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## Lexical Properties in Implementation of Sound Change

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When a child acquires the phonemic distinctions of a language, there must be a necessary mapping of the emerging phonological properties onto words in the mental lexicon. This paper examines the phonological-lexical interface in the implementation of sound change in development. We first consider the potential variables that are thought to be relevant to sound change in developing and fully-developed systems, with an explicit focus on the lexical properties of word frequency and neighborhood density (Kučera & Francis, 1967; Landauer & Streeter, 1973). WORD FREQUENCY is defined as the number of times a given word occurs in a language; whereas, NEIGHBORHOOD DENSITY is the number of words that minimally differ from each other on the basis of one phoneme substitution, deletions, or additions (e.g., 'an,' 'pan,' 'and' are all "neighbors"). Word frequency and neighborhood density have been implicated as relevant organizing variables of the mental lexicon in the domains of both production and perception. We then present a reanalysis of the patterns of sound change exhibited by two children to illustrate how word frequency and neighborhood density systematically, but differentially impact specific phonological properties. We conclude with a discussion of the implications that lexical factors hold for our understanding of the organization of the developing mental lexicon, in general, and the process of lexical diffusion, in particular.

### 1. Productive sound change in developing systems

Children vary in their implementation of productive sound change, with two general patterns having been reported: across-the-board change (Smith, 1973; Donegan & Stampe, 1979) and lexical diffusion (Ferguson & Farwell, 1975; Stoel-Gammon & Cooper, 1984). ACROSS-THE-BOARD CHANGE is characterized by rapid and complete use of a newly acquired sound to all relevant words in a child's expressive vocabulary. This type of change is generally associated with adult-like underlying representations. That is, a child has target appropriate representations at a first point in time, but output rules (or constraint rankings) affect these, leading to production errors (Menn, 1978). Once rules are eliminated (or constraints reranked), then correct production of all relevant lexical entries occurs in wholesale fashion. Across-the-board change is consistent with the Neogrammarian perspective that "sounds change" (Bloomfield, 1933). LEXICAL DIFFUSION, on the other hand, is characterized by gradual changes in production that occur on an item-by-item basis. This type of change is traceable to nonadult-like underlying representations, whereby a child is required to modify the phonological structure of only those particular words that are initially represented in a manner unique from the ambient language. This modification

occurs in a piece-meal fashion because a child must identify which words are members of the specific phonological category. However, not all members of that category will be represented in an identical way; thus, only some words will undergo change. Lexical diffusion is consistent with the premise that "words change" (Chen & Wang, 1975). Of these two general patterns of change, lexical diffusion is more predominant in acquisition. Lexically diffuse change has been reported for young children who are normally developing (e.g., Leonard, Newhoff, & Mesalam, 1980; Velten, 1943), as well as children who are older but delayed in their acquisition of the phonological system (e.g., Elbert & McReynolds, 1975, 1978). Interestingly, even in presumed cases of across-the-board change (Smith, 1973), reanalyses of the data have subsequently demonstrated that the seemingly all-or-none change was far more gradual, and wholly consistent with patterns of lexical diffusion (Dinnsen, 1996).

