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Research Report

Phonological and morphophonological effects on grammatical development in children with specific language impairment

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Abstract

Background: Five-year-olds with specific language impairment (SLI) often struggle with mastering grammatical morphemes. It has been proposed that *verbal* morphology is particularly problematic in this respect. Previous research has also shown that in young typically developing children grammatical markers appear later in more phonologically challenging contexts.

Aims: The main aim was to explore whether grammatical deficits in children with SLI are *morphosyntactic* in nature, or whether *phonological* factors also explain some of the variability in morpheme production. The analysis considered the effects of the same phonological factors on the production of three different morphemes: two verbal (past tense *-ed*; third-person singular *-s*) and one nominal morpheme (possessive *-s*).

Methods & Procedures: The participants were 30 children with SLI (21 boys) aged 4;6–5;11 years (mean = 5;1). The data were collected during grammar test sessions, which consisted of question/answer elicitations of target forms involving picture props. A total of 2301 items were analysed using binary logistic regression; the predictors included: (1) *utterance position* of the target word, (2) *phonological complexity* of its coda, (3) *voicing* of the final stem consonant, (4) *syllabicity* (allomorph type) and (5) *participant* accounting for the individual differences in the responses.

Outcomes & Results: The results showed a robust effect of *syllabicity* on the correct morpheme production. Specifically, syllabic allomorphs (e.g., *She dresses*) were significantly more challenging than the segmental ones (e.g., *He runs*) for all three morphemes. The effects of other factors were observed only for a single morpheme: *coda complexity* and *voicing* helped explain variability in past tense production, and *utterance position* significantly affected children's performance with the possessive. The *participant* factor also had a significant effect, indicating high within-group variability - often observed in SLI population.

Conclusions & Implications: The systematic effect of *syllabicity* across both verbal and nominal morphemes suggests morphophonological influences in the grammatical development of children with SLI that cannot be fully explained by syntactic deficits. Poorer performance in producing syllabic allomorphs can be accounted for by much lower overall frequency of these forms, and by the 'tongue-twisting' effect of producing similar segments in succession, as in *added* [ædəd], *washes* [wɒʃəz]. Interestingly, the greater acoustic salience of the syllabic allomorphs (an extra syllable) does not enhance children's abilities to produce them. These findings suggest that the interconnections between different levels of language have a stronger effect on the grammatical development of children with SLI than might be expected. *Allomorphy* should, therefore, be taken into account when designing language assessments and speech therapy, ensuring that children receive sufficient practice with the entire set of allomorphic variants.

Keywords: specific language impairment, grammatical morphemes, morphophonology, allomorphy, coda complexity, utterance position.

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What this paper adds?

What is already known on this subject?

Delayed acquisition of grammatical morphology in children with SLI is often thought to be associated with morphosyntactic deficits. However, there is some evidence that phonological factors may also play a role in explaining their difficulties in learning grammar. This paper explores various phonological interactions across different types of grammatical morphemes in order to better understand the factors affecting grammatical development in children with SLI.

What this study adds?

This study examined verbal (past tense *-ed*; third-person singular *-s*) and nominal (possessive *-s*) morphemes, demonstrating that the production of all three morphemes is systematically affected by *syllabicity* (e.g., allomorph type). Specifically, adding syllabic allomorphs (e.g., *She dresses*) appears to be significantly more challenging than adding segmental ones (e.g., *He runs*). The findings suggest that learning the patterns of morphophonological alternations may be particularly problematic for children with SLI, leading to additional difficulties in mastering grammar. Therefore, allomorphy and possibly other morphophonological effects require special attention from speech therapists during assessment and intervention.

Introduction

Early acquisition of grammar

Children's understanding of the organizational principles of their first language becomes deeper and more complex over time. This process of gradual development of the linguistic competence in young children has long been an object of intense scientific interest (Bloom 1970, Brown 1973). For English-speaking children, one of the major characteristics of early acquisition are morphological errors of omission (Clark 2003), when children use bare stems without any morphological markers, as in *Every day she dance* or *Two bus*.

Some have proposed that these omissions may be caused by children's incomplete syntactic or semantic representations (Wexler 1994). However, more recently it has also been shown that phonological factors have a significant effect on early morpheme production, with some phonological contexts being more challenging for adding grammatical morphemes than others. These constraints include, for example, the phonological complexity of the coda and the position of the target word within the utterance-two factors that have been found to systematically affect children's early verbal (Song *et al.* 2009) and nominal morpheme productions (Theodore *et al.* 2011, Mealings *et al.* 2013).

The systematicity and robustness of these effects across morphemes provide extensive evidence that phonology is an important component of morphological development. For example, the plural form *buses* is often produced by 2-year-olds as '*buseh*' [bɐsə] or '*buss*' [bɐss] (Mealings *et al.* 2013). Such partial realizations suggest that it is phonological or articulatory difficulties which make production of these morphemes challenging. If so, this would indicate a possible dissociation between young children's receptive and expressive skills, demonstrating their awareness that the morpheme is required, despite omitting it in actual speech.

Morpheme acquisition in children with SLI

Variability in early morpheme production is also typical for children with SLI, who, despite their normal physical and cognitive abilities, lag behind their peers in terms of language development (Leonard 1998, Bishop and Norbury 2008). Since this language impairment is diagnosed by excluding other possible causes, the term 'SLI' can potentially cover a broad range of deficits in receptive and expressive skills. In other words, children with SLI form a heterogeneous population (Dale and Cole 1991, Leonard 1998, Conti-Ramsden and Botting 1999). Nevertheless, it has been shown that, in general, English-speaking children with SLI find it particularly challenging to use auxiliary verbs (Cleave and Rice 1997, Grela and Leonard 2000) and bound grammatical morphemes (Leonard 1998, Norbury *et al.* 2001, Rice *et al.* 1995), and they continue to omit a large proportion of these morphemes for an extended period of time.

