on the basic non-word / $\text{dep}\partial$ / are shown in table 2. The structure of the NWs based on the other three basic words vary in the same ways as those based on / $\text{dep}\partial$ / . The variants of the basic non-words were constructed using five binary phonological parameters, three of which control aspects of 'syllabic structure' (including the addition of consonants to form consonant clusters such as 'pr' and 'kl') and two of which control aspects of 'metrical structure' (involving stress patterns). Each parameter has two options: marked or unmarked (Harris 1994). The unmarked structure occurs in all languages and appears early in the phonological acquisition process whereas the marked structure occurs only in a subset of languages and is acquired relatively late.<sup>3</sup>

Of the three parameters controlling syllable structure, one establishes whether an *onset* contains one consonant (unmarked, e.g., / $\text{dep}\partial$ /) or a consonant cluster (marked, e.g., / $\text{drep}\partial$ /). Another determines

whether a *rhyme* is open, i.e., ends in a vowel (unmarked, e.g., / $\text{dep}\partial$ /) or is closed, i.e., ends in a consonant (marked, e.g., / $\text{demp}\partial$ /). A third establishes whether a *word ends* in a vowel (unmarked, e.g., / $\text{dep}\partial$ /) or a consonant (marked, e.g., / $\text{dep}\text{f}$ /). The two parameters controlling metrical structure establish whether a weak syllable is adjoined to the beginning (*Left Adjunction*) or the end of the non-word (*Right Adjunction*). Adjunction adds to the metrical complexity of a word and constitutes the marked option. Left Adjunction leads to the marked stress patterns WS (e.g., / $\text{b}\partial^{\text{L}}\text{dep}\partial$ /) or WSW (e.g., / $\text{b}\partial^{\text{L}}\text{dep}\partial$ /) and Right Adjunction to the marked pattern SWW (e.g., / $\text{dep}\partial^{\text{R}}\text{f}\text{f}$ /). Words with both Left and Right Adjunction are the most complex metrically and have the marked stress pattern WSWW (e.g., / $\text{b}\partial^{\text{L}}\text{dep}\partial^{\text{R}}\text{f}\text{f}$ /).

The five parameters of the TOPhS allow us to look at the effects of phonological complexity in general (by counting how many of these five parameters are 'marked'), or specifically at 'syllabic complexity' (the number of marked syllable parameters, Onset, Rhyme and Word End) or 'metrical complexity' (the number of marked metrical parameters, Left and Right Adjunction). To analyse the effect of length, we counted the number of syllables in each non-word. Table 2 shows (for non-words based on / $\text{dep}\partial$ /) which parameters are marked (highlighted in bold and underlined in non-word) and also gives a count for overall phonological complexity, syllabic complexity and metrical complexity as well as the number of syllables.

The relationship between length and complexity on the TOPhS is shown in table 3. It shows the number of non-words that have a particular number of marked structures and number of syllables. The correlation between the number of marked structures (phonological complexity) and the number of syllables (length) is  $r = 0.27$ ,  $p = 0.009$ .

The participants were told they would hear some 'funny, made up words', which they should try to repeat into a microphone. The list of TOPhS non-words was audio recorded by a female native English speaker using a Bruel and Kjaer sound level meter

**Table 2. Structure of the TOPhS test (van der Lely and Harris 1999) using one of the four basic words as an example. Three other basic words were used in the same way to create the remaining non-words.**

TOPhS non-word	Syllable parameters				Metrical parameters			Total number of marked structures	Number of syllables
	Onset	Rhyme	Word end	Number marked	Left adjusted	Right adjusted	Number marked		
d e p e	u	u	u	0	u	u	0	0	2
<b>dr</b> e p e	m	u	u	1	u	u	0	1	2
d e <b>mp</b> e	u	m	u	1	u	u	0	1	2
d e p -	u	u	m	1	u	u	0	1	1
<b>be</b> d e p e	u	u	u	0	m	u	1	1	3
d e p e <b>ri</b>	u	u	u	0	u	m	1	1	3
<b>dr</b> e <b>mp</b> e	m	m	u	2	u	u	0	2	2
<b>dr</b> e p -	m	u	m	2	u	u	0	2	1
d e <b>mp</b> -	u	m	m	2	u	u	0	2	1
<b>be</b> <b>dr</b> e p e	m	u	u	1	m	u	1	2	3
<b>dr</b> e p e <b>ri</b>	m	u	u	1	u	m	1	2	3
<b>be</b> d e <b>mp</b> e	u	m	u	1	m	u	1	2	3
d e <b>mp</b> e <b>ri</b>	u	m	u	1	u	m	1	2	3
<b>be</b> d e p -	u	u	m	1	m	u	1	2	2
<b>be</b> d e p e <b>ri</b>	u	u	u	0	m	m	2	2	4
<b>dr</b> e <b>mp</b> -	m	m	m	3	u	u	0	3	1
<b>be</b> <b>dr</b> e <b>mp</b> e	m	m	u	2	m	u	1	3	3
<b>dr</b> e <b>mp</b> e <b>ri</b>	m	m	u	2	u	m	1	3	3
<b>be</b> <b>dr</b> e p -	m	u	m	2	m	u	1	3	2
<b>be</b> d e <b>mp</b> -	u	m	m	2	m	u	1	3	2
<b>be</b> <b>dr</b> e p e <b>ri</b>	m	u	u	1	m	m	2	3	4
<b>be</b> d e <b>mp</b> e <b>ri</b>	u	m	u	1	m	m	2	3	4
<b>be</b> <b>dr</b> e <b>mp</b> -	m	m	m	3	m	u	1	4	2
<b>be</b> <b>dr</b> e <b>mp</b> e <b>ri</b>	m	m	u	2	m	m	2	4	4

Note: u, Unmarked; m, marked.

