Learning morphophonological alternations across languages and populations

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Abstract

Young children are typically *inconsistent* in the use of grammatical morphemes – alternating between the correct forms and morpheme omissions/overgeneralisations. This period is *protracted* in children with language-learning difficulties, such as Specific Language Impairment (SLI), and in children acquiring languages with complex morphological systems (e.g., Russian). It has been variously claimed that children's early morpheme productions are constrained by their still developing phonological skills, limited vocabulary and understanding of syntax. Thus, a better understanding of the linguistic phenomena affecting grammatical morpheme acquisition is essential for modelling child language development and language assessment/intervention.

This thesis focuses on the effects of *morphophonological alternations* on morpheme acquisition. In the first study I predicted that the existence of several formal representations of a morpheme (i.e., allomorphs) might delay its mastery, particularly in atypical populations. Using productions of English-speaking children with SLI, I demonstrated that *segmental* allomorphs (e.g., *She runs*) are mastered earlier than the *syllabic* ones requiring an additional syllable (e.g., *She dresses*). The second project followed up on these results using an experiment with nonce verbs. It showed that both typically developing (TD) 5-year-olds and those with SLI have similar difficulties in producing syllabic allomorphs of the past and present tense morphemes. The consistency of the results suggests a significant effect of allomorphy on morpheme production, i.e., children's difficulties are not rooted solely in their limited understanding of morphosyntax.

The third project investigated similar phenomena in Russian, for which the acquisition of nominal declensions extends to school age. The awareness about vowel deletions and stress patterns was investigated in an experiment with real and nonce words in 4–7-year-olds. The results showed a growing sensitivity to morphophonological patterns with age, particularly apparent in real words. The latter suggests *high lexicalisation* of the vowel deletion pattern. However, stressed vowels were deleted/preserved with more accuracy, indicating that the various types of morphophonological patterns might have a *joint effect* during morpheme production.

The consistency of the findings across languages and populations suggests that morphophonological alternations need to be taken into account during research and clinical intervention, particularly when studying atypical populations such as SLI.

Personal Declaration

The research presented in this thesis is my original work and it has not been submitted for a higher degree in any other institution. In addition, I certify that all information sources and literature used are indicated in the thesis. The research projects presented in this dissertation have gained approval from Macquarie University Human Research Ethics Committee (reference numbers 5201100885 and 5201200921).

Some of the material in this thesis has already been submitted/accepted for publication. Chapter 2 is based on the publication as in (1). Chapter 3 is based on the publication as in (2). Chapter 4 is based on the publication as in (3).

(1) Tomas, E., Demuth, K., Smith-Lock, K. & Petocz, P. (In press). Phonological and morphophonological effects on grammatical development in children with Specific Language Impairment. *International Journal of Language & Communication Disorders*.

(2) Tomas, E., Demuth, K. & Petocz, P. (In submission). Perception and production of English present and past tense allomorphs in children with and without SLI. *Journal of Child Language*.

(3) Tomas, E., van de Vijver, R., Petocz, P. & Demuth, K. (In submission). Acquisition of nominal morphophonological alternations in Russian. *Applied Psycholinguistics*.

I additionally certify that I was the first author of all the chapters of this thesis, and that all the initial data coding and analysis have been performed by me prior to sharing my results with other researchers involved in the project. The data presented in (1) were available as a corpus of audio-recordings, which I transcribed and analysed without referring to any previously analysed materials resulting from the original experiment. I designed and carried out the experiments presented in (2) and (3) – in consultation with my principle supervisor Katherine Demuth, and with my collaborators Ruben van de Vijver and Peter Petocz.

Signed:

Ekaterina Tomas (Student Number: 42525918)

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Chapter I. Introduction

Challenges to learning grammatical morphology in children

Children's early productions are characterised by the *inconsistent* use of grammatical morphemes. Thus, their speech contains grammatically correct forms, as well as morpheme omissions and overgeneralisations. This period of *variable use is protracted* in children from atypical populations (such as children with SLI, hearing loss, etc.) and also in children learning languages with complex morphological systems. In learners of Russian, for example, the mastery of nominal declensions extends to school age (Ceytlin, 2000). Therefore, studying morpheme acquisition in children as well as identifying the linguistic phenomena affecting this process, are essential for theoretical understanding of the process of child language development as well as language assessment/intervention.

The main challenge in modelling the process of child language development lays in the fact that children learn their first language *implicitly*: by being exposed to the linguistic environment rather than given instructions about its structure and patterns (Ellis, 2005; Frensch & Rünger, 2003; Seger, 1994). As a result, the traditionally recognised levels of language, such as phonology, morphology and syntax, are being mastered *in interaction*. In other words, when children master morphology, their early productions are constrained by their still developing phonological skills, as well as limited vocabulary and understanding of syntax.

Factors influencing morpheme acquisition

Multiple approaches have been proposed to better explain the mutual effect of various linguistic phenomena in the course of child language development. However, since this thesis focuses specifically on the acquisition of grammatical morphology, the theories discussed in this section will be the ones that are associated with this particular process.

Due to the implicit way in which children master their first language, their understanding of its organisational principles, i.e., the ability to follow systematic patterns, becomes more consistent *gradually* (Cleeremans, 1993). In English, this gradual development is best characterised by young children's variable use of grammatical morphemes in obligatory contexts. In other words, along with the correct forms, children regularly make errors of omission, using bare stems without any morphological markers (Clark, 2003), as in *She dance every day* instead of *She dances every day*. Gradually, the proportion of morpheme omissions decreases, until children reach adult-like competence in their productions (Brown, 1973).

Two approaches have been proposed to help explain this inconsistency in children's use of grammatical morphemes: syntactic and phonological. These theoretical frameworks will be discussed in greater detail in experimental chapters of this thesis. However, it seems worth mentioning principal differences between the two, in order to understand possible factors influencing morpheme acquisition in young children. The syntactic approach suggests that morpheme omissions are due to children's incomplete syntactic or semantic representations (Wexler, 1994; Wexler, 2000; Freudenthal, Pine, & Gobet, 2006; Hoover, Storkel, & Rice, 2012). Therefore, verbal morphology is likely to be more problematic due to its more complex syntactic structure. In contrast, observing similar patterns in children's acquisition of verbal as well as nominal morphology, an alternative explanation has been proposed; namely, that the phonological factors might be partly responsible for morpheme omissions in early speech. Specifically, it has been shown that some phonological contexts appear to be more challenging for producing grammatical morphemes than others (Song, Sundara, & Demuth, 2009; Theodore, Demuth, & Shattuck-Hufnagel, 2011; Mealings, Cox, & Demuth, 2013). These more phonologically problematic contexts may result from prosodic constraints (i.e., the target appears utterance medially rather than finally: *She runs every day* is more challenging than *Every day she runs*) or phonological complexity of the coda (i.e., consonant clusters, as in *She stands*, are more difficult to articulate than vowel–consonant sequences, as in *She plays*).

Additional challenges to mastering grammatical morphemes seem to be coming from children's vocabulary size and the quality of the input they hear (Ambridge & Lieven, 2011; Armstrong & Oates, 2008; Cartmill et al., 2003; Devescovi et al., 2005; Pine, Conti-Ramsden, Joseph, Lieven, & Serratrice, 2008; Simon-Cereijido & Gutiérrez-Clellen, 2009; Theakson & Lieven, 2005). In other words, frequency of the grammatical forms in speech, and the use of the target morphemes with a broader range of lexical items, both affect the order and the rate of their acquisition.

To summarise, it has been claimed that children's early morpheme productions are constrained by their still developing phonological skills, limited vocabulary and understanding of syntax. However, there is an additional potential source of difficulties to learning morphemes in children, specifically the various *morphophonological alternations*, which take place when adding grammatical markers to stems. This thesis sheds new light on this relatively neglected topic in child language acquisition – morphophonological effects on language development.

Morphophonological effects on morpheme production

It has been noted that in English some allomorphs tend to appear later in children's productions. Specifically, children tend to omit *syllabic allomorphs*, which add another (unstressed) syllable to the stem (e.g., *This girl dresses herself*), for a longer period of time than the *segmental* ones, which add a single consonant (e.g., *This cat licks itself*). This has been supported by evidence from children's spontaneous speech (Brown, 1973), elicited productions (Berko, 1958), and elicited imitations (Mealings et al., 2013). In addition, some morphophonological alternations have been shown to affect grammatical development in children learning other languages (MacWhinney, 1978), including recent investigations in children learning Dutch, German and French (Kager, van der Feest, Fikkert, Kerkhoff, & Zamuner, 2007; Kerkhoff, 2003, 2007; Royle & Stine, 2013; van de

Vijver & Baer-Henney, 2011, 2012, 2013; Zamuner & Johnson, 2011; Zamuner, Kerkhoff, & Fikkert, 2011).

Despite this evidence, the role of morphophonological alternations in understanding grammatical development is not yet clearly understood. Two main areas of interest are relatively unexplored. The first one is associated with how the various morphophonological alternations are mastered by children: at what age do children become aware of the morphophonological regularities governing allomorphy in roots and suffixes? Can all the morphophonological patterns be generalised? If so, is there a certain order in which the various alternations are mastered, and which patterns are acquired first and why? In systems with a greater number of morphophonological alternations how do these patterns interact and do the various types of morphophonological patterns have a joint (i.e., stronger) effect on morpheme production?

The second area of interest is associated with how the acquisition of morphophonological alternations affects the mastery of different grammatical morphemes themselves. Specifically, it is not yet clear how robust the morphophonological effects across various types of morphemes (e.g., nominal vs. verbal suffixes) might be. Does variability in morphemic representations – i.e., allomorphs – delay or facilitate morphological acquisition (Höhle, 2009; Jolly & Plunkett, 2008)? Specifically, it has been shown that *bootstrapping* mechanisms play important role in children's language development (Pinker, 1984). Simply put, bootstrapping involves using information about lower levels of language as a cue for mastering higher levels. For example, prosodic bootstrapping is associated with using prosodic information – e.g., stress, rhythm, intonation, pitch, etc., – for discovering the grammatical structure of a given language (Morgan & Demuth, 1996). Therefore, it seems important to investigate whether morphophonological patterns, such as the existence of several allomorphs for a morpheme, provides information that these segments are linguistically relevant at a higher morphosyntactic level?

In addition, could the problems in acquiring morphophonological patterns account for the protracted mastery of grammatical morphemes in atypical populations, such as children with SLI? If so, could the difficulty in mastering morphophonological patterns be used as a clinical marker of SLI, especially in languages with rich morphophonological systems?

Exploring these two aspects of morphophonology and their role in child language development will help determine how morphophonology should be integrated into the models of language acquisition, and whether it needs to be taken into account during research and clinical assessment/intervention. Since morphophonology – like other levels of language – represents a *system of patterns*, it is also likely to be mastered in a similar way. Therefore, investigating morphophonological acquisition provides additional information about the learning mechanisms behind the process of child language acquisition in general.

Thesis focus, aims and structure

This thesis explores the role of morphophonology and the acquisition of various morphophonological alternations in children's early speech, from both typical and atypical populations and across two languages. It comprises three projects investigating morphophonological patterns associated with word inflection in verbs and nouns. The first two studies focus on the English language, and explore how allomorphy – the existence of several realisations of the same morpheme, as in /s/, /z/ and /əz/ for the 3rd person singular -*s* – affects children's abilities to produce, and also to perceive, grammatical morphemes. In addition, these studies give comparison between children with SLI and their TD peers, in order to discover whether the two populations follow the same path in learning morphophonological patterns, or whether mastering the various formal representations of the same more morphemes is particularly problematic for children SLI. The third study investigated segmental and suprasegmental alternations in Russian nominal declensions, focusing on how children master complex interacting patterns and whether these can be generalised when analysing nonce words. These studies are discussed in more detail below.

Chapter 2. Phonological and morphophonological effects on grammatical development in children with Specific Language Impairment

This study investigated the nature of difficulties in learning grammatical morphemes in children with SLI. Specifically, it investigated whether these children's problems are predominantly morphosyntactic in nature (Rice, Wexler, & Cleave, 1995; Rice & Wexler, 1996), or whether phonological phenomena have also a significant effect on the morpheme acquisition process (Marchman, Wulfeck, & Weismer, 1999; Chloe R. Marshall & van der Lely, 2007; Polite, 2011), as it was established for the TD population (Kirk & Demuth, 2009; Mealings et al., 2013 *inter alia*). I predicted that the various *morphophonological alternations* might have a significant effect on morpheme acquisition in children with SLI. Specifically, the existence of several formal representations of a morpheme (i.e., allomorphs) might delay its mastery, particularly in atypical populations.

The first study was a corpus-based investigation, exploring such effects as phonological complexity of the coda in a target word (i.e., so-called "*simple*" VC codas, as in *plays*, compared to "*complex*", more articulatorily challenging CC/CCC consonant clusters, as in *stands*), utterance position of the item (i.e., *final* compared to *medial*, as in *Now she stands* vs. *She stands now*) and also the type of allomorph (i.e., *segmental*, which adds a single consonant to the stem, as in *She sits*, compared to *syllabic* allomorphs, which create additional syllable, as in *She dresses*). The data were available on the nominal possessive marker -*s* and verbal morphemes of tense and agreement – 3rd person singular -*s* and past tense -*ed*. The results demonstrated that allomorphy has a robust and systematic effect on morpheme production, with the *syllabic* allomorphs being consistently more problematic across all three morphemes. This evidence suggested that allomorphy has a stronger effect on the language development of children with SLI than might have been anticipated.

These findings also raised questions about the status of morphophonology in the theoretical models of child language acquisition. Specifically, does productive allomorphy affect language development in children with SLI in the same way as in their TD peers? In addition, does allomorphic variation influence both children's production as well as their perception skills? In other words, is it the *difficulty to articulate* an additional unstressed syllable, or the *overall delay* in mastering some of the allomorphs due to their *lower frequency*? Finally, are children at age five able to *generalise* these morphophonological patterns when adding morphemes to non-word stems, or are these patterns mastered later? These questions were investigated in the second study, which compared the effects of allomorphic variation in TD and SLI populations.

Chapter 3. Perception and production of English present and past tense allomorphs in children with and without SLI

This study investigated the perception and production skills of five-year-old TD children and those without SLI with two grammatical morphemes – past tense *-ed* and 3rd person singular *-s*. The experiment included a perception/grammaticality judgement task and a production/"wug" test using with the same set of CVC nonce verbs in order to control for lexical frequency and phonotactics. The results demonstrated that in both children with SLI and their TD peers syllabic allomorphs were significantly more challenging in production, but not in perception. Importantly, these observations held true for both morphemes, suggesting that morphophonological patterns may be mastered independently from morphosyntax. In addition, despite the overall poorer performance of children with SLI, both groups showed similar patterns in perception and production of the two allomorphs. This supports the idea of the delay rather than deviance in language development of children in the SLI group. However, although the difficulty in mastering allomorphy does not seem to be unique to SLI, these children might benefit from more practice with the syllabic morphemes during intervention.

These findings raised questions about the acquisition of morphophonological patterns in other languages, particularly those with a greater number of morphophonological alternations and constraints. Such languages include Russian – a language, in which the various types of morphophonological processes work in complex interaction. For example, creating case forms in nouns often involves suprasegmental alternations – when the position of stress shifts from one syllable to another depending on the declension class. In addition, these same nouns frequently experience alternations on segmental level, such as historical changes in vowels and consonants. Similarly to what we have observed for English, this complexity of the morphophonological system might create challenges to Russian-speaking children in acquiring grammatical morphemes. In addition, mastering the segmental and suprasegmental alternation patterns is likely to be particularly problematic for Russian-speaking children with SLI. In fact, a protracted difficulty in following the various morphophonological patterns might turn out to be a reliable clinical marker of SLI in Russian. However, some baseline evidence from TD population of children and adults is required to establish the significance of morphophonological alternations in morpheme production before one can turn to studying these effects in children with SLI.

Chapter 4. Learning morphophonological alternations of the Russian nominal system in 4–7-year-old children

Russian-speaking children find the acquisition of nominal declensions challenging, reaching adult-like competence only by school age. This paper explores the effects of morphophonological alternations on this process. We predicted that some of the patterns, such as vowel–zero alternations could be difficult to generalise, particularly in younger children, due to 1) the *low frequency* of the alternating vowels in the lexicon, and 2) a tendency to *preserve stem integrity*, thus satisfying the "faithfulness constraint" (Alan Prince & Smolensky, 2002). In addition, it investigated the emergence and the growing awareness about the various morphophonological patterns in the course of child language development. The ability to generalise morphophonological patterns was tested in children aged 4–7 years and adults, using an elicited production task – "wug" test (Berko, 1958) – with real and nonce words. The results demonstrated a strong overall lexicalisation of the complex morphophonological patterns in Russian, i.e., children did not consistently generalise the interacting complex patterns, and even adults chose different strategies when declining nonce compared to real words.

However, we also observed age-specific differences in the participants' productions. Thus, children as young as 5 years already show sensitivity to morphophonological patterns and start drawing fine distinction between real and nonce words in their productions. This supports the idea of the frequency effects, i.e. following the various morphophonological patterns is restricted to familiar words. By the age of 7, most children reach adult-like consistence in declining real, but not nonce words. The latter can probably be explained by the overall complexity of the morphophonological system, which results in a delayed generalisation of the patterns governing the use the appropriate allomorphs.

This study lays the foundation for future research of morphophonological development in children learning languages with rich morphophonology. Furthermore, these results provide baseline evidence for studying the same morphophonological phenomena in Russian-speaking children from atypical populations, such as simultaneous bilinguals, children with hearing loss and those with SLI.

Chapter 5. General discussion

This chapter brings together the findings presented in the three papers, summarising the typical characteristics of the processes of morphophonological development in children across the two languages and in both typical and atypical populations. It gives a general discussion of the results, arguing that morphophonological alternations significantly affect morpheme production in children. It also points out that in systems with rich morphophonology, the morphophonological patterns might be lexicalised (i.e., learned as part of a lexical item), and that the various types of types of patterns might have a joint effect on the learners' accuracy in a production task. This chapter concludes with the summary of the theoretical and practical implications of the findings, drawing conclusions about the potential role of morphophonology in course of grammatical development.

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Chapter II. Phonological and morphophonological effects on grammatical development in children with Specific Language Impairment

Abstract

Background & Aims: 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. The main aim of the present study 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*; 3rd 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, and 4) *syllabicity* (allomorph type); 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* [æd̲əd̲], *washes* [wɒʃ̲əz̲]. 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.

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*; 3rd person singular -*s*) and nominal (possessive -*s*) morphemes, demonstrating that production of all three morphemes are 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 morphoponological 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 organisational 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 <u>dance</u>* or *Two <u>bus</u>*.

