

Markedness and the grammar in lexical diffusion of fricatives

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(Received 18 April 2001; accepted 6 November 2001)

Abstract

This paper examines the contributions of markedness and a child's grammar to the process of lexical diffusion in phonological acquisition. Archival data from 19 preschoolers with functional phonological delays were submitted to descriptive analyses of productive sound change in fricatives. Children's presenting fricative inventory, the fricatives newly learned, and their position of occurrence were varied, with word frequency and neighbourhood density measured. Results indicated that lexical diffusion of fricatives occurred differentially by word position. Positional, featural and structural markedness further converged such that change in unmarked structure of any type was implemented in low frequency words. A child's presenting fricative inventory was not directly affiliated with systematic patterns of diffusion. These results have clinical applications for the evaluation of productive sound change and theoretical implications for deterministic models of lexical diffusion and processing models of word recognition.

Keywords: lexical diffusion, phonological delay, word frequency, neighbourhood density.

Introduction

The study of phonological acquisition has the potential to offer unique insight to our understanding of lexical processing in perception and production. Two psycholinguistic variables have received primary attention in studies of lexical processing—a word's frequency and its neighbourhood density. *Word frequency* refers to the number of occurrences of a given word in the language, whereas *neighbourhood density* is defined as the number of phonetically similar counterparts of a given word based on one phoneme substitutions, deletions or additions (e.g., the neighbours of 'take' include among others 'tick', 'tape', 'ache' and 'steak'). For adults, the effects of word frequency and neighbourhood density have been shown to impact the speed

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and accuracy of lexical processing, with high frequency words and words from low density neighbourhoods being most facilitative. Systematic replications of these effects have been obtained across a variety of behavioural tasks in perceptual and productive domains (Landauer and Streeter, 1973; Goldinger, Luce and Pisoni, 1989; Cluff and Luce, 1990; Vitevitch, 1997a; b; Luce and Pisoni, 1998; Vitevitch and Luce, 1998; 1999). Such robust results imply that a word's frequency and its neighbourhood density serve to structure the organization of the mental lexicon so as to expedite spoken word recognition. In recent extensions to phonological acquisition, these same variables are beginning to surface as also relevant to the formation of and change in children's grammars (Charles-Luce and Luce, 1990; 1995; Dollaghan, 1994; Beckman and Edwards, 2000; Gierut, Morrisette and Champion, 1999; Morrisette, 1999; Morrisette and Gierut, 2001; in press; Munson, 2001; Storkel, 2001, in press; Storkel and Morrisette, 2002). For children, it appears that high frequency words facilitate perception and production in parallel to the findings from adults (Leonard and Ritterman, 1971; Hohne, Jusczyk and Rendanz, 1994; Jusczyk and Aslin, 1995; Metsala, 1997). The role of neighbourhood density is less clear. Some studies show that infants and toddlers evidence behavioural preferences for dense neighbourhoods in early lexical development (Jusczyk, Luce and Charles-Luce, 1994; Logan, 1992). Other studies report that lexical neighbourhoods of young children are less dense than those of adults, thereby allowing for holistic representations of words (Charles-Luce and Luce, 1990; 1995; cf. Dollaghan, 1994). Still other studies suggest that production accuracy improves when children are presented with low density words as input (Gierut *et al.*, 1999; Morrisette and Gierut, 2001; in press). It is too soon to know whether these differences among the findings are domain-specific to perception versus production, attributable to developmental shifts during language acquisition (Metsala and Walley, 1998; Garlock Walley, and Metsala, 2001; Storkel, in press) or simply due to methodological variance. This notwithstanding, the behavioural effects imply nonetheless that neighbourhood density is likely a relevant organizational component in language acquisition.

In this paper, we continue this general line of study by specifically examining the influence of word frequency and neighbourhood density on changes in the accuracy of children's production of target sounds in words. Such changes are associated with interword variability (Ingram, 1979) and have oftentimes been characterized by the process of lexical diffusion (Jakobson, 1968; Drachman, 1976; Locke, 1979; 1983; Leonard, Newhoff and Mesalam, 1980; Macken, 1980). Lexical diffusion in acquisition has been described as the case of a child producing a newly learned target sound in some but not all relevant words of the ambient language (Ferguson and Farwell, 1975). Typically, a target sound emerges first in just a few words and may be limited in its distribution. The result is that some words are produced target-appropriately, whereas others are not. With time, a child's accurate sound production gradually extends to all pertinent words. It is in this regard that we herein use the terms 'lexical diffusion' and 'sound change'.

While interword variability has been well-documented in phonological acquisition, the change from incorrect to correct production of sounds in words is not well understood. With exception of well-defined influences of phonetic context, the factors that motivate developmental sound change have not yet been identified. Attention had been given to the functional attributes of a child (Vihman, 1981; Vihman, Ferguson and Elbert, 1986), but recently has shifted to examinations of the words themselves as contributing to the process. The premise is that a word's frequency

and its neighbourhood density may differentially influence the case-by-case emergence of accurate sound production in words. Importantly, this line of study emphasizes the necessary intersection between the phonemic contrasts of a language and the words that bear these contrasts in the differentiation of meaning (Labov, 1987; 1994). There is thus an interface between the emergence of sounds and words in a child's grammar.