According to Optional Infinitive/Extended Optional Infinitive hypothesis, these errors of omission are syntactic in nature (Rice *et al.* 1995), affecting primarily verbal tense and agreement morphology. However, other studies have shown that at least some of the variability in these children's use of grammatical morphemes can be explained by the effects of phonological context (Marshall and van der Lely 2007, Marshall, Harcourt-Brown, Ramus & van der Lely 2009; Polite 2011), suggesting that children have some knowledge of the morpheme despite their failure to reliably produce it. In addition, some of the recent findings show that the interconnections between different levels of language have stronger effects on the grammatical development in children with SLI than might be anticipated. Specifically, morphophonological processes, such as allomorphic variation, liaison, contraction and elision may be especially challenging for these children (Royle and Stine 2013). If so, the concept of impaired morphophonological abilities should be integrated into descriptive models of SLI.

Despite the findings mentioned above, it is not yet clear whether the phonological factors that influence the production of grammatical morphemes in younger typically developing (TD) children have the same effect on children with SLI across various morphemes. The aim of this study was therefore to provide a more in-depth investigation of this issue, examining the effects of phonological constraints and morphophonological alternations on morpheme production in children with SLI to determine whether they reveal the same tendencies as have been found for TD children.

Phonological constraints on morphological development

The factors of interest in this study are four constraints on morpheme production: *coda complexity*, *stem coda voicing*, *utterance position* and *syllabicity* (syllabic versus segmental/non-syllabic allomorphs). We will first consider the significance of these effects for TD children and then discuss current findings in children with SLI.

Evidence from TD children

Previous studies have found that grammatical development in English-speaking 2-year-olds is significantly affected by *phonological complexity* of the target coda. Specifically, children are more accurate when adding grammatical morphemes to lexical stems that end in a vowel rather than in a consonant. In other words, items ending in a simple coda (e.g., *plays*) are presumably easier to articulate than those ending in complex codas/consonant clusters (e.g., *sits*) (Song *et al.* 2009).

Voicing can also affect children's abilities to produce morphemes, due to the difference in the order of acquisition between voiced and voiceless stops and fricatives. It has been shown that English voiceless stops (e.g., [p], [t], [k]) are usually acquired earlier in coda position than their voiced counterparts ([b], [d], [g]) (Kehoe and Stoel-Gammon 2001), and [s] is acquired before [z] (Smit 1993). Moreover, lexical stems ending in a voiced consonant require adding a voiced allomorph (e.g., *stands* [stændz]), thus creating *clusters* of voiced consonants that should be more challenging to produce than unvoiced clusters (e.g., *sits* [sɪts]). In Berko's (1958) classical study, no significant differences were found between voiced and voiceless conditions. However, these voicing contrasts were studied within different allomorphs. Thus, the voiced condition included both phonologically simple (e.g., *plays*) and complex (e.g., *stands*) codas. Although simple codas are always *voiced*, they are typically acquired *earlier*. Therefore, not taking the *coda complexity* factor into account might have mitigated the results, masking possible voicing effects.

It has also been demonstrated that TD children are sensitive to the *utterance position* of the target form. Specifically, they are more likely to produce grammatical morphemes when the target word is in utterance-final rather than utterance-medial position, e.g., *Every day he reads* versus *He reads every day*, and this has been found to affect both verbal and nominal morpheme production (Song *et al.* 2009, Theodore *et al.* 2011). This could be due to (1) final phrase lengthening, which provides greater time for producing the final syllable and all segments or (2) increased articulation ease due to the absence of a following word.

It has further been shown that *syllabic allomorphs* (e.g., *washes*) are usually later-acquired by TD children than segmental allomorphs (e.g., *climbs*). This has been supported by evidence from children's spontaneous speech (Brown 1973), elicited productions (Berko 1958), and elicited imitations (Mealings *et al.* 2013). However, the systematicity and robustness of this pattern for different morphemes and across age groups has not yet been given full consideration. For example, there is a question about the source of the delayed acquisition of the syllabic allomorphs: is it driven by the challenge of articulating similar sounds in succession (e.g., *added*), or due to the lower frequency of these allomorphs in the speech input children hear and produce?

Evidence from children with SLI

Due to their more mature chronological age, 5-year-olds with SLI might not be affected in the same way by the phonological effects observed in TD 2-year-olds. However, there is evidence suggesting that, for example, *coda complexity* might have a similar effect on morpheme production in children with SLI as it does in TD children. Thus, some studies have reported a higher proportion of morpheme omission in the context of complex codas (Polite 2011), and even in older 9–16-year-old children with SLI (Marshall and van der Lely 2007). However, the age of the participants in the latter study raises some concerns. Specifically, in TD children the reported regular past tense forms are typically acquired by about 3;6 (Brown 1973). Since overall children with SLI demonstrate an approximate 2-year delay in their language development (Rice 2013), those participants who continue omitting grammatical markers at the age of 9–16 are likely to have additional problems (e.g., articulatory deficits) on top of their difficulties in acquiring morphology. Furthermore, the participants in the Polite's (2011) study showed high overall accuracy and very small differences between the two conditions-77% versus 74% correct productions for simple versus complex codas, respectively. Therefore, it remains unclear how robust the effect of the coda complexity might be for children with SLI.

The effects of *voicing* on the speech of children with SLI have been investigated in a number of studies, and no significant differences have been established between voiced and voiceless conditions (Oetting and Horohov 1997, Marchman *et al.* 1999). However, just like in TD children, the possible confounding factors such as *coda complexity* have not been controlled for when examining this issue. This problem therefore requires further investigation.