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, Sundara & Demuth 2009) and nominal morpheme productions (Theodore, Demuth & Shattuck-Hufnagel 2011; Mealings, Cox & Demuth 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 realisations suggest that it is phonological or articulation 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 & 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 & Cole 1991; Leonard 1998; Conti-Ramsden & Botting 1999). Nevertheless, it has been shown that, in general, English-speaking children with SLI find it particularly challenging to use auxiliary verbs (Cleave & Rice 1997; Grela & Leonard 2000) and bound grammatical morphemes (Leonard 1998; Norbury, Bishop & Briscoe 2001; Rice, Wexler & Cleave 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, Wexler & Cleave 1995), affecting primarily verbal tense and agreement morphology. However, other studies have shown that at least some of the variability in the SLI children's use of grammatical morphemes can be explained by the effects of phonological context (Marshall & van der Lely 2007; 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 & 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 vs. 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., *pl<u>ays</u>*) are presumably easier to articulate than those ending in complex codas/consonant clusters (e.g., *si<u>ts</u>*) (Song, Sundara & Demuth 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 & 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* [stæn<u>dz</u>]), thus creating *clusters* of voiced consonants that should be more challenging to produce than unvoiced clusters (e.g., *sits* [sɪts]). In Berko's classical study (1958), 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* vs. *He reads every day*, and this has been found to affect both verbal and nominal morpheme production (Song, Sundara & Demuth 2009; Theodore, Demuth & Shattuck-Hufnagel 2011). This could be due to a) final phrase lengthening, which provides greater time for producing the final syllable and all segments, or b) 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 allomophs 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 & 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 (Mabel L 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 study (2011) showed high overall accuracy and very small differences between the two conditions – 77% vs. 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 & Horohov 1997; Marchman, Wulfeck & Ellis Weismer 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 &

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 generalising this result.

It has further been proposed that *syllabic* allomorphs tend to be later acquired by children with SLI (Oetting & Horohov 1997; Marchman, Wulfeck & Ellis Weismer 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 summarise, 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 realisation 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 realisation, 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, b). It focused on studying these children's abilities to correctly use grammatical morphemes. Data collection spanned three years (2010–2012), 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) 3rd person singular -*s*, and 3) possessive marker -*s*.

Typically developing 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 realised as [t], [d], or [əd]; the targets therefore included 10 words for each allomorph with mostly monosyllabic stems. However, 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.

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

Morpheme	Target items for each condition and their counts (number)			Utterance position: medial (proportion)
	Segmental allomorphs		*Syllabic allomorphs*	
	Simple codas	Complex codas		
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 (.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 (.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 (.15)

[1] Note that Australian English is non-rhotic, so words like "*water*" have a CVCV structure.

Participants

All the participants included in this study had been attending one of the Language Developmental Centres in Western Australia. These centres provide specialised 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 Evalua- tion of Language Function (CELF) (Wiig et al. 2006) as Preschool Language Scale (PLS) (Zimmerman et al. 2002) or the Clinical Evaluation of Language Function (CELF) (Wiig et al. 2006) as, 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 & Capute 2005), Denver Developmental Screening Test (Frankenburg *et al.* 1992), and Griffiths Mental Development Scales (Griffiths 1970). Although the scores on every standardised 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., 1–1.5 SD below the mean on the standardised language assessments; (2) normal non-verbal IQ, i.e., within the normal range (85–115 points) on the standardised cognitive skills tests; and (3) no hearing loss, neurological impairment or other diagnosis that would account for their language impairment.

In addition to standardised 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 [*pe<u>pt</u>*] 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 9 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*; 3rd 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, b 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-minute 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 3 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 standardised protocol (see 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 overgeneralisation or partial realisation. 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 overgeneralisation (e.g., *She pickses flowers*) or produce a partial realisation of the morpheme (e.g., *She twist-t* (meaning '*twisted*') *the stick*). The analysed data included only those instances of full realisations 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 3rd 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=.01. The results of the Hosmer-Lemeshow goodness-of-fit test indicated that our data fit the model for all three morphemes (see table 2).

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

Morpheme	Factors					Hosmer-Lemeshow test
	Coda complexity	Voicing	Utterance position	Syllabicity	Participant	
Past *-ed*	**p*<.001, OR=4.22	**p*<.001, OR=.34	*p*=0.224, OR=0.78	**p*<.001, OR=.21	**p*<.001, df=10	*p*=.078
Present *-s*	*p*=0.023, OR=1.96	*p*=0.240, OR=0.76	*p*=0.394, OR=1.2	**p*<.001, OR=.11	**p*<.001, df=9	*p*=.82
Possessive *-s*	*p*=0.339, OR=0.76	*p*=0.298, OR=0.80	**p*<.001, OR=.30	**p*<.001, OR=.02	**p*<.001, df=12	*p*=.495

Note: 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; d) *Syllabicity*: 1) syllabic allomorph, 2) segmental allomorph.

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 boxplots 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.

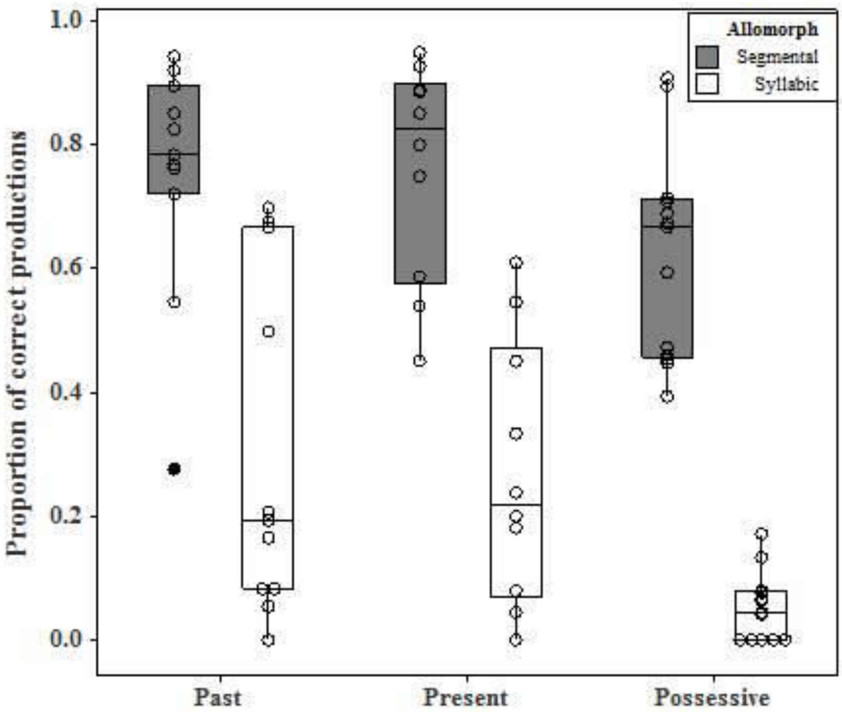

Figure 1. Proportions of correct productions of past tense -ed, 3rd person singular -s and possessive -s morphemes as a function of syllabicity (syllabic/segmental allomorph)

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.

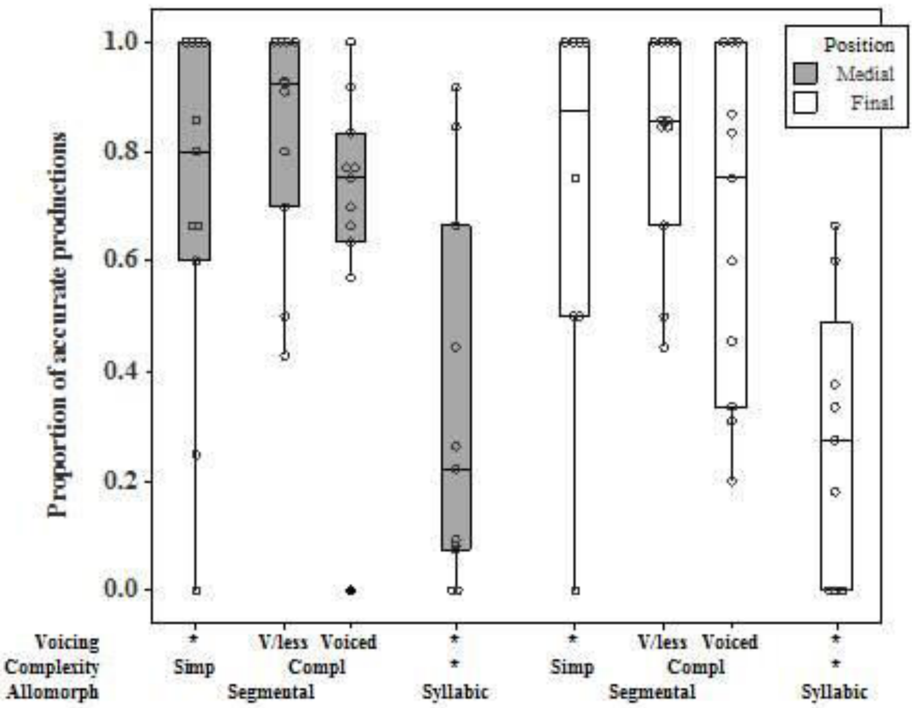

Figure 2. Past tense -ed morpheme production as a function of morphophonological constraints, with boxes representing interquartile ranges and empty circles – individual values

As anticipated, based on the findings for TD populations, consonant clusters were more problematic than simple codas, with the latter being correctly produced 4 times more often (OR=4.22). In addition, morphemes resulting in voiceless clusters proved to be less challenging, and were roughly 3 times more accurately produced than those which created voiced clusters (OR=.34). Utterance position did not show any significant effect on morpheme production. However, when adding syllabic allomorphs, the participants were approximately 5 times less accurate than when using segmental allomorphs (OR=.21).

Present tense morpheme

The results for 3rd 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=.11). As illustrated in figure 3, *coda complexity*, *voicing* or *utterance position* did not show any significant effect on morpheme production.

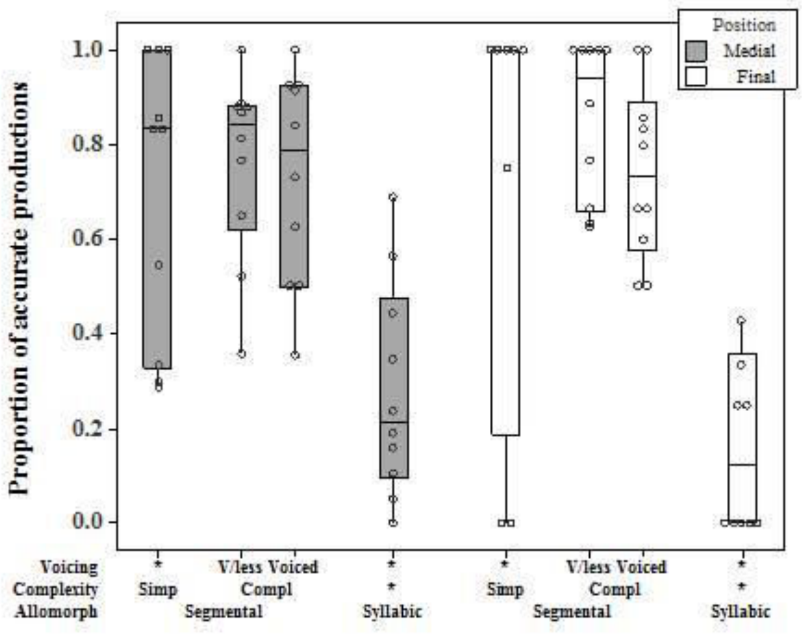

Figure 3. Present tense -s morpheme production as a function of morphophonological constraints, with boxes representing interquartile ranges and empty circles – individual values

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=.02).

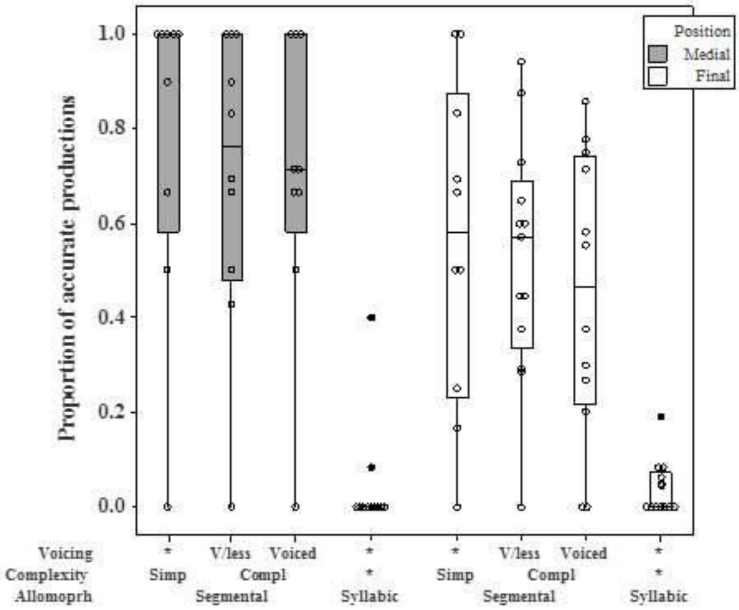

Figure 4. Possessive morpheme -s production as a function of morphophonological constraints, with boxes representing interquartile ranges and empty circles – individual values

Interestingly, the possessive morpheme was added correctly more often when the target appeared utterance-medially (OR=.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 & 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 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*?

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, 3rd 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 syllable and word structures appear in the input they hear (e.g., Roark & Demuth 2000; Levelt Schiller & Levelt 2000). Guided by this observation, we calculated the frequency of syllabic vs. segmental allomorphs in child-directed speech using the Providence Corpus (Demuth, Culbertson & Alter 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 3rd person singular *-s*; and 242 – for the possessive *-s*), all of which contained the target 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 vs. 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 (see 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.

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

Morpheme	One-proportion test results and confidence intervals (CI)			
	Total tokens	Proportion of segmental allomorphs	95% CI	p-value
Past *-ed*	467	0.83	(0.79, 0.86)	*p<.001
Present *-s*	698	0.95	(0.93, 0.96)	*p<.001
Possessive *-s*	242	0.90	(0.86, 0.94)	*p<.001

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* [ædəd], *brushes* [brʌʃəz]). 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, Carpenter & Just 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 & Loeb 2005; Marshall & 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.

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 summarise, 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 allomophic 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 crosslinguistically.

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 realisations 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 (see 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 realisations 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 realisations, such as syllabic allomorphs (e.g., *She dresses* as opposed to *She runs* for 3rd 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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Appendix: Sample elicitations for the target morphemes

1. 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?’

2. 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?’

3. 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?’

Chapter III. Perception and production of English present and past tense allomorphs in children with and without SLI

Abstract

Previous research shows that English-speaking typically developing (TD) children and children with Specific Language Impairment (SLI) start producing segmental before syllabic inflectional morphemes (e.g., /rɐn<u>z</u>/ vs./dres<u>əz</u>/). However, it is unclear if similar results are found in perception. This study compares the abilities of five-year-old TD children and those with SLI to produce as well as perceive segmental vs. syllabic allomorphs of the past tense *-ed* and 3rd person singular *-s* morphemes. The results demonstrated that in both populations syllabic allomorphs were significantly more challenging in production, but not in perception. Importantly, these observations held true for both morphemes, suggesting that morphophonological patterns may be mastered independently from morphosyntax.

Introduction

Morphophonological development

Morphophonological alternations result from various phonological processes taking place during word inflection and derivation. In English, these include productive allomorphy in verbal and nominal suffixes. For example, depending on the phonological context, English past tense *-ed* has three formal representations, or allomorphs: /t/, /d/, /əd/, as in *washed* /wɔʃt/[2], *cleaned* /kli:nd/, *dusted* /dɐstəd/. Similarly, 3rd person singular *-s* also has three allomorphs: /s/, /z/, /əz/, as in *sits* /sɪts/, *runs* /rɐnz/, *dances* /dænsəz/. These same three realisations – /s/, /z/, /əz/ – are also found in the nominal plural *-s* (e.g., *cats* /cæts/, *dogs* /dɔgz/, *fishes* /fɪʃəz/) and in possessive *-s* morphemes (e.g., *cat'*/s/ / *dog'*/z/ / *fish'*/əz/ *tail*).

Syllabic allomorphs of the same morphemes, which add new unstressed syllables to the stem (i.e., /əd/ and /əz/), tend to appear later in children's spontaneous speech than segmental ones, which add a single consonant (i.e., /t/ or /d/, and /s/ or /z/) (Brown, 1973). This has been verified in experimental settings as well – during elicited production (Berko, 1958) and elicited imitation tasks (Mealings, Cox, & Demuth, 2013). Interestingly, the delayed acquisition of the syllabic allomorphs has also been observed in Spanish (Kernan & Blount, 1966), showing that in plural morpheme production, allomorph *-s* is often generalised, appearing in place of the syllabic *-es*, as in **papels* for *papeles* ('papers') and **camions* for *camiones* ('trucks').

Possible explanations for the delayed mastery of syllabic allomorphs include 1) *frequency effects*, i.e., syllabic allomorphs have much lower occurrence in child-directed speech (Brown, 1973; Jolly & Plunkett, 2008; Mealings et al., 2013; Tomas, Demuth, Smith-Lock, & Petocz, in press); 2) *articulatory challenges*: a syllabic allomorph constitutes an additional unstressed syllable (Leonard, Eyer, Bedore, & Grela, 1997; Leonard et al., 2003; Mealings et al., 2013; Tomas et al., in press) and also results in a

[2] The IPA-based vowel phoneme symbols used throughout this paper are adjusted for Australian English and used as recommended in Harrington et al. (1997).

sequence of similar segments separated by a reduced vowel, as in *The man* /nɔdəd/, which might be challenging to produce (Tomas et al., in press); and 3) *processing limitations*: adding another unstressed syllable lengthens the stem, thus putting more pressure on short-term phonological working memory (Gathercole, Willis, Emslie, & Baddeley, 1991).

Recent findings also suggest that the use of grammatical morphemes in children with SLI depends on allomorph types. Children are diagnosed as having SLI if, despite normal physical and cognitive abilities, their language development is delayed (Leonard 1998; Bishop & Norbury 2008). Several theories have been proposed regarding the underlying causes of SLI, including syntactic deficits (Rice, Wexler, & Cleave, 1995; Rice & Wexler, 1996; Rice, Tomblin, Hoffman, Richman, & Marquis, 2004) and phonological deficits (Goad, 1998; Marshall & van der Lely, 2007; Polite, 2011; Ramus, Marshall, Rosen, & Van Der Lely, 2013). However, recent evidence from French and Dutch suggests that morphophonological processes such as allomorphic variation, liaison, contraction and elision may also be challenging for this population (Rispens & De Bree, 2014; Royle & Stine, 2013). In English-speaking children with SLI, it has been shown that producing past tense *-ed* (Marchman, Wulfeck, & Weismer, 1999; Oetting & Horohov, 1997; Tomas et al., in press), as well as 3rd person singular *-s* and possessive *-s* (Tomas et al., in press) depends on the required type of allomorph. Specifically, across various types of morphemes syllabic allomorphs have consistently been found to be significantly more challenging (Tomas et al., in press). However, these studies did not use equal numbers of items per condition nor did they take lexical and allomorph frequency into account, which restricted generalisation of their findings. Therefore, an experiment with balanced design, controlling for possible confounds, is required to verify these results.