Two complementary perspectives have been adopted in evaluating the effects of word frequency and neighbourhood density in productive sound change. One approach focuses on the words in the input as facilitating production accuracy (Gierut *et al.*, 1999; Morrisette and Gierut, 2001; *in press*). This work has been experimental in nature, utilizing preschool children with functional phonological delays as participants. These children have severely restricted consonantal inventories that contribute to their extreme unintelligibility. They warrant clinical treatment to induce change in the sound system, with treatment being implemented as a clinical experiment. The independent variable has been the frequency or density of words introduced in treatment of a particular sound and the dependent variable, generalization to other untreated sounds in untreated words and contexts. Through manipulations of this type, the frequency and density of words in the input that enhance phonological learning are beginning to be identified. In general, high frequency words as input facilitate the greatest change in production accuracy of sounds, whereas high density words promote little to no productive change in a child's phonology.

A second approach examines the differential influence of word frequency and neighbourhood density on the accuracy of children's outputs (Gierut and Morrisette, 1998; Morrisette, 1999; 2000). This approach has been computational, and it too draws upon the population of children with functional phonological delays. Because these children's sound systems change slowly, production accuracy can be tracked systematically and longitudinally on a word-by-word basis. The frequency and density of the words that change from incorrect to correct can be described and compared to those other words that do not evidence comparable productive gains. The result is a characterization of lexical diffusion in acquisition, with documentation of the words in children's outputs that are most susceptible versus resistant to accurate sound production.

Two such computational studies are particularly relevant (Gierut and Morrisette, 1998; Morrisette, 1999). In both, the focus was change in children's production accuracy of fricatives and the corresponding words that supported these improvements. The results yielded competing descriptions of lexical diffusion despite the fact that both studies relied on the same set of data. On the one hand, Gierut and Morrisette (1998) claimed that words which undergo change in production accuracy are influenced by general principles of markedness. In their study, when an unmarked fricative was learned, the words that changed from incorrect to correct production accuracy were from high density neighbourhoods. In contrast, when a marked fricative was learned, productive change took place in high frequency words. From this, lexical diffusion appeared to be implemented differentially depending on whether the fricative being learned was unmarked or marked. On the other hand, Morrisette (1999) argued that lexical diffusion was influenced by the segmental composition of a child's presenting grammar. Here, one child implemented accurate production of fricatives in high frequency words; whereas another produced fricatives accurately in words from high density neighbourhoods. Whichever was the primary property,

either frequency or density, applied consistently throughout the course of lexical diffusion for a given child. Moreover, the particular property that emerged as primary in sound change was determined by the featural complexity of a child's phonemic inventory (cf. Rice and Avery, 1995). From this, lexical diffusion was thought to occur differentially in words relative to a child's grammar.

The difference between these studies underscores a common theme in the acquisition literature, namely the antagonism between universal patterns and individual differences. By one interpretation, lexical diffusion was attributed to universal properties of markedness; yet by another, it was associated with individual differences in inventory composition. In this paper, we aim to disambiguate and extend these perspectives by addressing the relative contributions of markedness versus a child's unique grammar in the process of lexical diffusion. To build on the prior studies, we limit our evaluation to the acquisition of fricatives. Children albeit normal or delayed in development often exhibit errors in fricative production (Ingram, Christensen, Veach and Webster, 1980). Consequently, this class of sounds permits an evaluation of change in production of words from incorrect to correct. There is also variability among children in the particular fricative that emerges first in the sound system. In normative reports, /f/ is often cited as children's first fricative (Smit, Hand, Freilinger, Bernthal and Bird, 1990); yet other longitudinal studies have shown that children choose among a range of fricatives (Edwards, 1979; Stoel-Gammon and Cooper, 1984). These developmental observations facilitate an analysis of individual variation as based on a child's presenting fricative inventory. From an alternate markedness perspective, featural relationships among fricatives have been well-documented. For languages of the world, it is generally accepted that coronal is the least marked place of articulation (Paradis and Prunet, 1991; cf. Goad, 1996). /s/ is often thought to be the most basic fricative; whereas labial /f/ and other coronals such as nonanterior /ʃ/ or distributed /θ/ are considered featurally more complex (Stemberger and Stoel-Gammon, 1991; Stoel-Gammon and Stemberger, 1994). Moreover, there are additional markedness relationships among fricatives that further bear on phonological acquisition. Fricatives have been observed to emerge first in postvocalic position and only later in prevocalic contexts (Smith, 1973; Ferguson, 1978; Edwards, 1979; cf. Dinnsen, 1996). Postvocalic position is thereby claimed to be unmarked, with prevocalic position being marked. This adds a positional dimension to the apparent markedness of fricatives.

Thus, the purpose of this paper is to examine the role of a child's presenting grammar, featural markedness and positional markedness in lexical diffusion of fricatives. A child's presenting grammar is operationally defined by which fricative emerged first in the sound system, either /s/ or /f/. Featural markedness is operationally defined by which fricatives were then learned by a child, either unmarked or marked segments. Positional markedness is operationally defined by the context of occurrence of these fricatives, either prevocalic or postvocalic positions. From applied perspectives, the findings will serve to identify which kinds of words are most susceptible to productive sound change as potentially informative to clinical treatment. Theoretically, the results will better establish the contributions of universal versus child-specific variables to productive sound change through lexical diffusion.

Methods

The phonologies of 19 children were considered in this post hoc examination of lexical diffusion. Children were ages 3;5 to 5;4 (mean 4;5) and had previously

participated in an on-going research program on the learnability of sound systems at Indiana University (NIH DC01694). To provide background about these children and their phonological systems, it is first necessary to begin with a brief overview of the learnability program and its associated archival database. We then outline the procedures of this study.