**Table 3. Number of non-words in TOPhS with each combination of number of syllables and marked structures.**

		Number of syllables				Totals
		1	2	3	4	
Number	0	0	4	0	0	4
of	1	4	8	8	0	20
marked	2	8	8	16	4	36
structures	3	4	8	8	8	28
	4	0	4	0	4	8
Totals		16	32	32	16	96

(model 2231). A 3 s silent interval occurred after each non-word. The children heard the digitally recorded non-words via Sennheiser AD475 headphones and their repetitions were recorded onto a DAT tape (TCD-D8) via an external Sony Electret condenser microphone. The non-words were presented without breaks in a set random order. Repetitions were transcribed on-line and subsequently verified against the recording by the first author. We primarily used the total number of non-words correct (TNC), rather than a percent phoneme correct (PPC) score, as we were mainly interested in the overall phonological structure of the word. Furthermore,

when Graf Estes *et al.* (2007) compared TNC versus PPC scoring for the NRT they found TNC had a lower effect size and thus was more conservative. However, we also re-analysed the results with PPC scoring to see if this had any influence on the results. Inter-rater reliability was computed by comparing the transcriptions for four randomly selected children with SLI (26%) with those of an independent transcriber working from the digital recording. Children with SLI were used for reliability testing as they made more errors than controls and were also deemed more difficult to transcribe. Phoneme by phoneme inter-rater agreement for these four transcriptions was 99%.

#### *Verb Agreement and Tense Test (VATT) (van der Lely 2000)*

The VATT considers a child's ability to use past tense and third-person singular agreement for ten regular and ten irregular verbs (each group containing five high- and five low-frequency verbs), balanced for neighbourhood effects. The participants completed 40 sentences to describe 20 picture stimuli in both the present tense, requiring third-person singular agreement (e.g., *every*

day Woody slams the door) and past tense (e.g., *yesterday Woody slammed the door*). In this study, we scored past tense responses as correct if tense was marked, even if this meant over-regularization of irregular verbs (e.g., *maked, gived*). Thus, we assessed syntactic tense marking per se, rather than the lexical-morphological stored knowledge of irregular past tense forms. The addition of the 3rd person singular and past tense morphemes can lead to word final clusters which are phonologically more complex. In the VATT, a cluster is required for correct production of agreement<sup>4</sup> for 17/20 verbs, and of past tense for 11/20 verbs. Therefore, the phonological demands are greater for agreement than past tense production in this test.

## Results

Tests of normality (Shapiro–Wilk) showed that scores on the TOPhS for both the age controls and the SLI group deviated significantly from normality (Age:  $p = 0.003$ ; SLI:  $p = 0.03$ ). In the case of the age controls this was due to one outlier who scored significantly lower than the others. When this score was removed, the age control data were normally distributed ( $p = 0.30$ ). The presence or absence of this score made no difference to the significance of any of the results, so this participant's scores were included in all analyses. In the case of the children with SLI, a histogram (figure 1) shows the deviation from normality was due to a bimodal distribution where no participant scored between 47 and 68 correct out of 96.

The children with SLI therefore cannot be considered to be a homogeneous group with respect to

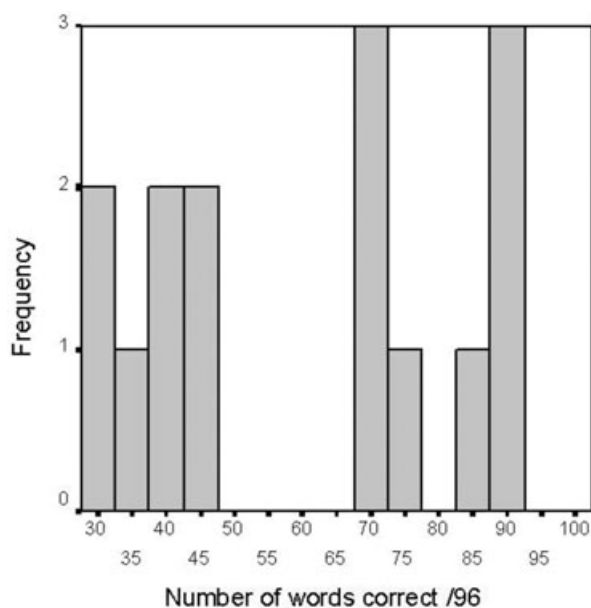


Figure 1. Histogram showing bi-modal distribution of SLI scores on TOPhS test.

their NWR abilities. For this reason we split them into two groups on the basis of their scores on the TOPhS: 'SLI-high' (eight participants, mean = 79, SD = 9.3) and 'SLI-low' (seven participants, mean = 39, SD = 6.2). Shapiro–Wilk tests on these two groups were non-significant indicating normal distributions. These smaller groups were used for all further analyses. The control participants had been individually matched to the participants with SLI, so it was possible to create new control groups for the two new SLI groups. The controls who had been individually matched to the participants in the SLI-low group on language formed a new Language Control-low group (henceforth 'LC-low') and those who had been matched on age formed a new Age Control-low group (henceforth 'AC-low'). Those controls individually matched to the participants in the SLI-high group formed new Language Control-high (henceforth 'LC-high') and Age Control-high (henceforth 'AC-high') groups.

A box plot (figure 2) of TOPhS scores for the two SLI groups and their individually matched language and age controls shows the SLI-low group achieved much lower scores on the TOPhS than any of the other groups. Indeed there was no overlap between the SLI-low group and the other five groups. In contrast, the SLI-high group achieved similar scores to all control groups.