The systematicity of allomorph effects across various types of morphemes suggests that mastering grammatical morphology is probably in some way correlated with the process of morphophonological development in children with SLI. However, a direct comparison between SLI and TD populations is required to fully explore these phenomena. In particular, it is not clear whether processing and producing morphophonological alternations is equally or less challenging for TD children as it is for their peers with SLI. In addition, there is no study investigating allomorphic effects on morpheme *perception*. Perhaps the addition of the extra syllable in syllabic allomorphs makes them more perceptually salient than segmental ones. If this is the case, perhaps the delayed acquisition of syllabic allomorphs is only a production problem.

Interestingly, studies of Dutch and German that explore children's emerging sensitivity to morphophonological patterns (Kager et al., 2007; Kerkhoff, 2003, 2007; van de Vijver & Baer-Henney, 2011, 2012, 2013; Zamuner & Johnson, 2011; Zamuner et al., 2011) demonstrate that children learning these languages also master some allomorphs of the same morphemes before others. This cross-linguistic evidence underlines the importance of the in-depth study of morphophonological phenomena in English. In addition, Zamuner *et al.* (2011) have shown that Dutch-speaking TD 4-year-olds cannot yet generalise simple morphophonological patterns of final devoicing in their production of nonce words. Therefore, it is not clear whether English-speaking TD children and those with SLI will be able to make morphophonological generalisations at the age of 5, particularly since children with SLI of this age continue to omit a large proportion of tense and agreement markers in speech (Rice et al., 1995; Smith-Lock, Leitao, Lambert, & Nickels, 2013).

Present study

This paper explores the perception and production of segmental vs. syllabic allomorphs across two morphemes of tense and agreement – 3rd person singular *-s* and past tense *-ed*. It investigates these phenomena in Australian-English-speaking TD children and those with SLI, in order to establish whether the two populations acquire morphophonological patterns in a similar way, and whether five-year-old children are able to generalise these patterns when producing nonce verbs.

Based on previous reports about the later emergence of the syllabic morphemes in children's speech, we predicted poorer production accuracy in adding syllabic allomorphs compared to segmental allomorphs, for both the present and past tense. We also expected that *perceiving* syllabic allomorphs might not be as challenging as producing them, for two reasons. Firstly, as the syllabic allomorphs have more phonological content (Mealings et al., 2013) this might make them more perceptually salient for children. Secondly, if children's omissions of syllabic allomorphs are rooted in articulatory difficulties (Tomas et al., in press), this might not be apparent in a grammaticality judgement task, which does not require verbalising the target forms.

In order to establish the systematicity of the correlation between allomorphy and the mastery of grammatical morphemes, the experiment investigated these phenomena across both past tense *-ed* and 3rd person singular *-s* morphemes. We expected to observe similar effects in the perception and production of both morphemes. This would suggest that the problems in acquiring grammatical morphemes are not restricted to children's limited knowledge of morphosyntax (Rice & Wexler, 1996; Wexler, 2000), but are also due their difficulties in mastering morphophonological alternations.

Method

Participants

The participants were monolingual Australian-English-speaking children with SLI and TD controls. The SLI group included 13 children (11 boys) aged between 5;0 and 6;3 (mean=5;7, SD=0;6), and the controls were 19 TD children (11 boys) also aged between 5;0 and 6;3 (mean=5;4, SD=0;4).

The participants in the TD group were recruited from the Sydney metropolitan area. Out of 21 recruited children, 2 potential participants could not meet the eligibility criteria and were subsequently excluded from the study. Specifically, one child had a history of hearing problems, and the other one was raised by bilingual parents – native speakers of Cantonese.

The participants with SLI were recruited and tested in one of the specialised schools in Perth, Western Australia – North East Metropolitan Language Development Centre (NEMLDC). These centres provide specialised language and academic intervention for children with language learning difficulties. Entry into the school requires being diagnosed as having SLI by a speech language pathologist. Children of eligible age attending NEMLDC were each given the Information and Consent forms, which were distributed by the school authorities. Both children and their parents/guardians were required to give consent to take part in the study. Those children who returned signed the forms – 58 in total – were invited to participate. During screening assessments 44 potential participants proved ineligible due to their performance on standardised tests. If the child demonstrated below average non-verbal IQ on the Kaufman Brief Intelligence Test (KBIT-2) (Kaufman & Kaufman, 2004) and/or marginal score on Clinical Evaluation of Language Fundamentals Preschool-2 (CELF-P2) (Wiig, Secord, & Semel, 2006) language assessment (i.e., 86–88 points), their testing was discontinued. In addition, one eligible child requested to withdraw from the study during the experiment (see more information on screening tests in table 1). Importantly, although there is some evidence that non-verbal IQ scores should be used with caution when testing children with SLI (Miller & Gilbert, 2008), using this type of measurement is considered a standard practice in clinical research of SLI (Coady & Evans, 2008; Ramus et al., 2013; Rice & Wexler, 1996 *inter alia*). In addition, we used this tool to ensure that the participants in our study would not have additional cognitive deficits preventing them from understanding and completing various tasks with nonce words.

Table 1. Mean (SD) scores on language (CELF-P2) and cognition (KBIT-2) tests in groups.

Group	*CELF-P2*	*KBIT-2*
TD	110.2 (11.9)	109.5 (12.1)
SLI	78.5 (4.9)	93.8 (7.8)

The recruitment and testing procedures were approved by Macquarie University Human Research Ethics Committee; the collaboration with NEMLDC received an additional approval from the Department of Education of Western Australia.

Standardised assessments

A battery of standardised tests was used prior to the experiment to ensure that the participants in both groups were eligible for the study. The screenings were carried out during a separate session, in most cases a few days prior to the experiment, but on two occasions on the same day with an hour break before the experimental session. The screenings assessed 1) *language skills*, using core language subtests – Sentence Structure, Word Structure and Expressive Vocabulary – in CELF-P2; 2) *non-verbal IQ*, using KBIT-2; 3) *morphological development*, using the screener pack of the Test of Early Grammatical Impairment (TEGI) (Rice & Wexler, 2001); and 4) *articulatory skills*, using a 3-minute non-word repetition task.

The standardised language and cognition assessments (CELF-P2, KBIT-2 and TEGI) were carried out either by the experimenter –i.e., a linguist trained to administer the tests by a professional Speech Language Pathologist (SLP), – who screened the TD controls in Sydney, or by an SLP, who assisted with testing the children with SLI on the site in Western Australia. Each of the participants included in the SLI group showed a significantly poorer performance on the language/CELF-P2 test than is expected for their age (i.e., scoring less than 85 points, or more than 1SD below the mean) along with an average or higher IQ/KBIT-2 score (i.e., scoring above 85 points, or less than 1SD below the mean). In contrast, the TD children had an average or higher KBIT-2, and CELF-P2 language test score, i.e., scoring above 85 points on both tests. Table 1 contains the mean and SD values for each group. In addition, all the participants in the TD group successfully passed the TEGI test, thus demonstrating normal grammatical development. As expected, children in the SLI group found TEGI challenging: out of 13 children 12 failed the test, and 1 participant scored a marginal value. However, this child's data were included in the analysis for the SLI group due to low performance in the other assessments.

All participants were given the final assessment – a non-word repetition/articulation screening. The articulation screening was administered in order to ensure the children's ability to produce the relevant sound combinations in non-morphemic contexts. It contained 16 nonce words presented in a random order. The endings of the target items matched the inflections of the verbs used in the experiment. For example, the nonce words /hɔdz/ and /hɔzəz/ were similar to the CVC stems with 3rd person singular *-s* morphemes that would be used in the study. The full list of nonce words used during the articulation screening is given in the Appendix. This articulatory screening task was administered by the experimenter, who produced the words one by one, asking the child to repeat them. The answers were audio-recorded and then transcribed in IPA, using perceptual cues. The response was labelled as 'correct', if it contained the relevant ending (i.e., the onset consonant or the vowel could be substituted). For example, for the nonce word /mezd/, the production [nezd] was accepted as 'correct', although the initial consonant was changed; whereas the responses [mez] and [medz] were both considered as 'errors' as their endings did not match the target. For each item we allowed up to 3 attempts, and the last one was used for scoring. To meet the inclusion criteria the child needed to correctly repeat the endings of at least 14 out of 16 items. The importance of carrying out a similar type of articulation screening when studying the acquisition of grammatical morphemes has previously been demonstrated in a number of studies, including Smith-Lock et al. (2013) and Tomas et al. (in press). All the children in the TD group successfully passed this test.

Six potential participants with SLI failed this test, and were excluded from the analysis, reproducing the endings of only 6–11 nonce words. Importantly, these children attempted to complete the experimental tasks; however, unlike all other TD and SLI participants, none of them could finish the elicited production ("wug") test; thus, their data were not used in the present analysis.

Stimuli

Twelve CVC nonce verbs were used as target items. The first stem consonant was a stop – /g/, /k/, /p/, /t/ – or a nasal – /n/, /m/. The stem consisted of a short vowel, followed by either /d/ or /z/. The latter allowed minimising the number of nonce verbs used in the experiment. For example, both nonce words *giz* and *ked* required either a syllabic or a segmental allomorph depending on the morpheme added (e.g., past tense /gɪz<u>d</u>/ vs. /ked<u>əd</u>/ compared to 3rd person singular /gɪz<u>əz</u>/ vs. /ked<u>z</u>/). Using a minimum number of nonce verbs was essential for successfully carrying out the "wug" test: the smaller the number of novel verbs the less pressure on the children's working memory and phonological storage (Gathercole, 2006), which would allow them to stay more focused on the task. This phenomenon also explains why other *-s* morphemes (e.g., possessive *girl'<u>s</u>* [*hat*] or plural [*two*] *girl<u>s</u>*) were not included in the study: testing nominal in addition to verbal morphemes would require two sets of stimuli – one with nouns and another one with verbs, – thus doubling the number of target stems.

Since previous research has not found any voicing effects on morpheme production for either population (Berko, 1958; Marchman et al., 1999; Oetting & Horohov, 1997; Tomas et al., in press), this study did not include the comparison between voiceless (e.g., *She* /sɪt<u>s</u>/) vs. voiced (*She* /rʌn<u>z</u>/) allomorphs. Instead, we investigated possible differences between the voiced segmental and the syllabic allomorphs in both target morphemes (e.g., past tense *buzzed* /bʌz<u>d</u>/ vs. *noded* /nɔd<u>əd</u>/, and 3rd person singular *runs* /rʌn<u>z</u>/ vs. *dresses* /dres<u>əz</u>/). In addition, investigating syllabic /-əz/ and /-əd/ vs. *voiced* segmental allomorphs

/-z/ and /-d/ maximised the comparability between the conditions, ensuring they differed mainly in whether the stem contained an additional schwa or not. Moreover, it has been experimentally shown that, when learning morphemes, both TD children and those with SLI are sensitive to the frequency of the inflected tokens in speech, demonstrating positive correlation between the frequency of the grammatical form and the likelihood of its retrieval (Oetting & Horohov, 1997; Matthews & Theakston, 2006; Rispens & De Bree, 2014). Therefore, in order to control for the effects of lexical frequency, the stimuli in this experiment were nonce verbs with CVC structure and the same set of 12 items was used in both experimental tasks.

Four native speakers of Australian English – all professional experimental linguists – were familiarised with the full list of nonce words to ensure that these sufficiently differed from real words. A few stems that are occasionally used in urban slang (e.g., *pud* 'lazy, useless or very weak person') were included in the final set of items, but due to their very low frequency, a typical five-year-old would be unlikely to know it. In addition, to ensure unambiguous and clear contexts for the stimuli, all nonce verbs were paired with animated videos, each representing a unique action. The final list of items contained only those CVC stems that were approved by each of the four native speakers. Table 2 provides a full list of the targets.

Table 2. Nonce verbs used in the experiment sorted by stem vowel.

	Stem vowel (real word example)				
	/ɪ/ (stick)	/e/ (vet)	/æ/ (cat)	/ɐ/ (bus)	/ɔ/ (got)
Item	*giz*	*ged, ked, nez*	*nad, kad, paz*	*nud, pud, muz, tuz*	*goz*

The stimuli were associated with 12 animated pictures of cartoon monsters, each performing an action associated with a particular nonce verb. For example, one of the slides included a pony carrying a boat on its head, which was called "*kedding*". This same slide was then used during familiarisation as well as in both the experimental tasks. Within each task the nonce verb stem appeared twice – with one of the target morphemes, as in *She* <u>*keds*</u> *my boat* [*every day*] for 3rd person singular *-s*, and *She* <u>*kedded*</u> *my boat* [*yesterday*] for past tense.

Familiarisation

This task was used to familiarise the participants with the full list of nonce verbs, so that they were more confident in perceiving/producing them during the experiments. It involved the repetition of 24 sentences (12 non-word stems with 2 target morphemes), with the nonce verbs embedded in 4-word utterances. For example, *He* <u>*nads*</u> *my plates* for 3rd person singular *-s*, and *He* <u>*nadded*</u> *my plates* for past tense *-ed*. The stimuli were pre-recorded productions of a female native speaker of Australian English, and the participants were asked to "repeat after the lady" – after the audio stimulus was played back.

Grammaticality judgement

This task was used to assess children's abilities to perceive the absence/presence of the morphemes in obligatory contexts. Our study involved 24 stimuli, i.e., 12 nonce verbs with 2 tense morphemes. Each stimulus appeared as a pair of sentences – one grammatical and one ungrammatical, – which were introduced as responses of two cartoon animals to the experimenter's questions. The child was asked to choose the response that "sounded better". For example, for the question "*What does this pony do every day?*" the child heard the following pre-recorded answers: 1) *He* <u>*nads*</u> *my plates*, and 2) *He* <u>*nad*</u> *my plates*. The phrases were produced by two female native speakers of Australian English, and each voice was associated with one of the two animals. The grammatical responses were pseudorandomised across the animals.

"Wug" test

This classical (Berko, 1958) elicitation method allowed exploring children's abilities to produce the morphemes in obligatory contexts. It involved children answering 24 questions about "things that happen every day" (i.e., 12 items, requiring 3rd person singular *-s*) and "things that happened yesterday" (i.e., the same 12 nonce verbs, requiring past tense *-ed* morpheme).

Procedure

The experiment was administered over a 20-25-minute one-on-one session between the experimenter and the child, which took place after the preliminary screening assessments. The tasks were presented to the participants in the same order, and all included practice items followed by the test stimuli. During the experiment, the participant was seated in front of a laptop and the stimuli appeared as a set of animated pictures in a PowerPoint presentation. The participants were instructed that they would be asked to play three language games: "*I will show you pictures of some monsters doing funny things. Then we will talk about the things they do during three simple games. Before each new game we will practice for a bit to make sure you understand the rules.*" The children were told that during the games they will speak about "things that happen every day" (i.e., using 3rd person singular *-s*) and "things that happened yesterday" (i.e., past tense *-ed*). The stimuli for both target morphemes were presented to each of the participants. However, the order of Present vs. Past tense stimuli sets, and pseudorandomised, the order of stimuli within each block was fixed.

The children's responses were audio-recorded using a digital voice recorder Olympus VN-5500PC or Olympus WS750M. The experiment comprised three tasks: 1) familiarisation, 2) grammaticality judgement, and 3) elicited production ("wug") test. Detailed descriptions of the protocols are given below.

Familiarisation task

The items were introduced in the following manner: first, a slide with an animated picture appeared, and then the experimenter gave a prompt like "*Look at this monster. What does he do every day? Let's listen!*" and played the embedded audio file. Typically, the participants needed a single attempt for each item. However, in cases when the child failed to give a response, requested a repetition of the prompt or changed the target stem (e.g., produced /gɪdz/ instead of *gized* /gɪzd/), the experimenter introduced the item again. Up to three attempts were allowed in these cases. This ensured that all participants had heard and produced the target nonce verbs correctly before proceeding to the perception and production tasks.

Perception task: grammaticality judgement

The children were asked to help two animals (a fox cub and a kitten), who were said to be learning English and thus were occasionally "getting mixed up". The task involved saying whose response to the experimenter's question "sounded better" – the cat's answer or the fox's answer.

Each stimulus was presented over two slides. First, the slide with an animated picture appeared on the computer screen. The experimenter gave a prompt like "*I showed our animals this picture and said: "This happens every day, what does this monster do every day?"*" The next slide showed the animals sitting side by side, and the experimenter played pre-recorded audio files, saying "*And the foxie said* [the first audio played]: *"He nezes my pet"... And the kitten said* [the second audio played]: *"He nez my pet"... Who gave a better answer this time?*" The child was asked to say whose answer sounded better, and their responses were audio-recorded for later analysis. If the child pointed to the picture instead of voicing their grammaticality judgement, the response was voiced by the experimenter. The stimuli were introduced once, unless the child requested a repetition or could not make the judgement after the first attempt. Although we would allow up to three attempts for each item, none of the participants required more than one repetition. In fact, on average, the second attempt was requested in less than 5% of the cases.

Production task: "wug" test

In this experiment participants were instructed to answer the experimenter's questions about the pictures on the computer screen. The items were presented in the following manner: "*Remember this monster? He loves nadding my plates. He does it every day. Does he nad my plates? You tell me that.*" The participant was then expected to give an answer like *He nads my plates every day*. If the child did not produce a full sentence (e.g., said *Nad every day* instead), the experimenter gave an additional prompt like "*Start with "every day"...*" or "*Tell me the whole thing*". If these attempts to elicit a full – grammatical or ungrammatical – sentence were unsuccessful, the experimenter gave the first few words of the target phrase, as in "*Yes, so every day he n...*", after which the child finished the sentence. Importantly, the reason for choosing this type of elicited production technique and not the classic cloze version of Berko's original "wug" test was to a child the opportunity to construct full sentences, thus activating the nonce verbs' morphosyntactic functions. Up to three attempts to complete the sentence were allowed for each item, and only the final production was included in the analysis.

Analysis

Coding

The audio-recordings of the children's grammaticality judgements (i.e., perception task) were coded as "correct" or "incorrect", depending on whether the response matched the grammatical sentence.

