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Prosodic Licensing and the development of phonological and morphological representations

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One of the challenges for understanding the processes underlying the acquisition of phonology has been the variability found in early speech productions. Our recent research suggests that much of this is due to the phonological (or prosodic) context in which words (and their segments) appear. This paper explores some of the recent findings on children's acquisition of phonological/prosodic units as a function of syllable and word structure, showing how acoustic analysis provides evidence of children's developing phonological representations from their first words. It then shows that similar processes can account for the variable emergence of early grammatical morphemes, suggesting that these are also *Prosodically Licensed*. These findings are discussed in terms of a developmental model of language planning and production.

Introduction

There has been much research on the development of phonological representation, with gradual learning curves being the norm, even for an individual child. Thus, a given child at a given stage of development may produce a particular segment, syllable structure, prosodic word structure, or grammatical morpheme only 25%, 50%, or 75% of the time, before finally exhibiting adult-like use of target forms in obligatory contexts. Such variability in the development of phonological and morphological structures is characterized differently across studies. At the segmental level, some report first appearance of a sound, as well as the age at which most children achieve more systematic use of a particular segment (Dodd, Holm, Hua & Crosbie 2003; Ingram 1981; Smit 1993). However, a child's use of a particular segment may depend, in part, on where in the syllable or word it occurs (e.g., onset consonants vs. coda consonants). Thus, we might expect a particular segment to

be more reliably produced in some phonological/prosodic contexts than others. However, until recently, little was known about the possible phonological/prosodic context effects on children's early acquisition of segments, how this interacts with the use of particular syllable/word structures, and the implications this has for the development of phonological representations.

The same situation exists for studies reporting on children's use of grammatical morphemes. For example, in the classic study of the emergence of grammatical morphology in the speech of Adam, Eve and Sarah, Brown (1973) documented when each child had 'acquired' each grammatical morpheme. This was measured in terms of 95% percent use in obligatory contexts across three consecutive recording sessions. This is a fairly rigorous test of morpheme use, and much higher than that used by others in the field (e.g., above 80% use overall is typically considered quite good – e.g. Demuth & McCullough 2009). This raises the question, then, of what kind of morphological representations a child may have when a grammatical morpheme is produced only 50% of the time. Should this be considered as not having any representation at all (i.e. 'random' use)? Many researchers have suggested that such behavior implies a lack of adult-like syntactic structure (Radford 1990) or a lack of semantic understanding about the use of such morphemes (Hyams 2007). However, research by Gerken and McIntosh (1993), Gerken (1996) and Demuth (1994; 2001) and colleagues suggests that the phonological/prosodic context in which a grammatical morpheme appears can influence the likelihood that a child will produce it. This could therefore account for much of the variability found in children's early productions. This in turn raises the question of what children actually 'know' about the structure of their language, and when. In particular, it suggests that, just as discourse context is essential for assessing children's knowledge of syntax, so too prosodic context plays a critical role in assessing the nature of children's developing phonological and morphological representations. The implications for understanding the mechanisms underlying phonological and morphological development, as well as for assessing the language abilities of those with language delay (phonological delay, SLI, hearing loss, etc.), is enormous.

This paper reviews what is known about prosodic effects on children's development of phonological and morphological representations, focusing on interactions at the levels of the mora, syllable, foot, prosodic word, and phonological phrase. In particular, it shows that the acquisition of 'phonology' goes far beyond the acquisition of segments alone, interacting with many other levels of prosodic structure. This is perhaps most clearly illustrated with reference to the Prosodic Hierarchy, as developed by Nespor and Vogel (1986) and Selkirk (1984; 1996). Viewed from this perspective, it is perhaps not surprising that the acquisition of phonology takes years to master, playing an important role in understanding children's planning and production of words, morphemes, and utterances.

Interactions at the segmental/prosodic interface

A child's use of a particular segment (phoneme) may be influenced by the prosodic structure in which it occurs. Given that English exhibits word-minimality effects (a word must contain two moras (i.e. a foot) of structure (Prince & Smolensky 2004)), we wondered if perhaps children would also be more likely to preserve a coda consonant in the context of a preceding short vowel (*sit*) compared to a preceding long vowel (*seat*). If so, this would provide support for the observation that early codas are also prosodically licensed, being more likely to occur when they are required to preserve word-minimality. Data from 2-year-olds using an elicited imitation task (with picture prompt) suggests that this is the case, with children more likely to preserve the coda when the preceding vowel is short (monomoraic) than long (bimoraic) (Miles, Cox, Yuen & Demuth in submission).