The TOPhS scores of each of the two SLI groups were compared with those of their individually matched controls using one-way ANOVAs with Group as the between subjects variable (SLI, LC, AC). When comparing the 'SLI-high' group with their individual matches, no significant effect of Group was found,  $F(2,29) = 0.64$ ,  $p = 0.53$ ,  $\eta^2 = 0.04$ . In contrast, a highly significant effect of Group was found for the 'SLI-low' group and their individually matched controls,  $F(2,25) = 151.13$ ,  $p < 0.001$ ,  $\eta^2 = 0.92$ . Post-hoc Bonferroni corrected  $t$ -tests showed that this was due to highly significant differences with very large effect sizes between the 'SLI-low' group and both control groups (SLI-low versus LC-low:  $p < 0.001$ ,  $d = 7.08$ ; SLI-low versus AC-low:  $p < 0.001$ ,  $d = 9.64$ ). These findings are particularly striking when we consider the ages of the children: the SLI-low group ranged in age from 11;4 to 14;8 and all scored well below the youngest control (age = 5;4, score = 66) despite being 6–9 years older. Exactly the same pattern of similarities and differences were found using PPC scoring, the effect sizes for the comparisons of the SLI-low group using PPC scoring were SLI-low versus LC-low:  $d = 4.22$ ; SLI-low versus AC-low:  $d = 4.45$ .

### Comparison of the two SLI groups

To investigate further the nature of the differences between the two SLI groups, we compared their ages

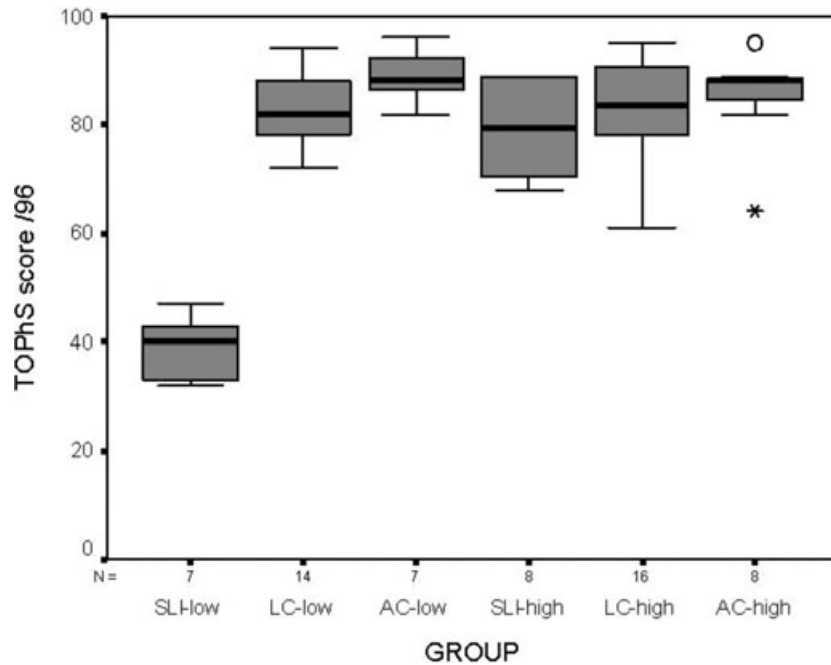


Figure 2. Boxplot showing distribution of TOPhS scores (/96) for SLI-low and SLI-high groups, their language and age controls.

Table 4. Mean (SD) scores of the two SLI groups and their comparison.

	SLI-high	SLI-low	<i>p</i> -value	<i>d</i>
TOPhS TNC (/94)	79.4 (9.3)	38.7 (6.2)	<b>&lt;0.001</b>	<b>5.08</b>
TOPhS PPC	0.97 (0.02)	0.85 (0.05)	<b>&lt;0.001</b>	<b>3.24</b>
VATT total (/40)	32.1 (6.2)	9.6 (6.8)	<b>&lt;0.001</b>	<b>3.48</b>
VATT agreement (/20)	16.8 (2.7)	3.6 (4.9)	<b>&lt;0.001</b>	<b>3.40</b>
VATT tense (/20)	15.1 (4.0)	6.0 (3.4)	<b>&lt;0.001</b>	<b>2.63</b>
Age (months)	155.3 (15.2)	159.1 (15.6)	0.63	-0.25
BPVS raw score	95.0 (16.0)	86.6 (11.4)	0.27	0.60
<sup>a</sup> TROG raw score	15.6 (2.8)	15.1 (1.9)	0.44	
<sup>a</sup> CELF Receptive <i>z</i> -score	-2.06 (0.35)	-2.21 (0.29)	0.42	
Concepts & Directions raw score	17.7 (7.2)	13.9 (5.8)	0.28	0.58
Word Classes raw score	19.9 (2.2)	17.1 (6.5)	0.33	0.60
<sup>a</sup> Semantic Relationships raw score	8.8 (4.8)	10.6 (6.1)	0.96	
<sup>a</sup> CELF Expressive <i>z</i> -score	-2.20 (0.34)	-2.19 (0.35)	0.88	
<sup>a</sup> Formulated Sentences raw score	22.4 (7.0)	17.7 (7.4)	0.10	
<sup>a</sup> Recalling Sentences raw score	26.0 (10.7)	17.7 (14.8)	0.09	
Sentence Assembly raw score	9.9 (3.8)	10.4 (4.1)	0.79	0.13
BAS-II <i>z</i> -score	0.03 (1.96)	-0.13 (0.68)	0.70	0.19
WORD Reading Accuracy raw score	30.9 (12.6)	24.4 (4.9)	0.23	0.71
WORD Spelling Accuracy raw score	27.1 (8.0)	22.7 (5.3)	0.24	0.69
WORD Reading Accuracy <i>z</i> -score	76.5 (17.6)	66.6 (5.5)	0.17	0.74
WORD Spelling Accuracy <i>z</i> -score	79.8 (14.4)	70.1 (8.4)	0.15	0.80

Note: <sup>a</sup>Non-parametric test carried out due to non-normal distributions. Significant values are shown in bold.

and scores on the TOPhS, VATT and the standardized language, literacy and performance tests using two-tailed *t*-tests (or Wilcoxon signed ranks tests for non-normally distributed data). Where raw scores were inappropriate, *z*-scores were used. Table 4 shows these data along with the *p*-values and effect sizes (*d*) for the *t*-tests. The two groups differed significantly (with large effect sizes) on the TOPhS and VATT (total, agreement and

tense), but not on age or any of the other standardized tests. Despite no significant differences between the two SLI groups on the WORD, all three SLI participants with normal scores on Reading accuracy were in the SLI-high group. Of the additional two who had normal scores on Spelling accuracy, but not Reading accuracy, one was in the SLI-low and one in the SLI-high group.