The production task full sentence responses were transcribed from the audio recordings. For the target forms the transcriber used perceptual cues and, in ambiguous cases, acoustic evidence analysed in *Praat* (Boersma & Weenink, 2014) to decide whether the morpheme was present, and then coded as either "correct" or "incorrect". The "correct" productions included forms containing the appropriate allomorph, and “incorrect” were the cases of omission. Other incorrect productions, such as 1) partial realisations (e.g., /gez/ instead of /gedz/), 2) overgeneralisations (e.g., /mɐzdəd/ for /mɐzd/), or 3) metathesis (e.g., /gɪdz/ for /gɪzd/), were not used in the analysis. Together with instances of missing values (i.e., when the child skipped an item or gave an unintelligible response) these excluded productions amounted to a total of 70 items, constituting 5% of the overall dataset from the total of 1536 responses. Therefore, the final set of analysed productions contained 1466 items (872 responses from TD children and 594 from SLI group).

A reliability check was carried out for 12.5% of the data. A second transcriber analysed the grammaticality judgements and elicited productions of four participants – two TD children and two children with SLI – following the same coding protocols. The results demonstrated 96% consistency between the transcribers. The remaining 4% of the cases were re-examined again, and the final decision was reached by consensus.

Model

A binomial generalised linear model was applied to analyse the data, using the proportion of correct answers as the response variable. The final version of the model included four main effects – *Allomorph* (segmental vs. syllabic), *Task* (perception/judgement vs. production/“wug”), *Group* (TD vs. SLI) as fixed effects, and *Participant*, capturing individual differences, as a random effect. The *Tense* variable (past tense -*ed* vs. 3rd person singular -*s* morpheme) was excluded from the final model, due to its non-significant effect on performance. The final model also included two interactions: *Group*Task* and *Task*Allomorph*.

Results

The statistical analysis was carried out in *SPSS*, version 21. In order to account for the overdispersion of the data, the standard errors of the parameters were adjusted using the Pearson chi-square scaling method. The goodness-of-fit test indicated that the data fit the model (scaled deviance value=209.88, *df*=219, *p*=0.66). Figure 1 gives the overall summary of the output, illustrating the effects of the three main factors of interest included in the model – *Allomorph*, *Task* and *Group* – on the proportion of correct responses. In addition, it captures children's performance as a function of *Tense*, suggesting that overall the participants performed in a similar manner regardless of which morpheme was attempted.

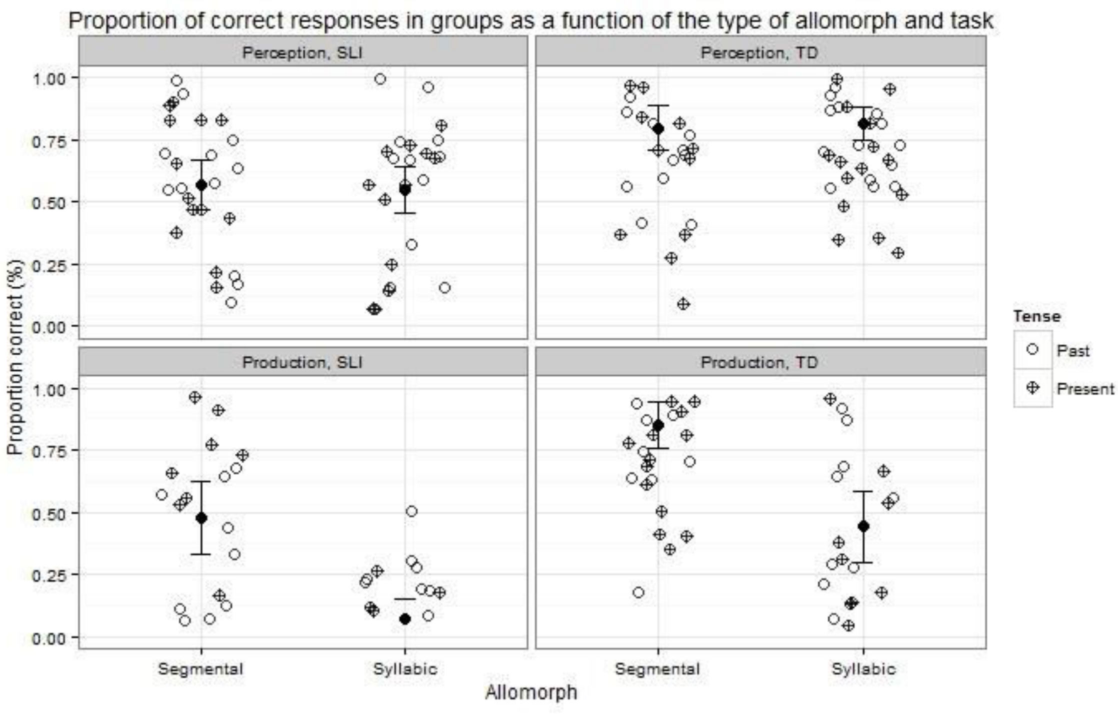

Figure 1. The effects of Allomorph, Task and Tense on morpheme perception and production across TD and SLI children.

The results summarised in table 3 demonstrate that all three factors of interest had a robust effect on the proportion of correct responses (*p*-values <0.001 for each factor). In addition, there was a significant interaction between *Task* and *Allomorph*, as well as a marginally significant effect for *Group*Task* for both morpheme perception and production.

Table 3. Summary of the Generalised Linear Model output estimating the effects of Group, Allomorph, Task and Participant on the proportion of correct responses.

Model effects				Estimated Marginal Means		
Factor	*Chi-Square*	*df*	*p-value*	*Interaction*	*(Level*Level)*	*Mean (SE)*
Group	68.15	1	<.001	Task* Allomorph	Perception*Segmental	.78 (.037)
Allomorph	33.42	1	<.001			
Task	29.24	1	<.001		Perception*Syllabic	.77(.038)
Participant	53.10	29	.004		Production*Segmental	.81 (.038)
Group*Task	3.77	1	.052		Production*Syllabic	.25(.045)
Task*Allomorph	32.65	1	<.001			
Incident rate ratio				Group* Task	SLI*Perception	.55 (.046)
Factor (Level 1)		*Value*				
Group (SLI)		.007			SLI*Production	.2 (.042)
Allomorph (Segmental)		13.02			TD*Perception	.87 (.028)
Task (Perception)		7.37			TD*Production	.76 (.043)

The *Allomorph* variable was a significant predictor of the proportion of correct responses, with the segmental allomorphs having 13.02 times higher incident ratio than the syllabic ones. In addition, the significant *Task*Allomorph* interaction suggests that the production of syllabic forms was the most challenging for all children.

As an independent variable, *Task* also had a significant effect on overall performance; as predicted, the perception task (i.e., choosing one of the options as grammatical) appeared to be less problematic than the elicited production (i.e., adding an appropriate morpheme to the verb stem), with the incident ratio of about 7:1.

Also as expected, the significance of the *Group* factor suggested that children in the SLI group performed consistently lower than children in the TD group. The estimated marginal means for *Group*Task* showed a marginal effect (p=.052) on performance, indicating a trend toward significance for this interaction. Specifically, children with SLI found the production task particularly challenging, performing over 2.5 times more poorly in the "wug" test compared to the grammaticality judgement task.

Finally, the significance of the *Participant* predictor indicated high variability within the groups, which is clearly observable in figure 1.

Discussion

This study explored the effects of allomorph type on the proportion of correct responses in 5-year-old children with SLI and their TD peers. Our aim was to investigate the phenomenon of allomorphy with tense morphemes – 3rd person singular *-s* and past tense *-ed* – and to compare children's perception and production skills. A grammaticality judgement tasks and an elicited production ("wug" test) task with nonce verbs were used to assess children's acquisition of segmental and syllabic allomorphs.

The results showed that both TD children and children with SLI found it more difficult to add syllabic allomorphs to the verb stems, as in *Every day she* /gɪzəz/ *my hat* or *Yesterday she* /kedəd/ *my boat.* Observing similar behaviour across the groups supports the idea of a delay and not deviance in the language development of children with SLI. However, the tendency towards significance for the *Group* by *Task* interaction suggests that, as has previously been suggested (Tomas et al., in press), children with SLI might benefit from more practice with producing syllabic allomorphs during intervention.

Interestingly, the allomorph effects were only observed in children's *productions*. In contrast, in the grammaticality judgement task, the participants performed with equal accuracy regardless of the allomorph attempted. When discussing the delayed acquisition of the syllabic allomorphs in the *Introduction*, the possible explanations included phonological working memory limitations, i.e., adding another syllable to the stem puts more pressure on the processing load. If this was the case, we would expect poorer performance in discriminating syllabic allomorphs. However, based on the results of the grammaticality judgement task, we may conclude that at least in disyllabic forms, extra syllable/more phonetic content of the syllabic forms does not negatively affect their perception. On the contrary, although the morphophonological pattern governing the use of the syllabic allomorphs seems to be *generalised later*, the greater phonetic content of these forms may be responsible for their enhanced *perception* and thus result in better than expected grammaticality judgement scores, i.e., function as a compensatory mechanism.

Importantly, although it is clear from figure 1, that overall SLI group performed with poor accuracy (mean=56.06%, SE=3.32%), the results of a t-test showed that their answers were not 'random'. For this, we created a normal distribution of random numbers with mean=50 and sample size and variance equal to those observed in SLI group. The comparison of the means showed that the choices of children with SLI were significantly above chance level (t= -2.43, df=101.96, p=0.017, CI [-20.96; -2.12]). However, some explanations should still be given in regards to low overall scores observed in SLI population. Since all children were given instructions about their role in the task, and then practiced on a few real and nonce word items (not included in the analysis), it is unlikely that their scores were due to not fully comprehending the task. It is more probable that because of their delay in grammatical development these children were not as sensitive to the morpheme presence/absence as their TD peers.

In addition, the non-significant effect of the *Tense* factor (3rd person singular *-s* vs. past *-ed* morpheme) suggests that the ability to generalise morphophonological patterns systematically influences morpheme acquisition in children. Therefore, we may conclude that the challenges found in producing syllabic allomorphs may be morphophonological in nature, and that morpheme omissions cannot be solely attributed to children's limited morphosyntactic skills (Rice et al., 1995; Wexler, 2000). This raises important theoretical questions about the role of morphophonology in the course of morphological development, and the need to integrate it into theoretical models of language acquisition. In addition, the results of this study suggest that allomorphy needs to be taken into account during language assessment and intervention, especially for atypical populations. In particular, it would appear that children with SLI are likely to benefit from more practice in producing syllabic allomorphs.

Conclusion

This study demonstrates that syllabic allomorphs of verbal inflectional morphemes are more challenging to produce than segmental ones. Interestingly, this no allomorph effects were observed in the perception/grammaticality judgement data, suggesting that the greater phonetic content of the syllabic allomorphs might benefit their perception. Importantly, these observations held true for both morphemes, suggesting that morphophonological patterns may be mastered independently from morphosyntax.This suggests that morphophonological patterns need to be taken into account in research and during clinical assessment/intervention. Future investigations are required to understand more fully the general effects of morphophonology on grammatical development in children, particularly in languages with complex morphophonological patterns.

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Appendix: items presented during a non-word repetition screening of articulation skills

1. Imitating the stem + 3rd person singular *-s* context:
   a) consonant–consonant sequence: /hɔdz/, /vɪdz/, /tædz/, /kɔdz/;
   b) consonant–schwa–consonant sequence: /hɔzəz/, /læzəz/, /dezəz/, /rɪzəz/;
2. Imitating the stem + past tense *-ed* context:
   a) consonant–consonant sequence: /bɪzd/, /kæzd/, /mezd/, /dɔzd/;
   b) consonant–schwa–consonant sequence: /hɔdəd/, /tɔdəd/, /lædəd/, /vɪdəd/.

Chapter IV. Acquisition of nominal morphophonological alternations in Russian

Abstract

Russian-speaking children find the acquisition of nominal declensions challenging, reaching adult-like competence only by school age. This paper explores the effects of morphophonological alternations on this process. A “wug” test with real and nonce words was carried out on children 4;0–7;11 and adults. It involved producing Genitive singular forms, deleting target vowels (e.g., $ko'm\underline{o}k_{Nom,sg} – kom'ka_{Gen,sg}$) or preserving them (e.g., $p^{j}i'l\underline{o}t_{Nom,sg} – p^{j}i'l\underline{o}ta_{Gen,sg}$), depending on phonotactics and stress position. The results showed that children’s sensitivity to morphophonological patterns steadily increases with age, particularly in real words. Specifically, 4-year-olds tended to preserve vowels across all conditions. Seven-year-olds showed adult-like behaviour with real, but not with nonce words, suggesting *high lexicalisation* of the pattern. However, vowels under stress were alternated/preserved with greater accuracy, indicating that the various types of morphophonological patterns might have a *joint effect* during morpheme production.

Introduction

Russian has a complex morphophonological system as a result of the joint effects of segmental alternations and suprasegmental processes. The former include diachronic changes, such as vowel–zero alternations in so-called “yer vowels” (e.g., $l\underline{o}b_{Nom,sg}$ – $lba_{Gen,sg}$, ‘forehead’, coming from Old Slavic $*l\underline{\text{ъ}}b\text{ъ}_{Nom,sg} – l\underline{\text{ъ}}ba_{Gen,sg}$ [3]) and historic palatalisation of consonants (e.g., $dru\underline{g}_{Nom,sg}$ – $dru\underline{z}^{j}'ja_{Nom,pl}$, ‘friend’). Suprasegmental processes are associated with the position of stress within the word paradigm (e.g., $'d\underline{o}m_{Nom,\ sg}$ – $'d\underline{o}ma_{Gen,sg} – do'm\underline{a}_{Nom,pl}$, ‘house’) and across related words (e.g., $'d\underline{o}m$ – $do'm\underline{a}sn^{j}ij$, ‘home’– ‘homely/domestic’). The main aim of the present paper is to explore how Russian-speaking children learn nominal declinations and how this process is affected by 1) the position of stress, and 2) alternations in vowels. It also investigates how these segmental and suprasegmental factors interact with one another, i.e., whether stress position, for example, helps the learners to determine the vowel type.

In this section, we first review previous studies investigating the development of morphophonological patterns in children, and discuss how those results have been integrated in theories of language acquisition. We then discuss typical stress patterns in Russian and explain the role of stress on vowel quality and vowel reduction. Finally, we explore the phenomenon of morphophonological alternations in “yer vowels”, as well as final devoicing in consonants occurring throughout the entire lexicon.

Morphophonological development

The emergence of the case system in the course of child language development together with common errors in early productions have long been the focus of research in Russian linguistic tradition (Ceytlin, 2000, 2006; Gvozdev, 1949; Ionova, 2007; Lepskaya, 1997; Ufimtseva, 1979, 1981). However, most of this research focuses on the semantic and syntactic functions of the grammatical cases and how these are being integrated into the

[3] Here and in other similar cases the asterisk symbol (*) indicates a reconstructed proto-form.

child's language system over time. Therefore, relatively little is yet known about the role of *morphophonology* in the grammatical development of Russian-speaking children. Specifically, it is not clear how children master morphophonological patterns, which often contain several stem representations due to segmental and suprasegmental alternations throughout case paradigm.

It has been argued that phonological contexts help children to acquire these alternations since they are based on phonotactics (i.e., the distributional restrictions of speech sounds) without recourse to morphology (Hayes, 2004; A. Prince & Tesar, 2004). In this respect, yer–zero alternations are particularly interesting, as they are governed by generalisations that hold across the entire lexicon (e.g., vowel–zero alternations never occur with high or low vowels) as well as those lexically restricted (i.e., yer alternations are non-productive unless they occur in suffixes).

A number of recent studies have investigated the acquisition of morphophonological alternations in German and Dutch, finding that some allomorphs are mastered earlier than others (Kager et al., 2007; Kerkhoff, 2003, 2007; van de Vijver & Baer-Henney, 2011, 2012, 2013; Zamuner & Johnson, 2011; Zamuner et al., 2011). Similar observations have previously been made about English- and Spanish-speaking children (Berko, 1958; Kernan & Blount, 1966). However, this raises several questions about the status of similar phenomena in languages with rich, fusional morphology like Russian. Specifically, how strong is the overall effect of morphophonological complexity on grammatical development in children? Are the various types of patterns, such as stress position and phoneme alternation, acquired independently from each other? Is it possible to observe the joint effect/interaction of these patterns on morpheme production? Which types of suprasegmental and segmental patterns are mastered earlier and which ones later? Finally, how strong is the lexicalisation of these patterns; in other words, could they be generalised and applied when declining nonce words?

Zamuner *et al.* (2011) demonstrated that by the age of 4, Dutch-speaking children do not yet generalise simple morphophonological regularities, such as final devoicing (e.g., [bɛt]$_{Nom,sg}$ – [bɛdən]$_{Nom,pl}$, ‘bed’). Specifically, although children already use both voiced and voiceless stem allomorphs in real words, they do not apply this knowledge to produce nonce words. This suggests that children learning languages with a greater number of morphophonological alternations, such as Russian, are likely to start showing sensitivity to the systematic changes after the age of 4 years.

Stress patterns in Russian

Russian is a language with *variable stress*, i.e., it can fall on any syllable. Importantly, the position of stress is also *not stable* throughout the word paradigm, so that the various case forms, for example, may have different prosodic structures, as in (1). However, in the majority of Russian nouns the stress remains on the same syllable across all case forms, as shown in (2) (Švedova, 1980).

(1) *'tom*$_{Nom,sg}$ – *'toma*$_{Gen,sg}$ – *to'ma*$_{Nom,pl}$ – *to'mov*$_{Gen,pl}$ (‘volume/book’).

(2) *'spor* $_{Nom,sg}$ – *'spora*$_{Gen,sg}$ – *'sporɨ* $_{Nom,pl}$ – *'sporov*$_{Gen,pl}$ (‘argument/bet’).

In Russian linguistic tradition, the system of stress patterns across case forms and their associated inflections are known as *accentologic types* (Red’kin, 1971; Shapiro, 1986; Švedova, 1980). Thus, the *dominant accentologic type* in nouns is characterised by stress that is fixed on the same syllable across all case forms, as illustrated in (2). The frequency of this accentologic type throughout the lexicon is likely to result from the unmarked nature of the inflected forms, i.e., the word paradigm comprises the forms with the same prosodic structure, which ensures their greater formal resemblance.