Archival database

Children recruited to the learnability program through public announcement were required to meet certain entry criteria. Of most importance, they had to score at or below the 7th percentile ($M=1$) on the *Goldman Frisloe Test of Articulation* (Goldman and Frisloe, 1986) relative to age- and gender-matched peers and produce at least six target sounds in error across contexts on this measure. In addition, they had to demonstrate normal hearing (ASHA, 1985), oral motor structure and function (Robbins and Klee, 1987), receptive and expressive language (Dunn and Dunn, 1981; Hresko, Reid and Hammill, 1981; Newcomer and Hammill, 1988) and non-verbal intelligence (Levine, 1986). Children were monolingual speakers of English with no known history of developmental, cognitive, perceptual, motor or social lags other than those involving the sound system, as determined by parent report. This entry information served to establish that children were evidencing functional phonological delays that warranted clinical treatment.

Eligible children were then enrolled in an experimental clinical treatment program. Generally, this involved imitative and spontaneous production of a target sound or sounds to pre-established time- and/or performance-based criteria (cf. Gierut and Champion, 2001). Treated sounds were child- and experiment-specific, although sounds were routinely taught in the initial position of nonword stimuli. Throughout treatment, probe measures were administered to systematically track longitudinal change in children's phonological systems (Gierut, Elbert and Dinnsen, 1987). The probes sampled production of all target English phonemes in each relevant context in several mono- and polymorphemic words as elicited in a spontaneous picture-naming task. Probe lists may be found in Gierut *et al.* (1987, p. 477), Gierut (1998, p. 499) and Morrisette (1999, p. 233–237). Probes were administered at regularly scheduled intervals prior to, during and following treatment. Probe responses were audio-recorded and phonetically transcribed by trained listeners, with interjudge transcription reliability computed. Transcription data were then entered into an archival database for use in this and related post hoc descriptive research (e.g., Dinnsen, O'Connor and Gierut, 2001).

Child selection and group assignment

Archival phonological data from 19 of 116 children were identified for use in this study. Selection was based on a child's presenting phonemic inventory with particular attention to the fricative repertoire. Following preestablished criteria (Gierut, Simmerman and Neumann, 1994), the full phonemic inventory was determined based on a two-time occurrence of minimal pairs. The subset of fricative phonemes was then examined in detail. Children were selected for study only if they presented with either /s z/ or /f v/ at the first sampling point in time that was available in the archive. One and only one place category within the fricative series was required, either unmarked coronal or marked labial, but not both. Voicing was left free to vary. Inventories consisting of fricative phonemes other than these were set aside.

Thus, two place categories defined children's presenting fricative inventories for purposes of evaluating the role of individual differences in lexical diffusion. In all, 9 children used only unmarked coronal fricatives and 10 children, marked labial fricatives to the exclusion of all other fricatives.

Children were further subdivided into groups on the basis of the fricative phonemes that were subsequently learned, as demonstrated by generalization performance on probe measures. Consider that those with an unmarked presenting inventory (/s z/) could have only learned fricatives that were typologically more marked, namely /f v θ ð ʃ/. By comparison, those with a marked presenting inventory (/f v/), could have either learned marked fricatives /θ ð ʃ/ and/or unmarked fricatives /s z/. In this way, the featural markedness of newly learned fricatives was taken into account.

The end result was three subgroups of children: Unmarked presenting inventory learning Marked features (hereafter, U→M), Marked presenting inventory learning Marked features (M→M) and Marked presenting inventory learning Unmarked features (M→U). Table 1 displays the three types of presenting fricative inventories and the corresponding fricatives to be learned.

Probe samples and operational definitions

With reference to the archival database, we examined change in children's production accuracy of all probe words that contained the relevant fricatives. Probe data from the first sample obtained prior to treatment were compared to the those data obtained immediately after the completion of treatment. The number of probe words considered in the computational analyses was 4256 tokens across children and samples. Reliability of these data was 92% interjudge consonant transcription agreement (range: 87–98% with 16 153 consonants transcribed). The resulting characterization of lexical diffusion was derived solely from these probe data, with several distinct advantages worth mentioning. First, probe words remained constant within and across children; they mirrored the frequency and density characteristics of words in the English language; and they sampled children's spontaneous production of the full range of target fricatives across word positions. This ensured sampling uniformity that could not have been similarly guaranteed if, for example, connected speech samples been used instead. Second, probe data were systematically obtained at comparable intervals relative to the experimental manipulation of treatment for all children. This constrained the length of time during which changes in production accuracy could have taken place. Again, this lent uniformity to the data. Third, it has been acknowledged that the timing of speech samples may distort the characterization of lexical diffusion (Locke, 1983; Ingram, 1988), such that sound change may be inadvertently missed as a consequence of when a sample had been obtained. Yet because these children were already experiencing phonological delays, it was necessary to allow sufficient time to pass between probe administrations so as to maximize the potential for productive sound change. This was achieved by limiting the number of samples to two, while extending the interval of time between samples. Finally, although all children received treatment, treatment effects were not central to this examination of lexical diffusion. The reason is two-fold: treatment was aimed at improving production accuracy of nonword stimuli, whereas our interest was in change in the production accuracy of real words; and previous research has demonstrated that lexical diffusion does not take place differentially for treated as compared to untreated sounds (Morrisette, 2000; Morrisette and Gierut, 2001).

Table 1. *Subgroup and probe word characteristics*

Subgroup	Presenting grammar		Featural markedness		Positional markedness	
	Fricative inventory	Fricatives learned	Unmarked postvocalic	Marked prevocalic	Frequency ¹	Density ²
Unmarked→Marked	/s z/	/f v θ ð ʃ/	Frequency ¹ 1-1702	Density ² 0-25	Frequency ¹ 1-10595	Density ² 0-28
Marked→Marked	/f v/	/θ ð ʃ/	3-1702	0-17	2-10595	0-24
Marked→Unmarked	/f v/	/s z/	1-1573	0-26	1-1990	0-29

¹Frequency range of probe words per 1 million as based on Kučera and Francis (1967).²Density range of probe words as based on Luce and Pisoni (1998).