Given that children apparently carry out productive change on the basis of words, rather than sounds, it would be informative to know which words will be more (or less) vulnerable to change. If lexical identity were responsible for sound change, then this would be most revealing of lexical structure, composition, and representations in acquisition. Unfortunately, however, aside from the dichotomous characterization of across-the-board change versus lexical diffusion, we know little about the process of sound change in developing systems. There have been few attempts to determine the lexical properties that may govern productive sound change (Leonard & Ritterman, 1971; Tyler & Edwards, 1993). For the most part, only working hypotheses with indirect empirical validation have been advanced. To illustrate, with regard to the property of word frequency, recent connectionist accounts of phonological acquisition have proposed that input frequency establishes relative relationships between phonological units (Menn & Matthei, 1992; Stemberger, 1992). Frequency is said to account for the accessibility of certain outputs, as well as common error patterns in production, such as between-word interactions, and regressive and progressive idioms. In these accounts, however, frequency effects have been modeled only on the basis of subjective impressions. Actual counts of the segments or words in question relative to the erred productions have not been reported. Similarly, for neighborhood density, Ingram (1989) predicted that the acquisition of new sounds would be influenced by their functional load. FUNCTIONAL LOAD is defined as the number of lexical items in a target language that are differentiated by a particular phonemic opposition (King, 1967; Martinet, 1955). (Notice that functional load is essentially synonymous with neighborhood density, but at a segmental level.) Presumably, the greater the functional load (i.e., the higher the density), the earlier a segment will be acquired, thereby discouraging homonymy in a child's output (see Kornfeld & Goehl, 1974; Locke, 1979; Priestly, 1980; Vihman, 1981 for views on the role of homonymy in productive sound change in acquisition). Taken together, these available developmental hypotheses offer a prediction that changes in production will likely take place in high frequency words and in high density neighborhoods during the course of phonological acquisition.

## 2. Perceptual evidence of lexical formation and change in developing systems

In contrast to production, there is considerably more evidence on the role of lexical variables in language acquisition that comes from experimental studies of infant speech perception. These investigations have largely been concerned with identifying properties of the speech signal that infants attend to perceptually as they learn to extract words from the spoken input. Two studies serve to illustrate the general influence of word frequency and neighborhood density in early speech perception (see Jusczyk, 1997 for a more complete review and discussion). Jusczyk and colleagues (Hohne, Jusczyk, & Rendanz, 1994; Jusczyk & Aslin, 1995) exposed infants to sets of words that were frequently repeated in stories versus other words that were infrequently repeated. The infants listened preferentially to the frequently occurring words, suggesting that they not only attended to certain specific words, but they also differentiated these items on the basis of their frequency of occurrence. In a related study of neighborhood density, Jusczyk, Luce, and Charles-Luce (1994) presented infants with phonotactically permissible nonword stimuli. The phonotactic patterns occurred either frequently or infrequently in English. Infants again exhibited listening preferences for the phonotactically permissible frequent patterns. The significant extension here was that infants selectively attended to frequency as it also overlaid upon the structural properties of words. The hypothesis which emerged from this study was that infants work hard to build dense neighborhoods in early word learning. Thus, evidence from infant speech perception also suggests that high frequency words and high density neighborhoods will be strongly favored in the earliest formations of the developing lexicon.

Additional evidence on the role of neighborhood density in lexical change comes from experimental and computational studies of spoken word recognition in young children. In experimental studies, Pitrat, Logan, Cockell, & Gutteridge (1995) manipulated the neighborhood density of familiar words in assessing the auditory word recognition skills of normal children, aged 2 to 4 years. Children were asked to recognize spoken words from high versus low density neighborhoods in a picture-pointing task. A main finding was that children recognized words from high density neighborhoods more accurately than those from low density neighborhoods, even at the youngest age. This outcome lends further support to the notion that developmental organization of the lexicon may be based on dense neighborhood structure.

Other computational studies of the receptive and expressive lexicons of children demonstrated that neighborhood density continued to increase with age (Charles-Luce & Luce, 1990, 1995; Logan, 1992). Younger children had less dense neighborhoods than older children or adults, a finding that was generally consistent with corresponding increases in lexical size. Because neighborhood structure was relatively sparse with few acoustically similar items in the developing lexicon, Charles-Luce and Luce (1990, 1995) advanced the hypothesis that young children may only need global strategies to recognize words uniquely. That is, fine-grained phonetic and phonological details may be lacking in lexical representations, yet words will still be recognizable by a child. An alternate

analysis and interpretation was offered by Dollaghan (1994), who argued that sparse neighborhoods and small lexicons do require detailed phonological coding in order for similar forms to be recognized. For a young child, the mere occurrence of just one phonologically similar form will "crowd" a small neighborhood space, thereby necessitating a more specific representation. While these computational studies offer mixed views, a key issue that remains is the degree of phonological distinctiveness in a child's lexical representations as it bears on neighborhood structure. We will return to this issue in 6.0 following our reanalysis of productive sound change by two children.