Synchronic vowel alternations: stress effects on phoneme neutralisation

Most Russian vowels systematically exhibit phonological reduction – neutralisation of their contrastive features in unstressed position (Hamilton, 1980; Barnes, 2007). For example, the vowel [o] in *'dom*$_{Nom,sg}$ (‘house’) contains full vowel quality and quantity under stress. However, when the stress shifts to the inflection as in *do'mam*$_{Dat,pl}$, the stem vowel is reduced to [ə], as in [də'mam]. Importantly, it is not only the phoneme /o/ that neutralises to [ə], but also /a/, as in the pair [taz]$_{Nom,sg}$ – [tə'zam]$_{Dat,pl}$ ('tub'). As a result, two reduced vowels are neutralised into a single allophone, i.e., the unstressed [ə] can be /o/ but can also be /a/. Therefore, it is often problematic to determine the correct phoneme underlying the unstressed allophone, and the only way to identify the vowel is to place it under stress. Similarly, the phonemes /e/ and /i/, when unstressed, are reduced to a single allophone [ɪ], as in [m^{j}ex]$_{Nom,sg}$ – [m^{j}ɪ'xa]$_{Nom,pl}$ ('fur') and [p^{j}ir]$_{Nom,sg}$ – [p^{j}ɪ'rɨ]$_{Nom,pl}$ ('feast'). In this study we investigate both types of vowel reduction, i.e., 1) /a/ and /o/ into [ə]; and 2) /e/ and /i/ into [ɪ]as the target phonemes used in the experiment are /o/ and /i/.

In classical linguistic tradition phoneme neutralisation in vowels has often been described as displaying two degrees of reduction, depending on the phonetic and prosodic context (Avanesov, 1972; Bondarko, 1977; Trubetskoi, 1969). For example, post-tonic vowels undergo stronger reduction than pre-tonic ones, which is often reflected in phonetic transcription by using two different symbols. Thus, in the word *ko'robka*$_{Nom,sg}$ ('box') the pre-tonic vowel is traditionally transcribed as [ɐ] and the post-tonic vowel as [ə]: [kɐ'ropkə]. However, recent studies suggest that there is only one degree of *categorical* vowel reduction – from stressed to unstressed – and that the greater neutralisation between the unstressed allomorphs (e.g., between the pre-tonic [ɐ] and the post-tonic [ə]) is "purely gradient" (Barnes, 2004, 2006, 2007). In this paper we will use the latter approach, since we are primarily interested in the phenomenon of *neutralisation* (i.e., whether it is possible to determine the phoneme underlying an allophone or not), and not in the *degree* of final reduction. Therefore, throughout the paper we will be using symbol [ə] for the reduced /a/ and /o/ phonemes, and [ɪ] for reduced /e/ and /i/, regardless of the degree of reduction.

Diachronic vowel alternations: Russian "yers"

As a Slavic language, Russian shows vowel–zero alternations occurring in stem vowels that have originated from so-called *yers*. These yers used to be two extra short vowels, which later underwent a transformation: depending on their phonotactic position; they were either elided or merged with the mid-vowels [e] and [o] (Gorshkova & Khaburgaev, 1981). *Havlik's Law* identifies the phonological contexts in which this deletion/merge process occurred. In *strong positions* the reduced vowels merged with full vowels. These included 1) stressed positions, or 2) positions before another syllable containing a reduced vowel. In other – predominately unstressed – positions, constituting *weak* contexts, yers were deleted (Havlík, 1889). Since the process of yer elision vs. realisation as a full vowel depends on the phonological context, modern Russian inflection at times demonstrates the phenomenon of the so-called 'transitive', or 'fugitive' vowels (i.e., alternations of [e] and [o] with zero) in place of former yers (Gorshkova & Khaburgaev, 1981). As an example, let us consider the contemporary alternation in [rot]$_{Nom,sg}$ – [rta]$_{Gen,sg}$ ('mouth'). Historically, this noun contained two yers in the Nominative singular – **'rъtъ*. The second yer – the inflection – appeared in weak position, and thus has elided in accordance with Havlik's Law (i.e., resulting in **rъt*). In contrast, the first vowel was in strong position as it preceded a syllable with another yer. Therefore, the stem yer transformed into the mid-vowel [o] found in contemporary [rot]$_{Nom,sg}$. However, when another inflection – containing a full vowel – is added to the stem, as in **rъ'ta*$_{Gen,sg}$, the stem yer appears in a weak position since it no longer precedes a yer, and thus, requires deletion – [rta]$_{Gen,sg}$. To summarise, vowel–zero alternations are governed by the phonological context they appear in as well as stress position, and result in systematic allomorphic variation.

Importantly, these alternations are restricted *only* to vowels that originated from yers. Thus, a stem containing a mid-vowel /e/ or /o/, which has never been a yer, does not alternate with zero. For example, in a pair [p^j$\underline{e}$n^j]$_{Nom,sg}$ – [pn^{j}i]$_{Nom,pl}$ ('stump') the stem contains a former yer, whereas the pair [t$^{j}\underline{\text{e}}$n^{j}]$_{Nom,sg}$ – ['t$^{j}\underline{\text{e}}$n^{j}i]$_{Nom,pl}$ (‘shadow’) contains a full mid-vowel /e/ – hence, no alternation. This poses an apparent problem for Russian-speaking children who need to learn when to alternate the stem vowel with zero as in (3), and when to preserve it as in (4), since both alternating and non-alternating vowels may appear in almost similar phonological contexts.

(3) Typical alternating CVCVC stems (Nominative/Genitive, singular) – yer vowel underlined:

bu'g$\underline{o}$*r – bu'gra* (‘hill’)

'p^{j}*ep*$^{j}\underline{e}$*l – 'p*^{j}*epla* (‘ash’)

'v^{j}*et*$^{j}\underline{e}$*r – 'v*^{j}*etra* (‘wind’)

(4) Words with similar phonotactics (Nominative/Genitive, singular) containing non-alternating mid-vowels (underlined):

'mus$\underline{o}$*r – 'mus*$\underline{o}$*ra* (‘rubbish’)

'fak$^{j}\underline{e}$*l – 'fak*$^{j}\underline{e}$*la* (‘torch’)

'd^{j}*ev*$^{j}\underline{e}$*r*^{j} *– 'd*^{j}*ev*$^{j}\underline{e}$*r*^{j}*a* (‘brother-in-law’)

Words containing alternating vowels are typically non-productive, which suggests that vowel–zero alternations are restricted to a closed class of lexical items. However, some studies claim that adult native speakers show an awareness of the phonotactic patterns of these “yer alternations”, which can be generalised and used when declining nonce words (Becker & Gouskova, 2012; Gouskova & Becker, 2013; Gouskova, 2012). This process would then appear to be similar to what has been observed in English past tense formation, where participants have been able to apply *irregular* patterns to nonce verbs (Rumelhart & McClelland, 1986; Pinker & Prince, 1988; Albright & Hayes, 2003). In other words, the various systematic exceptions can be interpreted by native speakers as another system of rules, and thus some lexically restricted patterns can be applied to nonce words with similar phonotactics.

Russian studies of yer alternations have investigated the abilities of adults to generalise the alternation pattern when declining nonce words. The following observations have been made: 1) participants were more likely to delete mid-vowels /e/ and /o/ than high or low vowels, 2) deletions were unlikely to violate the *Sonority Sequencing Principle* (Selkirk, 1984), as in a nonce word [kəs'nʲet]$_{Nom,sg}$ – *[kəs'nta]$_{Gen,sg}$); and 3) deletions were more acceptable in disyllables than in monosyllables, reflecting frequencies in the lexicon (Gouskova & Becker, 2013).

Despite this evidence, one should be cautious about making inferences from the nonce word experiment investigating yer alternations. This is because the ability to generalise the pattern ultimately depends on whether the pattern is *productive* or restricted to a closed class of lexical items. Importantly, the *productive* yer alternations appear only in *productive morphemes* containing former yers. These include, for example, the nominative suffixes *-ok* and *-et͡s* illustrated in the examples (5a) and (5b). A similar alternation pattern is found in words that are *etymologically* bimorphemic, but synchronically represent a single morpheme, as in (5c)–(5e) (Vasmer, 1986)[4].

(5) Real words with vowel–zero alternations in the Nominative/Genitive, singular:

a. *prɨ'ʐ-ok – prɨ'ʐ-k-a* (‘hop’)

b. *sa'mʲ-et͡s – sa'm-t͡s-a* (‘male’)

c. *'pʲeret͡s – 'pʲert͡s-a* (‘bell pepper’)

d. *'tanʲet͡s – 'tant͡s-a* (‘dance’)

e. *'rɨnok – 'rɨnk-a* (‘marketplace’)

The evidence that some of yer alternations may be productive is supported by lexicographic data, which we will discuss in the *Present Study* section of the paper.

[4] (5c) *'pʲeret͡s* (‘pepper’) originated from Old Slavic **pьpьrь + ьt͡s*, from the Latin root *piper* (‘pepper’);
(5d) *'tanʲet͡s* (‘dance’) came from Old French **danse*, through Polish *tan+iec*;
(5e) *'rɨnok* (‘marketplace’) came from German *Ring,* (IPA: /ʀɪŋ/), through Polish *rynek*.

Word-final devoicing

Like other Slavic languages, Russian exhibits neutralisation of voicing contrast word-finally (Kulikov, 2012 *inter alia*). As a result, pairs of consonants with different phonemic realisations, lose their contrastive features and become indistinguishable from one another in these contexts. For example, the two phonemes /g/ and /k/ $\rightarrow$ [k] when they appear in word final position; thus the coda consonant in a word like $[\text{lu}\underline{\text{k}}]_{Nom,sg}$ can be the allophonic realisation of either phoneme. It is only after adding an inflection that the learner is presented with an unambiguous context, which allows us to define the correct underlying phoneme, as in $[\text{lu}\underline{\text{k}}]_{Nom,sg}$ – $[\text{'lu}\underline{\text{g}}\text{a}]_{Gen,sg}$ (‘meadow’) and $[\text{lu}\underline{\text{k}}]_{Nom,sg}$ – $[\text{'lu}\underline{\text{k}}\text{a}]_{Gen,sg}$ (‘onion’). Since the majority of Russian consonants appear in voicing pairs (e.g., /b/–/p/, /b^j/–/p^j/, /d/–/t/, /d^j/–/t^j/, /v/–/f/, /v^j/–/f^j/, /g/–/k/, etc.) and many nouns in the Nominative singular end in a consonant, mastering this phonological process is important for learning to produce the correct declension of a given word. For example, if a noun ends in a consonant which has a voiced/voiceless pair, and the learner is given only its Nominative form, as in $[\text{lu}\underline{\text{k}}]_{Nom,sg}$, both $[\text{'lu}\underline{\text{g}}\text{a}]_{Gen,sg}$ and $[\text{'lu}\underline{\text{k}}\text{a}]_{Gen,sg}$ are possible output forms for the Genitive singular. The importance of this phenomenon in the context of our study is rooted in the fact that some of our stimuli were nouns ending in voiceless *-k*; this point is further discussed in the *Present Study* section.

Present Study

The goal of the present study was to investigate whether Russian-speaking children can generalise interacting morphophonological patterns. In particular, we wanted to determine whether the position of stress and the phonetic context of the target vowel affected the ability of children to decline nonce words. To this end, we ran a structured elicited production “wug”-type experiment, using equal numbers of real and nonce words, and studied how children of different ages declined these items. We then compared their performance to that of adults. By studying the behaviour of several age groups, we hoped to ascertain the age at which children start showing sensitivity to Russian morphophonological processes, and when they reach adult-like competence.

Designing the stimuli

The study aimed at investigating the effects of three main factors of interest: type of target vowel, position of stress, and word type.

Vowel type

For the purposes of this study we created a corpus of CVCVC nouns, using Zaliznjak's Grammatical Dictionary, which contains 93392 Russian words (Zaliznjak, 1977). In order to control for vowel type, we selected only disyllabic noun stems with mid-vowels, i.e., CVCeC and CVCoC structures. Table 1 provides the frequency counts for each condition.

Table 1. Counts for the target CVCVC stems and the proportions of alternating cases in Grammatical Dictionary (Zaliznjak, 1977) with the systematically alternating structures highlighted in grey.

Consonant sequence	Vowel type*	Total cases	Alternating stems: total (proportion, %)
Obstruent–Sonorant	CVObs+o+Son	88	12 (14)
	CVObs+e+Son	92	17 (18)
Sonorant–Obstruent	CVSon+o+Obs	102	50 (49)
	CVSon+o+k	52	49 (94)
	CVSon+e+Obs	66	33 (50)
	CVSon+e+t͡s	33	33 (100)

* CVSon+o+k and CVSon+e+ t͡s are subsets of CVSon+o+Obs and CVSon+e+Obs, respectively.

The use of disyllabic forms is based on previous findings by Gouskova and Becker (2013) that monosyllabic stems are less likely to contain former yers. This observation has also allowed us to exclude a large proportion of stems containing a monosyllabic root plus a monosyllabic prefix from the sample (e.g., *za-'vod* 'manufacture'), since monosyllabic roots naturally behave like monosyllabic stems in general.

Since it has been established that adult native speakers are sensitive to vowel deletions which result in sonority sequencing violations as in [kəs'nʲet] –*[kə<u>sn't</u>a] (Gouskova & Becker, 2013), we wanted to further explore the effects of syllable structure on yer alternations. To this end, we compared real words with CV+Sonorant+e/o+Obstruent structure to those with CV+Obstruent+e/o+Sonorant. Items with sonorant–obstruent sequences are much more likely to have an alternating vowel between them, as in *m^{j}e'lok*$_{Nom,sg}$ – *m^{j}e'lka*$_{Gen,sg}$ ('chalk'). Specifically, 83 out of 168 words with sonorant–obstruent structure contained a former yer. In contrast, among 180 obstruent–sonorant words only 29 contained a historic yer.

Therefore, we focused on the CV+Sonorant+e/o+Obstruent structure to further characterise the phonological contexts in which the alternations were more likely to occur. Importantly, out of 83 alternating stems, 82 had either *-ok* or *-e͡ts* endings. The only exception was the disyllabic root *lo'mot^j*$_{Nom,sg}$ – *lo'mt^{j}a*$_{Gen,sg}$ (archaic term for 'slice'), which, despite ending in *-ot^j*, also requires vowel deletion in the Genitive case. Thus, both -*ok* and *-e͡ts* endings, which also represent productive high-frequency nominative suffixes, seem to consistently contain former yers. In fact, in 85 words with non-alternating mid-vowels none ended in *-e͡ts* and only 3 very low-frequency nouns ended in *-ok*, as in *'morok*$_{Nom,sg}$ – *'moroka*$_{Gen,sg}$ (archaic term for 'darkness').

Based on the distribution and frequency of former yers in the lexicon we restricted the list of items for the experiment to nouns with a CV+Sonorant+e/o+Obstruent structure. These belonged to one of two classes: 1) words ending in *-ok*/*-e͡ts*, which are likely to be interpreted as former yers, and thus alternate with *-øk/-ø͡ts*, as in *bu'lok*$_{Nom,sg}$ – *bu'lka*$_{Gen,sg}$; and 2) words ending in other obstruents that were likely to be interpreted as containing non-yer mid-vowels [e]/[o], and thus be preserved throughout the case paradigm, as in *da'lop*$_{Nom,sg}$ – *da'lopa*$_{Gen,sg}$. Both real and nonce words had equal numbers of items for each alternation type.

Word type: real vs. nonce words

Using both real and nonce words with the same phonotactic structure allowed us to establish 1) children's sensitivity to morphophonological alternations in the lexicon; and

2) whether children were able to generalise the knowledge of these morphophonological processes when declining nonce words. This furthermore enabled us to draw conclusions about the status of yer alternations; specifically whether the morphophonological pattern is lexicalised (i.e., restricted to a closed class of real words) or whether it is a productive rule that can be applied to any novel word.

Nonce words were created by changing vowels in the initial, non-target syllable or changing one or more consonants, in a real word with the required phonotactic structure. For example, *'tanet͡s* ('dance') served as a prototype for the nonce word *'banet͡s*, *ko'net͡s* ('end') – for *'kenet͡s*. Due to the limited number of real words with the required structure, four items differed in 2 phonemes, as in the pair *'vɨrok* – *'rɨnok* ('marketplace'). All words represented legal CVCVC structures, which were examined independently by two native speakers of Russian.

Stress position

This factor was investigated in order to establish whether participants would follow the expected pattern, preserving stress in initial position or shifting it to another syllable. Additionally, since the absence of stress is responsible for phoneme neutralisation in vowels, we investigated whether this affected participants' abilities to correctly alternate/preserve the target vowel.

Therefore, 16 out of 32 nonce words and 11 out of 32 real words carried stress on the first syllable. For each condition we expected to observe the dominant stress preservation strategy, as in *da'lo̲p*$_{Nom,sg}$ – *da'lo̲pa*$_{Gen,sg}$. Note, however, that in order to preserve the prosodic structure in the yer condition, the stress needs to be placed on the inflection, as in *bu'lo̲k*$_{Nom,sg}$ – *bu'lka̲*$_{Gen,sg}$. All real words belonged to the dominant accentologic type, as in *'rɨ̲nok*$_{Nom,sg}$ – *'rɨ̲nka*$_{Gen,sg}$ ('marketplace'), *ko'mo̲k*$_{Nom,sg}$ – *ko'mka̲*$_{Gen,sg}$ ('ball').

Final devoicing effects

In addition to the main factors discussed above, we have also taken into account the effects of final consonant devoicing. One of the target stems used in the experiment ended in *-ok*, i.e., had a voiceless consonant. Importantly, it is precisely the *-ok* ending in that systematically alternates with *-øk*, and not *-og*. However, since both consonants appear word-finally, the voicing contrast is neutralised. Thus, for example, [pə'rok] can represent either the Nominative form of either *po'rok*$_{Nom,sg}$ ('fault') or *po'rog*$_{Nom,sg}$ ('threshold'). The underlying consonant only becomes apparent in the Genitive case, as in *po'roka*$_{Gen,sg}$ vs. *po'roga*$_{Gen,sg}$.

In our experiment all items were presented in the Nominative singular. Since yer alternation is observed only in disyllables ending in *-ok,* the correct determination of the vowel type ultimately depended on participants' interpretation of the final consonant as underlyingly either voiced or voiceless. Therefore, we accepted both interpretations of the stem, reassigning the production to a different class when necessary. For example, for the nonce word [bu'lok] two productions – [bu'lka] and [bu'loga] – were counted as correct, one representing a yer and the other one a non-yer type, depending on the underlying final consonant. However, due to the high frequency of the *-ok* suffix in Russian, we expected the former interpretation to be more common.

Age groups

Two factors helped determining the age groups of the participants for the study. Firstly, as demonstrated in Zamuner *et al.* (2011), even at the age of four, Dutch-speaking children are not yet able to generalise simple morphophonological patterns of final devoicing in their production of nonce words. Therefore, it seemed unlikely that their peers, learning a language with rich morphophonology, would have been able to systematically generalise the interacting segmental and suprasegmental patterns in a similar task.