Sound change was operationally defined strictly in terms of production accuracy relative to target lexical items. This is in keeping with the notion of lexical diffusion in acquisition as associated with interword variability. A word was defined as susceptible (or vulnerable) to sound change if a target fricative improved from incorrect to correct production across samples. For example, if a child produced /θ/ in the word ‘thumb’ as [t] at the first sampling point but [θ] at the subsequent point, then this would be taken as sound change. Words that did not change were also considered. Operationally, a word was defined as resistant to sound change if a target fricative remained incorrect across samples. Continuing the example, if the child continued to produce target /θ/ as [t] in the subsequent sample, then this would be taken as no sound change. Variations in the substitute over time were also interpreted as no change. In these cases, a child’s productions would have shifted from one to another incorrect output as in the example of /θ/ being produced as [t] and later as [f]. Despite different substitutes, the target fricative would still have remained incorrect across samples, constituting no improvement and thereby sustaining apparent interword variability.

These operational definitions were supplemented in two ways. First, accurate productions over time were excluded from the data set. In such cases, productions would have remained correct throughout, thereby providing no opportunity to evaluate improvements. Second, productions that were accurate at the first sample, but inaccurate at the subsequent sample were also excluded. This would be indicative of a potential regression and at odds with our concern with words susceptible (or resistant) to improvements through lexical diffusion. It should be noted that the occurrence of these was uncommon, with just 19 of 4256 tokens (0.4%) having been excluded for these reasons.

By applying these operational definitions, we arrived at two sets of fricative words, forms that did versus did not undergo productive sound change. These words were further organized by context differentiating pre- from postvocalic fricatives, thereby addressing the issue of positional markedness. The result was prevocalic change/no change words and postvocalic change/no change words for each child in each subgroup.

Coding and analysis

The word frequency and neighbourhood density of every word that did and did not change in production were coded. Frequency and density values were obtained from an on-line database comprised of 20 000 words of the 1964 Merriam-Webster Pocket Dictionary (Nusbaum, Pisoni and Davis, 1984; see also <http://www.artsci.wustl.edu/~msommers> for general availability). This database reports frequency counts from Kučera and Francis (1967) and density values from Luce and Pisoni (1998) as based on an adult lexicon. It is by far the most comprehensive with respect to inclusion of the probe words examined in this study, although a number of other lexical databases are available from both adult and child sources (e.g., Rinsland, 1949; Kolson, 1960; Brown, 1984). While some may ask whether an adult lexical database is appropriate for use with children, the two are positively correlated (Walley and Metsala, 1992; Jusczyk *et al.*, 1994) and furthermore, are thought to be equivalent given the inherent properties of a normal distribution (Kelly and Martin, 1994). Most important to our purposes, lexical databases from

adult and child sources yield an identical characterization of lexical diffusion in phonological acquisition (Dale and Gierut, 2001; Selfridge and Gierut, 2001).

Children's coded data were used to compute the mean frequencies of words containing fricatives that did versus did not change in production accuracy for a given subgroup. Mean data were then compared to determine if the words that changed were of relatively high (or low) frequency compared to the other words that did not change. The same computation and comparison was completed for mean neighbourhood densities by subgroup. The examination of relative change based on proportional means was necessitated for three reasons. First, the distribution of sounds in language is not balanced equally across words by frequency or density. In English, for example, /f/ has an asymmetric distribution, occurring primarily in low frequency words (Crystal, 1995). Our use of proportional data takes into account such characteristics of the ambient language by acknowledging the actual dispersion of sounds in the lexicon. This notwithstanding, the probe measure did provide each subgroup with an opportunity to change words with similar frequency and density characteristics, no matter the fricatives being learned. Table 1 illustrates that, across the different subgroups, probe words had overlapping values of frequency and density. Second, prior studies have often preset the operational definition of high frequency at 100 occurrences per 1 million and high density at 10 neighbours (e.g., Luce, 1986; Morrisette, 1999). For children, these arbitrary criteria may be too stringent in defining change. The reason is that children as compared to adults would not have had the same period of exposure to a word thereby affecting its frequency, and their lexicons are presumably less dense in neighbourhood structure (Charles-Luce and Luce, 1990; 1995). Our use of relative means accommodates these potential developmental differences. Third, alternate analyses of the data were completed using log transformations to minimize skewing and also transformations to normalize the range of variability in the frequency and density of probe words. These alternatives resulted in the exactly the same characterization of sound change as did the evaluation of proportional means; consequently, we report the most basic and directly interpretable of the analyses, that being the latter.

The interpretation of relative mean data was descriptive and not statistical in nature. This was largely due to the limited sample sizes available, both in terms of the number of relevant phonologies available and the words that changed in production accuracy (cf. Morrisette, 1999). This notwithstanding, a descriptive approach to lexical diffusion during phonological acquisition is wholly consistent with cross-linguistic studies of sound change in fully developed languages as conducted within historical linguistics (e.g., King, 1969; Labov, 1994).

Results and discussion

Post-hoc descriptive analyses of sound change in fricatives are reported independently by word position for each of the three subgroups of children: U→M, M→M and M→U. The relevant dimensions of comparison are the mean frequency and neighbourhood density values of the words that changed in production accuracy of fricatives relative to those other words that did not change. Figures 1 and 2 display respectively the frequency and density results in the unmarked postvocalic position and figures 3 and 4, in the marked prevocalic position. The potential contributions of a child's presenting grammar as reflected by the pretreatment fricative inventory, featural markedness of the fricatives being learned and positional markedness of their context of occurrence are discussed relative to the process of lexical diffusion.

