Investigating the impact of prosodic complexity on the speech of children with Specific Language Impairment *

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Abstract

Children with Specific Language Impairment (SLI) have difficulty with, amongst other things, non-word repetition tasks. This paper presents preliminary research into the nature of the phonological deficit in SLI. We report results from four SLI children tested on a new set of non-words which, unlike previous sets, takes metrical and syllabic complexity into account. Most errors occur in non-words with adjoined syllables. The implications of this finding for the nature of the phonological deficit in SLI, and its possible impact on syntactic and morphological abilities, are discussed.

1 Introduction

In this paper we investigate the phonological abilities of children with Specific Language Impairment (SLI). Although deficits in non-word repetition characterise many children with SLI, little is known about these children's phonological representations. Here we outline preliminary research with the aim of addressing this issue.

Children with Specific Language Impairment (SLI) have significantly impaired language acquisition despite the absence of any obvious language-independent cause, such as hearing loss, low non-verbal IQ, motor difficulties or neurological damage (Leonard, 1998). Furthermore, the impairment is noticeable at the outset of language development: it does not emerge in later childhood as the result of some sort of trauma or illness, and it often persists into adulthood (Bishop, 1997; van der

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Lely, Rosen & McClelland, 1998). It is estimated to affect around 7% of the population, and it impacts significantly on school and career attainment.

Within the SLI population as a whole, deficits have been diagnosed with the core grammatical areas of syntax, morphology and phonology, and, to a lesser extent, in the lexicon. Most researchers would agree that syntactically simple sentences, inflectional errors, poor phonological abilities and delayed lexical acquisition are characteristic of SLI (Bishop, 1997; Leonard, 1998). The picture is complex, though, because the range of impairments and their level of severity, stage of resolution and degree of compensation all vary greatly between individuals.

There are two main perspectives regarding the causes of SLI. The first is a cognitive perspective, which holds that an input-processing deficit, such as poor short term memory, limited processing capacity and/ or a temporal processing deficit, interferes with various aspects of language acquisition - including phonology - as well as with non-linguistic cognitive skills (Ellis-Weismer, Evans & Hesketh, 1999; Gathercole & Baddeley, 1990; Leonard, 1989, Tallal, 1976). The alternative is a linguistic perspective, which claims that there is a deficit specific to grammatical aspects of language - again, including phonology - and independent of non-linguistic skills (Gopnik, 1990; van der Lely *et al*, 1998; Rice, Wexler & Cleave, 1995).

These perspectives relate in turn to the larger debate of how the brain is organised, and how specialised cognitive systems such as language develop. Some researchers claim that general-purpose mechanisms become specialised through experience during development, and they therefore contend that pure developmental impairments of a specialised system such as language cannot exist (e.g. Elman, Bates, Johnson, Karmiloff-Smith, Parisi & Plunkett, 1996; Karmiloff-Smith, 1998). Others argue that genetically determined specialised mechanisms underlie different cognitive abilities, including language, and therefore predict that pure primary impairments of specialised systems will exist (Fodor, 1983; Pinker, 1991, 1999). Research into SLI is likely to shed valuable light on this issue.

2 Non-word repetition tests

The need to identify language impairments at an early age so that remediation can begin as young as possible has led to various tests being proposed as diagnostic for SLI. One such test is the Children’s test of Non-word Repetition (CNRep, Gathercole & Baddeley, 1996). The test consists of forty non-words between two and five syllables long. These non-words are presented either on cassette tape or by the administrator, and the child must repeat them immediately. Each of the repetition attempts is scored as either correct (and given a score of 1) or incorrect (scored as 0).

Gathercole & Baddeley (1990) propose that the CNRep taps into children's phonological short-term memory abilities. They claim that SLI children perform poorly on the test because they have limited capacity in their phonological store, and/ or an unusually rapid decay rate for items held there. If children are poor at retaining a short-term representation of speech sounds, they are likely to have difficulty in forming long-term representations of new words. This in turn impacts on the identification of syntactic structures, because word sequences are not retained long enough for grammatical analysis. In other words, Gathercole & Baddeley propose that phonological short-term memory deficits are primary in SLI, and that the other language problems arise as a consequence.

Gathercole & Baddeley's claims have not gone unchallenged, however, and alternative explanations that take a psycholinguistic perspective have been proposed. Snowling, Chiat & Hulme (1991) stress that the difference between phonological memory and other phonological processes, such as phonological segmentation and articulatory execution, cannot be ignored when interpreting the results of the CNRep. Van der Lely & Howard (1993) argue that the causal arrow is reversed, so that linguistic deficits are actually the cause of phonological short-term memory deficits. In a similar vein, Edwards & Lahey (1998) hypothesise that the deficit lies not in the ability to hold phonological information in short-term memory, but rather in the formation or storage of phonological representations.

From a phonological point of view there are questions over the non-words chosen for the CNRep. Syllable number is the only variable along which children's performance is measured. Yet within a set of words of identical syllable number, various types of syllable and foot structure occur. The design of the test does not allow a fine-grained investigation of which structures cause errors. This raises the possibility that while performance on the CNRep might indeed correlate with language abilities, it does not warrant the conclusion that it is syllable length *per se*, and by extension a deficit in phonological short-term memory, that causes non-word repetition difficulties. Without due consideration of phonological factors it seems unwise to evoke short-term memory deficits as the reason for poor performance. We caution that *correlation* is not the same as *cause*, and that the deficit might instead be in forming correct phonological representations in the first place rather than in retaining them.

Various studies have shown that factors other than syllable number influence non-word repetition. Wordlikeness is one such factor. Dollaghan, Biber & Campbell (1995) found that non-words with stressed syllables corresponding to real words are repeated significantly more accurately than those with non-lexical stressed syllables. If these words are familiar to the child, Dollaghan *et al* claim that capacity is freed up in working memory for remembering a greater number of syllables. Our proposal would be that it is easier to create a phonological representation of a non-word when a portion of it can be retrieved from long-term memory, so that the entire non-word does not need to be created *de novo*. Many non-words chosen for the CNRep task contain real words within them, including **hámpent**, **deférmification**, **únderbrantuand** and **reútterpation**. A similar point might be made about derivational morphemes. Some of Gathercole & Baddeley's words have derived morphological endings, as in **blonterstaping**, **defermication**, **loddernapish**, **contramponist**. It follows that children with large vocabularies and/ or a good knowledge of morphological structure are more likely to make analogies with familiar words, thereby gaining higher scores. As children with SLI tend to have poorer vocabularies and impaired morphological abilities, such deficits could account for, or at least contribute to, poor performance on the CNRep, and a correlation between poor CNRep scores and SLI is therefore not surprising.