Segments are also variably produced depending on whether they occur at the beginning or end of a word or syllable. Children typically acquire onset consonants before coda consonants, such that a high frequency segment such as /t/ might be realized in a word like *top*, but not in a word like *cat*, even though /t/ tends to be the first coda consonant acquired in English (cf. Kehoe & Stoel-Gammon 2001; Stites, Demuth & Kirk 2004; Zamuner, Gerken & Hammond 2005). Similarly, a significant number of children show acquisition of /ɾ/ in Brazilian Portuguese in syllable-initial-within-word position long before they acquired the same sound in syllable-final-within-word position, and stress does not seem to be a factor (Yavaş 1988).

Positional effects can be found in complex clusters. For example, /s/ tends to appear earlier in children's coda clusters in a word like *box* or *wasp* than it does in onset clusters such as *sky* or *spot* (Kirk & Demuth 2005). Thus, the *position* in which a target segment appears in a syllable or word can have a major effect on the likelihood that it will be produced at a certain stage of development.

This is all the more interesting since we tend to think of these segments being the same phoneme, regardless of the context in which they appear. Although there are obvious acoustic differences in the realization of an onset vs. coda stop (e.g., VOT vs. closure, etc.) and an onset vs. coda fricative (e.g., differences in frication duration), the assumption is typically that this should not impact on the realization of these segments. This might, however, be a factor for the acquisition of /l/, where some consider light (onset) /l/ and dark (coda) /l/ to be two different segments (cf. *leap* vs. *peel*). Indeed, Smit (1993) suggests that /l/s are first acquired in onset position around the age of 4, and only later acquired in coda position, around the age of 6. This may be due to the challenges of learning to coordinate the two articulatory gestures needed to produce this segment in these two different prosodic contexts (Lin & Demuth 2013). However, for most other consonants, this is

less of an issue. Thus, all else being equal, we might expect the acquisition of a segment to occur simultaneously across all positions in a word. That this is not the case suggests that the use of a particular segment at a specific point in development is heavily influenced by the prosodic context in which it occurs.

Further support for this claim comes from the observation that word-internal coda consonants tend to appear more often in stressed compared to unstressed syllables in English (Kirk & Demuth 2006), and similar findings are reported for Spanish (Lleó 2003). Thus, the coda consonant /k/ in a nonce word is more likely to be produced when it occurs in a syllable that is stressed (e.g., BAKnal) compared to the same sequence when it is unstressed (e.g., bakNAL). A possible explanation for this finding is that the stressed syllable is *longer* in duration than the unstressed syllable, providing the young child with additional time to produce the coda consonant. This is apparently confirmed by the observation that English-speaking children are also good at producing coda consonants in word-final position, even when these occur in an unstressed syllable (e.g., NALbak). In a non-word imitation task, the word-final consonant is also phrase-final, and therefore subject to phrase-final lengthening (Lehiste 1972), providing more time for the child to fully articulate the coda. Thus, both stressed and final syllables facilitate coda production, whereas unstressed word-medial coda consonants are more likely to be omitted in children's early speech. Once again, the production of a segment interacts with the prosodic environment, being influenced not only by syllable structure, but also prosodic word structure, stress, and phrase-final lengthening.

Interactions at the morphology/syllable structure interface

Many inflectional morphemes in English are encoded with a consonant, with /s, z/ and /t, d/ being the most frequent (e.g., plural, 3rd person singular, past tense). The plural is typically acquired early, perhaps due to its high frequency in the input children hear (around 75% of all *-s* morpheme tokens and types are plurals vs. 20% for 3rd person singular). However, the acquisition of tense morphemes has been notorious for the variable and protracted acquisition patterns found, leading to proposals that these are syntactically difficult (Radford 1990). However, Marshall and van der Lely (2007) found that SLI children's use of the past tense morpheme was worse with increasing phonotactic complexity in the coda. Thus, the production of the past tense morpheme in a word like *sewed* was good, where the morpheme was the only coda consonant. However, when the coda was more complex (e.g., *kicked*), performance diminished, and was even lower in a three coda cluster (e.g., *danced*). These findings suggest that the more complex the syllable structure, the lower the use of the grammatical morpheme.