In addition, Russian has a relatively complex case system, and although by the age of 2–2;6 children are typically able to choose the case appropriate for a given *syntactic function*, they still often add inflections from wrong declension classes, leave out obligatory prepositions and violate morphophonological constraints. Even at the age of 3;0–3;6 knowledge about the declension paradigms is still at early stages of its development, and adult-like consistency in the correct use of most cases is reached only by school age (Ceytlin, 2000). Based on these observations we set the minimum age of our participants to 4;0, studying the emergence of morphophonological sensitivity and its development in children aged 4–7 years.

Objectives and predictions

This study aims to further explore morphophonological development in children and fill in the gaps that remain unexplored in the area. Specifically, the main objective of this paper is to investigate the ability of native speakers to generalise interacting morphophonological patterns. In addition, we want to determine at what age children start showing sensitivity to the various segmental and suprasegmental processes, and how their skills improve with age. Finally, this study investigates whether the various types of morphophonological patterns are mastered independently; and if this is the case, in which order they are acquired.

Based on the previous findings and general trends in the lexicon, we made the following predictions about the outcomes of the experiment. Firstly, due to the rarity of productive yers in Russian, we expected that the participants would find generalising the vowel deletion pattern problematic, particularly young children. In contrast, the stress preservation pattern is likely to be followed with higher accuracy across age groups, since it is both by far the most frequent nominal stress pattern, and it also ensures greater resemblance of the various case forms of a given word.

Secondly, based on previous evidence from Russian (Ceytlin, 2000) and Dutch (Zamuner et al., 2011), we predicted that children would start showing sensitivity to morphophonological patterns around the age of 5 or older. In addition, their progress in following the various morphophonological patterns is likely to be more apparent in real words due to their expending vocabulary, and by school age would probably reach adult-like competence.

Finally, we expected the various types of patterns – segmental (i.e., vowel alternations) and suprasegmental (i.e., stress patterns) – to be mastered independently from one another, and the segmental changes to be later acquired since they create multiple formal representations (i.e., allomorphs) of the same morphemes. However, despite their independent acquisition, the morphophonological patterns might have a joint effect on the performance, making some contexts systematically more challenging. Thus, for example, when stress does not fall on the target vowel, native speakers might be less likely to follow the vowel deletion pattern, as the unstressed/neutralised allophone creates a more ambiguous phonetic context.

Method

Participants

The participants were 62 Russian-speaking children and 20 adults recruited in Novosibirsk (Russian Federation). The children were analysed in three age groups: 4-year-olds, 5–6-year-olds, and 7-year-olds (see table 2 for numbers and gender distributions). We additionally collected adult baseline data, to which we compare the children's performance.

Table 2. Age and gender distributions in four groups of participants.

Group	No. participants	Age range (*mean*)	Gender
Group1	21	4;0–4;11 (*4;6*)	10 boys, 11 girls
Group2	21	5;0–6;9 (*5;8*)	5 boys, 16 girls
Group3	20	7;0–7;11 (*7;6*)	10 boys, 10 girls
Group4 (controls)	20	21–76 (*41;2*)	10 males, 10 females

Using the grouping as outlined above, i.e., analysing 5- and 6-year-olds within one group was justified by the preliminary findings from this experiment. Specifically, the initial dataset included productions from 45 children (16 four-year-olds, 15 five-year-olds, 5 six-year-olds, 9 seven-year-olds) and 18 adults. Multiple versions of the binary logistic regression model were applied to the data, using age as a continuous predictor and as a grouping factor. The results indicated that the age predictor in children has the best explanatory power when used as a grouping factor with the following three levels: 4-year-olds, 5–6-year-olds and 7-year-olds. In addition, child and adult data required two separate models, due to the adults' almost 100% accuracy with real words; in other words, the lack of variability in adult productions of real words made them incomparable to children. Using these preliminary results, we collected additional data for equal numbers of participants in each group.

Stimuli

The stimuli consisted of 64 test items (plus 6 practice stimuli). The main factors of interest – vowel type and stress position – were taken into account when both selecting 32 real words and creating 32 nonce words. The stimulus words were presented by the experimenter – a Russian native speaker – from a laptop in a PowerPoint presentation. Each item was associated with a picture of a real or non-existent object/creature. The real and nonce nouns were introduced in random order, so as to minimise the possibility that the participants would be creating forms by analogy, i.e., following the patterns that govern a particular condition. Table 3 contains the full list of test items.

Table 3. Real and nonce words in the Nominative case form.

Word	Alter-nation	Target vowel			
		E vowel		*O* vowel	
		unstressed	stressed	unstressed	stressed
Real	+	*'ranʲet͡s* ‘backpack’ *'pʲerʲet͡s* ‘bell pepper’ *'palʲet͡s* ‘finger’	*ve'net͡s* ‘crown’ *sa'mʲet͡s* ‘male’ *bo'rʲet͡s* ‘wrestler’ *go'nʲet͡s* ‘messenger’ *ma'lʲet͡s* ‘lad’	*'rɨnok* ‘market-place’	*ko'mok* ‘ball’ *ɕe'nok* ‘puppy’ *t͡ɕu'lok* ‘stocking’ *ho'rʲok* ‘ferret’ *su'rok* ‘marmot’ *vʲe'nok* ‘garland’ *mʲe'lok* ‘chalk’
	–	*'t͡ɕerʲep* ‘skull’ *'bʲerʲeg* ‘shore’	*ʐɨ'ljet* ‘vest’ *bʲi'lʲet* ‘ticket’ *ma'nʲeʐ* ‘playpen’ *ru'lʲet* ‘roll’ *va'lʲet* ‘knight’	*'molot* ‘hammer’ *'volos* ‘hair’ *'kolos* ‘[plant] ear’ *'gorod* ‘city’ *'korob* ‘chest’	*pʲi'lot* ‘pilot’ *po'rog* ‘threshold’ *sʲi'rop* ‘syrup’ *ko'mod* ‘cabinet’
Nonce	+	*'polʲet͡s* *'banʲet͡s* *'kʲenʲet͡s* *'gʲemʲet͡s*	*pa'nʲet͡s* *ta'lʲet͡s* *ka'rʲet͡s* *gʲi'lʲet͡s*	*'fʲirok* *'dɨnok* *'ʐurok* *'vɨrok*	*pu'rok* *bu'lok* *kʲiʲ'lok* *gu'lok*
	–	*'tʲerʲep* *'pʲerʲek* *'ʂerʲep* *'dʲerʲek*	*tʲi'lʲet* *bʲi'nʲet* *pu'rʲet* *ba'rʲet*	*'dolot* *'koros* *'golop* *'torop*	*pʲi'rot* *tʲi'rop* *da'lop* *dʲi'rop*

Procedure

Morphophonological development of the participants was assessed using an elicited production task similar to the “wug” test (Berko, 1958) with real and nonce words. The participants were tested individually by the same experimenter. The sessions were audio-recorded using a digital voice recorder Olympus VN-5500PC.

During the experiment, the participant was seated in front of a computer screen and received the following instructions: “I will show you some pictures of familiar creatures and objects, and also some funny monsters you have never seen before. I will be telling you what they are called, and will ask you to use these words in a game. To make sure you understand the rules, we will practice for a bit first!” (See Appendix for the Russian version of this introductory statement). After that, 6 practice items – 4 real and 2 nonce words – were introduced, and then 64 test items followed.

The protocol for both practice and test items was the same. The participant first saw a picture of a single object/creature introduced by the experimenter: "*Here is a* $X_{Nom,\ sg}$". The next slide showed two identical items together and the experimenter asked the participant to finish the sentence "*Here are two* $X_{Gen,\ sg}$", which requires the Genitive singular form of a given word. Examples are provided in table 4.

Table 4. Nominative–Genitive pairs with real-word examples.

Vowel	First syllable stress			Second syllable stress		
	Nom, sg	*Gen, sg*	*Example*	*Nom, sg*	*Gen, sg*	*Example*
YER	CV́Cet͡s	CV́Ct͡s-a	*ranʲet͡s – rant͡sa* ('backpack')	CVCet͡s	CVCt͡s-á	*borʲet͡s – bort͡sa* ('wrestler')
	CV́Cok	CV́Ck-a	*rɨnok – rɨnka* ('marketplace')	CVCók	CVCk-á	*surok – surka* ('marmot')
Non-YER	CV́CVC	CV́CVC-a	*gorod – goroda* ('town')	CVCV́C	CVCV́C-a	*pʲilot – pʲilota* ('pilot')

Typically, the participants needed only a single attempt to produce the target Genitive singular form. However, in cases when participants failed to give a response, requested a repetition of the prompt or changed the stem (e.g., substituted [tʲiˈlʲet͡s] for the target [tʲiˈlʲet]), the experimenter introduced the item again. Up to three attempts were allowed for each item; in all cases only the last response was used for the analysis.

Coding

The data were transcribed from the audio recordings by the experimenter, using perceptual cues. If there was any doubt, spectrograms and waveforms were consulted using Praat (Boersma & Weenink, 2014). Each target item was originally classified in terms of the following three binary parameters: 1) real/nonce word; 2) yer/non-yer type of vowel (i.e., alternating/non-alternating stem); 3) stress on the 1st /2nd syllable. For example, the word ['rɨnok]$_{Nom,sg}$ (‘marketplace’) was described as 1) real; 2) yer type; 3) 1nd syllable stress. During coding, the target Genitive singular productions were labelled as ‘correct’ or ‘incorrect’ depending on whether they followed the morphophonological patterns expected for their class. Thus, a correct production simultaneously satisfied two criteria: it followed the expected vowel deletion/preservation pattern, and preserved the position of stress. For instance, the production ['rɨnka]$_{Gen,sg}$ was ‘correct’ as it demonstrated vowel deletion expected for the yer vowel and preserved the position of stress. In contrast, both *[rɨn'ka]$_{Gen,sg}$ and *['rɨnoka]$_{Gen,sg}$ were labelled as incorrect: in the first the stress was misplaced, while the second violated the alternation pattern. Note, however, that the labels ‘correct’/‘incorrect’ were used conventionally, i.e., to signal whether the productions reflected the general trends in the lexicon (see table 1 for frequency counts).

To ensure consistency in the transcriber’s judgements, a reliability check was performed for 15 % of the data. These included equal proportions of responses for each age group, which were examined by another transcriber, a linguist and native speaker of Russian. This second transcriber was instructed to transcribe each production following the same protocol, i.e., include only the last response for each item and use perceptual cues to code. The two transcripts were then compared, reaching 98% consistency between coders with respect to the 1) vowel presence/deletion and 2) stress position. In cases of mismatch in the judgments (e.g., the first researcher transcribed the production as ['rɨnoka] and the second as ['rɨnka]), the item was re-examined by the first transcriber in Praat, who made a final decision based on this last examination.

Due to final devoicing in Russian, participants gave variable interpretations of the stem for the items ending in *-ok* in 4% of the cases. For example, the nonce word *bu'lok* was occasionally analysed as *bu'log*. In this case, the item was reassigned to a different class, and labelled as correct/incorrect depending on whether it followed the alternation and stress patterns associated with this class. For example, as *bu'log* ends in a *-g*, the vowel is expected to be preserved. Thus, the 'correct' production is *bu'loga*, whereas **bu'lga* would be counted as incorrect.

Analysis

The analysed dataset included the productions of 64 test items by each of the 82 participants. Out of the total 5248 trials 36 items were excluded because participants failed to produce valid forms, either skipping items or producing a non-target type of stem. For example, the target CVCVC stem of the real-word item *'kolos* was occasionally substituted with the diminutive form *kolo's<u>ok</u>*.

The final set of items included 5212 forms, comprising 3935 child and 1277 adult productions. Due to the number of factors and interactions, as well as differences in the overall adult and child performance, the data could not fit a single model. Specifically, almost 100% accuracy of adults with real words (ceiling effects), made their productions incomparable with the child data, particularly with that of 4-year-olds'. Analysing children and adults together would be possible only if the number of significant interactions was sacrificed or a large proportion of data excluded from analysis (e.g., the productions of real words in adults were excluded from the sample), thus oversimplifying the model. Therefore, the outputs for child and adult subsets were analysed separately.

Results

Two similar binary logistic regression models were applied separately to the child and adult data, using tools available in *Minitab 17 Statistical Software*. The same three main factors of interest – *Vowel* type (yer/non-yer), *Stress* position ($1^{st}/2^{nd}$ syllable), *Word* type (real/nonce word) – and their interactions were used as predictors of the correct responses. The children's model also included *Group* as an independent factor and its interactions with the other three predictors, so as to investigate age-specific differences. Unlike the other main predictors, *Group* included not two, but three levels: 4-year-olds, 5–6-year-olds and 7-year-olds. Overall, children showed greater variability in their responses than the baseline adult population, as indicated by the difference in the R^2 values between the models: 57.6% for the adult data, and 19.17% for the child data. Table 5 summarises the output of the analysis with all significant predictors highlighted in grey.

Table 5. Summary of the binary logistic regression models applied to adult and child data, with the asterisks (*) indicating statistically significant values.

	Factors: levels	Adults			Children		
		χ^2	*p* value	*Coef.*	χ^2	*p* value	*Coef.*
Main factors	*Vowel*: yer vs. non-yer	0	0.99	0.01	139.9	* <.001	2.1
	Stress: 1st vs. 2nd syllable	0.2	0.65	0.6	69.2	* <.001	1.4
	Word: real vs. novel	150.5	* <.001	-6.2	9.7	* 0.002	-0.5
	Group: 4 years vs. 5–6 years vs. 7 years	–			31.5	* <.001	0.5; 1.2
Interactions	*Vowel*Stress*	39.3	* <.001	-3.2	125.1	* <.001	-1.7
	*Stress*Word*	1.4	0.24	1.2	2.5	0.11	-0.3
	*Vowel*Word*	27.2	* <.001	4.2	0.6	0.44	0.1
	*Group*Vowel*	–			19.6	* <.001	-0.7, -0.7
	*Group*Word*	–			18.9	* <.001	-0.1; -0.8
	*Group*Stress*	–			2.9	0.23	0.3; 0.2
Model	Hosmer-Lemeshow goodness-of-fit test; R^2	χ^2=0.8, *p*=0.98; R^2= 57.6%			χ^2=6.9, *p*=0.33; R^2=19.2%		

Importantly, the two models were made as similar as possible even if it meant keeping an interaction that was non-significant for one of the models, e.g., *Vowel*Word* interaction for children. The outputs for the child and adult datasets are given in separate subsections below. The graphs and the final summary in the *Discussion* and *Conclusion* bring together the overall findings, comparing the models.

Child Data

The analysis revealed significant main effects of *Vowel* type (χ^2=139.9, *p*<.001), *Stress* factor (χ^2=69.2, *p*<.001) and also *Vowel*Stress* interaction (χ^2=125.1, *p*<.001). As suggested by the *Vowel* type coefficient, children were roughly 2 times more accurate in producing targets in the non-yer condition (e.g., *'molot*$_{Nom,sg}$ – *'molota*$_{Gen,sg}$, 'hammer'). The position of *Stress* also had a robust effect on correct production, both as an independent factor, and in interaction with *Vowel*. Specifically, children were 1.5 times more accurate in vowel alternation/preservation when it was stressed, as in $m^{j}e\text{'}l\underline{o}k_{Nom,sg}$ – $m^{j}e\text{'}lka_{Gen,sg}$ (‘chalk’) and $s^{j}i\text{'}r\underline{o}p_{Nom,sg}$ – $s^{j}i\text{'}r\underline{o}pa_{Gen,sg}$ (‘syrup’). However, children were significantly more successful when declining words in the non-yer condition, with the coefficient of –1.7. In other words, the appearance of non-yer vowels in their non-reduced form (e.g., $s^{j}i\text{'}r\underline{o}p_{Nom,sg}$ – $s^{j}i\text{'}r\underline{o}pa_{Gen,sg}$) helps identifying these vowels as candidates for preservation.

Another significant predictor of children’s performance was the *Group* variable. From the coefficients in table 5 we conclude that the children’s accuracy increases with age at a more or less steady pace. In addition, the *Group*Vowel* interaction suggests that older children alternate vowels with zero more often, thus applying a less conservative strategy when declining words.

Finally, *Word* type – both on its own and when interacting with the *Group* variable – was also significant. Specifically, children were 2 times more accurate when declining real rather than nonce words. However, this pattern was also affected by the age of the participants. Specifically, 4-year-olds did not show any difference between real and nonce words, and even high-frequency items used in everyday life often violated the expected patterns. For example, the word $\text{'}pal^{j}e\widehat{ts}_{Nom,sg}$ (‘finger/toe’) containing a yer vowel was incorrectly paired with $*\text{'}pal^{j}\underline{e}\widehat{ts}a_{Gen,sg}$ instead of $\text{'}pal^{j}\widehat{ts}a_{Gen,sg}$. Since, younger children showed a preference for a conservative strategy, thus preserving stem integrity regardless of its phonotactics, the differences between the age groups are particularly apparent within the yer condition. Figure 1, which gives the summary of the entire data set, illustrates this pattern. Here the levels for *Stress* include *stress1* and *stress2* for words with first- and second- syllable stress, respectively. Target *Vowels* are either alternating *yers*, or *non-yers* which need to be preserved. *Words* are either *real* or *nonce words*.

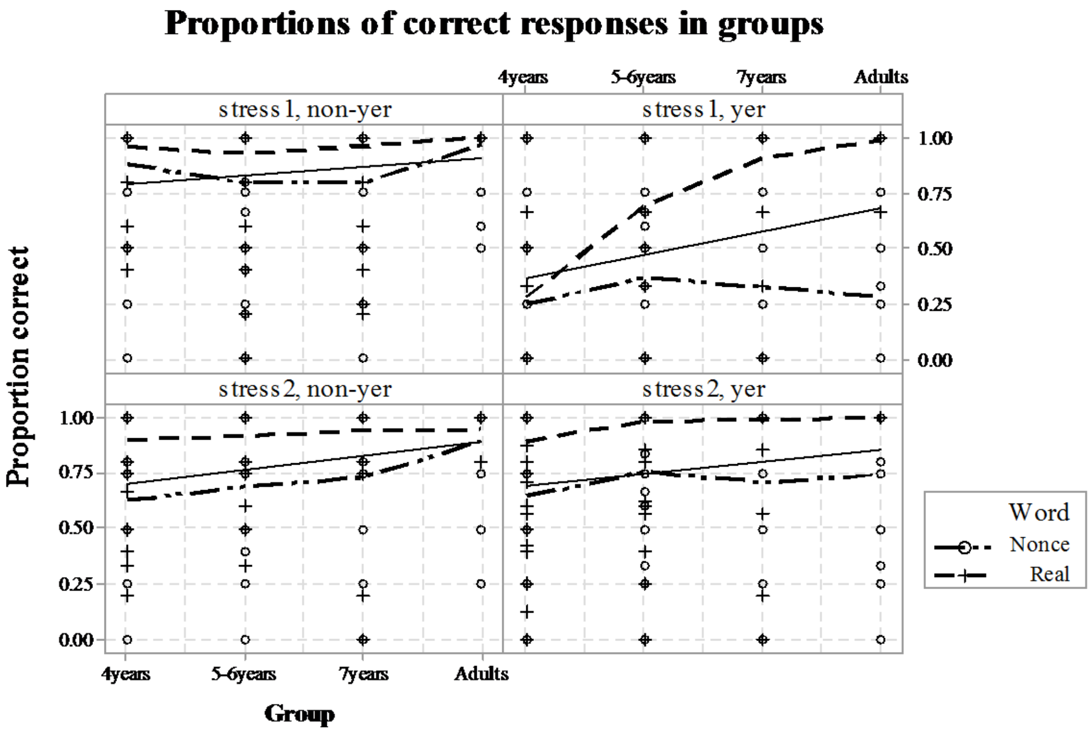

Figure 1. The proportion of the correct responses in groups as a function of three binary categories (stress position, type of target vowel and word type), with the dashed lines representing lowless .5 degree smoothing for each condition. Pluses and circles show the spread of individual data points, and the solid line – linear regression fit.