**Table 5. Mean (SD) scores and ranges on the VATT: agreement, tense and comparisons of performance within and across groups.**

Group	Agreement		Tense		Agreement versus Tense, <i>p</i> -value
	Mean (SD)	Range	Mean (SD)	Range	
SLI-low	3.6 (4.9)	0–14	6.0 (3.4)	0–10	0.03
LC-low	19.2 (0.8)	19–20	17.9 (2.6)	12–20	<0.001
<i>Comparison of -low groups (p-value)</i>					
SLI-low versus LC-low	<0.001		<0.001		
SLI-high	16.6 (2.8)	12–20	14.4 (3.7)	7–18	0.09
LC-high	17.1 (5.0)	4–20	17.0 (3.7)	10–20	0.84
AC-high	20.0 (0.0)	20–20	19.4 (0.5)	19–20	0.11
<i>Comparison of -high groups (p-values)</i>					
Comparison of all-high groups	0.03		0.006		
SLI-high versus LC-high	0.35		0.03		
SLI-high versus AC-high	0.01		<0.001		

Note: Values differ slightly from those shown in Table 4 as data were missing for both language and age controls for one SLI-high child, whose data were excluded from this table and statistical analyses.

As the VATT is not standardized, it is important to establish whether either or both of the two groups of participants with SLI in fact had difficulties on this measure and whether this impairment was greater than would be expected given their general language levels. Initially data were collected for the participants with SLI and their language controls only. The SLI-low group showed no overlap with their language controls, whereas the SLI-high group showed a very high degree of overlap with their language controls (table 5). Therefore, data were also collected for the age controls for the SLI-high group. It was not necessary to collect data for the age controls for the SLI-low group as they were obviously more impaired than their language controls, so a difference from their age controls was assumed. Non-parametric tests were used to compare the SLI groups with their control groups and the resulting *p*-values are shown in table 5.

The results show that the SLI-low group performed much worse than their language controls on both tense and agreement. In contrast, the SLI-high group had significantly poorer performance on tense but not agreement than their language controls and on both tense and agreement than their age controls. We also analysed whether within each group, performance differed between tense and agreement. The *p*-values in table 5 showed that the SLI-low group were significantly worse at agreement than tense, while their language controls showed the opposite pattern. The SLI-high group and their controls showed no significant differences between tense and agreement.

At the recruitment stage we had analysed whether the children with SLI differed from their controls on the BPVS and TROG. However, this was done with the whole SLI group, not the smaller SLI-low and SLI-high groups. These smaller groups should not differ from their language controls since they were individually

matched on these tests, but we wanted to ensure that both SLI groups (as well as the overall combined group) were indeed impaired relative to age controls on the BPVS and TROG. *T*-tests confirmed that both SLI groups differed from their age controls, scoring significantly lower on both the BPVS (SLI-low:  $p < 0.001$ ; SLI-high:  $p = 0.007$ ) and TROG (SLI-low:  $p = 0.001$ ; SLI-high:  $p = 0.03$ ).

In summary, the SLI-low group were impaired compared with age controls on both the BPVS and TROG tests, while having equal scores on these tests to their language controls. However, they were worse than their language controls on the VATT and the TOPhS tests. The SLI-high group scored worse than language controls on tense, but not agreement, BPVS, TROG or TOPhS. However, they were impaired relative to age controls on the VATT, BPVS, and TROG, but not the TOPhS, despite scoring at least 1.5 SD below the mean on both receptive and expressive language measures on the CELF-3. The two SLI groups did not differ significantly from each other on the BPVS, TROG, CELF-3 or WORD; only on the VATT and the TOPhS.

#### *Relationship between TOPhS and other language and literacy measures*

In order to investigate the relationship between performance on the TOPhS and other language and literacy measures in both typical development and in SLI, separate correlations were performed for the 45 TD controls and 15 children with SLI. Spearman rank correlations were used for the non-normal SLI data, while Pearson *r* and partial correlations (partialling out age which was significantly correlated with everything) were used for the normally distributed TD control data. The results are shown in table 6 and a scatter-

**Table 6. Correlation coefficients of TOPhS TNC score with other measures. Partial correlations for controls partial out age.**

	SLI	Controls	
	Spearman <i>r</i>	Pearson <i>r</i>	Partial correlations
Age	-0.003	<b>0.31*</b>	—
TOPhS PPC	<b>0.94***</b>	<b>0.93***</b>	<b>0.93***</b>
VATT (total)	<b>0.91***</b>	0.28	0.27
VATT (agreement)	<b>0.97***</b>	<b>0.43*</b>	0.16
VATT (tense)	<b>0.89***</b>	<b>0.39*</b>	0.30
BPVS raw score	0.44	<b>0.42**</b>	<b>0.32*</b>
TROG raw score	0.41	<b>0.30*</b>	0.13
Reading Accuracy raw score	0.26	n.a.	n.a.
Spelling Accuracy raw score	0.41	n.a.	n.a.

Note: *p*-values (one-tailed):  $p > 0.05^*$ ,  $p > 0.01^{**}$ ,  $p < 0.001^{***}$ . All significant values are shown in bold. n.a., not available.