Similar findings have now been reported for the third person singular morpheme, where typically developing 2-year-olds are more likely to produce the morpheme in a simple coda (*see*<u>*s*</u>) compared to a complex coda (*hit*<u>*s*</u>), in both spontaneous speech and in elicited imitation tasks (Song, Sundara & Demuth 2009). Using a similar task, Theodore, Demuth and Shattuck-Hufnagel (2011) found that the plural morpheme was generally preserved in the context of a complex coda, but that cluster simplification also occurred (*pigs* > *piss*). This was also occasionally found in the case of possessives (Mealings & Demuth, in press-a). Thus, though the effects of the complex coda are seen, they may differentially affect the various segments of the coda cluster depending on the robustness of the morpheme being acquired. Since the plural is earlier acquired, and the morphological representation therefore more robust, cluster simplification leaves the morpheme intact at the expense of reducing the consonant of the lexical form. Interestingly, this tends to happen much more when the target word occurs utterance medially compared to utterance finally.

These findings are interesting in light of a recent study examining the production of morphemic vs. non-morphemic coda clusters (e.g., *rocks* vs. *box*) (Song, Demuth, Shattuck-Hufnagel & Menárd 2013). It was found that 2-year-olds used different articulatory gestures in producing the two different types of /ks/ coda clusters, with /k/ appearing to be the articulatory target in the lexical item *box*, but the /s/ appearing to be the articulatory target in the morphologically complex *rocks*. This would be consistent with the Theodore et al. findings above, where morphemic *-s* is retained at the cost of omitting the coda of the lexical base. This suggests that the representation of morphemic inflectional morphemes differs from that of tautomorphemic clusters, even at the early age of 2. Perhaps children of this age are already prosodifying this morpheme at the level of the prosodic word, above the level of the lexical item itself (cf. Goad, White & Steele 2003; Selkirk 1996). Or perhaps these findings have more to do with lexical access and online processing of morphological composition. This finding points to the need for a developmental model of speech planning and production in order to better understand the nature of children's developing phonological and morphological representations, and the implications this has for understanding how and why children produce the forms they do.

Interactions at the morphology/phrasal interface

Many of the above effects (coda/morpheme omission, cluster reduction) are found especially in utterance medial position, and less so utterance finally (cf. Mealings & Demuth in press-b). Recall that coda consonants are more likely to be produced

in the context where syllables have a longer duration, i.e. in either a stressed syllable or word and phrase finally. In the study of children's spontaneous use of the 3rd person singular *-s*, it was therefore interesting to find that 2–3-year-olds were more likely to produce the morpheme utterance finally than utterance medially (Song et al. 2009). We suspect that this is also due to the fact that phrase final position, where the final syllable is longer than others, affords more time to produce the entire syllable. Thus, the coda/morpheme that occurs phrase finally will be more likely to be produced.

We might then also expect that morphemes that tend to occur phrase finally tend to be more perceptible. If so, it may be easier for children to learn such morphemes, since they can be better perceived. This in turn should enhance encoding of these morphemes in the lexicon, thereby facilitating subsequent production as well. Since English is an SVO language, verbs tend to occur phrase medially, whereas nouns tend to occur phrase finally. In fact, corpus counts suggest that, on average, about 75% of 3rd person inflected verbs occur in phrase medial position, in both child and child-directed speech (Song et al. 2009). This means that only 25% of inflected verbs occur in the privileged phrase final position. In contrast, nouns occur in this phrase final position at least 50% of the time. Since nouns are also more frequent than verbs, the child hears many more plurals in phrase final position, facilitating encoding of the morphemes in this position. Perhaps, then, it is not surprising the plural morphology is acquired before verbal tense/agreement morphology, given the different prosodic contexts in which plurals tend to appear (Hsieh, Leonard & Swanson 1999; Song et al. 2009).