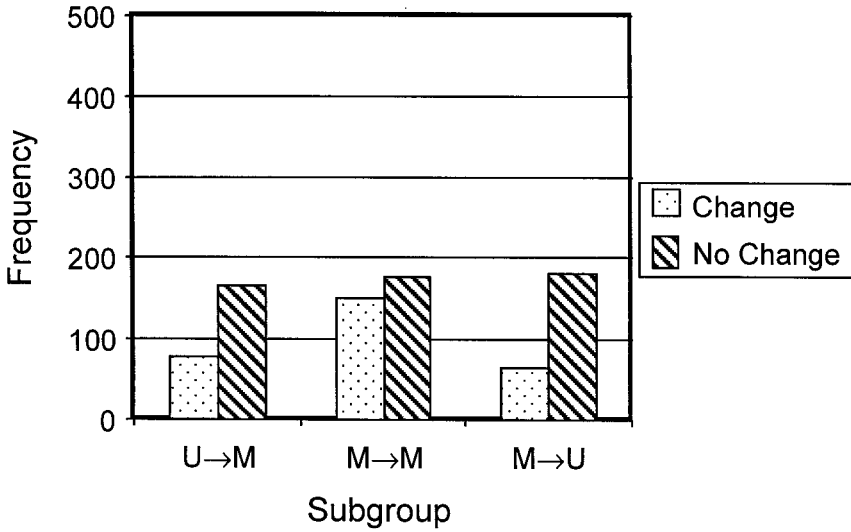


Figure 1. Mean frequency values (per 1 million) of words that did and did not change in postvocalic fricative production for each subgroup: $U \rightarrow M$ (Unmarked presenting grammar learning Marked features), $M \rightarrow M$ (Marked presenting grammar learning Marked features), and $M \rightarrow U$ (Marked presenting grammar learning Unmarked features).

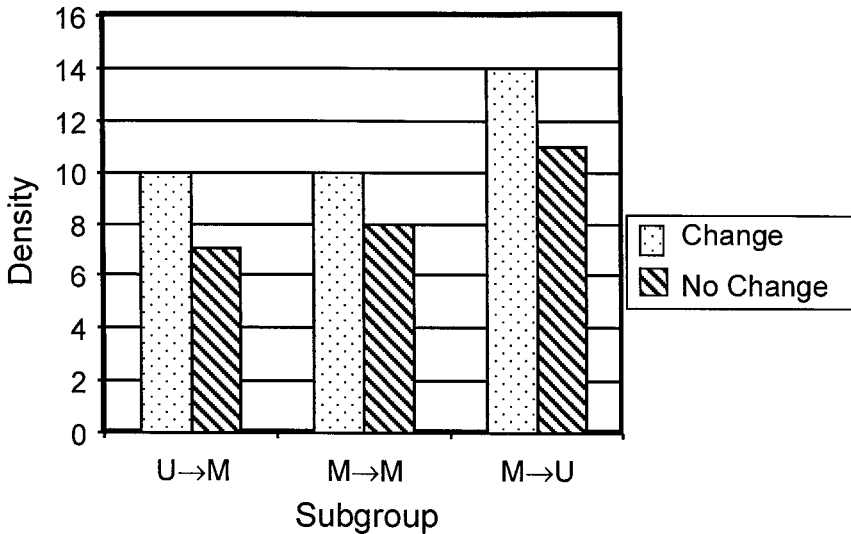


Figure 2. Mean neighbourhood density values of words that did and did not change in postvocalic fricative production for each subgroup: $U \rightarrow M$, $M \rightarrow M$ and $M \rightarrow U$.

Diffusion of postvocalic fricatives

To establish the influence of a child's grammar in sound change, we examined the subgroups $U \rightarrow M$ and $M \rightarrow M$ as the relevant comparison. Notice that the only difference between these groups was in the presenting fricative inventory, with the former evidencing only unmarked coronals and the latter, only marked labials.

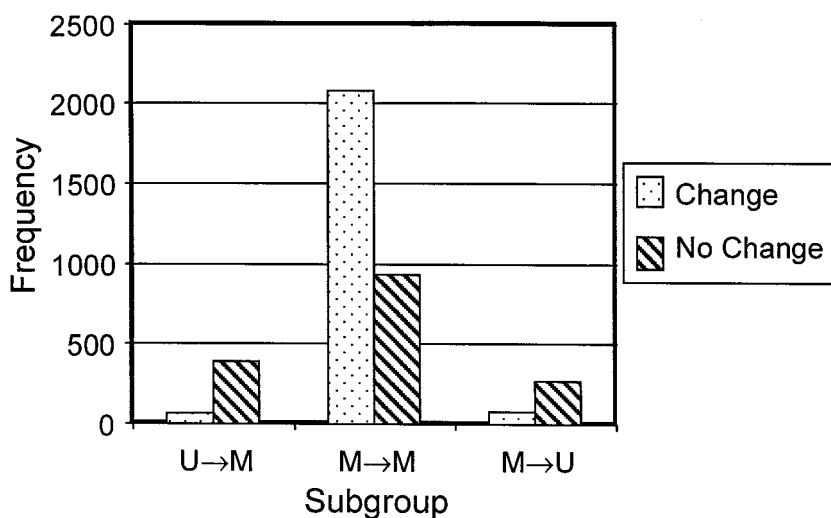


Figure 3. Mean frequency values (per 1 million) of words that did and did not change in prevocalic fricative production for each subgroup: U→M, M→M and M→U.