Consonant complexity is a second factor that might influence non-word repetition. Gathercole & Baddeley (1990) found that non-words with consonant clusters were harder for children to repeat, although the effect was similar for both normally developing and language impaired participants. They interpreted this difficulty with clusters as being related to articulation problems. In contrast, Bishop, North and Donlan's (1996) study found that while consonant clusters affected repetition accuracy in both groups, the effect was significantly greater for the SLI group.

The aim of this present study is to investigate whether prosodic complexity plays a role in the performance of a small number of SLI children on non-word repetition tasks. We use the Test of Phonological Structure (TOPhS), a set of ninety six non-words created by Harris and van der Lely (1999, unpublished) These non-words have been constructed using five parameters along which syllabic and foot structure are systematically varied using combinations of marked and unmarked parameter values. This approach therefore allows a fine-grained analysis of children's phonological difficulties.

The remainder of the paper is structured as follows. In §3 we discuss the nature of the phonological deficit in SLI. In §4 we outline a model of prosodic complexity and link this model of complexity to the notions of parameters and markedness. In §5 and §6 we present our methodology and data from four children with SLI. Finally, in §7 we discuss the implications of our results for the nature of the phonological deficit in SLI.

3 The nature of the phonological deficit in SLI

Although most research into SLI has focused on morphosyntax, it is acknowledged that phonology is also in need of thorough investigation. It is not yet clear whether children with SLI have a particular difficulty with phonology, or whether this difficulty arises solely as a consequence of a more general language delay. Earlier research, summarised by Leonard (1998), suggested that children with SLI acquire segments (i.e. speech sounds) later than do non-impaired children. In more recent research there has been an increasing awareness that prosodic difficulties can affect segmental production, not only in SLI (e.g. Bortolini & Leonard, 2000; Orsolini, M., Sechi, E., Maronato, C, Bonvino, C. & Corcelli, A., 2001; Sahlen, Reuterskiold-Wagner, Nettelbladt & Radeborg, 1999) but also in other phonological disorders (e.g. Chiat, 1989; Harris, Watson & Bates, 1999).

Recent work by Orsolini and her colleagues (Orsolini *et al*, 2001) showed that Italian-speaking SLI children have difficulty in representing complex syllabic structures, and suggested that the nature of their difficulty is not simply due to delayed phonological development. In disyllabic words there is a strong tendency to simplify the onset of the first syllable if it is complex (e.g. grande becomes gande). Yet those children don't simplify the rhyme of the first syllable from CVC to CV. If that post-nuclear consonant is simplified, it becomes geminate with the onset of the second syllable (e.g. por.ta is simplified to pot.ta rather than to po.ta, where . indicates the syllable boundary). In Orsolini *et al*'s study, an influence of syllable number on segmental realisation was seen in only 40% of the SLI children. In another study, Bortolini & Leonard (2000) showed that English-speaking SLI children omit significantly more consonants in word-final position than normally developing controls matched on mean length of utterance. They also reduce word-final consonant clusters on almost 80% of occasions.

Not just syllable structure, but also metrical structure may affect segmental realisation in SLI. For example, Sahlen *et al* (1999) found that prosody affects segmental production in word and non-word repetition tasks undertaken by Swedish-speaking children with SLI; unstressed syllables are omitted six times more often in pre-stressed (i.e. Weak-Strong) positions than in post-stressed (i.e. Strong-Weak) positions in both types of word. Similarly, the English-speaking children in Bortolini & Leonard's (2000) study omit word-initial weak syllables from real words on approximately 90% of occasions.

Analysis by Peiris (2000) of non-word repetition data collected from one individual with SLI using the TOPhS found that onset clusters, closed rhymes and antepenultimate stress all pose significant difficulty for repetition. No significant impact on repetition accuracy was found for word-final consonants (versus word-final vowels) and unstressed (versus stressed) initial syllables. Although those results concur with some previous findings (e.g. Orsolini *et al*, 2001) they conflict with others (e.g. Leonard & Bortolini, 2000; Sahlen *et al*, 1999), which demonstrates the need for further research in this area.

4 Prosodic complexity, parameters and markedness

In most non-word repetition studies, stimuli are varied along a single dimension of STRING COMPLEXITY, based on a brute count of the number of phonemes or syllables in a given token. In contrast, the TOPhS sets out to test the effects of relative PROSODIC complexity on the repetition task. Non-word stimuli are varied along a series of prosodic parameters controlling metrical structure and syllable-internal constituency. For example, one of the metrical parameters relates to whether stress falls on the first or second syllable of a word, as in the real word exemplars **cíty** versus **settée**. One of the syllabic-constituency parameters relates to whether a syllable onset is simplex (as in **pay**) or complex (as in **play**).

The relative complexity of a given prosodic structure can be understood in terms of how MARKED it is, as revealed by universal preferences in cross-linguistic distribution and language acquisition. Relative to a less marked option, a more marked structure occurs in fewer languages and appears later in phonological development. For example, the marked status of complex onsets is confirmed by the fact that many languages lack them altogether as well as by the fact that, in languages that do have them, they are acquired later than simplex onsets.

The non-word stimuli used in TOPhS are constructed on the basis of five binary parameters that together go a long way towards establishing the major typological outlines of syllabic and metrical structure. Three of the parameters regulate choices in the complexity of syllabic constituency, with English selecting the marked setting in every case: simplex versus complex onsets; open versus closed syllables; vowel versus consonant at word ends. Each of these parameters embodies a unidirectional implicational universal: selection of the marked setting means a language accommodates both of the structural options defined by the parameter. For example, with the onset parameter set at marked, a language such as English allows for words with simplex onsets as well as words with complex onsets.