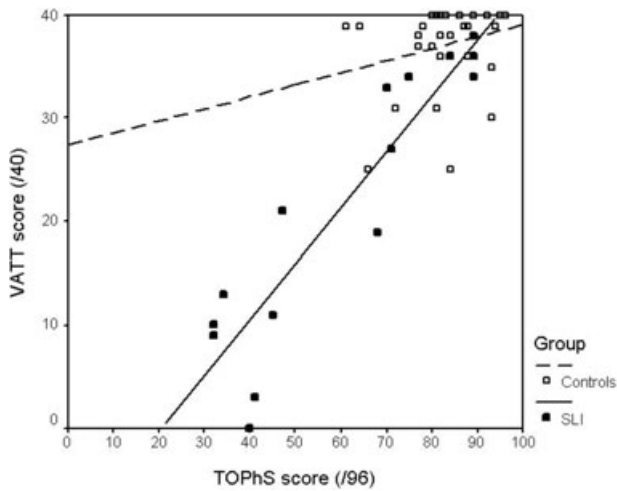


Figure 3. The relationship between TOPhS and VATT for the participants with SLI versus controls.

plot showing the relationship between the TOPhS and the VATT for the two groups is shown in figure 3.

For TD controls, only the partial correlations with TOPhS PPC and the BPVS were significant (table 6). For the children with SLI, their TOPhS TNC scores did not correlate with age and correlations with the standardized language and literacy measures did not reach significance. However, their TOPhS TNC scores showed very strong, highly significant correlations with PPC scores and with the VATT (total, agreement and tense) scores. Indeed the correlation with agreement was almost perfect ( $r = 0.97$ ). This contrasts with much lower non-significant correlations between the TOPhS and VATT in the controls once age had been partialled out ( $r = 0.16$  for agreement). This lack of significant correlations could be due to ceiling effects in the controls on the VATT (figure 3). Therefore, the TD correlations were repeated, excluding all data from participants who scored 39 or 40 (out of 40) on the VATT. The TNC scores on the TOPhS of those excluded ranged from 76

to 96 correct (out of 96). This left only 22 TD participants whose TOPhS TNC scores ranged from 61 to 95 correct. The Pearson correlations for the remaining TD participants were not significant (Total:  $r = 0.33$ ,  $p = 0.13$ ; tense:  $r = 0.36$ ,  $p = 0.11$ ; agreement:  $r = 0.23$ ,  $p = 0.30$ ), and neither were the partial correlations, partialling out the effect of age (Total:  $r = 0.19$ ,  $p = 0.41$ ; tense:  $r = 0.21$ ,  $p = 0.36$ ; agreement:  $r = 0.11$ ,  $p = 0.62$ ).

#### *Influence of length and phonological complexity*

Next we compared the TD group ( $n = 45$ ) and the SLI-low ( $n = 7$ ) and SLI-high ( $n = 8$ ) groups on the factors inherent in the non-words which may influence performance on the TOPhS. We considered the relationship between performance and two factors underlying the non-words: length and phonological complexity. All analyses in this section were carried out by-items, where the dependent variable was the proportion of participants in each group correctly repeating each non-word (whole word score). We also looked at the mean PPC for each non-word.

Figures 4 and 5 show the influence of length (number of syllables; figure 4) and phonological

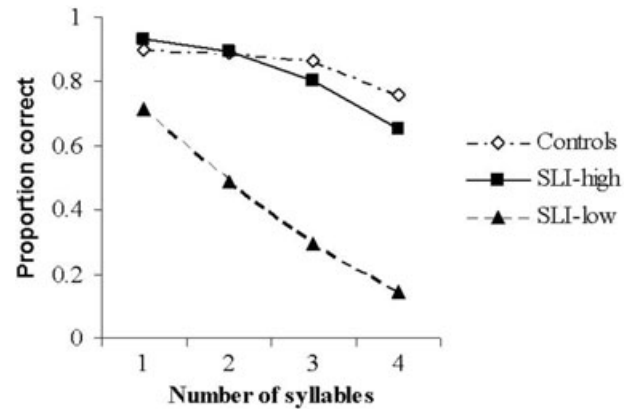


Figure 4. The influence of length (number of syllables).

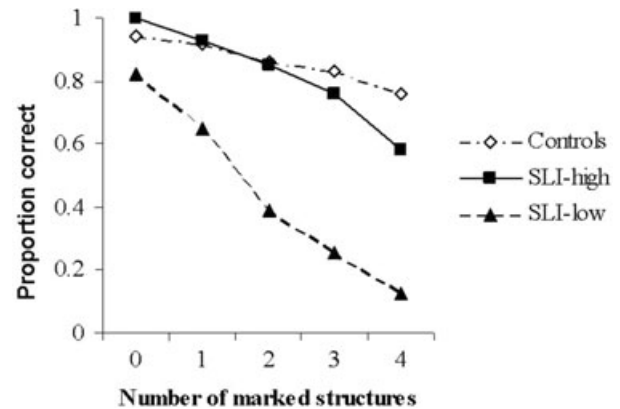


Figure 5. The influence of phonological complexity (number of marked structures).

**Table 7. Spearman rank correlations ( $r$ ) and partial correlations for length, metrical complexity and added consonants, partialling out the other two factors.**

	Spearman $r$			$r$ when the other two are partialled out		
	SLI-low	SLI-high	Controls	SLI-low	SLI-high	Controls
<b>Correct/incorrect scoring</b>						
<i>Length</i>	<b>−0.64***</b>	<b>−0.46***</b>	<b>−0.33***</b>	−0.10	0.03	0.14
Phonological complexity	<b>−0.61***</b>	<b>−0.51***</b>	<b>−0.41***</b>			
Metrical complexity	<b>−0.71***</b>	<b>−0.56***</b>	<b>−0.46***</b>	<b>−0.38***</b>	<b>−0.32**</b>	<b>−0.35***</b>
Syllabic complexity	−0.14	−0.16	−0.10			
Added consonants	<b>−0.39***</b>	<b>−0.32***</b>	−0.17	<b>−0.49***</b>	<b>−0.36***</b>	−0.14
Word end	<b>0.28**</b>	0.13	< −0.01			
<b>Percentage phonemes correct scoring</b>						
<i>Length</i>	<b>−0.38***</b>	<b>−0.23*</b>	−0.02	0.15	0.02	0.08
Phonological complexity	<b>−0.60***</b>	<b>−0.39***</b>	−0.06			
Metrical complexity	<b>−0.49***</b>	<b>−0.27**</b>	−0.04	<b>−0.38***</b>	<b>−0.19*</b>	−0.10
Syllabic complexity	<b>−0.30**</b>	<b>−0.24*</b>	−0.05			
Added consonants	<b>−0.45***</b>	<b>−0.37***</b>	−0.07	<b>−0.50***</b>	<b>−0.33**</b>	−0.08
Word end	0.06	0.04	−0.05			