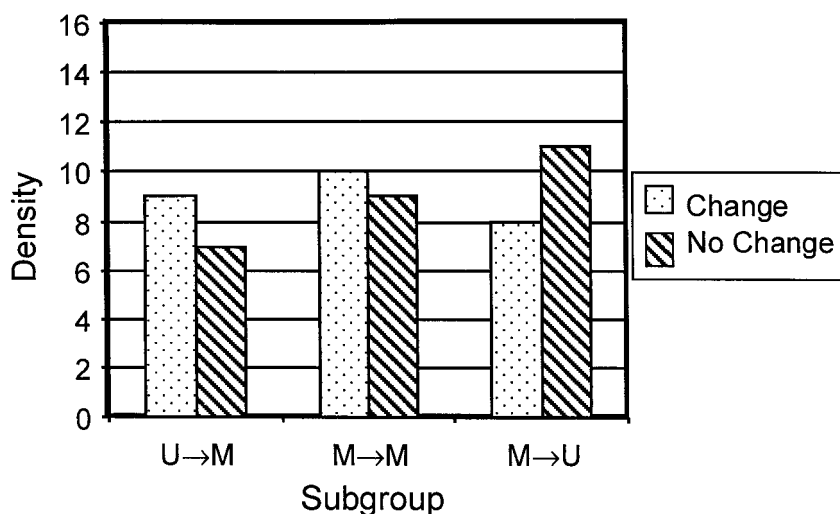


Figure 4. Mean neighborhood density values of words that did and did not change in prevocalic fricative production for each subgroup: U→M, M→M and M→U.

Featural and positional markedness were held constant given that marked fricatives were being learned in the unmarked postvocalic position by both subgroups. Figure 1 shows that children whose inventory consisted of unmarked fricatives implemented sound change in relatively low frequency words. For the U→M subgroup, mean word frequency values associated with change versus no change in fricatives were 77 versus 165 (per 1 million) respectively. This same pattern of low frequency change was observed for the M→M comparison group who presented with only marked fricatives. For this subgroup, mean frequencies of words that changed were 149 relative to 176 for words that did not change in fricative production. In figure 2, productive sound change based on neighbourhood density was also shown to be

similar across subgroups. For both the $U \rightarrow M$ and $M \rightarrow M$ subgroups, words that changed in fricative production were from relatively high density neighbourhoods, averaging 10 phonetically similar counterparts. Together, these data support that lexical diffusion of postvocalic fricatives occurred in words of low frequency and high density. Children implemented productive sound change in a uniform way despite differences in their presenting fricative inventories. This suggests that lexical diffusion of fricatives in the unmarked postvocalic context was not uniquely influenced by a child's grammar.

Turning next to featural markedness, the relevant comparison was between the subgroups $M \rightarrow \underline{M}$ and $M \rightarrow \underline{U}$. The only difference between these groups was in the markedness of the fricatives that were learned; the presenting fricative inventory and postvocalic context were held constant across groups. In figure 1, it can be seen that change consistently took place in relatively low frequency words. This was true for both subgroups even though the fricatives being learned were featurally marked as opposed to unmarked across children. In figure 2, a similar pattern was observed for neighbourhood density. Productive change in fricatives, albeit marked or unmarked, was consistently implemented in relatively high density neighbourhoods. There were again no differences in the words that changed by lexical diffusion across subgroups, even though there were differences in the markedness of the fricatives being learned.

The collective findings for postvocalic position are summarized in table 2. It can be seen that neither a child's presenting fricative inventory nor the markedness of fricatives being learned played a role in lexical diffusion. Rather, a consistent pattern of sound change in low frequency and high density lexical items was observed for postvocalic position.

Diffusion of prevocalic fricatives

In prevocalic position, the comparison again involved the subgroups $U \rightarrow M$ versus $M \rightarrow M$ in establishing the role of a child's grammar in lexical diffusion. Figure 3 shows that productive sound change was implemented in relatively low frequency words for the subgroup $\underline{U} \rightarrow M$. That is, when the presenting inventory included only unmarked fricatives, productive change took place in relatively low frequency words. The reverse occurred for the subgroup $\underline{M} \rightarrow M$. When the presenting inventory consisted of only marked fricatives, productive change was implemented in relatively high frequency words. This suggests that a child's presenting inventory may have differentially influenced lexical diffusion on the basis of a word's frequency, such that low frequency words were affiliated with unmarked inventory structure and

Table 2. *Summary of results*

Presenting grammar \rightarrow Fricatives learned	Positional markedness			
	Unmarked postvocalic		Marked prevocalic	
	Frequency	Density	Frequency	Density
Unmarked \rightarrow Marked	low	high	low	high
Marked \rightarrow Marked	low	high	high	high
Marked \rightarrow Unmarked	low	high	low	low

high frequency words with marked inventory structure. Figure 4 shows however that neighbourhood density was not similarly affected by children's inventories. Both subgroups of children $U \rightarrow M$ and $M \rightarrow M$ instated productive sound change in relatively dense neighbourhoods. The presenting grammar therefore appeared to impact only the frequency, but not the density of words that underwent lexical diffusion.

In terms of featural markedness, subgroup differences were also observed in the comparison between $M \rightarrow M$ and $M \rightarrow U$. Differences were noted in both dimensions, frequency and density. For frequency (figure 3), children who learned marked fricatives ($M \rightarrow M$) evidenced production gains in relatively high frequency words. In contrast, those who learned unmarked fricatives ($M \rightarrow U$) implemented productive changes in relatively low frequency words. High versus low frequency forms were associated with learning marked versus unmarked fricatives respectively. A similar pattern obtained for neighbourhood density (figure 4). When marked fricatives were learned ($M \rightarrow M$), the words that changed in production accuracy came from relatively high density neighbourhoods. Conversely, when unmarked fricatives were learned ($M \rightarrow U$), they were produced accurately in words from relatively low density neighbourhoods. Dense versus sparse neighbourhoods were affiliated with learning marked versus unmarked fricatives respectively. Thus, there was a complete dissociation between sound change in marked and unmarked fricatives on frequency and density grounds. Learning marked fricatives followed a pattern of change in high frequency, high density forms; whereas learning unmarked fricatives was traced to low frequency, low density forms. The featural markedness of the fricatives that were learned thereby contributed differentially to the process of lexical diffusion.