The three syllabic parameters are set out in Table 1, together with real-word models and examples drawn from the non-word data set. In each of the examples, the segment string illustrating the relevant parameter is underlined.

Table 1 Syllabic parameters used in the TOPhS

Syllabic parameter		Settings		Real word	Non-word
(a)	Onset	Unmarked	Simplex	**pawn**	*pɪf*
		Marked	Complex	**prawn**	*prɪf*
(b)	Rhyme	Unmarked	Open	**city**	*pɪfi*
		Marked	Closed	**filter**	*pɪlfi*
(c)	Word end	Unmarked	V-final	**city**	*pɪfi*
		Marked	C-final	**sit**	*pɪf*

Parameters b and c are typically conflated in traditional treatments of English phonology, reflecting the view that a word-final consonant closes the syllable occupied by the preceding vowel. The assumption is in fact contradicted by a wide range of evidence (see Harris & Gussmann 2002 for a summary of the relevant literature). For example, typological variation confirms that two distinct parameters are involved here: some languages allow for word-internal closed syllables but not word-final consonants, while some others show the reverse combination.

As to metrical structure, the main focus of the present study is on the location of the stress foot relative to word edges. The English foot conforms to several of the patterns associated with unmarked metrical structure: it is binary; it establishes the size of the minimal word; and it is trochaic, displaying a left-dominant stress pattern (see Hayes 1995). Binarity is satisfied moraically, i.e. by two weight-bearing positions. To correspond to a foot, the two morae of a minimal word in English are either divided over a disyllabic trochee (as in **cíty**) or contained within a monosyllable consisting of a long vowel (as in **see**) or a vowel followed by a consonant (as in **sit**).

In the unmarked case, the edge of a foot is aligned with the edge of a word. Words consisting of a single foot have perfect alignment at both edges (as in the **cíty, see, sit** examples just cited). In polysyllabic words, misalignment is possible, resulting in marked stress patterns. Two of these feature in the non-word data set, both involving the adjunction of an unstressed syllable at a word's edge. In one pattern, an unfooted syllable is adjoined at the beginning of a word, as in **ba(nána)**, **de(níal)** (feet parenthesised). The other involves right-edge adjunction, where an unfooted syllable separates the end of a foot from the end of a word, resulting in antepenultimate stress, as in **(Jénni)fer**, **(fánta)sy**.[1] The two parameters responsible for these patterns are summarised and exemplified in table 2.

Table 2 Metrical parameters used in the TOPhS

METRICAL PARAMETER		SETTINGS		REAL WORD	NON-WORD
(a)	Left adjunction	Unmarked	No	**cíty**	***kɛ̱tə***
		Marked	Yes	**banána**	***fəkɛ̱t***
(b)	Right adjunction	Unmarked	No	**cíty**	***ˈkɛ̱tə***
		Marked	Yes	**Cánada**	***ˈkɛ̱tə***

The marked status of metrical adjunction is confirmed by the fact that unfooted word-edge syllables are typically truncated in early phonological development, as in ***na̱nə*** for **banana**.

In certain respects, string-based and prosody-based measures of complexity converge. For example, the extra segment that renders **play** longer than **pay** also contributes to the complexity of the onset in **play**. In other respects, however, the two types of measure produce quite different results. For example, on a phoneme or syllable count, **city** and **settee** are of equal complexity. However, in terms of metrical structure, **settee** is more complex than **city** by virtue of containing a left-adjoined syllable.

5 Method

5.1 Construction of the TOPhS

The TOPhS requires the child to repeat non-words that are systematically varied with respect to the five prosodic parameters described in section 4. The stimulus database was constructed around four sets of 24 non-word forms, yielding a total of 96 stimuli. Within each set, forms were varied in complexity along the five prosodic parameters set out in Tables 1 and 2. Each set thus contains stimuli ranging from a maximally simplex form, displaying only unmarked structures (e.g. ***kɛ̱tə***), through progressively more complex forms, containing various permutations of marked structures (e.g. ***fəkɛ̱stələ***). These non-words are presented in randomised order.

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[1] An alternative analysis of such forms is to treat them as ending in a ternary (dactylic) foot (see for example Burzio, 1994). The theoretical distinction is not crucial to the present study, since antepenultimate stress must be considered marked under any analysis.

Table 4 provides illustrative examples of non-words based on the CVCV form ***dɛ̲pə***. In this table, **u** and **m** indicate unmarked and marked structures respectively. All non-words conform to the phonotactic constraints of English and are intended to be applicable to all dialects of English.

Table 4 Examples of non-words based on the CVCV form **dɛ̲pə**

NON-WORD	ONSET	RHYME	WORD END	LEFT ADJUNCTION	RIGHT ADJUNCTION
dɛ̲pə	u	u	u	u	u
drɛ̲pə	m	u	u	u	u
dɛ̲mpə	u	m	u	u	u
dɛp	u	u	m	u	u
bədɛ̲pə	u	u	u	m	u
dɛ̲pəri	u	u	u	u	m
bədrɛ̲pə	m	u	u	m	u
dɛ̲mpəri	u	m	u	u	m
bədrɛ̲mpəri	m	m	u	m	m

Using the TOPhS we set out to test the three following predictions:-

a. Non-words with marked structures will be more difficult to repeat accurately than those with unmarked structures.

b. The greater the number of marked structures for a given non-word the greater the difficulty.

c. Marked syllabic and metrical structures will have different impacts on repetition accuracy.