Note:  $p$ -values (one-tailed):  $p > 0.05^*$ ,  $p > 0.01^{**}$ ,  $p < 0.001^{***}$ . All significant values are shown in bold.

complexity (number of marked structures; figure 5) on the TOPhS whole word performance of the three groups. The similarity of the two graphs is striking. Performance appears to be related to both factors, with the SLI-low group generally scoring lower, but also affected more by increasing length and complexity than the SLI-high and control groups, as shown by the steeper slopes of the lines. We analysed the data using Spearman (one-tailed)<sup>5</sup> rank correlations (due to the strong ceiling and floor effects). Table 7 shows the rank correlations ( $r$ ) for each of the three groups of participants on each variable. Length was measured in the number of syllables and phonological complexity in the number of marked structures. Phonological complexity was also divided into metrical versus syllabic complexity.

The results in table 7 show significant relationships for all three participant groups between the TOPhS whole word scores and both length and phonological complexity. However, when phonological complexity was divided into metrical versus syllabic complexity, the relationship with syllable complexity was not significant for any group. However, syllable complexity on the TOPhS consists of three parameters: Onset, Rhyme and Word End. The effect of Word End has not been studied previously. Therefore, we created a new variable: ‘Added consonants’, the number of additional consonants added (Onset and Rhyme). This was negatively correlated with performance in both SLI groups. In contrast, Word End showed a positive correlation for the SLI groups. Therefore, the non-significant correlation of syllable complexity with performance of the participants with SLI was due to the positive correlation of the Word End parameter in conjunction with the negative correlation of the Onset and Rhyme

parameters. The negative correlation of performance with the new Added Consonants variable is also in line with previous research.

The PPC scoring showed similar patterns for the SLI groups, where Added consonants, metrical complexity and length (as measured by number of syllables) were significantly related to TOPhS performance. However, using PPC scoring, the controls showed no significant relationships between TOPhS performance and any of the factors analysed.

Thus, in summary, using whole word scoring (proportion of participants correctly repeating each non-word) the performance of all groups was negatively correlated with both length and metrical complexity and the performances of the SLI groups were also negatively correlated with the number of consonants added to the stressed syllable (Added consonants: Onset and Rhyme). These factors predicted performance to the greatest extent in the SLI-low group and least in the control group. Using PPC scoring, the SLI groups showed a similar pattern as with whole word scoring, but the controls showed no obvious pattern.

Because metrical complexity and number of syllables are strongly correlated ( $r = 0.89$ ,  $p < 0.001$ ) in the TOPhS, it is not clear whether either factor has an independent effect on performance of all groups using whole word scoring or the SLI groups using PPC. Therefore, the final analyses considered the independent effects of length, metrical complexity and ‘Added consonants’ (Onset and Rhyme) for each group by carrying out one-tailed partial correlations for each of these with the TOPhS, partialling out the effects of the other two factors.<sup>6</sup> The results are also shown in table 7. These showed that length

was not independently correlated with performance for any group, using either scoring system; metrical complexity and Added consonants were independently correlated with performance for both SLI groups using both scoring systems; for the controls, metrical complexity was negatively correlated with whole word TOPhS performance but there were no significant correlations using PPC scoring.

## Discussion

The participants with SLI in this study showed a bimodal distribution in their ability to repeat the non-words of the TOPhS. Half achieved a similar degree of accuracy to TD control groups while the other half scored significantly worse. The effect size for the difference between the SLI-low group and their age controls using TNC scoring ( $d = 9.64$ ) was more than double the largest effect size ( $d = 4.34$ ) reported in the Graf Estes *et al.* (2007) meta-analysis, although using PPC scoring we found an effect size of  $d = 4.45$ . The finding of smaller effect sizes with PPC scoring is the opposite pattern to that in Graf Estes *et al.* (2007). However, they used the NRT which differs greatly from the TOPhS in construction, particularly in that it does not include any consonant clusters. Such a clear division of performance as we found within a group of children diagnosed with SLI has not been shown in previous studies. However, the division into children with high versus low performance on the TOPhS is probably responsible for the very large effect sizes for the differences between the SLI-low group and all other groups.

Table 8 summarizes our findings. The two SLI groups (low versus high TOPhS) did not differ significantly on any other language or literacy measure except verb agreement and tense marking (VATT).

Comparisons with age controls showed that while the SLI-high group had no detectable impairment in repeating non-words (TOPhS), both SLI groups were impaired in production of verb agreement and tense marking (VATT) and understanding of vocabulary (BPVS) and sentences (TROG). *Z*-scores on the CELF-3 showed that all the participants with SLI were impaired on this general receptive and expressive language test and their *z*-scores on the WORD showed that on average they also were impaired on literacy measures. However, three participants with SLI scored within the normal range on Reading Accuracy (who were all in the SLI-high group) and five on Spelling Accuracy (one of whom was in the SLI-low group).

Comparisons of the SLI participants with their language controls revealed particular difficulties over and above their general language difficulties for the SLI-low group with verb agreement and tense marking (VATT) and repeating non-words (TOPhS) and for the SLI-high group with tense marking only.

Correlations within the 15 children with SLI (SLI-low and SLI-high groups combined) versus the 45 TD controls (all control groups combined) showed the TOPhS TNC scoring correlated significantly with (1) the TOPhS PPC scoring for both groups, (2) the BPVS only for the controls, and (3) the VATT only for the participants with SLI. The low number of participants with SLI may be responsible for the lack of significance of some of their correlations. However, despite their low numbers, the correlation between their TOPhS and VATT scores was still highly significant.