Specifically, on the second panel (i.e., *stress1, yer* condition, as in *'rɨnok* ‘marketplace’) we observe that 4-year-olds decline both real and nonce words with an equally poor accuracy of about 25%. However, the older children were significantly more accurate declining real words (i.e., reaching the average of about 70% of the correct responses in 5–6-year-olds and 90% – in 7-year-olds). However, the proportions of correctly declined nonce words in the same condition remain on relatively low level. This suggests high lexicalisation of the alternation patterns in Russian. In addition, the significant differences in the curves for the items with stressed vs. unstressed vowels underline the important role of stress in determining vowel types.

Adult Data

Overall, adults showed much less within-group variability, particularly in the way they treated real words, which they declined with almost 100% accuracy. Therefore, the greatest effect on the proportion of correct responses had the *Word* predictor – i.e., whether the item was a real or a nonce word. This observation is supported by the numbers in table 5, which show that nonce words were declined correctly 6 times less often than the real ones The only incorrectly declined real noun was the word *valʲet* (‘knave’), which was often paired with **valʲta* instead of *valʲeta*. However, this is a frequent overgeneralisation in adult spontaneous speech; in fact, **valʲta* is included as a “colloquialism” in some contemporary dictionaries (Ivanova, Lopatin, Nechaeva, & Cheltsova, 2004).

Participants’ success in producing the Genitive forms for the nonce words was also significantly affected by two interactions. The first was *Word*Vowel* interaction. Its coefficient indicated that nonce words in the yer condition (e.g., *'banʲe͡ts*$_{Nom,sg}$ – *'ban͡tsa*$_{Gen,sg}$) were over 4 times more problematic than those belonging to the non-alternating class (e.g., *'koros*$_{Nom,sg}$ – *'korosa*$_{Gen,sg}$).

The second was a *Vowel*Stress* interaction, which significantly affected adults’ productions in the same manner as was observed in children. Specifically, correctly preserving/deleting vowels when they were stressed (e.g., *da'lop*$_{Nom,sg}$ – *da'lopa*$_{Gen,sg}$ or *gu'lok*$_{Nom,sg}$ – *gu'lka*$_{Gen,sg}$) was about 3 times easier than when they were unstressed – in other words, reduced to [ə]/[ɪ] (e.g., *'gol*[ə]*p*$_{Nom,sg}$ – *'gol*[ə]*pa*$_{Gen,sg}$ or *'zur*[ə]*k*$_{Nom,sg}$ – *'zurka*$_{Gen,sg}$). The nature of this effect is discussed in the next section.

Discussion

Overall, children showed greater variability in their responses than adults (see the R^2 values in table 5). This effect is also observable in figure 1, where the distribution of correct responses ranges from 0 to 100% for both real and nonce words. This variability is probably rooted in the complexity of the Russian morphophonological system, which is likely to lead to high lexicalisation of the morphophonological patterns. This complexity is additionally confirmed by the statistical output summarised in table 5, demonstrating a number of significant factor interactions, which explains why generalisation of the morphophonological patterns is challenging.

However, despite this variability, there are several distinct patterns which demonstrate that learning morphophonological alternations significantly affects the acquisition of grammatical morphemes in children, and that adult native speakers are more systematic in following these patterns when declining nonce words. The results have shown that both segmental and suprasegmental patterns affect productions both independently as well as in interaction. Specifically, *Vowel* type (i.e., yer/non-yer condition) has a strong correlation with the proportion of correct responses. As predicted, the participants were generally more successful with non-alternating stems. This is likely to result from 1) much higher overall frequency of these stems in the lexicon; and 2) fewer formal representations (i.e., allomorphs) of the same morphemes, resulting from no alternation. Since even the adult population shows variability in the strategies applied when declining nonce words in the yer condition, we conclude that the vowel alternation pattern is lexicalised. However, when the target vowel is stressed, native speakers are better at following the expected preservation/deletion pattern. In other words, stressed vowels were much easier to attribute to an appropriate yer/non-yer class, which is illustrated in figure 1: when the target vowel is stressed (*stress2* condition) the overall accuracy in deleting yer-type vowels for both real and nonce words is relatively high even at the age of 4. However, productions in the *stress1* condition are much less accurate. This confirms our prediction that stress position might affect the learners' ability to posit the correct type of vowel alternation.

As discussed in the *Introduction*, we also wanted to investigate the reverse effect, i.e., whether the process of vowel deletion influences the speakers' ability to preserve stress. Specifically, when the target vowels in the yer condition (i.e., in words ending in *-ok* and *-e͡ts*) are stressed, the stress needs to shift to the following vowel – now the inflection, – as in *ko'mok*$_{Nom.,sg}$ – *kom'ka*$_{Gen,sg}$ (‘ball’). The results demonstrated that there was not a single error that violated this pattern, i.e., there were no productions such as *'*komka*$_{Gen,sg}$ in the entire dataset. This suggests that stress has an effect on the ability to correctly alternate/preserve vowels, whereas vowel type does not seem to contribute to ascertaining the position of stress. Thus, we conclude that, within the Russian morphophonological system, the acquisition of suprasegmental patterns, such as stress position and accentologic types, is likely to precede the mastering of segmental changes such as vowel alternations.

In addition, stress significantly contributes to the successful performance in children and adults as an independent factor, reflecting speakers’ familiarity with the various accentologic types that govern Russian nominal declensions. Although the dominant accentologic type requires the preservation of stress on the same syllable throughout the declension paradigm, as in *po'rog*$_{Nom,sg}$ – *po'roga*$_{Gen,sg}$ – *po'rogi*$_{Nom.,pl}$ (‘threshold’), there are several other accentologic types which involve stress shifts when the form changes from the Nominative singular. For example, *p*^{j}*i'rog*$_{Nom,sg}$ – *p*^{j}*iro'ga*$_{Gen.,sg}$ – *p*^{j}*iro'g*^{j}*i*$_{Nom.,pl.}$ (‘pie’) or *'korob*$_{Nom,sg}$ – *'koroba*$_{Gen.,sg}$ – *koro'ba*$_{Nom.,pl.}$ (‘box/chest’). It is apparent from these examples that the stress in nouns either remains on the same syllable, or moves to the inflection, and that there is no obvious phonotactic rule for determining the accentologic type of a word prior to seeing its declension paradigm. However, as hypothesised, overall participants chose to follow the dominant stress pattern, thus preserving its position when producing Genitive singular form (see figure 2). This confirms that the frequency of the pattern in the lexicon and the greater phonological resemblance of the output forms (i.e., that the word has the same stem in Nominative and Genitive) have a positive correlation with the proportion of correct responses.

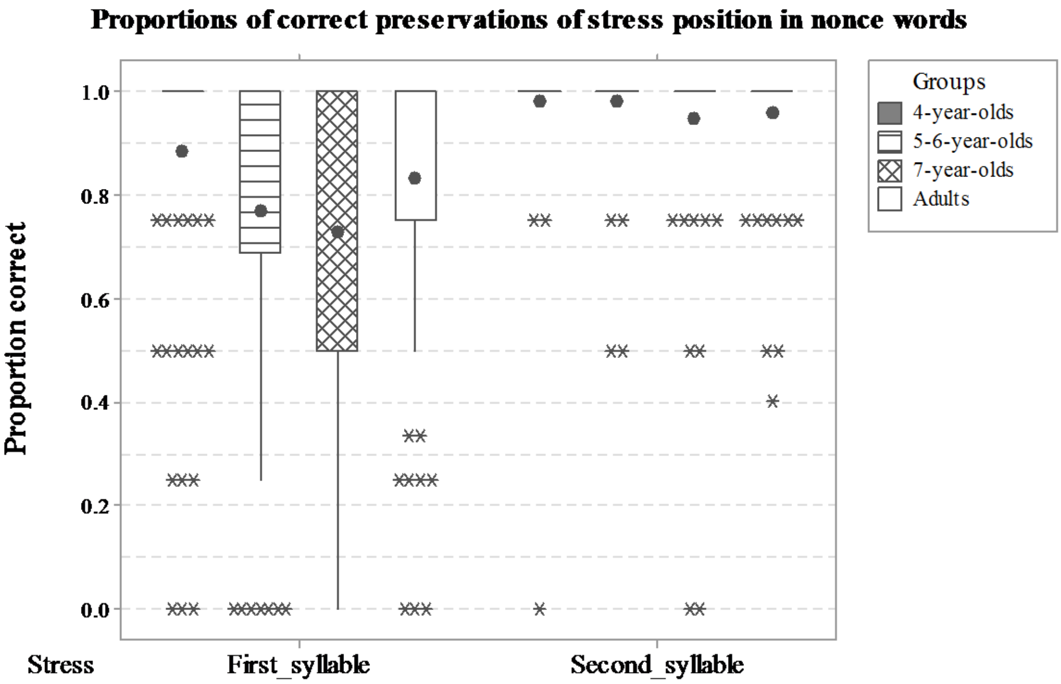

Figure 2. Proportions of correct stress preservations in nonce words as a function of position. Boxes represent interquartile ranges, whiskers stand for end points of the data, asterisks – for outliers, and black dots – for the mean values.

Despite the overall high proportion of stress preservations, the existence of other accentologic types is likely to account for the most common "stress errors" – the shifts of stress to the inflection. For example, when the stress fell on the first syllable, as in *'zurok*, participants often moved it towards the end, producing **zu'rka*$_{Gen.,sg}$ instead of the target *'zurka*$_{Gen.,sg}$ (see figure 2). Interestingly, depending on age, participants differed in the types of stress errors they made. Specifically, 4-year-olds very rarely misplaced stress, and when they did, they only shifted it to the inflection. The same trend was observed in the majority of 5–6-year-olds (96% of the cases). However, for the older children and adults, the variability in the types of stress errors increased. Thus, only 88% of the stress misplacements in 7-year-olds and 73% in adults are the shifts to the inflection. In other cases the speakers placed the stress on the first syllable instead. For example, the nonce word *da'lop* was occasionally paired with **'dalopa*$_{Gen.,sg}$ instead of the target *da'lopa*$_{Gen,sg}$ This pattern goes counter to what is predicted by the nominal accentologic types. However, it probably indicates sensitivity to other morphophonological processes. For example, some Russian nouns exhibit these shifts during derivation, as in *ku'sok* ('slice/bite') – *za'kuska* ('snack'), and also when they follow prepositions, which form a single prosodic word, as in *dom* ('house') – *'iz domu* ('out of the house').

Therefore, we conclude that, as predicted, Russian-speaking adults and children generally followed the expected stress preservation pattern. The misplacements of stress were due to participants' increasing knowledge about other accentologic types in Russian as well as stress shifts during derivation.

The effects of stress position on the proportion of correct responses

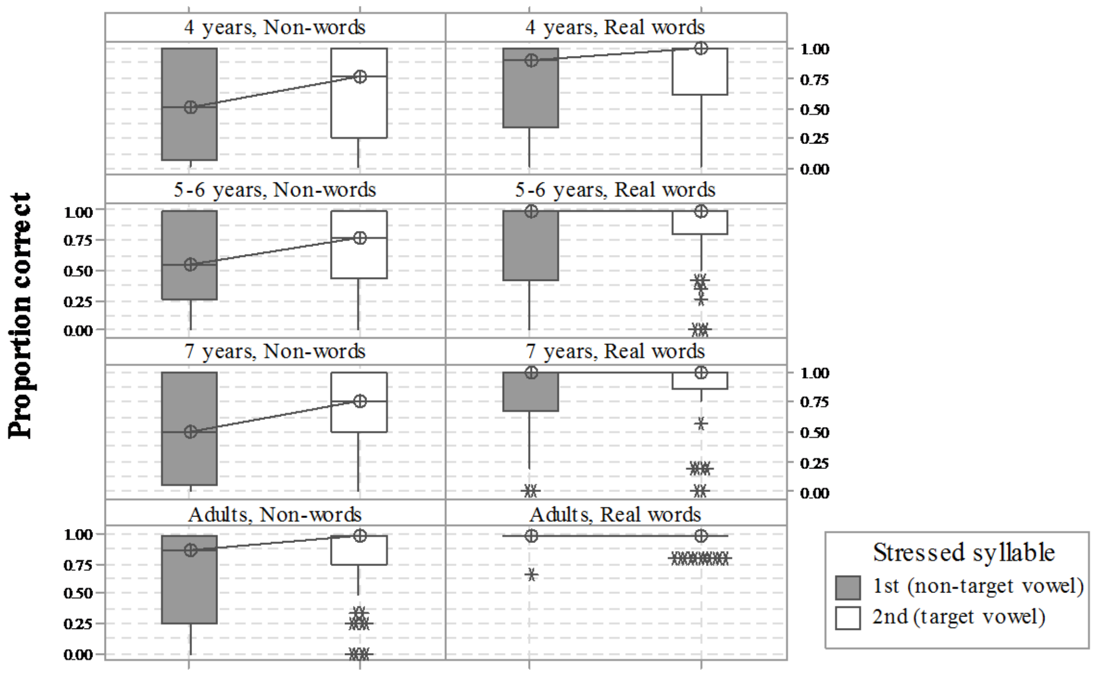

Figure 3. Proportions of productions as a function of stress position and word type across age groups. Boxes represent interquartile ranges, whiskers stand for end points of the data, and asterisks – for outliers. The lines between the boxes show the distances between the median values between the two conditions.

Finally, as predicted based on the evidence from Russian (Ceytlin, 2000, 2006) and Dutch (Zamuner et al., 2011), at the age of 4 children do not yet show sensitivity to nominal morphophonological patterns. The process of morphophonological development is likely to be additionally influenced by children's vocabulary size. Thus, in figures 1 and 3 we observe that only at the age of 5 do children start treating real and nonce words differently, suggesting that children below that age might not be confident with making generalisations about morphophonological patterns.

Conclusion

The present study investigated whether Russian-speaking children and adults can generalise interacting segmental and suprasegmental patterns when declining nominal nonce words. In addition, we were interested in determining the age of emerging sensitivity to these various morphophonological processes. Finally, we wanted to investigate whether segmental and suprasegmental alternations were mastered independently; and if this was the case, in which order they were acquired.

Our results demonstrated that participants found it problematic to generalise morphophonological patterns for vowel deletion when declining nonce words. Despite the fact that the stimuli in the yer condition ended in *-ok* and *-et͡s*, which in real words systematically contain former yers, even the adult population did not systematically generalise this pattern when declining nonce words. Rather participants applied various strategies during the task: some preferred to preserve the stem integrity, while others tended to alternate the vowels in the yer condition. This variability in strategies is likely to be due to the joint effect of interacting segmental and suprasegmental processes in Russian, which makes generalisation of the patterns challenging.

However, there were some distinct age-specific features revealing the developing sensitivity to the various morphophonological processes. Specifically, out of all age groups 4-year-olds tended to apply the most conservative strategy, preserving the position of stress as well as the target vowel across the conditions. Children aged 5–6 years began to systematically differentiate between real and nonce words, demonstrating a higher proportion of the correct responses for the former, possibly due to their expanding vocabulary. In addition, children in this age group started to occasionally alternate yer-like vowels in nonce words, showing developing sensitivity to morphophonological patterns. As they grow older, children seem to become less conservative in the suprasegmental strategies they use. Thus, they started to systematically shift the word stress from its initial position in the Nominative case to other syllables when producing Genitive singular forms, violating the predicted pattern. This behaviour was particularly apparent in 7-year-olds, who demonstrated greater within-group variability as well as less consistency in their preferred strategies. This finding is probably due to the older children's greater experience in declining real words belonging to different accentologic types and often characterised by systematic stress shifts, as well as their familiarity with the various suprasegmental shifts occurring during derivation.

Over time, children also become more consistent in the correct preservation/deletion of the target vowels, particularly in cases when these appear with stress. The latter is likely to result from the joint effect of segmental and suprasegmental factors. In other words, stress seems to help avoiding potential ambiguity in determining the underlying phoneme, thus helping to "filter out" inappropriate candidates for alternation/preservation. Therefore, we conclude that the suprasegmental effects (e.g., stress position) seem to positively influence the acquisition of the segmental patterns (e.g., vowel alternations). However, one should note that the children's constantly improving abilities to correctly decline nouns were particularly apparent in their analysis of real words. This suggests that 1) children's *vocabulary size* strongly affects the rate at which segmental and suprasegmental patterns are acquired; 2) the vowel alternation pattern is *lexicalised*, i.e., restricted to a closed class of words and mastered as part of a lexeme.

Finally, our data demonstrate high within-group variability. The variability among adults suggests that, due to the complexity of the morphophonological system and the interacting nature of some of its patterns, participants *applied different strategies* when declining nonce words. Thus, some speakers preferred a more conservative strategy, preserving the vowels across conditions, whereas others attempted to follow morphophonological patterns observed in the lexicon. On the other hand, the variability in children might additionally suggest that the participants of the same *chronological age* may have differed in terms of their *language skills*. Since children develop their linguistic competence at a different pace, an alternative grouping criterion might have been more appropriate for the analysis of the developmental trajectories, particularly in a cross-sectional study. For example, vocabulary size or the results in a standardised language test could be used for this purpose.

To summarise, these findings demonstrate that the interactions between different levels of language, such as phonology and morphology, have a significant effect on language acquisition in children and on their grammatical development. This becomes particularly apparent when looking at languages with rich morphological and morphophonological systems like Russian. Therefore, it seems important to take into account morphophonology when building models of child language development. This may also be helpful for understanding the acquisition of morphemes in atypical populations such as simultaneous bilinguals and children with Specific Language Impairment, with implications for assessment and intervention.