It has also been shown that *utterance position* significantly affects SLI morpheme production when using past tense *-ed* suffix. Specifically, participants have been significantly more accurate in producing correct forms in sentence-final position (Dalal and Loeb 2005). This finding is consistent with what has been previously established for TD populations. However, we wanted to investigate the robustness of this effect across more than one morpheme before generalizing this result.

It has further been proposed that *syllabic* allomorphs tend to be later acquired by children with SLI (Oetting and Horohov 1997, Marchman *et al.* 1999). As before, this pattern mirrors the observations in TD population. However, in these studies the analysis was based on a small number of syllabic tokens; it thus requires further empirical evidence before making confident inferences about the SLI population in general. Although it seems natural that increasing the word length by adding another syllable could make production more challenging, the longer duration of the syllabic allomorphs should also make them more perceptually salient (Mealings *et al.* 2013). The greater acoustic content thus might serve as an additional cue for children with SLI, improving their abilities to perceive the morphemes and enhancing acquisition.

To summarize, phonological factors seem to explain some of the variability in morpheme production in both TD and SLI populations. However, the systematicity and robustness of the phonological effects in children with SLI is not yet clear. Since these children are older and thus have better motor control skills than TD 2-year-olds, it seems important to investigate how this might compensate for the phonological constraints on morpheme production observed in much younger TD children. It could be the case that the effects of phonological factors extend beyond articulatory difficulties, and that acquiring morphophonological regularities is another problematic area for language development in children with SLI.

The aim of the present paper was to analyse *coda complexity*, *voicing*, *utterance position* and *syllabicity* within one model, considering their possible interactions, and to compare the results across morphemes of different types. At a glance, these factors seem to be of a diverse nature. But all these phenomena involve different levels of segmental, syllabic, and phrasal phonology that affect the realization of inflectional morphemes. Due to their possible interactions, it seems essential to study them within one model to ensure there are no confounds.

When addressing these issues, we were guided by the general hypothesis that children with SLI should reveal similar patterns of morpheme acquisition to that of younger TD children. Furthermore, if there is a morphophonological component to the problem of inflectional morpheme realization, we would expect to observe similar effects on both verbal and nominal morphemes.

Method

Data

The data were drawn from speech samples collected during the investigation of the efficacy of various intervention methods on the language development of children with SLI (Smith-Lock *et al.* 2013a, 2013b). It focused on studying these children's abilities to correctly use grammatical morphemes. Data collection spanned three years (2010–12), aiming at establishing whether the intervention programs significantly improved children's performance in general, and if so, which methods and activities gave the best results for more rapid language development.

Before and after treatment, each participant was tested on the same set of 30 target items for a particular grammatical morpheme. This paper includes only data from the pre-intervention sessions, and compares children's production of three grammatical markers: (1) past tense *-ed*, (2) third-person singular *-s* and (3) possessive marker *-s*.

TD controls were not included in the original experiment. However, when designing the stimuli, the researchers first tested all target items on a group of twenty TD children age-matched with the SLI group. The final set of stimuli consisted only of the forms that were successfully elicited from the TD children 100% of the time. The items used in the experiment were all familiar verbs and nouns (both common and proper) balanced on the basis of the required *allomorph* type. For example, the past tense morpheme can be realized as [t], [d], or [əd]; the targets therefore included 10 words for each allomorph with mostly monosyllabic stems. However,

Table 1. Target forms for each morpheme and number of items per condition

Morpheme	Target items for each condition and their counts (number): Segmental allomorphs: Simple codas	Segmental allomorphs: Complex codas	Syllabic allomorphs	Utterance position: medial (proportion)
Past tense *-ed*	watered, cried, stirred (77)	squeezed, paddled, smiled, crawled, combed, buzzed, climbed, hopped, skipped, touched, danced, walked, shopped, dropped, licked, jumped, kicked (414)	pointed, ended, needed, twisted, added, folded, counted, landed, painted, melted (239)	474 (0.65)
Present tense *-s*	wears, plays, cries (94)	needs, opens, reads, drives, climbs, smiles, runs, coughs, skips, kicks, walks, cuts, laughs, picks, sits, counts, jumps (481)	touches, freezes, watches, hisses, squeezes, brushes, squashes/crushes, kisses, mashes, washes (222)	601 (0.75)
Possessive *-s*	bee's, May's, Mary's, boy's (98)	Doug's, Carl's, dog's, Em's, Bob's, man's, Hope's, Jack's, Pat's, Brett's, Blake's, Kate's, Pip's, cat's, duck's, sheep's (447)	Joyce's, church's, Josh's, Grace's, Blanche's, Mitch's, Rich's, Trish's, horse's, fish's (229)	118 (0.15)

they were not perfectly balanced in terms of coda types; thus, the majority of words in the voiced allomorph [d] condition had CVC/CVCC stems as in *buzzed*, and also a few CCV ones, as in *cried*. Although most items had monosyllabic stems, there were a few disyllables (e.g., the CVCV stem in *watered*[1]). The full list of target forms is presented in table 1.

Participants

All the participants included in this study had been attending one of the Language Developmental Centres in Western Australia. These centres provide specialized language and academic intervention for children with SLI. Entry into the school requires being diagnosed as having SLI by a speech language pathologist. Children's language skills were assessed either with the Preschool Language Scale (PLS) (Zimmerman *et al.* 2002) or the Clinical Evaluation of Language Function (CELF) (Wiig *et al.* 2006) as one part of an extensive assessment process for referral to the school. Referral information also included evidence that children's non-verbal cognitive skills were within the normal range, as attested by a psychologist or paediatrician, using one of the following assessment tools: Wechsler Preschool and Primary Scale of Intelligence (Wechsler 2002), Cognitive Adaptive Test (Accardo and Capute 2005), Denver Developmental Screening Test (Frankenburg *et al.* 1992), and Griffiths Mental Development Scales (Griffiths 1970). Although the scores on every standardized assessment were not available for the researchers in the present study, all the participants in this project were professionally attested as having (1) at least moderately impaired receptive or expressive language, i.e., 1.0–1.5 SD below the mean on the standardized language assessments; (2) normal non-verbal IQ, i.e., within the normal range (85–115 points) on the standardized cognitive skills tests; and (3) no hearing loss, neurological impairment or other diagnosis that would account for their language impairment.