### 3. Lexical variables in fully-developed systems

In contrast to proposals that high frequency words and high density neighborhoods are vulnerable to change in acquisition, evidence from fully-developed systems paints a somewhat different picture in both production and perception. Patterns of historical sound change contribute to the production side; whereas, psycholinguistic studies of auditory word recognition bear on the perceptual side.

Early research in historical linguistics largely maintained that the probabilistic properties of language, such as word frequency or neighborhood density, had little to do with phonological change:

If statistics were relevant to phonological change, there should be evidence that these statistics are part of what a speaker 'knows' about the phonology of his language—part of his competence...And...no evidence shows that statistical information in some more subtle sense is part of a speaker's competence." (King, 1969: 201)

In recent reports and demonstrations, however, some more attention has been given to the issue of lexical identity in sound change. It is important to mention, first, that there are two main types of historical sound change: changes that merge phonological categories, and changes that split such categories. Word frequency and neighborhood density seem to have different vulnerability depending on the whether the historical change involves a merger or a split; in fact, the effects are exactly opposite. Although cases of historical mergers are more prevalent, we limit our discussion to splits in order to parallel the case of acquisition, whereby new distinctions are being added to a child's phonological system. For a discussion of mergers, the reader is referred to Labov (1994) and references therein, particularly Martinet (1955) and Zipf (1929).

The evidence from historical sound change in production supports that splits will first occur in low frequency words (Malkiel, 1979; Phillips, 1984). The premise is that less frequent forms will be vulnerable to experimentation in production; whereas, more frequent forms will remain invariable because they are functionally more essential in communication. Historical occurrences of splits also first occur in high density neighborhoods, thereby affecting sounds with high functional loads (Aleshire & Streeter, 1970; Chen, 1972). As in first language acquisition, the explanation that has been offered for this effect relates to homonymy and the speaker's need to distinguish phonologically ambiguous words. Interestingly, the effect of historical change in high density

neighborhoods appears to be relative to the particular language undergoing the change (Chen, 1972). Labov (1994: 328) suggests that in order to explain such differential effects across languages, the constructs of neighborhood density/functional load may need to be elaborated. Consideration should be given to lexical opposition and lexical predictability: LEXICAL OPPOSITION refers to the number of minimal pairs that depend on a distinction; whereas, LEXICAL PREDICTABILITY is whether the distinction depends on minimal pairs. Low lexical opposition (i.e., low density) implies high lexical predictability, but not vice versa. Stated another way, a new distinction may mark only a few minimal pairs, but nevertheless, this distinction will be highly predictable and unique, even in the absence of minimal pairs. To summarize the production facts from fully-developed systems, the words most susceptible to change will be low frequency forms, and forms in high density neighborhoods, but the notion of neighborhood density may require further refinement.

On the perception side, studies of spoken word recognition and lexical access have been central to understanding the importance of word frequency and neighborhood density in lexical organization. In particular, adults recognize high frequency words more rapidly than low frequency words; similar effects are found for words from low density neighborhoods. These findings are robust having been replicated across a variety experimental paradigms (see Luce, 1986 and references therein for a comprehensive review). As with historical sound change, however, the lexical constructs have had to be developed in a more multifaceted way to account for the experimental evidence. In particular, Luce (1986) demonstrated that there is an interrelationship between a word and its neighbors along the frequency dimension, such that the processing advantage for high frequency words will only be apparent when NEIGHBORHOOD FREQUENCY is also taken into account. That is, a given high frequency word may reside in a high density neighborhood with many phonologically similar forms, and these related forms may themselves be of high frequency. In this case, high neighborhood frequency will negatively impact, and consequently, slow word recognition. A converse facilitating effect on word recognition is observed when neighborhood frequency is low. Thus, for perception in fully-developed systems, the critical lexical properties are high frequency words and low density neighborhoods, bearing in mind the qualifications about neighborhood frequency.