5.2 Participants

Seventeen children with severe, persistent specific language impairment (SLI) who attend a specialist residential school were tested on the TOPhS (Ebbels, unpublished data). From these, four children representing a range of the types and levels of difficulty were selected for detailed statistical and phonological analysis. The ages of the four participants range from 12;8 to 14;8 (years; months). The children were assessed using the following tests:

a. British Picture Vocabulary Scales, BPVS, a test of receptive vocabulary (Dunn, Dunn, Whetton & Burley, 1997)

b. Test of Word Finding, TWF, a test of expressive vocabulary (German, 1986)

c. Clinical Evaluation of Language Fundamentals-3 (UK), CELF-3, various subtests of vocabulary and grammar which give receptive (Rec), expressive (Exp) and total language scores. (Semel, Wiig & Secord, 1995)

d. British Ability Scales, BAS, a test of non-verbal IQ (Elliot, Smith and McCullogh 1996)

The children all score significantly below the mean expected for their age on the language measures and within the expected range on the non-verbal test, confirming the diagnosis of SLI (normal range for a z-score, which is a measure of standard deviation from the mean, is ±1). These scores are presented in Table 5.

Table 5 Language and non-verbal assessments for four SLI participants in this study

				CELF-3			BAS
Child	**Age**	**BPVS z-score**	**TWF z-score**	**Rec Lang z-score**	**Exp Lang z-score**	**Total Lang z-score**	**Mean z-score (3 sub-**
DS	12;8	-0.87	-1.93	-2.00	-2.33	-2.33	1.17
GD	14;3	-1.67	-2.33	-2.40	-2.40	-2.40	-0.73
TF	14;8	-2.00	-2.33	-2.33	-2.40	-2.33	-0.53
LN	13;1	-1.00	-1.87	-2.40	-1.67	-2.40	-0.90
Mean	**13;8**	**-1.38**	**-2.12**	**-2.28**	**-2.20**	**-2.37**	**-0.25**

5.3 Procedure

Testing was carried out in a quiet room. The children heard the digitally recorded non-words through high quality headphones and their repetitions were recorded onto a DAT tape. Repetitions were transcribed on-line by the second author and then subsequently verified against the recording. The first author then also transcribed the data. There was 99% interrater agreement. Where there were differences, the first and second author came to an agreed transcription. For the purposes of the statistical analyses all responses were scored as either correct or incorrect.

6 Results[2]
6.1 Group analysis

In order to establish whether foot structure, syllable structure or syllable number have the greater effect of the accuracy of repetition, a 2 (foot markedness) x 2 (syllable markedness) x 4 (syllable number) x 4 (child) ANOVA was carried out. This revealed significant main effects of foot markedness ($p<0.001$), child ($p<0.001$) and syllable number ($p=0.018$). Significant interactions were found between foot markedness and child ($p=0.007$), syllable number and child ($p=0.006$) and syllable number and syllable markedness ($p=0.026$). Significant 3-way interactions were also found between syllable number, syllable markedness and child ($p=0.044$) and between child, foot markedness and syllable markedness ($p=0.019$). Post hoc tests (using Bonferroni's procedure) revealed that the scores for 1 and 2 syllable non-words were not significantly different from one another and neither were the scores for 3 and 4 syllable non-words. However, all other pairwise comparisons were significant (all $p<0.001$). These analyses show that foot markedness and syllable number have a significant impact on the accuracy of non-word repetition but that syllable markedness does not. We suggest that the syllable number effect is due to the effect of right adjunction, which, according to our analyses, exerts a significant effect on performance. The effect of foot markedness and syllable number varies from child to child.

The effect of individual foot structures was investigated using a 2 (left adjunction) x 2 (right adjunction) x 4 (child) ANOVA. This revealed significant main effects of left adjunction ($p<0.001$), right adjunction ($p=0.004$) and child ($p<0.001$). Significant interactions were found between left and right adjunction ($p=0.002$), between left adjunction and child ($p<0.001$) and between right adjunction and child ($p<0.001$). Both foot structures affect performance, with the group as a whole being worse at repeating non-words with an unstressed initial syllable and/ or antepenultimate stress. The effects of these structures also interact with one another and have different effects on individual children.

A 2 (onset) x 2 (rhyme) x 2 (word end) x 4 (child) ANOVA revealed no significant main effect of any of the syllable structures but a significant main effect of child ($p=0.001$) and a significant interaction between child and word end ($p=0.006$). The interaction between child and word end occurred because three of the children increased their scores when non-words ended in a consonant (contrary to expectation), whereas one decreased hers. Possible reasons for these findings are discussed in section 6.2.

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[2] The statistical analysis of both group and individual data is summarised in Tables 6 – 8 in the Appendix.

Post hoc tests for child using Bonferroni's procedure revealed that the scores for children TF (39) and GD (34) were significantly lower than the scores for children DS (72) and LN (71), (p<0.001).

That our analyses show significant interactions with 'child' indicates a lack of homogeneity in this small sample of SLI children. Further statistical and phonological analyses were conducted on an individual basis, and we present these for each child in turn in section 6.2. The phonological analysis is important because while the statistical analysis shows which parameters significantly affect overall repetition accuracy, the phonological analysis reveals the main loci of each child's errors.

6.2 Individual subject analyses

6.2.1 Child DS. A 2 (foot markedness) x 2 (syllable markedness) x 4 (syllable number) ANOVA revealed no significant main effects or interactions. More detailed analyses using a 2 (onset) x 2 (rhyme) x 2 (word end) ANOVA also revealed no significant main effects or interactions, but a 2 (left adjunction) x 2 (right adjunction) ANOVA revealed a significant main effect of left adjunction (p=0.046). This analysis shows that DS's difficulties are with non-words containing a left-adjoined syllable. Phonological analysis shows that he preserves complex onsets in non-words which lack a left-adjoined syllable, but that they are sometimes simplified where they occur after an adjoined syllable, regardless of whether or not there is additional right adjunction. For example, *dɪfrɪmpl* becomes *dɪfɪnpl*, *dɪfrɪpələ* becomes *dɪfɪpələ* and *fəklɛstələ* becomes *fəkɛstələ*.

Note that in all the examples discussed so far the overall foot structure of the word is maintained. There are, however, three examples where this is not the case. In *dɪfrɪpl* the left-adjoined syllable is lost, while in *kɛstələ* the right-adjoined syllable is lost. *dɪfrɪp* is realised with two equally-weighted syllables.