In addition to standardized tests, all participants had to pass an articulation screening-to ensure their ability to produce the relevant phoneme combinations in non-morphemic contexts. This involved repetition of monosyllabic non-words with the target sounds on the end of the stems, as in [*pept*] for the past tense targets. Since the aim of the present study was to examine possible phonological constraints on children's morpheme production, only those children who made no more than one error in this screening task were included in the analysis.

In order to examine *variability* in the children's morpheme productions, we set an additional inclusion criterion. Thus, only those children who used the target morpheme correctly in 15–85% of the obligatory contexts were included in study. Out of a total of 47 participants who passed the articulation screening, 30 met this criterion. Although this excluded several potential participants, it also avoided any ceiling or floor effects.

The final analysis for this project was therefore based on the data from nine girls and 21 boys with SLI aged 4;6–5;11 years (mean age = 5;1). The participants were tested either on their ability to add morphemes of tense/agreement (past tense *-ed*; third-person singular

-s), or possessive *-s*. In the original experiment two target morphemes were assigned for each child, depending on their performance in a brief grammar screening test (see Smith-Lock *et al.* 2013a, 2013b, for a detailed description of the procedure). For the most part our data contain information on one target morpheme for each participant. However, there were four children who showed sufficient variability in producing two target morphemes. Thus, the analysis was based on data from 11 participants on past tense morpheme *-ed* (mean age = 5;1), 10 on the present tense *-s* (mean age = 5;2), and 13 on the possessive *-s* (mean age = 4;6).

Procedure

The experiment was administered during a separate 15–20-min one-on-one session between the speech language pathologist (SLP) and the child, which took place after the preliminary screening assessments. The task consisted of question–answer elicitations of the 30 target items, which were presented along with picture props in random order across subjects. For example, the SLP could give the following description of a scene and say: 'This man loves running. What does he do every day?' The child was then expected to give answers like 'He runs' or 'He runs every day'. No practice trials were used during the experiment. However, if the participant failed to produce the target form, the SLP provided an additional prompt like 'Does he run? Yes. Now you tell me that.' Up to three attempts to give the correct response were allowed for each form, after which the tester moved to the next item. The elicitation process went in accordance with a standardized protocol (see the appendix for the examples). Prior to the testing the SLPs were trained in both group and individual sessions, which consisted of an explanation of the test and observation of its administration. The SLPs were also observed while testing pilot children and were provided with hands-on feedback and demonstration. The frequency with which the tester completely failed to elicit the required form varied from child to child, depending on the severity of their problems with learning grammatical morphemes. However, for those children whose data were analysed in the present study, responses were available for at least 28 out of 30 items.

The analysis presented in this paper includes the full set of 30 stimuli for each morpheme, plus any additional spontaneous responses of non-target words elicited during the session that contained the target form. These were not numerous, however, and did not exceed 10 % of the data for each child. For example, a child might reply 'He jogs and he runs', in which case both *jogs* and *runs* were included in the list of analysed items, even though *jogs* was not a target form. If the child used the form multiple times, all the attempts were counted, regardless of whether the items contained the target morpheme or not. For example, from the sentence 'Because he <u>wanted</u> to hop and hop, and he <u>hopped</u>, and he <u>hop</u>, and he <u>hop</u>' four items were used for the analysis of the past tense forms-two as correct productions (*wanted, hopped*), and other two as the cases of omission (the last two instances of 'he hop').

Other types of unsuccessful attempts, such as grammatically or semantically incomplete answers or ambiguous forms, direct imitations or delayed responses were not included in the analysis. For instance, in the following example the SLP attempted two times to elicit the possessive form of 'cat':

(1) The SLP points at a picture with a cat standing near a ball.
SLP: This ball belongs to the cat. Whose ball is it?
Child: The cat!
SLP: Yes, but who does the ball belong to? This is the . . .
Child: The cat's ball.

The first use of the target word was excluded from the analysis as it was not clear from the recording whether the child was referring to the animal (as in *There is the cat*) or using the possessive without the grammatical marker (i.e., intended: *cat's*, produced: *cat*). Therefore, only the second utterance was retained in the data set. Likewise, in the following example, the child's form was both potentially grammatical and discourse appropriate, but did not contain the target grammatical morpheme, apparently, due to the truncated nature of the child's utterance (i.e., no subject included).

(2) The SLP points at a picture with a man running.
SLP: The man likes to run. What does he do every day?
Child: Run.

Such forms were again ambiguous, and were therefore not included in the analyses reported here. In total, approximately 220 items (about 11 % of the initial data set) were excluded from the analysis. See the appendix for other examples of correct versus incorrect/error responses.

Analysis

The data were transcribed from the audio recordings, and then coded, depending on whether the morpheme was produced, omitted, or appeared with an error, such as overgeneralization or partial realization. In cases where the presence of the morpheme was not clear to the transcriber (less than 8% of data), the token was re-examined by a second transcriber, and a final decision was made by consensus.

After transcription, the data were coded according to error type. Most often these were errors of omission, when a target word would be produced as a bare stem (e.g., *He kick the ball every day*). In a very few cases (less than 5% of the data) a child would make an error of overgeneralization (e.g., *She pickses flowers*) or produce a partial realization of the morpheme (e.g., *She twist-t* (meaning '*twisted*') *the stick*). The analysed data included only those instances of full realizations and full omissions, where the child's response was ungrammatical if the morpheme was missing.