## Good NWR performance among children with SLI

Only half of the participants with SLI were impaired on the TOPhS (the SLI-low group) despite all the participants with SLI having low language scores on

Table 8. Summary of findings

Test	SLI low versus high	Comparison with controls		Correlated with TOPhS?	
		SLI-low	SLI-high	SLI	Controls
TOPhS	Low < high	< Lang, < Age	= Lang, = Age	n.a.	n.a.
TOPhS PPC	Low < high	< Lang, < Age	= Lang, = Age	Yes ++	Yes ++
VATT tense	Low < high	< Lang, < Age	< Lang, < Age	Yes ++	No
VATT agreement	Low < high	< Lang, < Age	= Lang, < Age	Yes ++	No
BPVS	Low = high	= Lang, < Age	= Lang, < Age	No	Yes
TROG	Low = high	= Lang, < Age	= Lang, < Age	No	No
WORD Reading Accuracy	Low = high	< Age (from <i>z</i> -score)	< Age (from <i>z</i> -score)	No	
WORD Spelling Accuracy	Low = high	< Age (from <i>z</i> -score)	< Age (from <i>z</i> -score)	No	
CELF-3 Receptive Language	Low = high	< Age (from <i>z</i> -score)	< Age (from <i>z</i> -score)		
CELF-3 Expressive Language	Low = high	< Age (from <i>z</i> -score)	< Age (from <i>z</i> -score)		
BAS-II <i>z</i> -score	Low = high	= Age (from <i>z</i> -score)	= Age (from <i>z</i> -score)		

Note: Lang, language controls; Age, age controls.

the CELF-3. The finding that some children with SLI do well on the TOPhS concurs with previous studies showing that some children with SLI pass NWR tests (Bishop *et al.* 2006, Botting and Conti-Ramsden 2001, Chiat and Roy 2007, Gardner *et al.* 2006). The practical implication is therefore that NWR tasks should not be used in isolation as a screen for identifying SLI.

It has been proposed that the presence or absence of co-occurring dyslexia could account for variation in performance in children with SLI (Catts *et al.* 2005). Indeed, studies have found that children with SLI only without dyslexia, did not differ significantly from age controls (Bishop *et al.* 2009, Rispens and Parigger 2010). Those studies split the participants with SLI by reading abilities and found significant differences in NWR abilities. In contrast, we split the participants by NWR performance and found no significant differences in their reading abilities. Three of the SLI-high group had reading abilities within the normal range, but the other five had impaired reading accuracy (with good NWR). Therefore, the findings suggest that while children with SLI without dyslexia probably do have good NWR abilities, as suggested by Catts *et al.* (2005), the reverse is probably untrue (i.e., that good NWR abilities predict good reading abilities) because some of the SLI-high group had poor reading abilities despite scoring well on NWR.

Given the older age of the participants, it is possible that the SLI-high group had had difficulties with phonology and/or other factors underlying NWR in the past which had resolved while their impairment in other language areas persisted. However, this interpretation is inconsistent with the previous findings that while some children with SLI appear to outgrow their general language difficulties, they remain impaired in NWR (Bishop *et al.* 1996) suggesting this is a persistent deficit. Thus, it seems unlikely that the current language difficulties of the SLI-high group are due to difficulties with phonology, phonological short-term memory or storage, or lower level processes involved in speech perception and processing, as all of these would also be expected to impair their ability to repeat non-words. Thus, some other factor must underlie their language difficulties.

Some theories of SLI provide possible non-phonological explanations, particularly for difficulties with verb agreement and tense marking: these include difficulties establishing agreement (Clahsen 1989) or knowing that tense and agreement are obligatory in matrix clauses (Rice *et al.* 1995). The impairment on tense marking (even relative to language controls) of all the children with SLI supports Rice and Wexler's (1996) hypothesis of an extended optional infinitives stage in SLI. However, given that the participants with

SLI were in their teenage years, this problem does not appear to be one of delay, but to be part of an ongoing developmental impairment and fits with Rice *et al.*'s (2009) recent findings of a lower asymptote in children with SLI. However, these theories do not account for the reduced understanding of vocabulary and sentences of the SLI participants. One hypothesis which can explain difficulties understanding sentences, is van der Lely's (2005) Computational Grammatical Complexity (CGC) hypothesis, which was developed from her Representational Deficit for Dependent Relations hypothesis (RDDR; van der Lely 1998). The CGC hypothesis puts forward that abstract hierarchical structures are impaired in children with SLI and that different components of grammar may be independently impaired but have a cumulative impact on performance. Thus, the SLI-high group could be assumed to have difficulties with syntax and morphology, but have spared phonology, with vocabulary difficulties arising from difficulties using syntax to aid vocabulary learning (van der Lely 1994).

#### *Relationship between NWR and other language and literacy measures*

The SLI-low and SLI-high groups differed significantly on only two tests: the TOPhS and the VATT (both tense and agreement). Within the whole SLI group (SLI-low and SLI-high groups combined), significant correlations were also found between these measures. However, among the TD controls, the correlations in this study were weak and non-significant and appeared to be largely mediated by age. The lack of correlations could have been due to a ceiling effect in the controls on the VATT test, but this persisted when those scoring near ceiling were excluded. Thus, performance on the TOPhS appears to be related to syntactic and morphological agreement and tense marking in sentences in children with SLI, but not in TD children.

Correct production of many items on the VATT requires production of a word final consonant cluster (e.g., *drops*, *dropped*), more for agreement than tense. Marshall and van der Lely (2007) showed children with SLI (but not TD children) are less likely to suffix stems when the inflected form ends in a cluster. We showed in this study that the addition of consonants to form clusters affected the performance of both the SLI groups (but not the TD children) on the TOPhS, with the SLI-low group affected to the greatest extent. Therefore, a significant correlation between the TOPhS and VATT tests amongst the children with SLI, but not TD children is unsurprising. Indeed, the SLI-low group were the only group who had worse performance on agreement (which required more clusters) than tense.