Word-final *-ɛmp* is reduced on two out of four occasions to *-ɛm*, in the two non-words *dɛmp* and *drɛmp*. Because neither of these words has an adjoined syllable, the reduction process appears to be independent of foot structure. Internal rhymes are always retained in non-words which lack a left-adjoined syllable but are sometimes lost in non-words which do have one – *bədɛmpə* becomes *fədɛpə* and *dɪfɪmpl* becomes *dɪfrɪpl*. Notice that in DS's realisation of *dɪfɪmpl*, although the rhyme is simplified the onset actually becomes a cluster. A complex cluster is also created when *dɪfɪpl* becomes *dɪfrɪpl*. When the right-adjoined foot structure of *bədɛmpəri* is simplified to *pədɛmbri*, deletion of a schwa results in the labial stop and *r* becoming a complex onset. Problems with the foot structure of *bədɛmpəri* result in an onset cluster when it is realised as *dəpɛbdri*. It should be noted that onsets are only ever altered from simplex to complex in non-words where there is left adjunction.

6.2.2 Child GD. GD's data are perhaps the most interesting of all the four children. A 2 (foot markedness) x 2 (syllable markedness) x 4 (syllable number) ANOVA revealed a significant main effect of foot markedness ($p=0.001$) and a significant interaction between foot and syllable markedness ($p=0.028$). A 2 (onset) x 2 (rhyme) x 2 (word end) ANOVA revealed no significant effects. In contrast, a 2 (left adjunction) x 2 (right adjunction) ANOVA revealed significant main effects of left adjunction ($p<0.001$) and right adjunction ($p<0.001$), and a significant interaction between both of these ($p<0.001$). There was a negative correlation between the number of marked structures and repetition accuracy ($p=0.001$), indicating that as the number of marked structures increased so did the number of errors.

GD has few difficulties in repeating non-words with unmarked foot structures, but great difficulty when either type of adjunction occurs. Right-adjoined syllables may be omitted altogether, as when ***kɛtələ*** is realised as ***kɛklə*** and ***klɛstələ*** as ***klɛstə***. There are no instances, however, of left-adjoined syllables being omitted.

The statistical analysis presented above shows that there is a significant interaction between foot markedness and syllable markedness in GD's data. This difficulty manifests itself in simplifications of syllable structure in words where foot structure is marked, so that for example, ***sɪprɪfi*** becomes ***dɪfifi***, ***fəklɛst*** becomes ***kəlɛs*** and ***drɛpəri*** becomes ***dɛpəri***.

As a further illustration of this interaction, consider the onset cluster ***kl***, which is invariably realised as ***kəl*** where it follows a left-adjoined syllable. For example, ***fəklɛtə*** becomes ***kəlɛstə***, ***fəklɛt*** becomes ***kəlɛt***, ***fəklɛstə*** becomes ***kəlɛstə***, ***fəklɛst*** becomes ***kəlɛst***, ***fəklɛtələ*** becomes ***kəlɛtələ*** and ***fəklɛstələ*** becomes ***kəlɛstələ***. Separating the consonants with a schwa breaks up the cluster. The onset of the adjoined syllable is substituted, and this results in the overall foot structure of the word being maintained. This process does not occur where the initial syllable is stressed, presumably because to do so would result in a change of foot structure, so ***klɛt***, ***klɛtə***, ***klɛst*** and ***klɛstələ*** are unaffected. Similarly ***dr*** splits into ***dər*** when it follows an adjoined syllable. For example, ***bədrɛpə*** is realised as ***dərɛpə***. Even more interestingly, ***dr*** is most often realised as ***dəp***, resulting in ***bədrɛpəri*** becoming ***dəpɪfəri*** and ***bədrɛmpəri*** becoming ***bəpɛmpfəri***. Once again, this process does not occur where the initial syllable is stressed, so ***drɛmpə*** and ***drɛmpəri*** are unaffected.

Consonant clusters made up of a closed rhyme and an adjacent onset are frequently subject to error. Sometimes such clusters are split up, as when ***fɪmpələ*** becomes ***finɪpələ*** and ***pɪlfɪtə*** becomes ***sɪfɪfɪtə***, and the foot structure has to change to accommodate this by the creation of an unstressed initial syllable. In other cases simplification is achieved through deletion of the rhymal consonant, as when ***sɪprɪlfi*** is realised as ***pərɪfi*** and ***dɪfɪmpələ*** as ***səfɪfələ***.

GD makes a lot of consonantal substitutions when foot structure is marked. Sometimes these consonants are from the original non-word but in the wrong order, as when ***dɪfɪmpl*** becomes ***dɪpɪmpfl*** and ***dɪfɪmp*** becomes ***dəpɪmf***, while on other occasions they are entirely new, as when ***bədɛp*** is realised as ***pəfɛt***, ***bədɛperi*** as ***dəfɪfəli*** and ***sɪpɪlf*** as ***dɪfɪlf***. It is not generally possible to discern a pattern of substitution, although ***fəkɛt*** is repeated as the real word ***fəgɛt***.

6.2.3 Child TF. A 2 (foot markedness) x 2 (syllable markedness) x 4 (syllable number) ANOVA revealed a significant main effect of foot markedness (p=0.004) but no other significant main effects or interactions. A 2 (left adjunction) x 2 (right adjunction) ANOVA revealed significant main effects of both left adjunction (p=0.004) and right adjunction (p<0.001), and a significant interaction between these two structures (p=0.020). A negative correlation was found between the number of marked structures and repetition accuracy (p=0.007).

A 2 (onset) x 2 (rhyme) x 2 (word end) ANOVA revealed a significant main effect of word end (p=0.049). TF has greater success on words that end in a consonant, which is the marked option, but this could be an artefact of the design of this test. All the three or four syllable non-words we used end in a vowel, while all the one syllable non-words end in a consonant. The statistical analysis above showed that TF has great difficulty with non-words which are marked for either (and particularly both) of the foot parameters; all three syllable and four syllable non-words in this test have at least one adjoined syllable. In contrast, all one syllable non-words lack adjunction. We propose that the apparent difficulty with word end is due to difficulty with foot markedness, but that the design of the test does not allow us to distinguish between these factors.