A total of 2301 sentences were analysed: 730 for the past tense, 797 for the third-person singular *-s*, and 774 for the possessive morpheme *-s*. Coding the tokens according to their *utterance position* and *syllabicity* was applicable in all cases. *Phonological complexity* and *voicing* were only relevant for the segmental allomorphs.

Results

We applied a binary logistic regression model with five predictors to determine whether any could account for variability in morpheme production across the target markers. These predictors included the four main factors of interest (*coda complexity*, *voicing*, *utterance position* and *syllabicity*) and the additional variable *participant*, to account for possible individual differences in children's results. Since our model included multiple parameters, the significance level was set at $p = 0.01$. The results of the Hosmer–Lemeshow goodness-of-fit test indicated that our data fit the model for all three morphemes (table 2).

The analysis showed that two factors had a robust effect on morpheme production across all three suffixes: *participant* and *syllabicity*. Specifically, the syllabic allomorphs appeared to be significantly more challenging than the segmental ones. The box plots in figure 1 illustrate these differences in production rates across all the morphemes. The empty circles stand for the average performance of each participant on a particular condition, illustrating high within group variability; the black circles mark the outliers.

Since the *participant* predictor had a significant effect on production, we concluded that, as was expected, participants showed high within-group variability in their performance. However, the model for each of the three morphemes accounted for the possible influence of this factor on other predictors, indicating their respective significance despite within-group differences.

Other predictors, i.e., *coda complexity*, *voicing* and *utterance position*, did not show a systematic effect across the target morphemes. Their significance for the individual suffixes is discussed in the respective subsections below.

Past tense morpheme

Analysis of the past tense morpheme production showed that, although *utterance position* did not have a significant effect on children's performance, all three other factors (*coda complexity*, *voicing* and *syllabicity*) contributed to its variable production. This is illustrated in figure 2.

As anticipated, based on the findings for TD populations, consonant clusters were more problematic than simple codas, with the latter being correctly produced four times more often (OR = 4.22). In addition, morphemes resulting in voiceless clusters proved to be less challenging, and were roughly three times more accurately produced than those which created voiced clusters (OR = 0.34). Utterance position did not show any significant effect on morpheme production. However, when adding syllabic allomorphs, the participants were approximately five times less accurate than when using segmental allomorphs (OR = 0.21).

Present tense morpheme

The results for third-person singular production showed that only *syllabicity* had a significant effect on the accuracy, with the syllabic allomorphs being about 10 times less likely to be added correctly (OR = 0.11). As illustrated in figure 3, *coda complexity*, *voicing* or *utterance position* did not show any significant effect on morpheme production.

Possessive morpheme

Apart from *syllabicity*, the only factor that significantly affected children's performance was *utterance position*. This is illustrated in figure 4. As before, the syllabic allomorphs were much more challenging than the segmental ones. In this case, the difference between the two conditions was very large: syllabic suffixes were 50 times less likely to be produced correctly (OR = 0.02).

Interestingly, the possessive morpheme was added correctly more often when the target appeared utterance-medially (OR = 0.3), i.e. in the more phonologically challenging context. This was the opposite of what has been reported for TD children, who were more accurate when the morpheme appeared utterance finally (cf. Mealings and Demuth 2014). However, this difference may be explained by the nature of the present data. As shown by table 1, our data contained a much lower overall proportion of the possessives appearing in medial position (only 15% of the total) than was observed for other morphemes (65% and 75% for the verbal suffixes). Thus, children's responses to the possessive *-s* morpheme

Table 2. Effects of coda complexity, voicing, utterance position and syllabicity on the production of different grammatical morphemes

	Factors					
Morpheme	Coda complexity	Voicing	Utterance position	Syllabicity	Participant	Hosmer–Lemeshow test
Past *-ed*	$^*p < 0.001$, OR = 4.22	$^*p < 0.001$, OR = 0.34	$p = 0.224$, OR = 0.78	$^*p < 0.001$, OR = 0.21	$^*p < 0.001$, d.f. = 10	$p = 0.078$
Present *-s*	$p = 0.023$, OR = 1.96	$p = 0.240$, OR = 0.76	$p = 0.394$, OR = 1.2	$^*p < 0.001$, OR = 0.11	$^*p < 0.001$, d.f. = 9	$p = 0.82$
Possessive *-s*	$p = 0.339$, OR = 0.76	$p = 0.298$, OR = 0.80	$^*p < 0.001$, OR = 0.30	$^*p < 0.001$, OR = 0.02	$^*p < 0.001$, d.f. = 12	$p = 0.495$

Note: Asterisks indicate statistically significant values. The odds ratios (OR) compare the likelihoods of the correct productions with the binary terms introduced in the following order: (a) *Coda complexity*: (1) simple codas, (2) complex codas; (b) *Voicing*: (1) voiced, (2) voiceless; (c) *Utterance position*: (1) final; (2) medial; and (d) *Syllabicity*: (1) syllabic allomorph, (2) segmental allomorph.