The results of prevocalic sound change are summarized in table 2. In the marked context, a child's presenting inventory and featural markedness appeared to influence diffusion. Both the inventory and featural markedness differentially impacted sound change based on word frequency, but only featural markedness affected sound change based on neighbourhood density.

The grammar and markedness in lexical diffusion

Collectively, these results support that positional markedness may be a key variable guiding productive sound change in phonological acquisition. The reason is that differential change in fricatives was observed by context. In the postvocalic context, the words vulnerable to change were routinely low frequency and high density forms. In the prevocalic context, the words that changed were more variable in their frequency and density values. These contextual differences in lexical diffusion are in accord with the findings of studies of lexical processing in perception and production by adults and children (Fromkin, 1971; Marslen-Wilson and Welsh, 1978; Shattuck-Hufnagel, 1979; 1992; Walley and Metsala, 1990; Jusczyk, Goodman and Baumann, 1999; Swingley, Pinto and Fernald, 1999; Storkel, in press). The processing literature reports behavioural asymmetries in response to stimuli presented in the onset (initial) versus coda (final) position, but these had not been directly traced to markedness. This study of productive sound change in fricatives thereby extends general positional biases known to exist in lexical organization by suggesting a possible linguistic source.

Variability by context was additionally revealing of the contributions of a child's grammar and featural markedness to the process of lexical diffusion. At first glance, the data would seem to support an all-or-none role of the grammar and markedness.

Consider, on the one hand, that neither the grammar nor markedness differentially affected change in postvocalic fricatives; yet, on the other hand, both the grammar and featural markedness were seemingly relevant to change in prevocalic fricatives. The independence of these two factors is obscured. Upon close inspection, however, it appears that the markedness of fricatives being learned may supercede a child's presenting grammar in its contributions to lexical diffusion. The evidence is garnered from an integrated comparison across subgroups in the marked prevocalic position.

Along the dimension of word frequency, lexical diffusion routinely took place in low frequency words when affiliated with unmarked structure of any type. From the view of the presenting grammar, children who used only unmarked fricatives (U→M) evidenced change in low frequency items (table 2). Likewise, from the perspective of featural markedness, children who learned unmarked fricatives (M→U) did so in low frequency forms. Low frequency words apparently went hand-in-hand with unmarked structure, no matter if internal to the grammar or featural in nature. One hypothesis that emerges is that properties of markedness may generally guide the process of lexical diffusion by rendering low frequency words most vulnerable to change. This hypothesis receives added support from the findings reported above for positional markedness. Recall that in the unmarked postvocalic context, low frequency words were the ones that changed, associating once again low frequency with an unmarked phonological property. These results directly coincide with the evidence from lexical processing by adults (Dell, 1990; Vitevitch, 1997a; b; Luce and Pisoni, 1998). In production, low frequency words were shown to be most vulnerable to errors involving slips-of-the-tongue. In perception, low frequency words required greater time in retrieval and were identified with less accuracy. The unique extension of this study is that structural markedness of a child's grammar, featural markedness of fricatives learned and positional markedness of the context of occurrence all converged in establishing the connection between unmarked structure and sound change in low frequency words. These findings are consistent with the view advanced by Gierut and Morrisette (1998) that sound change is driven by markedness. They are also consistent with Morrisette's (1999) results that fricatives which are featurally less complex (i.e., unmarked) are learned in low frequency words. Markedness thus emerged as relevant to the process of lexical diffusion as predicted by word frequency.

Along the dimension of neighbourhood density, markedness also appeared to offset the impact of a child's grammar on sound change. The evidence comes from those children who learned marked as opposed to unmarked fricatives in the prevocalic position, independent of their presenting fricative inventories. Following from table 2, when children learned marked fricatives (i.e., U→M and M→M subgroups), sound change always took place in relatively dense neighbourhoods. By comparison, when unmarked fricatives were learned (M→U), productive change was evidenced in relatively sparse neighbourhoods. As with word frequency, a differential pattern of lexical diffusion could be attributed to markedness. Marked structure and dense neighbourhoods went together in sound change, whereas unmarked structure was affiliated with sound change in sparse neighbourhoods. This finding takes on added interest when incorporated with evidence from lexical processing. Because dense neighbourhoods consist of many phonetically similar words, a child is presumably under pressure to maintain distinctness among multiply competing forms (Dollaghan, 1994; Metsala and Walley, 1998; Storkel and Morrisette, 2002). In order to disambiguate among the competitors, words in dense neighbourhoods must

in some way be phonologically unique. One hypothesis is that children represent words in high density neighbourhoods with greater phonological detail (albeit not yet ambient) than words in low density neighbourhoods (Dollaghan, 1994; Metsala, 1997; Storkel, in press; Garlock *et al.*, 2001; see however Charles-Luce and Luce, 1990; 1995; Logan, 1992). From a processing perspective then, words in dense neighbourhoods would be more likely to undergo productive sound change. Moreover, words in dense neighbourhoods would have sufficiently rich phonological structure thereby providing the requisite support for continued featural elaboration and expansion (cf. Rice and Avery, 1995). In this study, the relationship between markedness and density was only observed when we considered the prevocalic fricatives being learned. An implication that follows is marked fricatives in marked contexts may have greater phonological substance, thereby rendering them vulnerable to lexical diffusion.