TF's stress patterns proved quite difficult to transcribe. In non-words with a left-adjoined syllable she has a tendency to make that syllable and the subsequent stressed syllable equally long. However, the second is realised with greater volume, and vowel quality is also realised correctly. Such non-words were transcribed as having correct stress for the purposes of the present analysis because of the volume and vowel quality distinctions made between unstressed and stressed syllables.

Left-adjoined syllables are frequently omitted. For example, ***bədrɛpə*** becomes ***drɛpə***, ***dɪfɪpələ*** becomes ***fɪpələ*** and ***dɪfɪmpələ*** becomes ***dɪpdʒələ***. Right adjunction causes errors through the loss of the non-final unstressed syllable. An interesting pattern emerges in the eight non-words with right adjunction whose last two syllables are ***pəri***. On four out of eight occasions the schwa is lost and its onset retained but as a *f*. Hence *bədrɛpəri* is realised as ***dədɛlfri***, ***dɛmpəri*** as ***dɛmpfri***, ***drɛmpəri*** as ***dɛmfri*** and ***bədrɛmpəri*** as ***bədrɛfri***. That this only happens on half the possible occasions shows the optionality of the process rather than its inevitability. The loss of a schwa in this position (the second of three nuclei in a Strong-Weak-Weak configuration) is not unexpected – the same process occurs in real words such as **med(i)cine**, **sep(a)rate** and **ref(e)rence** (Harris, 1994). What is unexpected is the appearance of the labio-dental fricative.

Like GD, TF makes a very large number of consonantal substitutions in non-words where she manages to maintain overall foot complexity. For example, ***bədrɛpə*** becomes ***fəpɛtə***, ***klɛtələ*** becomes ***tʃɛtʃələ***, ***sɪpɪfɪtə*** becomes ***bətɪfətə*** and ***dɪfrɪmpələ*** becomes ***dɪbrɪtʃələ***. We can discern no pattern to these substitutions.

TF shows a tendency to simplify complex onsets, particularly in words with left adjunction. For example, ***fəklɛtə*** becomes ***fəkɛktə***, ***frɪpələ*** becomes ***fɪpələ*** and ***bədrɛmpəri*** becomes ***bədɛfri***.

TF is the only one of the four children in this study to make vowel length errors. On four occasions she lengthens ***ɪ*** to ***i***. ***frɪmp*** is realised as ***frimp***, ***dɪfrɪp*** as ***dɪfrip***, ***frɪmpələ*** as ***fipilə*** and ***dɪfrɪpələ*** as ***fipɪtlə***.

6.2.4 Child LN. A 2 (foot markedness) x 2 (syllable markedness) x 4 (syllable number) ANOVA revealed a significant main effect of syllable number ($p=0.003$), and significant interactions between foot markedness and syllable number ($p=0.025$) and between syllable markedness and syllable number ($p=0.020$). However, in contrast to what the CNRep would predict and in contrast to the main effect in the overall group data, LN has greater success on words with four syllables. In order to investigate the reasons for this surprising result, we carried out a 2 (onset) x 2 (rhyme) x 2 (word end) ANOVA, which revealed a significant main effect of word end ($p<0.001$), and a 2 (left adjunction) x 2 (right adjunction) ANOVA, which revealed a significant main effect of right adjunction ($p=0.003$). LN is more accurate at repeating words which end in a vowel, while in contrast to the overall group data she finds the marked right adjoined structure easier than the unmarked non-adjoined structure. This explains why LN found the non-words with four syllables easier than those with only three – the former all have a right-adjoined syllable and end in a vowel.

LN makes the simplifications typical of a younger child who is developing phonology normally. Words with simple syllable and metrical structure, such as ***kɛtə*** and ***pɪfi***, are pronounced correctly. The only example of onset reduction is ***prɪlfɪtə*** being realised as ***pɪlfɪtə***. Word-final clusters are reduced on 2 out of 16 occasions through the loss of the word-final consonant – ***prɪlf*** becomes ***prɪl*** and ***dɪfɪmp*** becomes ***dɪfɪm***. Internal rhymes are always preserved. Unstressed syllables are omitted from only one non-word – the first syllable of ***bədɛ̱mpə*** is lost, leaving ***dɛ̱mpə***.

LN frequently substitutes ***θ*** for ***f*** in a way that is prosodically sensitive. ***f*** is consistently maintained in the onset of a stressed syllable, i.e. in the strong position of a foot. However, it is variably replaced by ***θ*** when it occurs word-finally or in the onset of an unstressed syllable, i.e. in weak foot positions. In the word-final case, ***f*** is repeated correctly when preceded by a closed rhyme (as in a) but is consistently produced as ***θ*** where the preceding rhyme is open (see b).

	NON-WORD TARGET	SUBJECT LN
a.	*pɪlf*	*pɪlf*
b.	*pɪf*	*pɪθ*
c.	*sɪpɪ̱lfi*	*sɪpɪ̱lfi*
d.	*sɪpɪ̱fitə*	*sɪpɪ̱fitə*
e.	*sɪpɪ̱fi*	*sɪpɪ̱θi*

Where the disyllabic sequence ***ɪ̱lfi*** occurs word-medially, ***f*** is always correctly realised (as in c). Where the sequence ***ɪ̱fi*** occurs word-medially, its correct realisation depends on whether or not an unstressed syllable follows, i.e. on whether there is right adjunction. Where there is right adjunction, ***f*** is repeated correctly (see d). However, in the absence of right adjunction ***θ***-replacement always occurs (see e).

A second pattern to note in LN's data is that word-final consonant clusters, rather than being simplified, are in fact often made more complex. For example, on every occasion the *ɛmp* ending becomes ***ɛmpt***, so ***dɛmp*** becomes ***dɛmpt***, ***drɛmp*** becomes ***drɛmpt***, ***bədɛ̱mp*** becomes ***bədɛ̱mpt*** and ***bədrɛ̱mp*** becomes ***bədrɛ̱mpt***. Similarly the ***-ɛp*** ending becomes ***-ɛpt*** on two out of four occasions. However, this pattern is not seen for non-words ending in ***-ɪp*** and ***-ɪmp*** – they never become ***-ɪpt*** and ***-ɪmpt***. We suggest that LN is using a strategy of making analogy with real words, perhaps **kept** and **slept** in the case of words that end with ***-ɛpt*** and **dreamt** (with an intrusive ***p***) and **tempt** in the case of ending in ***-ɛmp***. That no ***t*** is added to ***-ɪp*** and ***-ɪmp*** could be explained by the fact that there are no monomorphemic words ending in ***-ɪpt*** or ***-ɪmpt***. This pattern is again in contrast to the data for the other three children.