### 4. Lexical discrepancies in developing and fully-developed systems

When the evidence from developing and fully-developed systems is integrated, there are a number of inconsistencies regarding the lexical variables that may be facilitating in perception as opposed to production, and in developing as opposed to fully-developed systems. The findings are summarized on the following page, and provide the necessary background and motivation for a detailed examination of the phonological-lexical interface in acquisition.

	Evidence	Word Frequency	Neighborhood Density
Fully-Developed Systems	Production Perception	LO HI	HI LO
Developing Systems	Production Perception	HI HI	HI HI

It seems that the lexical properties relevant to production are complementary to those critical to perception for fully-developed systems. Further, there appears to be a shift in the importance of certain lexical properties as the system matures because data from developing systems only conform, in part, to evidence from fully-developed systems. Children presumably favor high frequency words in productive change, but adults prefer low frequency words. In perception, children's performance is facilitated in high density neighborhoods, but adults are aided by low density neighborhoods. These apparent discrepancies in the available data raise several questions about the role of word frequency and neighborhood density in acquisition, particularly as related to the process of lexical diffusion. Stemming from the above table, three hypotheses can be advanced. A first hypothesis is that lexical diffusion in acquisition will parallel the evidence from developing systems, with sound change occurring in high frequency words and in high density neighborhoods. Here, productive change is predicted to follow from other developmental observations. An alternate hypothesis is that lexical diffusion in acquisition will parallel other types of linguistic change, such that a speaker's productions will be influenced by the same lexical variables throughout the life span. In this case, productive change in development will follow from the production facts of fully-developed systems. A third hypothesis is that lexical diffusion in acquisition will be functionally motivated, such that sound change will occur in precisely those areas of the lexicon that facilitate word recognition for the listener. From this view, productive change in development will follow from the perceptual facts of fully-developed systems. These three hypotheses will be evaluated in our reanalysis of the patterns of productive sound change exhibited by two children.

### 5. Two cases of lexical diffusion in acquisition

In this section, we present a reanalysis of the longitudinal course of phonemic acquisition by two children exhibiting functional phonological delays. Children experiencing delays in phonological development are prime candidates for longitudinal studies of sound change because their consonantal systems are severely restricted relative to the target English language, and they require clinical treatment to induce changes in the productive phonology. Clinical treatment is administered as an experimental manipulation, thereby allowing individual lexical items to be systematically tracked and longitudinally monitored for productive sound change. Children evidencing phonological delay thus provide an accelerated version of sound change in progress.

The data for discussion are drawn from Gierut and Morrisette (1996) and Morrisette (1996).<sup>1</sup> To briefly recapitulate, Subjects 4 (CA 3;11) and 2 (CA 5;2) were selected for study because their sound systems were nearly identical

pretreatment, both experienced significant phonological gains following the same treatment procedures, and both were monitored longitudinally for an extended period of 9 months. During this time, the sound system of each child was sampled 14 times using a detailed probe measure consisting of more than 200 familiar and picturable lexical items (Gierut, 1985, 1998). The probe measure sampled all target English consonants and clusters in all relevant word positions, in derived and nonderived forms, and in multiple exemplars. At each sampling point in time, probe items were spontaneously elicited, audiorecorded, and then phonetically transcribed using narrow notation of the IPA. These probe data were used to determine which sounds were acquired by a child, and further, which lexical items containing the newly acquired sounds also changed from incorrect to correct productions. For a sound to be defined as 'acquired,' we relied on minimal pair criteria for determining phonemic contrasts, as established in the literature (Gierut, Simmerman, & Neumann, 1994). For a lexical item to be defined as 'changed,' a child had to first produce the probe word in error, and then later to correct this errored production, but also maintain production accuracy of the word at subsequent samplings (Morrisette, 1996). The frequency and density characteristics of every word that changed that also corresponded to a newly acquired phonemic distinction were coded. High frequency was defined by a count of 100 or greater as based on Kučera and Francis (1967); high density was defined as 10 or more neighbors as based on the distributional properties of the probe measure.