In order to test this perceptual hypothesis, Sundara, Demuth and Kuhl (2011) conducted an infant speech perception/looking study to determine if children around the age of 2 years notice the difference between grammatical and ungrammatical forms (where the 3rd person singular morpheme is missing). Indeed, children noticed the difference, showing a difference in looking time between the grammatical and ungrammatical sentences in phrase final position (e.g., *Now she cries* vs. **Now she cry)*. However, when the verb was embedded phrase medially, children did not show a looking time difference between the two forms (e.g., *She cries now* vs. **She cry now)*. This indicates that it is more challenging for children to perceive the 3rd person singular morpheme in utterance medial position – the context where it typically appears. These results suggest that learning verbal inflections may be delayed due to prosodic context effects. Thus, although learning about tense and agreement may be semantically more challenging than learning about number and plurality, the fact that the plural morpheme occurs both more often, as well as in a perceptually more salient context, may help explain why it tends to be earlier produced.

We have now replicated this utterance medial effect in several follow-up studies with a variety of morphemes. This effect has been found with plurals when they

were part of a consonant cluster (Theodore et al. 2011; 2012) (as mentioned above), and in *-es* /**əz**/ forms of the 3rd person singular as well. Thus, controlling for word length by using CVC**əz** matched words (possible in a dialect like Australian English: *ladders* vs. *buses*), 2-year-olds are less likely to produce the full /**əz**/ in *buses* (but not *farmers*) when the word is embedded in utterance medial compared to utterance final position (e.g., *The buses came* vs. *See the buses*) (Mealings, Cox & Demuth 2013). Though one might think that this could be a particular problem with producing a fricative+schwa+fricative sequence, this appears to be a more general problem of producing a C_1+schwa+C_1 sequence, since it appears to generalize to the past tense morpheme as well. For example, in a study with 4–5-year-old children diagnosed with SLI, all syllabic morphemes are particularly challenging, with very low use across morphemes (e.g., 3rd person singular: *catches*, possessive: *horse's*, and past tense: *added*). Interestingly, this problem appears in both verbal *and* nominal morphemes, and is not restricted to fricative contexts. It therefore seems more like an OCP effect in the context of a reduced vowel.

Phrase medial effects are also seen for the production of 3rd person singular *-s* when sentence length is manipulated. When 3-year-olds were asked to repeat 3-word and 5-word sentences in the context of a visual prompt, there was no effect on morpheme production utterance finally, with near ceiling performance for both. However, there was a large drop in performance utterance medially, with the morpheme produced in the longer 5-word utterances only 48% of the time (e.g., *He sits back* vs. *He* sits *back and swings*) (Mealings & Demuth in press-b). Thus, with increased grammatical complexity, these children were much more likely to omit the grammatical morpheme, but *only in utterance medial context*. Follow-up acoustic analysis of both the prompt children heard, and children's own productions, found no difference in the duration of these morphemes within the medial context for the 3-word and 5-word conditions. This then suggests that the effect found utterance medially was truly the combination of shorter duration *plus* the increased grammatical complexity and processing load needed to plan the rest of the (longer) sentence. (cf. Valian 1991). Recall that all these elicited production tasks are carried out in the context of a supportive picture, thereby reducing the need to remember what was said. However, planning for the upcoming words nonetheless appears to tax these children's processing abilities, resulting in fragile grammatical morphemes being omitted (see Valian (1991) for further discussion of such effects).

Interactions at the morphology/prosodic word interface

Research in the early 1990's began to report that children's variable use of grammatical morphemes such as articles could be conditioned by prosodic context

(e.g. Gerken & McIntosh 1993; Demuth 1994: Gerken 1996). In a series of elicited imitation experiments, Gerken (1996) showed that 2;3-year-olds were more likely to produce an article when it followed a monosyllabic verb than a disyllabic verb. Thus, use of the object article was significantly higher in sentences like *[Tommy] [kicks the] [rabbit]* than in a sentence like *[Tommy] [catches] the [rabbit]*. Note that in the first sentence, the article can be prosodified with the previous word to form a stressed-unstressed (Sw) trochaic foot. But this is not possible in the second sentence, since the disyllabic verb *catches* is already a Sw foot. This results in the article being left *unfooted*, where it is the subject to omission. This is very similar to the processes that underlie children's omission of unfooted syllables in lexical items like *banana* (> *nana*), though the two are probably prosodified at different levels of structure (at the level of the phonological phrase for the article, and the level of the prosodic word for the unfooted syllable in the lexical item). Interestingly, both processes tend to disappear around the age of 2;6, at least in English (Demuth 1996; Pater 1997). This strongly suggests that these are more general processes that operate on children's phonological representations at the level of the prosodic word and phonological phrase, where unfooted syllables can only be incorporated once these forms are permitted in the child's phonological grammar (Demuth 1996; Gerken 1996).