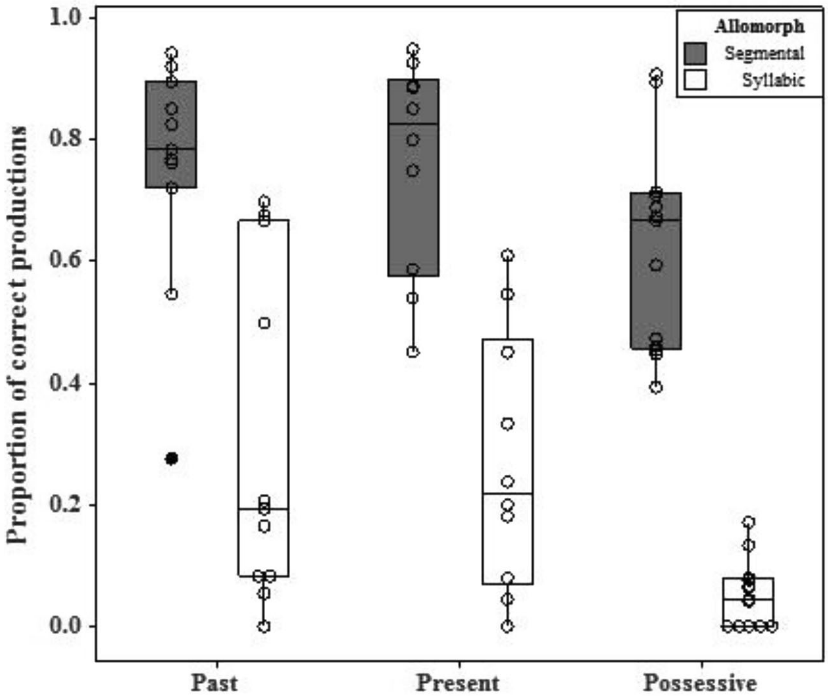

Figure 1. Proportions of correct productions of past tense -ed, third-person singular -s and possessive -s morphemes as a function of syllabicity (syllabic/segmental allomorph).

questions were more often single-noun utterances, and much less frequently full noun phrases-both acceptable in the context of a dialogue:

(3) SLP: Whose book is this?
(4) Child: The man's, or The man's book.

However, this disproportion in numbers suggests that the problem might be syntactic in nature: leaving out the head of the noun phrase led to an increase in morpheme omission-since there was no need to underline the syntactic relationship between the words; similarly, preserving the head of the noun phrase could be bootstrapping morpheme production, i.e. serving as an additional reminder of the need to indicate the relationship between two nouns.

Discussion

The results of the study suggest that *syllabicity* has a robust effect on morpheme production in children with SLI. It accounted for much of the variability in children's performance, not only for the verbal morphemes of tense and agreement (past tense, third-person singular), but also for the nominal marker (possessive). This suggests that, as with TD children, the process of morpheme acquisition in children with SLI has a phonological component that cannot be fully explained by incomplete morphosyntactic representations.

Possible explanations for the poorer performance on the syllabic allomorphs include frequency effects and difficulties in producing similar segments in succession. It has previously been shown that TD children's early productions reflect the frequency with which different

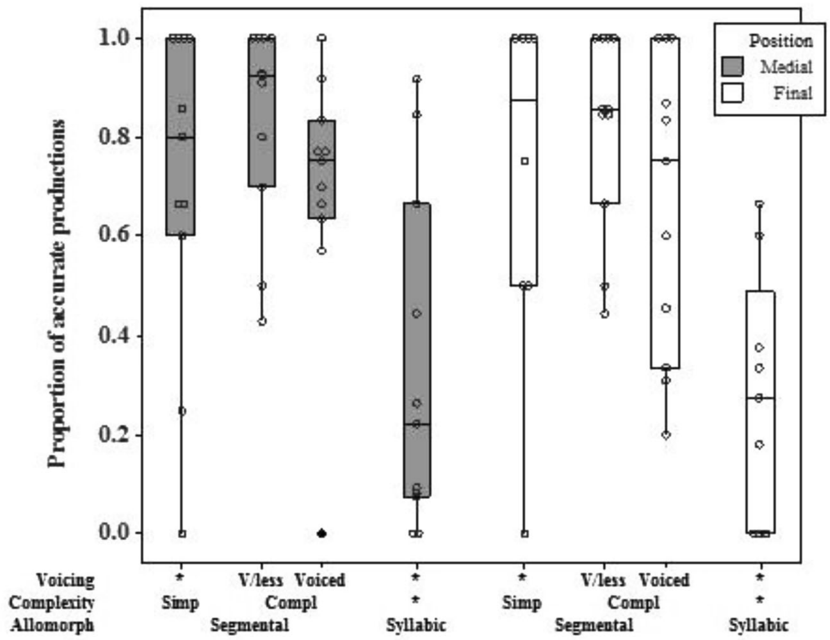

Figure 2. Past tense -ed morpheme production as a function of morphophonological constraints, with boxes representing interquartile ranges and empty circles—individual values.

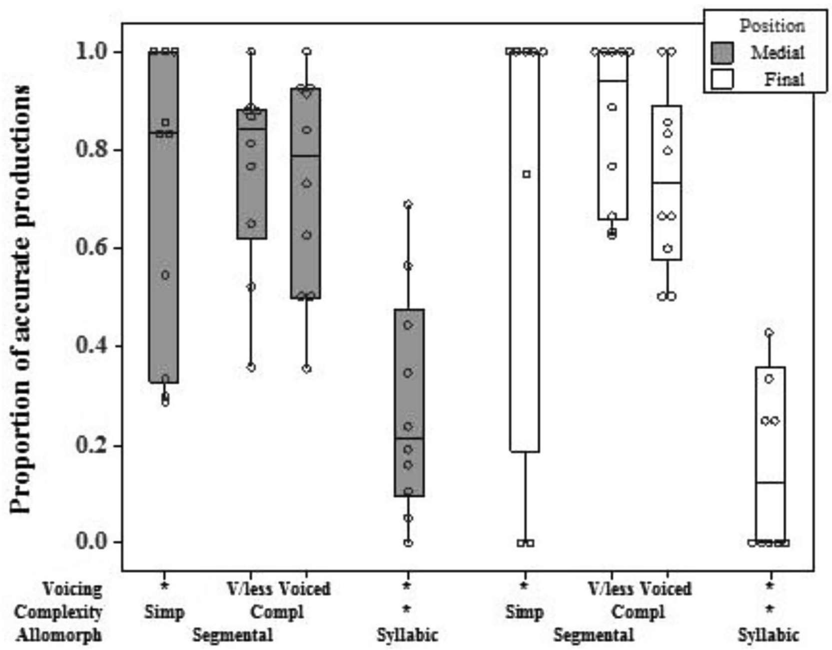

Figure 3. Present tense -s morpheme production as a function of morphophonological constraints, with boxes representing interquartile ranges and empty circles—individual values.