From this research, a hierarchy of factors may be suggested as influencing the process of lexical diffusion in phonological acquisition. Markedness in general appears to be central to promoting sound change in fricatives. Regardless of the kind of markedness (i.e., featural or positional) or the source of markedness (i.e., typological or child-internal), sound change was implemented differentially based on a word's frequency. Featural markedness may be next in importance because it was responsible for differential sound change by neighbourhood density, but only in the marked prevocalic position and when viewed independent of a child's presenting grammar. Featural markedness had a more limited scope. Perhaps of least importance was a child's presenting grammar. No consistent pattern of sound change associated with a word's frequency or its neighbourhood density was directly traceable to children's presenting fricative inventories. This suggests that individual differences may play less of a role in lexical diffusion than previously thought. Given this, lexical diffusion may be best interpreted from universal as opposed to child-specific or functional perspectives. This is wholly in accord with deterministic models of lexical diffusion that have been advanced for acquisition and fully developed sound systems (Labov, 1987; Rice and Avery, 1995; Boersma, 1999; Gierut *et al.*, 1999; Gierut, 2001).

The outcomes of this study hold applied and theoretical significance in guiding the direction of future research. From an applied perspective, the finding that markedness influenced sound change may assist in the clinical process for children with functional phonological delays. In particular, it may be possible to predict which words of a child's output will improve in production accuracy following treatment (for parallel predictions based on words of the input in treatment, see Gierut *et al.*, 1999; Morrisette and Gierut, 2001; in press). Following from the results of this study, generalization of fricatives in final position might first be expected to occur in low frequency and in high density words. Generalization in word-initial position would likely be dependent on which fricative was learned. To monitor for such predicted patterns of generalization, it will be necessary to structure probe measures to sample words of different (and relevant) frequencies and densities. Probes will need to take into account not only the sounds that may be mastered, but also the words that may actually support these productive gains. Patterns of lexical diffusion may ultimately be used to plan for generalization in treatment based on aspects of markedness. This will be a crucial extension because it will begin to bridge lexical properties of the input with those of the output. That is, it should be possible to establish which words trigger change in treatment in concert with which

words actually undergo change as a result of that treatment. Thus far, these have remained separate and often competing lines of investigation (cf. Gierut *et al.*, 1999; Morrisette and Gierut, 2001; in press).

Theoretically, it will be necessary to go beyond the study of fricatives in evaluation of the contributions of markedness in lexical diffusion. Obstruent stops, for example, are typologically unmarked word-initially and marked postvocally (Greenberg, 1978). From the present findings, it might be predicted that sound change affecting production of word-initial stops will occur in low frequency and high density words because this is the unmarked context. As another example, consonant clusters are thought to be unmarked in coda position, but marked in onsets (Lleó and Prinz, 1996). Predictably, coda clusters will also experience productive gains in low frequency and in high density items. Replications across language universals will help to establish whether lexical diffusion follows a consistent course regardless of the phonological property being learned.

These results hold potential for documenting diffusion in other populations and domains. The process of sound change in normally developing first and second language acquisition offer alternative testing grounds for these hypotheses. Similarly, the historical study of sound change in fully developed languages may lend further support to the validity of these findings (Phillips, 1984). From a reverse perspective, studies of lexical processing in children and adults may benefit from consideration of linguistic factors such as markedness in experimental manipulations or interpretations of results.

There are certain limitations that will also need attention in future research extensions. For instance, in this study, we did not examine the course of change exhibited by children presenting with and learning unmarked properties of language (e.g., U→U). This subgroup might include children who present with no fricatives in the inventory and who then learn the most basic fricative /s/. Children of this type offer the most primitive of phonological systems for potential insight to lexical diffusion at the earliest points in acquisition. In a related vein, our research defined markedness based on typological evidence, but an alternate approach would be to define markedness in terms of a child's own sound system (cf. Morrisette, 1999). From this perspective, /s/ might not be the most basic (unmarked) fricative in all cases and postvocalic position might not be the least marked. An independent as opposed to relational orientation may help to more finely delineate the contributions of children's grammars to lexical diffusion. It will also be necessary to replicate patterns of lexical diffusion for individual children in contrast to our examination of subgroup data. Complementary longitudinal data for a given child may reveal the actual course of lexical diffusion during language acquisition. Finally, it may be appropriate to apply alternate psycholinguistic factors as dimensions of sound change. Word frequency and neighbourhood density were considered herein, but a host of variables are known to affect lexical processing. These include, for example, familiarity, neighbourhood frequency, phoneme frequency, phonotactic probability and age of word acquisition (Walley and Metsala, 1990; 1992; Luce and Pisoni, 1998; Stoel-Gammon, 1998; Vitevitch and Luce, 1998; 1999; Storkel and Rogers, 2000; Garlock *et al.*, 2001; Storkel, 2001). Perhaps additional factors will emerge as influential to diffusion from examinations of complementary psycholinguistic variables. In sum, the continued study of lexical diffusion offers a promising, open-ended line of investigation that holds the potential to inform our understanding of phonological acquisition and interface of sounds and words in language.

Acknowledgements

This research was supported in part by grants from the National Institutes of Health DC01694, DC00012, DC04781 to Indiana University, Bloomington. We would like to especially thank Michele Morrisette, Annette Champion and Laura McGarrity for assisting with subject identification and preliminary analyses, and Rachel Dale for assisting with manuscript preparation.

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