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Appendix

The initial introduction of the task in Russian: «Я покажу тебе картинки, на которых нарисованы знакомые тебе предметы и животные, а также забавные монстры, которых ты никогда раньше не видел(а). Я буду тебе говорить, что изображено на картинке, а твоя задача будет использовать это слово в игре. Но сначала мы немножко потренируемся, чтобы тебе стали понятны правила!»

Chapter V. General discussion

This thesis focuses on the problem of *variable use* of grammatical morphemes in children, and on the linguistic *factors responsible for protracted morphological development*. Specifically, although the presented evidence comes from two languages and two populations, all three papers explore deeply related phenomena – the acquisition of various morphophonological alternations, occurring during word inflection in verbs and nouns.

In the Introduction we highlighted two areas of morphophonology that we then attempted to explore in the three studies: 1) the acquisition of morphophonology as a *system of patterns* (i.e., studying the acquisition of various types of morphophonological alternations, and their mutual effects/interactions); and 2) the *effects* of morphophonological alternations *on the mastery of grammatical morphemes* (i.e., whether producing some allomorphs is more problematic, despite children's understanding of the morpheme's grammatical functions).

The latter problem was investigated in Chapters 2 and 3, which explored the acquisition and the effects of allomorphy on the grammatical development of English-speaking children with and without SLI. The first study had a wider focus, exploring the effects of morphophonological, phonological and prosodic constraints on the abilities of children with SLI to add nominal and verbal morphemes. Specifically, it explored the systematicity of such factors as coda complexity, utterance position, voicing and the type of allomorph on children's abilities to add morphemes in obligatory contexts. The results demonstrated a robust effect of allomorphy across all three grammatical markers, with the syllabic allomorphs being consistently more problematic. Observing similar effects in verbal as well as nominal morphemes suggested that morphophonology seems to have a significant effect on the development of children with SLI independent of their knowledge of morphosyntax. Interestingly, we did not find other factors – phonological or prosodic – to have a consistent influence on these children's production abilities. It is likely, however, that although these effects have been previously observed in TD 2-year-olds, at the age of 5 years children with SLI who passed the articulation screening have largely outgrown these limitations. In contrast, these children's persistent difficulties in adding syllabic allomorphs signalled of the delayed acquisition of morphophonological patterns, which even in TD children tend to be mastered much later than phonological and prosodic constraints – after the age of 4 years (Zamuner et al., 2011 *inter alia*). This suggested that morphophonology may have a special role in course of child language development, and in particular, during their mastery of grammatical morphemes. Further research was required to clarify the validity of this assumption, preferably using a controlled behavioural experiment and looking at children's production and perception abilities to use the various allomorphs.

Thus, the consistency of the allomorph effects helped answering some of the research questions about the role of morphophonology in grammatical development formulated in the Introduction. Specifically, the results demonstrated that allomorphy influences the production of *various types* of morphemes (i.e., nominal as well as verbal suffixes). On the one hand, such consistency supports the idea that morphophonological patterns might significantly influence child language development in general. On the other hand, we may conclude that at least in this group of children with SLI, the existence of several types of formal representations (i.e., allomorphs) for each morpheme did not enhance morpheme acquisition; on the contrary, syllabic allomorphs were acquired much later than segmental allomorphs. Finally, since we observed similar effects not only in verbs but also in nouns, the limited understanding of tense and agreement (Rice et al., 1995) might not always be the corner stone of these children's difficulties when producing grammatical morphemes; in other words, their production deficits might be due to other linguistic factors, such as morphophonological alternations.

However, these elicited production data in the first study had limitations, leaving a number of questions about the acquisition of inflectional morphemes in English-speaking children still unanswered. Firstly, since the data included only evidence from children with SLI, it remained unclear whether the same patterns would be observed in their TD peers, or whether the delay in mastering morphophonological patterns in English is specific to children with SLI. In addition, in order to draw conclusions about the general process of acquisition of these patterns, it seemed important to study not only children's production but also their perception skills; in other words, to investigate whether children *perceive* the various types of allomorphs in a similar way as they *produce* them. In particular, we anticipated that syllabic allomorphs might be easier to perceive, since they include an extra syllable, rather than just a segment.

These observations lead to a follow-up experimental study, presented in Chapter 3. This project investigated both production and perception skills of the native speakers of Australian English. These were five-year-olds with SLI and their TD peers. The experiment involved two tasks, using the same set of CVC nonce verbs with past tense *-ed* and 3rd person singular *-s* morphemes. For example, the nonce word *giz* ([gɪz]) might have been embedded in *She gized my hat yesterday* or *She gizes my hat every day*. The study investigated the effects of allomorphy (syllabic vs. segmental allomorphs) and the type of task (perception vs. production) on the performance of children with and without SLI. The results demonstrated that allomorphy affects both populations in a similar way, suggesting a delay rather than deviance in morphophonological development of children with SLI. Specifically, the syllabic allomorphs were significantly more challenging in production, but not in perception across both tense morphemes. Two explanations were proposed to account for this phenomenon, i.e., the interaction between allomorphy and type of task. Firstly, it might be the case that segmental allomorphs are, indeed, *mastered earlier* – probably due to their higher frequency in speech (Brown, 1973; Jolly & Plunkett, 2008;

Mealings et al., 2013). However, because of their longer durations and more phonetic content (Mealings et al., 2013), syllabic allomorphs might be more perceptually salient. As a result, this greater perceptual salience of the syllabic allomorphs could compensate for their delayed mastery in a grammaticality judgement task.

Alternatively, if children are *equally aware* of the morphophonological conditions for using both types of allomorphs, the poorer performance in producing syllabic allomorphs is likely to be rooted in articulatory difficulties. In other words, adding another unstressed syllable to a stem and creating a sequence of similar segments separated by a reduced vowel, as in [lændəd], results in a more phonotactically challenging context, making production more difficult. Although all the participants passed the articulation screening prior to the experiment, thus demonstrating their ability to repeat the target sound combinations in isolation, adding these syllables in morphemic context, particularly embedded in a sentence, is more articulatory challenging. Future investigation is required to determine which of these two explanations has greater validity. However, overall the results demonstrate that allomorph effects are consistently observed in children's productions of grammatical morphemes across typical and atypical populations. In addition, children with SLI, whose use of the syllabic allomorphs exhibited floor effects, might benefit from more practice with these forms during intervention. Specifically, since it has been shown that children with SLI significantly benefit from grammatical interventions using focused stimulation, recasting and imitation of the target forms (Smith-Lock et al., 2013 *inter alia*), including a greater proportion of the syllabic forms in the list of practice items is likely to enhance their acquisition. For example, if a typical proportion of segmental vs. syllabic forms is 1:2, as in Smith-Lock et al. (2013), having at least equal numbers for each type may prove beneficial. Also, it might be advisable that a clinician focused on more frequent allomorphs first, and then gradually increased the proportion of syllabic targets during subsequent sessions.

These findings raised new questions about the effects of morphophonology on grammatical development in languages with a greater number of morphophonological alternations and constraints, such as, for example, Slavic or Turkic languages. Therefore, in order to further explore the acquisition of morphophonological patterns, the third study was carried out. It focused on studying the abilities of native speakers of Russian – a Slavic language with rich morphophonological system – to generalise complex interacting morphophonological patterns. Specifically, this project investigated the effects of vowel alternations and stress position on the participants' performance in declining real and nonce nouns during a "wug" test. The experiment was carried out on 82 participants: three age groups of children (4;0–7;11) and a control group of adults.

The results demonstrated a strong overall lexicalisation of the complex morphophonological patterns in Russian, showing that even older children and adults did not consistently follow morphophonological patterns in nonce words. However, we observed several age-specific patterns associated with the process of morphophonological development. Specifically, 4-year-olds did not yet draw a fine distinction between real and nonce words; in addition, they showed a preference for a more conservative strategy, avoiding alternating the vowels and shifting the stress across all conditions, thus preserving stem integrity. However, this evidence might signal of these children's inability to consistently *reproduce* systematic morphophonological alternations, while their skills in *perceiving* them in adult speech could be far more advanced. Therefore, further investigations are required to establish whether at this young age Russian-speaking children are able to detect violations of morphophonological patterns *perceptually*, which could be done using behavioural tasks or neurophysiological methods. One of the limitations of this study and similar investigations looking at other languages (Zamuner et al., 2011 *inter alia*), is that they all have focused mostly on young learners' *production* skills. Therefore, a study of their perception abilities is required for establishing with greater precision the starting point of the acquisition of morphophonology in children – which is essential for understanding the general process of gradual language development.

Unlike the youngest group, five-year-old children showed a systematic differentiation between real and nonce words, i.e., correctly alternating and preserving the vowels in familiar words. They also began extending their knowledge of alternation patterns to nonce words, demonstrating better results with the vowels that carried stress, i.e., those appearing in their full phonemic form. At the age of 7 children seem to reach adult-like competence in declining real words. However, when producing the target forms of the nonce words, they applied strategies that differed from those observed in the adult population. Specifically, they often overgeneralised the alternation pattern, deleting vowels in phonotactic contexts where vowel deletion is never observed in real words. In addition, they were more likely to violate the dominant stress pattern, shifting the stress from its original position to the inflection or to the preceding syllable. The former indicates the children's growing sensitivity to the variety of accentologic types (i.e., the stress patterns and associated case inflections within in Russian nominal declension system). The latter is probably an indication of their familiarity with the stress shifts during derivation. Therefore, we concluded that by school age children become consistent with following morphophonological patterns in real words, and also demonstrate sensitivity to the various segmental and suprasegmental alternations taking place in nominal declensions. However, knowledge about the typical morphophonological patterns does not yet transform into a solid system, thus resulting in frequent overgeneralisation errors and high within group variability in children's productions.

To summarise, these results demonstrate that some morphophonological patterns (e.g., vowel–zero alternations) in Russian are highly lexicalised, i.e., mastered as part of the lexical item. Therefore, the progress was most apparent in the production of real nouns, and even adults did not consistently generalise the alternation/preservation pattern when declining nonce words. The overall accuracy improves as children get more experience in producing the correct forms in spontaneous speech, and thus their progress is likely to be affected by lexical frequency. In the declension of nonce words, participants chose different strategies. This variability was observable both within and across the age groups. The within group variability is likely to be rooted in high complexity of the morphophonological system; in other words, participants find it challenging to generalise the interacting patterns even when they are systematically observable in the lexicon. The differences *across* age groups constituted a gradual shift from applying a conservative strategy (i.e., preserving the target vowel as well as the position of stress across all experimental conditions) to a more variable application of morphophonological patterns. Importantly, a more consistent behaviour was observed when the target vowel was stressed. This seemed to have created "less ambiguous" phonotactic contexts, as the stress helped ascertaining the underlying phoneme behind a target vowel. The interaction of vowel alternation and stress suggests that the various types of morphophonological patterns are likely to have a joint effect on morpheme production.

Overall, this study demonstrated that, in languages rich in segmental and suprasegmental alternations, the acquisition of morphophonology as a *system of patterns* is complicated by 1) the *interacting* nature of these patterns (e.g., vowels under stress are alternated/preserved with greater accuracy), and 2) *low frequency* of some patterns (i.e., yer alternations are rare in the lexicon, and most of them are non-productive). Therefore, young learners find it difficult to generalise these patterns, and even adults show a preference for various strategies when declining nonce words.

It has been claimed that children's acquisition of the Russian nominal declensions is protracted (i.e., the paradigms are fully mastered only around school age) due to complex morphosyntax (Ceytlin, 2000). Indeed, the choice of the appropriate inflection depends on the word's syntactic function, its gender, number and animacy. However, our results show that children's difficulties may be partly due to complexity of morphophonological system as well.

This study has important limitations. Firstly, as it was discussed above, the experiment provided information only about children's production skills, and a complimentary study is required to establish whether their perception abilities are more advanced. In addition, since the upper age limit for this investigation was set to 7 years, and the results showed that at this stage children do not yet demonstrate adult-like behaviour in declension of nonce words, it seems important to test more older children, in order to get a full picture of the acquisition process. Despite these limitations, our findings lay the foundation for future research of morphophonological development in children learning other languages with rich morphophonology. In addition, the results provide a baseline evidence for future investigations into acquisition of morphophonology in atypical populations, such as children with SLI. As we have pointed out in the Introduction, a protracted difficulty in following the various morphophonological patterns might even be a reliable clinical marker of SLI in Russian. Therefore, one of the directions for future research is the investigation of morphophonological development in a clinical setting, or in a population of bilinguals and second-language learners.

To conclude, this thesis brings together three projects exploring the acquisition of morphophonological alternations and their effects on learning grammatical morphemes in children. The overall results demonstrate that acquisition of morphophonology is important for the full mastery of grammatical morphemes in both typical and atypical populations. The findings further suggest that in languages with rich morphophonological systems like Russian, characterised by complex interacting alternations, some of the patterns are lexically restricted, i.e., mastered as a part of the lexical item. Therefore, the accuracy of the learners' productions, which overall increases with age, is most apparent in real words, suggesting correlation with the children's vocabulary size. Finally, we conclude that the robustness and systematicity of morphophonological effects across languages and populations indicate the important role of morphophonology for building models of language development. This in turn may have implications for intervention with atypical populations who are likely to require additional time to master morphophonological patterns.

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MACQUARIE UNIVERSITY

Ekaterina Tomas <ekaterina.tomas@mq.edu.au>

Approved- Ethics application- Demuth (Ref: 5201100885)

Ethics Secretariat <ethics.secretariat@mq.edu.au> Fri, Mar 9, 2012 at 3:14 PM
To: Prof Katherine Demuth <katherine.demuth@mq.edu.au>
Cc: Ms Ekaterina Tomas <ekaterina.tomas@students.mq.edu.au>

Dear Prof Demuth

Re: "Production of grammatical morphemes by children with specific language impairment" (Ethics Ref: 5201100885)

Thank you for your recent correspondence. Your response has addressed the issues raised by the Human Research Ethics Committee and you may now commence your research.

The following personnel are authorised to conduct this research:

Chief Investigator- Prof Katherine Demuth

Co-Investigator- Ms Ekaterina Tomas

NB. STUDENTS: IT IS YOUR RESPONSIBILITY TO KEEP A COPY OF THIS APPROVAL EMAIL TO SUBMIT WITH YOUR THESIS.

Please note the following standard requirements of approval:

1. The approval of this project is conditional upon your continuing compliance with the National Statement on Ethical Conduct in Human Research (2007).

2. Approval will be for a period of five (5) years subject to the provision of annual reports. Your first progress report is due on 09 March 2013.

If you complete the work earlier than you had planned you must submit a Final Report as soon as the work is completed. If the project has been discontinued or not commenced for any reason, you are also required to submit a Final Report for the project.

Progress reports and Final Reports are available at the following website:

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/forms

3. If the project has run for more than five (5) years you cannot renew approval for the project. You will need to complete and submit a Final Report and submit a new application for the project. (The five year limit on renewal of approvals allows the Committee to fully re-review research in an environment where legislation, guidelines and requirements are continually changing, for example, new child protection and privacy laws).

4. All amendments to the project must be reviewed and approved by the Committee before implementation. Please complete and submit a Request for Amendment Form available at the following website:

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/

human_research_ethics/forms

5. Please notify the Committee immediately in the event of any adverse effects on participants or of any unforeseen events that affect the continued ethical acceptability of the project.

6. At all times you are responsible for the ethical conduct of your research in accordance with the guidelines established by the University. This information is available at the following websites:

http://www.mq.edu.au/policy/

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/policy

If you will be applying for or have applied for internal or external funding for the above project it is your responsibility to provide the Macquarie University's Research Grants Management Assistant with a copy of this email as soon as possible. Internal and External funding agencies will not be informed that you have final approval for your project and funds will not be released until the Research Grants Management Assistant has received a copy of this email.

If you need to provide a hard copy letter of Final Approval to an external organisation as evidence that you have Final Approval, please do not hesitate to contact the Ethics Secretariat at the address below.

Please retain a copy of this email as this is your official notification of final ethics approval.

Yours sincerely
Dr Karolyn White
Director of Research Ethics
Chair, Human Research Ethics Committee

MACQUARIE UNIVERSITY

Ekaterina Tomas <ekaterina.tomas@mq.edu.au>

RE: HS Ethics Application - Approved (5201200921)(Condition met)

2 messages

Fhs Ethics <fhs.ethics@mq.edu.au> 20 February 2013 at 07:07
To: Professor Katherine Demuth <katherine.demuth@mq.edu.au>
Cc: Ms Ekaterina Tomas <ekaterina.tomas@students.mq.edu.au>

Dear Prof Demuth,

Re: "Acquisition of Grammatical Categories in Russian Language"(5201200921)

Thank you for your recent correspondence. Your response has addressed the issues raised by the Faculty of Human Sciences Human Research Ethics Sub-Committee and you may now commence your research.

This research meets the requirements of the National Statement on Ethical Conduct in Human Research (2007). The National Statement is available at the following web site:

http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/e72.pdf.

The following personnel are authorised to conduct this research:

Ms Ekaterina Tomas
Prof Katherine Demuth

Please note the following standard requirements of approval:

1. The approval of this project is conditional upon your continuing compliance with the National Statement on Ethical Conduct in Human Research (2007).

2. Approval will be for a period of five (5) years subject to the provision of annual reports.

Progress Report 1 Due: 20th February 2014
Progress Report 2 Due: 20th February 2015
Progress Report 3 Due: 20th February 2016
Progress Report 4 Due: 20th February 2017
Final Report Due: 20th February 2018

NB. If you complete the work earlier than you had planned you must submit a Final Report as soon as the work is completed. If the project has been discontinued or not commenced for any reason, you are also required to submit a Final Report for the project.

Progress reports and Final Reports are available at the following website:
http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/forms

3. If the project has run for more than five (5) years you cannot renew approval for the project. You will need to complete and submit a Final Report and submit a new application for the project. (The five year limit on renewal of approvals allows the Sub-Committee to fully re-review

research in an environment where legislation, guidelines and requirements are continually changing, for example, new child protection and privacy laws).

4. All amendments to the project must be reviewed and approved by the Sub-Committee before implementation. Please complete and submit a Request for Amendment Form available at the following website:

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/forms

5. Please notify the Sub-Committee immediately in the event of any adverse effects on participants or of any unforeseen events that affect the continued ethical acceptability of the project.

6. At all times you are responsible for the ethical conduct of your research in accordance with the guidelines established by the University. This information is available at the following websites:

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If you need to provide a hard copy letter of Final Approval to an external organisation as evidence that you have Final Approval, please do not hesitate to contact the Ethics Secretariat at the address below.

Please retain a copy of this email as this is your official notification of final ethics approval.

Yours sincerely,

Dr Peter Roger
Chair
Faculty of Human Sciences Ethics Review Sub-Committee
Human Research Ethics Committee

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