We therefore propose that the SLI-low group have an additional deficit in phonology which impacts on verb tense and agreement marking, especially where clusters are required, resulting in poorer performance in this group on the VATT and a strong relationship between the TOPhS and the VATT for the whole SLI group.

We found a weaker, but significant correlation between NWR and vocabulary in the TD controls. The correlations for the SLI group on vocabulary, TROG and literacy measures failed to reach significance. This could be in part due to low numbers of participants, but the findings are in line with many previous studies which found correlations between vocabulary and NWR in TD children (e.g., Briscoe *et al.* 2001, Gathercole and Baddeley 1989) but not children with SLI (e.g., Briscoe *et al.* 2001, Edwards and Lahey 1998, Gallon *et al.* 2007). Other studies also found a weak, but non-significant correlation with the TROG (e.g., Gallon *et al.* 2007, Montgomery 2004) and no significant correlations between literacy measures and NWR in children with SLI (de Bree *et al.* 2010).

#### *Influence of length and phonological complexity*

When we considered the effects of non-word length and phonological complexity, we found a strong correlation between NWR performance on the TOPhS and both length and phonological complexity for the participants with SLI; thus, these data could support all current theories of the underlying reasons for difficulty with NWR tasks among children with SLI: poor phonological storage (Gathercole 2006), or difficulties forming phonological representations (Chiat 2001, Edwards and Lahey 1998). However, length and complexity are related, so we used partial correlations to establish the independent contribution to the variance of each measure. These revealed that the performance of the SLI participants was related to both metrical complexity and the presence of consonant clusters. The effect of metrical complexity supports Chiat's (2001) view that some children with SLI have particular difficulties identifying the phonological segmental details in rhythmic structures. The effect of consonant clusters supports the view that at least some children with SLI have difficulties with phonologically complex representations (Gallon *et al.* 2007, Marshall and van der Lely 2007, 2009).

When the effects of consonant clusters and metrical complexity were partialled out, length (in terms of the number of syllables) was no longer significantly related to performance. Thus, the results suggest that the TOPhS test and possibly also other tests of NWR should not be primarily viewed as tests of short-term memory or phonological storage as shown by a length effect. If the findings from the partial correlations can be replicated

in larger studies specifically designed to contrast the influence of number of syllables versus phonological complexity, this would indicate that SLI is less likely to be caused by limited phonological short-term memory capacity or impaired phonological storage.

#### *Summary*

The number of participants in this study is small. This may mean that we were unable to detect some smaller differences between groups. However, the numbers were sufficient to detect large and highly significant differences between groups on some measures. If the findings can be replicated in larger studies, they raise important questions for theories of SLI. Although theories proposing a single underlying deficit for SLI may be more parsimonious, those currently available cannot account for the data in this study. Several researchers have proposed that dissociable deficits or risk factors may better account for the data. Bishop *et al.* (1999) proposed that a series of risk factors may be involved in SLI and those children with more than one risk factor are likely to show a more severe deficit. Bishop and Snowling (2004) proposed that children with classic dyslexia have poor phonological skills; poor reading comprehenders have poor semantic skills; but children with SLI have both poor phonological and semantic skills. Van der Lely (2005) proposed the Computational Grammatical Complexity Hypothesis (CGC) whereby children with SLI may have independent but interactive deficits in any one or a combination of phonology, morphology and/or syntax. In order to account for the data, we propose that all participants with SLI have impairments in syntax and morphology which affect their general language abilities, including marking of agreement and tense. However, we propose that the SLI-low group have an additional phonological impairment (which the SLI-high group do not have) which greatly affects their ability to repeat the non-words on the TOPhS and further impairs their ability to mark tense and particularly agreement in sentences accurately.

#### **Conclusions**

The main finding of this study is that the participants with SLI fell into two distinct groups. They all had significant syntactic and morphological difficulties with marking agreement and tense and also had severe difficulties with a general language test (the CELF-3), but only half had difficulties repeating the non-words of the TOPhS. If the findings can be replicated in larger studies, this would indicate the TOPhS and probably NWR tests in general should not be used in isolation to identify language impairments. Also, those factors that have been proposed to account for NWR difficulties

(e.g., difficulties with phonology, phonological short-term memory or storage, or with processing phonology, speech or brief acoustic cues) cannot account for the language difficulties of half of the participants who had no detectable difficulties with NWR (the SLI-high group), although they may account for some of the difficulties with verb tense and particularly agreement marking of the other half (the SLI-low group). The preliminary finding that phonological complexity (but not number of syllables) had an independent effect on performance suggests that the difficulties some children with SLI have with NWR are more likely to be due to difficulties with phonology per se rather than with phonological short-term memory or phonological storage.

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### Notes

1. One age control achieved a  $z$ -score of  $-1.15$  on the BAS, but showed no language difficulties, was matched to the child with SLI with the lowest  $z$ -score ( $-0.95$ ) on the BAS, and was exactly the same age; he was therefore considered to provide a good match.
2. The non-parametric Kruskal–Wallis and Wilcoxon-signed ranks tests were used because the data for the SLI and language control groups were not normally distributed (the SLI and TROG control groups were positively skewed, while the BPVS controls showed a bimodal distribution).
3. For more details, see Gallon *et al.* (2007), and for further theoretical background, see Harris (1994).
4. In English the ‘s’ morpheme conflates both tense and agreement marking.
5. One-tailed tests were used because the previous literature indicates that any relationship between the two measures is negative. Thus, we were only interested in a relationship in this direction.
6. It was not possible to carry out multiple regression because several assumptions necessary for the reliable interpretation of the results were violated, including normality in Carrays and multiple collinearity.

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