In a first report of these data, Morrisette (1997) examined individual differences in the children's implementation of sound change. Our intent here is to adopt the reverse perspective, examining the patterns of change common to both children relative to the hypotheses outlined in 4.0. The phonological properties of each child's pretreatment sound system, and changes in the composition of the inventories are shown below.

S4	CA 3;11	pre	m n ŋ	pb td kg	v	w j h
		post			f s z	
S2	CA 5;2	pre	m n ŋ	pb td kg		w j h l
		post			f v θ s z š	

Phonologically, both children expanded their phonemic repertoires by adding fricatives to the inventory. Subject 4 added the phonemes / f s z /; whereas Subject 2 added / f v θ s z š /. Notice that, for both children, the newly acquired phonemes included the universally default coronal fricative, as well as other more marked fricatives. Lexically, the types of words that changed relative to each newly acquired segment and phonological category are reported in the table on the following page.

		Default		Marked		
		coronal		labial	coronal	
		S4	HI		nonanterior	distributed
Density	S4	HI	HI			
	S2	HI	HI	LO	LO	
Frequency	S4	LO	HI			
	S2	HI	HI	HI	HI	

Notice that these children propagated sound change differentially depending on the type of phonological category being acquired. When the newly acquired segment was a presumed universal default place, then the words that changed were consistently from high density neighborhoods. In comparison, when newly learned segments were more marked, then the words that changed were uniformly of high frequency. High density and high frequency thus emerged as the more facilitating properties of productive sound change for these children. An important extension is that these factors apparently had different advantages when associated with specific phonological categories.

## 6. Implications for the phonological-lexical interface

In summary, the data from this computational examination of lexical diffusion are wholly consistent with other available acquisition facts from production and perception. The evidence continues to support the claim that the lexical items most vulnerable to change in acquisition will be high frequency words and words in high density neighborhoods. A novel finding is that children will appeal to these lexical properties differentially, depending on the phonological characteristics of the segment being acquired. Children apparently have knowledge of the phonological properties of language, but also how these properties are distributed, in terms of frequency of occurrence and phonotactic structure, across words of the ambient language. This underscores the intimate relationship between phonological and lexical properties of words in the developing mental lexicon. It further suggests that children's lexical representations must be sufficiently detailed so as to include relevant information about phonological and input structure. This is consistent with a view advanced by Dollaghan (1994) that lexical representations are finely coded even in the earliest formations of the lexicon. It must be qualified, however, that the present data only support a representational coding that is binary based on markedness. Moreover, this coding stems from presumed universal markedness values, and not a child's potentially unique representation of default properties (Bernhardt & Stoel-Gammon, 1996). In future studies, it will be important to compare independent versus relational analyses of children's phonologies in determining the role that lexical factors play in the implementation of sound change.

Preliminary findings of lexical diffusion in acquisition do not seem to exactly parallel the facts from fully-developed systems, in either production or perception. One possibility is that a more detailed evaluation of the lexical variables will be required in order to capture commonalities across the systems. For example, in acquisition, the construct of word frequency may need to be

extended to also include examinations of neighborhood frequency (Luce, 1986). Similarly, neighborhood density may need to include a look at the complementary properties of lexical opposition and lexical predictability (Labov, 1994). Another possibility is that the prominence of certain lexical properties in production and perception will change during development. It is likely that establishing a lexicon is distinct from modifying the categories of a lexicon that is already in place. In this regard, subsequent studies are needed to trace how a child's appeal to certain lexical properties may be altered in the course of development. Longitudinal studies will want to consider changes in production and perception, with an integration between the domains, and with identification of the specific circumstances that may motivate a shift in lexical focus.