We therefore wondered if the same patterns Gerken (1996) reported for elicited production experiments would be found in children's spontaneous speech. To examine this issue we collected data from 6 1–3-year-old children, audio/video recording their speech as they interacted with their mothers for approximately one hour every two weeks over a period of two years. The data were then orthographically and phonemically transcribed, with sound files and videos attached (see the Providence Corpus (Demuth, Culbertson, & Alter 2006), CHILDES database, http://childes.psy.cmu.edu/). We then coded the data for footed vs. unfooted prosodic contexts, and whether the article was produced or not. As in the Gerken (1996) study, we found that children were much more likely to produce those articles that occurred in a footed context, and only started to acquire unfooted articles several months later (Demuth & McCullough 2009). Thus, it appears that the elicited imitation procedures tap nicely into children's phonological abilities in this domain as well.

Lleó and Demuth (1999) took this further, showing that crosslinguistic differences in the rate at which children acquire articles could be attributed to language-specific differences in how these are prosodified. In particular, they showed that articles begin to appear much later in German than in Spanish. German articles take the form of an independent prosodic word (e.g., *das* 'the'). This means that the child who wants to say 'the ball' in German must produce two independent prosodic words. In contrast, Spanish articles are clitics that are prosodified with the

following word (e.g., *la+mesa* 'the table'), resulting in a wSw prosodic word where the article is earlier acquired. Since Spanish has many 3- and 4-syllable words (e.g., *muñeca* 'doll', *eskalera* 'stairs'), children's early prosodic word representations already contain two or three syllables by the age of 2 or before (Gennari & Demuth 1997). This led Demuth, Patrolia, Song, and Masapollo (2012) to suggest that the prosodic structure of the lexicon also plays an important role in determining when articles will be acquired. Thus, articles in Spanish are prosodically licensed early, being incorporated into three syllable structures, even at the expense of dropping a syllable in the lexical item itself (e.g., *la+ muñeca* > *a+meca* 'the doll'). The result is that articles are acquired earlier in Spanish (around 1;8 years) compared to a year later in German. Thus, the prosodic structure of an article, as well as the prosodic structure of the lexicon, can both influence when articles may be acquired.

Connelly (1984) was the first to note that children learning the southern Bantu language Sesotho tended to omit noun class prefixes on the (mostly) disyllabic nouns they produced, but not when the nominal root was monosyllabic. Thus, the same noun class prefix would be either omitted or produced depending on the syllable count of the nominal root (e.g., *(mo)-sadi* 'woman vs. *mo-tho* 'person'). This is consistent with the view that noun class prefixes are produced when they can be prosodified as part of a disyllabic, trochaic foot. Further quantitative analysis showed that this was indeed the case (Demuth & Ellis 2009), and that this tendency disappears around the age of 2;3–2;6 (Demuth, Machobane & Moloi 2009). These findings appear to generalize across neighboring Bantu languages (isiXhosa, Setswana), suggesting that this is an important early stage of development in Bantu languages more generally, with early variable noun class prefix use due to prosodic rather than semantic or syntactic constraints.

Note that Sesotho noun class prefixes, like Spanish and French articles, prosodically cliticize to the following noun. Sesotho also has penultimate lengthening at the end of a phonological phrase, somewhat similar to the default lexical penultimate stress of Spanish. This raised the question of what would happen in a language like French, where the *final* syllable of a phonological phrase is lengthened, resulting in an unbounded iambic foot. Would articles (and determiners more generally) be prosodically licensed in this type of a prosodic context as well? To explore this issue we collected longitudinal audio/video data from 4 French-speaking children and mothers from 1–3 years, resulting in the Lyon Corpus (Demuth & Tremblay 2008). Like the Providence Corpus, it now resides in the CHILDES database. Analysis of the data followed similar methods as that used for the Spanish and Sesotho studies, examining the contexts were articles/determiners should be used, and the number of syllables that occurred in the following word. The results showed that, like their Sesotho-speaking counterparts, the French-speaking children were much more likely to use determiners when the following