syllable and word structures appear in the input they hear (e.g., Roark and Demuth 2000, Levelt *et al.* 2000). Guided by this observation, we calculated the frequency of syllabic versus segmental allomorphs in child-directed speech using the Providence Corpus (Demuth *et al.* 2006), found on the CHILDES database (MacWhinney 2000). The data were drawn from the transcribed and morphologically coded utterances produced by six parents talking to their children between the ages of 2;10–3;1. This age group was chosen so as to approximate the SLI children's level of language development. The final set of items included 1407 utterances (467 items for past tense *-ed*; 698-for third-person singular *-s*; and 242-for the possessive *-s*), all of which contained the target

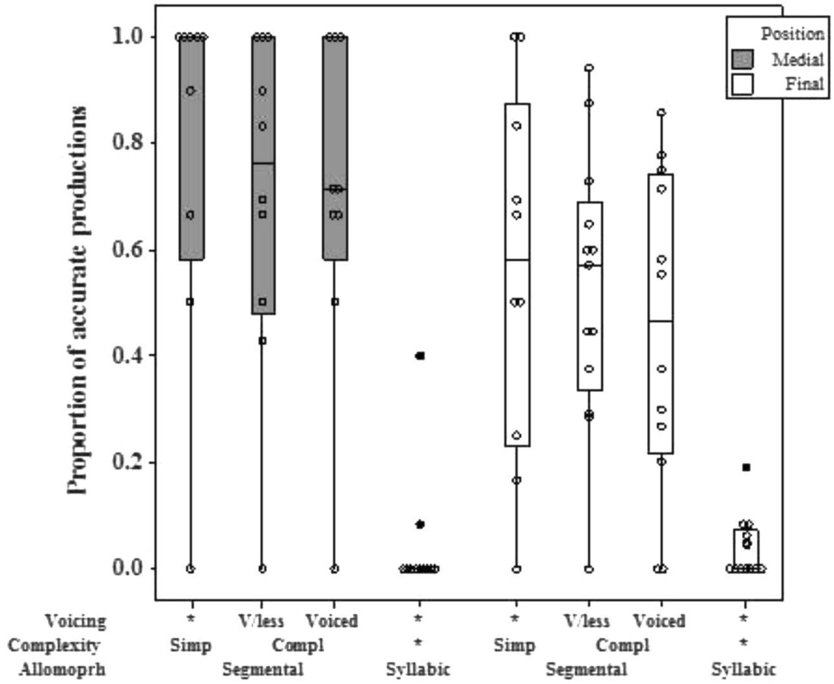

Figure 4. Possessive morpheme -s production as a function of morphophonological constraints, with boxes representing interquartile ranges and empty circles—individual values.

morphemes in their regular forms. The items were sorted according to allomorph type, whose frequencies were calculated and proportions compared. A simple one-proportion test was used to estimate the significance of the differences in the proportions for the syllabic versus segmental allomorphs for each morpheme. The results showed that, for all three morphemes, the proportion of segmental allomorphs was significantly greater than the syllabic ones (table 3). This finding confirms the idea that the delayed acquisition of syllabic allomorphs can be caused by their less frequent occurrence in the speech children hear.

Alternatively, children may find it more difficult to produce same/similar segments in succession separated by only the short reduced vowel schwa (e.g., *added* [æd̲əd̲], *brushes* [brʌʃ̲əz̲]). On the one hand, repetition of similarly sounding segments might incorrectly signal to the child that the morpheme is redundant-as if it were already added to the stem. This was proposed by Berko (1958). On the other hand, perhaps repeating similar word-final segments in an unstressed syllable presents challenges in terms of articulation (Mealings *et al.* 2013). This pattern can be likened with to the so-called 'tongue-twister effect' when sentences containing a large proportion of the same/similar word-initial phonemes become increasingly challenging to produce and perceive (Keller *et al.* 2003).

In the Introduction we discussed studies that have previously shown the significance of both *utterance position* and *coda complexity* on morpheme production in children with SLI (Dalal and Loeb 2005, Marshall and van der Lely 2007, Polite 2011). The fact that we did not systematically find this effect in our set of data may be due to the diversity of methods used across studies or to the wide variety of language deficits observed in children with SLI. In other words, since these children form a heterogeneous population, they may have deficits in more than one language domain; therefore, it is possible that the participants in the above studies had additional problems with articulation or syntax.

Recall that in the papers cited above there was no mention of any additional articulatory tests having been conducted. In contrast, the current study presents results only from those children who successfully passed the articulation screening prior to testing. The importance of applying this assessment tool is supported by evidence from the intervention therapy: children who were able to produce the relevant segments in non-morphemic contexts significantly improved after the treatment program, whereas those who failed the articulation screening were not as much affected by the intervention (Smith-Lock *et al.* 2013a). This raises the methodological question of whether, when studying phonological constraints and morphophonological alternations, it would be advisable to use a similar articulation test prior to the experiment. This would ensure that children's performance was not affected by articulation deficits, thus providing evidence from a more homogeneous population.

Table 3. Proportions of segmental (versus syllabic) morphemes used in (Providence Corpus) child-directed speech.

	One-proportion test results and confidence intervals (CI)			
Morpheme	Total tokens	Proportion of segmental allomorphs	95% CI	*p*-value
Past *-ed*	467	0.83	(0.79, 0.86)	*< 0.001
Present *-s*	698	0.95	(0.93, 0.96)	*< 0.001
Possessive *-s*	242	0.90	(0.86, 0.94)	*< 0.001

Note: Asterisks indicate statistically significant values.