7 Discussion

Using the TOPhS we set out to test the following predictions:-

a. Non-words with marked structures will be more difficult to repeat accurately than those with unmarked structures.

b. The greater the number of marked structures for a given non-word the greater the difficulty

c. Certain marked structures will have a greater impact on repetition accuracy than others.

The four SLI children whose non-word repetition data we report show differing error patterns and frequencies. However, some generalisations can be made for the group as a whole. With regards to predictions (a) and (c), marked syllable parameters have little effect on repetition accuracy. The marked settings that cause the most problems are instead the left- and right- adjoined syllables. We believe that we are the first to identify that right adjunction poses difficulties in SLI. In addition, although other authors have reported initial unstressed syllable omission (Bortolini & Leonard, 2000; Sahlen *et al*, 1999), they have not considered how the metrical environment affects syllabic and segmental accuracy. Although we do find examples of weak syllable omission, in the majority of cases marked metrical structure is correctly realised, yet syllabic and segmental errors occur in precisely those cases. In other words metrical complexity is the trigger for difficulties further down the prosodic hierarchy. With regards to prediction (b), only two of the four children showed a negative correlation between the number of marked structures and repetition accuracy.

Individual analysis of the data shows that for DS only left adjunction significantly affects performance, at times resulting in onset simplification where the adjoined syllable precedes a complex onset. For GD and TF both types of syllable adjunction affect performance, and these children scored much lower on the test than either LN or DS. In non-words with one or two adjoined syllables they make a high number of consonantal substitutions and have a tendency to simplify complex onsets. LN's non-word repetition accuracy is affected by right adjunction and word-final consonants. Unusually, she makes some non-word endings syllabically more complex than the target. She also shows errors in her realisation of *f*, which in strong foot positions is always realised correctly, but in certain weak positions becomes *θ*.

The aim of creating the set of non-words used in this study was to pinpoint more accurately, and from a phonological perspective, the locus of the phonological deficit in SLI, and to see how the findings support or contradict the prevailing theories as to the causes of SLI. So how does Gathercole and Baddeley's hypothesis that short-term phonological memory deficits are the cause of SLI fare? Syllable number was found to have a significant effect on the overall data. However, when data from each child were analysed separately, syllable number was found to significantly affect performance in only one child (LN), but she repeated four syllable non-words more accurately than three syllable ones. We therefore argue that it is not the length of words *per se* that causes repetition errors. Instead we propose that the problem rests with prosodic structure, and with metrical structure in particular. We are not claiming that length is *never* a factor on performance in non-word repetition tasks. Performance issues such as limited capacity in verbal short-term memory will affect performance because there is obviously an upper limit to the number of syllables that can be retained in short-term memory! The point is that for our data at least, the effect of a word's metrical structure must also be taken into account. So while Gathercole & Baddeley argue that poor phonological memory is the cause of the language difficulties faced by children with SLI, our interpretation is different. Instead we claim that difficulties in the formation of phonological representations cause poor phonological short-term memory and poor linguistic skills (c.f. van der Lely & Howard, 1993).

Under standard non-linear phonological assumptions, segmental material can only be phonetically realised when it is linked to prosodic structure. In principle, a deficit could separately affect either prosodic structure or the linking relation. If the deficit lies with the prosodic template, then we would expect to find errors where the sequence of segments is reproduced correctly but where the prosodic structure is faulty. Examples from the present study which conform to this pattern are GD's realisations of ***dɪfɪ̱p*** as ***dɪ̱fɪp*** and ***pɪ̱fɪtə*** as ***pɪfɪ̱tə***, and DS's realisation of ***dɪfrɪ̱p*** as ***dɪ̱frɪ̱p***. Each of these errors shows faulty foot structure. Another example of a prosodic error is GD's realisation of ***fəklɛ̱t*** as ***kəlɛ̱t.*** Here it is syllable structure that is faulty: the simplification of a complex onset is accompanied by a segmental reassociation that makes no provision for the initial ***f***.

On the other hand, where a deficit targets the linking of segmental material to correct prosodic structure, we expect to find errors where foot structure and syllable structure are correctly realised but where the melody has been incorrectly associated with it. TF's realisation of ***prɪ̱lfɪtə*** as ***prɪ̱ltɪfə*** and GD's realisation of ***dɪfɪ̱mp*** as ***dəpɪ̱mf*** are examples of these kinds of errors. A linking difficulty could also explain observations (Chiat, 1989; Ebbels, unpublished data) that segments in real words are prone to being misordered in SLI, as when **medicine** becomes ***mɛ̱sɪdən***, opposite becomes ***o̱səpɪt*** and **suddenly** becomes ***sʌ̱ndəli***. Interestingly, all these words have a right-adjoined syllable. However, in our data we rarely find non-words with just one type of error.

In sum, we claim that our data indicate that SLI children have an impaired phonological system. As with their syntactic abilities (e.g. Rice *et al*, 1995; van der Lely *et al*, 1998), this is not to say that complex structures are unavailable, merely that they are more error-prone. There is an ‘optionality’ in the production of complex foot and syllable structure. The question remains unanswered as to the state of the phonological representations underlying these children’s correct realisations. One possibility is that strings of segments are remembered as unstructured sequences. Problems in forming phonological representations could result in a strategy of ‘whole word storage’. The use of analogy between the non-words and stored words might then facilitate correct production. For instance, LN’s realisations of *ɛmp* as *ɛmpt* and *ɛp* and *ept* could result from analogies with **dreamt**, **kept** and **slept**. Analogy could also explain why GD realises *fəkɛt* as **forget**.