word was monosyllabic (e.g., *du lait* 'the milk') compared to disyllabic (e.g., *la couronne* 'the crown') (Demuth & Tremblay 2008; see Veneziano & Sinclair (2000) for similar findings). Thus, the prosodic licensing of determiners appears to be independent of foot directionality, appearing at an early stage of development crosslinguistically. Interestingly, there seems to be a universal tendency to produce determiners first as part of a foot, and only later at a higher level of structure.

Discussion

This paper has reviewed recent findings suggesting that much of the early variability found in children's production of segments and morphemes is due to Prosodic Licensing effects. That is, young children are more likely to use coda consonants and grammatical morphemes in phonologically 'unmarked' environments, where they are required by the grammar to meet word-minimality constraints, where they can form part of a (disyllabic) foot, or where there is more time to actually produce an inflectional morpheme, such as in the durationally longer syllable at the end of a phonological phrase.

It is well known that frequency effects and processing load also influence the likelihood that a child will use a particular segment, syllable structure or morpheme (Levelt, Schiller & Levelt 2000; Roark & Demuth 2000; Valian 1991). Recent studies manipulating utterance length show that these effects are more often observed utterance medially (Mealings & Demuth in press-a). We suspect that, in addition to better semantic transparency, one of the reasons English plural morphology is learned earlier is due to the fact that plurals are not only much more frequent than English verbal inflectional morphemes, but that nouns (and therefore plurals) tend to occur more often in the phonetically more salient phrase-final position, where the frication on the morpheme is durationally longer (Hsieh et al. 1999; Song, Demuth, Evans, & Shattuck-Hufnagel 2013). This leads to greater perceptual salience, facilitating encoding of the morpheme in the lexicon, thereby making it easier to retrieve and produce. Thus, although many other factors (frequency, processing load, etc.) may also contribute to a child's variable use of a consonant or morpheme, the phonological/prosodic environment is critical for predicting where this might be more likely to occur. Knowing about the prosodic structure of a language then facilitates making crosslinguistic predictions about how a particular form will be realized at early stages of phonological development. We anticipate these findings will also be highly relevant for assessing persistent problems of variability in the acquisition of language in other populations, including early L2 learners/bilinguals, children with SLI, and children with hearing loss.

What, then, do we make of the 50% use of a segment or morpheme? If it is systematically used in the 'easy' phonological contexts, this would indicate that the child does have a representation, but that it may not be as robust as at 75% or 100% use in obligatory contexts. This suggests that our notion of 'acquired' should more graded, rather than all or nothing. This would be more consistent with a more probabilistic, constraint-based type of learner than the more traditional, parameter-setting type of learner. Thus, we can think of 50% as meeting some of the constraints, but not others. This is consistent with the notion that a child will be 'more likely' to use a particular form in a particular context. Thus, all else being equal, we can expect that more children will produce a particular form in a particular context. Of course, all things are not always equal in spontaneous speech, leading to the types of variability documented here. Using more controlled experiments, however, we can explore the nature of these competing constraints, and how they interact with others in the process of language learning. This is exactly where the intersection of (for example) processing load and phrase medial position effects are found, with lower performance at the intersection of these two conditions.

The Prosodic Licensing Hypothesis thus provides a general framework for exploring the nature of developing grammars across languages and populations. If children can use a particular segment, syllable structure or morpheme in a prosodically licensed, 'easy', phonologically unmarked structure, this provides some assurance to the parent, researcher or clinician that the child has some knowledge of the phonology/phonotactics and/or syntax/semantics of the form. In the case of language delayed populations, this provides some evidence that learning to use the form in other contexts should develop as the child's phonological competence and working memory increase. If, on the other hand, the use of such forms in the phonologically 'easy' contexts is systematically missing, this may provide evidence that a different type of intervention is needed.

In sum, learning the phonology of a language is a complex task that takes years to complete. The Prosodic Licensing Hypothesis provides a framework for exploring how this process develops, leading to new discoveries about the acquisition of phonology along the way.

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