The robust effect of *syllabicity* demonstrated in the present study suggests that forms which require syllabic suffixes may present a particular challenge for children with SLI. Due to their longer duration, these suffixes carry greater phonetic content than their segmental counterparts, but this does not seem to improve the accuracy of these children's productions. It is still possible, however, that the longer duration of the syllabic allomorphs could improve children's performance in a perception or a grammaticality judgement task. These are areas for further research.

To summarize, our data suggest that children with SLI tend to acquire syllabic allomorphs later than segmental ones. This is likely due to the lower frequency of the syllabic forms or their greater articulatory complexity. Since TD children tend to master the syllabic forms later as well, this supports the idea of delay rather than deviance in these SLI children's language development. The systematicity of this morphophonological effect across verbal and nominal morphemes also has important theoretical implications. In particular, it suggests that, counter to predictions of the Optional Infinitive hypothesis, morpheme omissions cannot be fully explained by children's incomplete syntactic representations. Rather, morpheme omission is likely to be affected by a combination of factors, including phonological constraints and morphophonological processes. Specifically, finding the robust effect of allomorph type supports the idea proposed by Royle and Stine (2013) that morphophonology may be another problematic area that restricts these children's grammatical abilities, and thus it should be included in the descriptive models of SLI. In addition, learning morphophonological regularities may be particularly problematic in languages other than English, where rich allomorphic variation, as well as contractions, liaison and elisions occur. In such languages problems in acquiring various morphophonological patterns might even serve as a clinical marker of SLI. Further research is required to investigate the effects of morphophonological and phonological factors on SLI children's use of grammatical morphemes cross-linguistically.

Our results have also practical implications. Since screening tests often include only a few tokens for each grammatical morpheme, it is important to ensure that the types of items tested are balanced in terms of phonological context, and the allomorphic forms they take. This applies to intervention programs as well: taking into account the allomorphy and practicing with a full range of morpheme realizations may significantly improve children's overall morphological development.

The nature of the data presented in this study has its limitations. Firstly, the number of the original stimuli for each category was not always balanced. For example, there were fewer tokens ending in simple codas compared to those ending in a consonant cluster or in a syllabic allomorph (table 1). Secondly, although all items should have been familiar everyday words known by the typical 5-year-old, the selected target words have different frequencies in the input children hear, which might have affected children's performance. For example, the list of nouns used for testing possessive *-s* morpheme production contains a number of proper names, which naturally have much lower frequency than common nouns from the same list, e.g., *cat*, *dog*, *horse*. However, including word frequency as a factor was not possible as there was not enough data for building an adequate model. The phonetic contexts in which the items appeared in the children's utterances were also not controlled, since they were chosen by the participants themselves. This again led to unequal number of events in each category. In addition, although our model accounted for the possible differences between the participants, the fact that the children were only tested on one or two target morphemes does not allow us to study the effects of phonological factors *within* every child. Finally, our data give evidence of children's production skills, which may differ from their abilities to perceive the morphophonological contrasts. Follow-up studies involving both perception and production tasks are needed to control for lexical frequency and phonological structure, the number of words/syllables in the utterance and the target word's position in the sentence. This will provide a more thorough understanding of the nature of the morphophonological deficits in SLI speech.

This study has shown that 5-year-old children with SLI exhibit significant challenges producing syllabic allomorphs. The low frequency of the syllabic forms in children's input and speech may cause learning problems, persistently leading to their delayed acquisition across morphemes. The fact that these challenges are found for both verbal and nominal morphemes confirms that this may be due to phonological and frequency effects, and not limited to morphosyntactic problems with tense and agreement. Since allomorphy has such a robust effect on morpheme acquisition in children with SLI, it is advisable to use stimuli that are balanced in terms of the types of morpheme realizations they require during classroom assessments and intervention. Apparently, being particularly sensitive to frequency effects, children with SLI may need to have additional practice using less frequent morpheme realizations, such as syllabic allomorphs (e.g., *She dresses* as opposed to *She runs* for third-person singular *-s*), in order to successfully master grammatical morphemes. Our findings also suggest that children learning other languages-particularly those with highly complex morphophonology-may also exhibit persistent learning problems with low frequency allomorphs. Examining how morphophonological alternations are learned, using evidence from both perception and production tasks, will shed further light on the factors influencing language learning in children with SLI. This will in turn help inform more focussed assessment and intervention.

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Note

1. Australian English is non-rhotic, so words like 'water' have a CVCV structure.

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Appendix: Sample elicitations for the target morphemes

Past tense -ed

Sample stimulus: [child is shown a picture of a girls jumping over a skipping rope]
SLP: 'These girls love to skip. They did it yesterday. What did they do yesterday?'
Correct response: 'They/the girls skipped (yesterday)'
Incorrect responses: 'They skip', 'They are skipping'

Additional prompts (if a verb other than 'skip' was used):

SLP: 'Did they skip?'
If the child says 'yes', SLP continues: 'You tell me that. What did they do yesterday?'
If the child says 'no', SLP continues: 'I think they did. You tell me that. What did they do yesterday?'

Present tense -s

Sample stimulus: [child is shown a picture of a running man]

SLP: 'This man likes to run, he does this every morning. What does he do every morning?'
Correct response: 'He/the man runs (every morning)'
Incorrect responses: 'He run', 'He is running'

Additional prompts (if a verb other than 'run' was used):

SLP: 'Does he run?'
If the child says 'yes', SLP continues: 'You tell me that. What does he do every morning?'
If the child says 'no', SLP continues: 'I think he does. You tell me that. What does he do every morning?'

Possessive -s

Sample stimulus: [child is shown a picture of a man reading a book]
SLP: 'Look, this man has a book. Whose book is it?'
Correct response: 'Man's (book)'
Incorrect responses: 'Man book'

Additional prompt (if a noun other than 'man' was used):

SLP: 'This book belongs to the man. Whose book is it?'