Finally, if children do uphold a phonological-lexical interface as the present results indicate, then it should be possible to systematically manipulate and experimentally induce different degrees of sound change based on the frequency and density characteristics of words. Experimental manipulations would be particularly revealing of potential precedence relationships among lexical variables in productive sound change. For example, by extending the present results for presumed universal defaults, one prediction is that children who receive input (i.e., clinical treatment) that enhances words from high density neighborhoods will exhibit greater productive change. In comparison, for more marked segments, input in the form of high frequency words will predictably induce greater productive change. In our current research (Gierut, Morrisette, & Champion, 1997), we have experimentally examined the relative contribution of the full complement of lexical variables using an alternating treatments manipulation to validate and extend these predictions. Importantly, experimental manipulations of this sort also contribute to our theoretical understanding of phonological acquisition. In prior work, the gradual nature of productive sound change appeared to be just random variation within and across children's systems; but because experimental manipulations isolate the relative dominance of lexical factors in sound change, such variation can now be captured within current phonological frameworks (Gierut et al., 1997). In turn, these accounts can be extended more generally for better insight to the process of lexical diffusion. Consistent with Chen's (1972: 493) observations:

Much more detailed and better controlled study of the child's acquisition of phonology in the context of lexical diffusion would shed precious light on the implementation of sound change. It may well turn out that the lexically diffusional aspect of the ontogenic development of the child's learning process epitomizes the time dimension of the phylogenetic evolution of the linguistic system across generations. In this event the macrochronic scale of historical linguistics would shrink to a microchronic dimension where observation of the on-going changes becomes feasible.

## Endnotes

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1. Children were drawn from a larger study on the development of phonological categories, and were originally assigned the numbers S43 and S44 (as in Morrisette, 1996). As subsequently published in Gierut and Morrisette (1996) and in Morrisette (in review), these children bore the numbers S4 and S2, respectively, for purposes of discussion within and across children assigned to particular experimental conditions. Thus, the notation S4/S43 is interchangeable, as is S2/S44.

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## On the Status of Final Consonants in Early Child Language

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### 1. Preliminaries

It is commonly observed that early child language is marked by a preference for CV syllables (see e.g. Jakobson 1941, Ingram 1978). When final consonants ultimately emerge, they are standardly assumed to be syllabified as codas (Fikkert 1994, Demuth & Fee 1995, Stemberger 1996, inter alia). In this paper, I argue, on the contrary, that final consonants are initially syllabified as onsets of empty-headed syllables. I provide two types of arguments in favour of this position. First and foremost, phonetic and phonological properties of the child's outputs. Second, a learnability argument: I will demonstrate that if post-nuclear consonants are initially assumed by the child to be codas, in some languages, positive evidence will not be available for him/her to arrive at the correct analysis — if the correct analysis for the language being learned is that these consonants are in fact onsets. Naturally, this can only be possible if there are adult languages with empty-headed syllables and, further, that onsets of empty-headed syllables are unmarked vis-à-vis codas. Drawing on observations from the theoretical phonology literature, I will demonstrate that both of these hypotheses are supported.

The paper is structured as follows. In Section 2, I outline the various patterns that are observed with right-edge consonants in early grammars. In Section 3, the relationship between NoCoda and faithfulness constraints is addressed in light of the conclusions drawn from Section 2. The analysis is then outlined in detail in Section 4. This leads, in Section 5, to a comparison of the onset patterns that are observed with right-edge consonants and the emergence of true codas. In Section 6, supplementary data are provided from laterals, as earlier data focusses exclusively on obstruents. Finally, in Section 7, issues in learnability and markedness are addressed in light of the analysis proposed for the syllabification of final consonants.

### 2. The data

As can be seen from the table in (1) overleaf, the data on which I focus come from six English-speaking children. The conclusions that are drawn are based primarily on obstruent acquisition. However, in Section 6, I will provide supporting evidence from the acquisition of laterals; these data come from Marta, a Portuguese-speaking child discussed in Fikkert & Freitas (1997).