The TOPhS allows us to make more specific predictions as to how phonological difficulties interact with other linguistic abilities, such as inflectional morphology, which in English is usually marked by a coronal suffix. The possible impact of syllable structure on inflection in SLI has been previously suggested by Bortolini & Leonard (2000), who found a significant correlation between final consonant reduction in monomorphemic forms and the omission of consonantal inflections. In our study consonant clusters were reduced on only 11% of occasions, as compared to almost 80% in theirs. This discrepancy could be due to the older age of our participants (12;8 to 14;8) compared to those used by Bortolini & Leonard (3;7 to 5;9). The results from our study lead us to make a different prediction, namely that for our participants at least, there will be an interaction between foot structure of the inflected verb and the inflection itself. Realisation of the suffix might be affected by whether the inflected word has a right adjoined syllable. For example, we would predict that the three syllable σ̲σ*ɪd* or σ̲σ*ɪz* pattern (e.g. **merited**, **sandwiches**, **lavishes**), with antepenultimate stress, would have significantly greater rates of inflection omission than σ̲*ɪd* or σ̲*ɪz* forms. However, it is important to stress that phonology could have an effect on inflection which is *in addition* to a deficit in the morphosyntax proper, contra the claims of some phonologists, who reject the existence of a morphosyntactic deficit in SLI (e.g. Bernhardt and Stemberger, 1998; Stemberger, personal communication).

Children who make many errors on phonological tasks such as non-word repetition are predicted to have difficulties with phonological bootstrapping, which is the processing of phonological information in order to abstract lexical units and determine their order (Chiat, 2001). Chiat claims that these difficulties will impact on the learning of verb meaning, particularly for more abstract verbs where the semantics are less transparent, and will lead to difficulties in the acquisition of argument structure. Prosodic information has been shown to be important in the acquisition of double object dative structures in English, for example (Gropen, Pinker, Hollander, Goldberg & Wilson, 1989). Research is warranted into the relationship between SLI children's knowledge of verb argument structure and their performance on the TOPhS.

Further research is needed into how children with different patterns of language impairment perform on the TOPhS. Although it is accepted that SLI is a heterogeneous disorder, the existence of relatively homogeneous subgroups is controversial. On a modular account of language relatively pure impairments of different components of the language system should be identifiable. Van der Lely and her colleagues have amassed considerable evidence to support the existence of a subgroup of children, the so-called G(rammatical)-SLI group, who have a primary deficit in grammar (van der Lely *et al,* 1998). More recently Froud & van der Lely report a second subgroup of children, the so-called L(exical)-SLI group, who are characterised by a primary deficit in lexical abilities but whose syntax and morphology are significantly less impaired (Froud & van der Lely, 2001). It would be interesting to look at the errors that these subgroups make on the TOPhS, and to determine whether there are any qualitative and quantitative differences in their phonological abilities.

Bishop *et al* (1996) and Botting & Conti-Ramsden (2001) report the existence of SLI children, albeit a small minority, who achieve high scores on the CNRep. Our results suggest that a detailed assessment is required before concluding that such children have a normal phonological system. Just one marked prosodic structure, or combination of structures, might cause difficulties, indicating an underlying phonological deficit. The TOPhS is sensitive enough to pick this up.

In conclusion we have shown that for these four SLI children at least, a non-word’s metrical environment affects the syllabic and segmental accuracy of its realisation. Metrical complexity, and specifically the presence of adjoined syllables, triggers errors further down the prosodic hierarchy. We claim that these SLI children have a deficit in the formation of phonological representations. Further investigations are warranted in order to clarify whether the deficit is in the prosodic template itself or in the linking of segmental material to that template.

Appendix

Table 6: p-values for 2 (foot markedness) x 2 (syllable markedness) x 4 (syllable number) (x 4 (child)) ANOVA

	Group data	Individual data	DS	GD	TF	LN
Foot markedness	<0.001	Foot markedness	ns	0.001	0.004	ns
Syllable markedness	ns	Syllable markedness	ns	ns	ns	ns
Syllable number	0.018	Syllable number	ns	ns	ns	0.003
Child	<0.001					
Foot mark x syllable mark	ns	Foot mark x syll mark	ns	0.028	ns	0.025
Foot mark x child	0.007					
Foot mark x syllable number	.	Foot mark x syllable number	.	.	.	.
Syllable mark x syllable number	0.026	Syllable mark x syll num	ns	ns	ns	0.020
Syllable mark x child	ns					
Syllable number x child	0.006					
Foot m x syll m x syll num	.	Foot m x syll m x syll num	.	.	.	.
Foot m x syll m x child	0.019					
Syllable num x child x foot m	.					
Syllable num x child x syll m	0.044					
S num x child x foot m x syll m	.					

Table 7: p-values for 2 (onset) x 2 (rhyme) x 2 (word end) (x 4 (child)) ANOVA

	Group data	Individual data	DS	GD	TF	LN
Child	0.001					
Onset	ns	Onset	ns	ns	ns	ns
Rhyme	ns	Rhyme	ns	ns	ns	ns
Word end	ns	Word end	ns	ns	0.049	<0.001
Child x onset	ns					
Child x rhyme	ns					
Onset x rhyme	ns	Onset x rhyme	ns	ns	ns	ns
Child x onset x rhyme	ns					
Child x word end	0.006					
Onset x word end	ns	Onset x word end	ns	ns	ns	ns
Child x onset x word end	ns					
Rhyme x word end	ns	Rhyme x word end	ns	ns	ns	ns
Child x rhyme x word end	ns					
Onset x rhyme x word end	ns	Onset x rhyme x word end	ns	ns	ns	ns
Child x onset x rhyme x word end	ns					

Table 8: p-values for 2 (left adjunction) x 2 (right adjunction) (x 4 (child)) ANOVA

	Group data	Individual data	DS	GD	TF	LN
Left adjunction	<0.001	Left adjunction	0.046	<0.001	0.004	ns
Right adjunction	0.004	Right adjunction	ns	<0.001	<0.001	0.003
Child	<0.001					
Left x right adjunction	0.002	Left x right adjunction	ns	<0.001	0.020	ns
Left adjunction x child	<0.001					
Right adjunction x child	<0.001					
Left x right adjunction x child	ns					

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