USAGE-BASED MODELS OF LANGUAGE

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CSLI Publications
Center for the Study of Language and Information
Stanford, California

The Phonology of the Lexicon: Evidence from Lexical Diffusion

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In many areas of linguistics, examining the nature of diachronic changes leads to a more accurate modeling of synchronic systems.[1] Lexical diffusion—the way a sound change spreads through the lexicon—has, as yet, not been exploited as a potential source of evidence about the phonological shape of lexical representations. The present study contains evidence that sound change is both phonetically gradual and lexically gradual, and that the rate at which words undergo sound change is positively correlated with their text frequency. This correlation is found in monomorphemic words, regularly inflected words and irregularly inflected words. I argue that frequency effects in sound change may be explained by assuming that cognitive representations are impacted by every token of use.

The sound change about which new evidence will be provided here—*t / d*-deletion in English—has been vigorously studied by sociolinguists seeking to understand the factors controlling the variation found in this process. One of their findings is that the morphological status of the final /t/ or /d/ affects the rate of deletion. Special properties of phonological segments serving as morphemes have also been studied experimentally by psycholinguists. This paper proposes to bring together evidence from variation, experimental findings and data on text frequency to refine a usage-based model of lexical representation and morphological organization.

The first part of this paper examines lexical diffusion in general and the claim that frequency affects the diffusion of sound change. The evidence that *t/d*-deletion is more advanced in high frequency words is presented, and a view of phonetic variation compatible with the data is examined.

The second part of the paper addresses the morphological effects on the variation in *t/d*-deletion. The morphological model of Bybee (1985, 1988) makes certain predictions about the effect of *t/d*-deletion on regular verbs, and these are tested on the data. It is found that the frequency effect demonstrated for the corpus overall is also found among regularly inflected verbs, suggesting that at least high frequency regulars are listed lexically. A frequency effect is also found in the double-marked pasts, such as *told* and *slept*. It is argued that the apparent special properties of this class are due to the high frequency of many of its members.

1. Frequency Effects in the Lexical Diffusion of Sound Change

1.1 Lexical Diffusion

The study of lexical diffusion has primarily been directed at accounting for irregular results of sound changes, in particular, lexical items that appear not to have undergone a change (Wang 1969, Krishnamurti 1978). Changes that have occurred over very long periods of time have also been the subject of lexical diffusion studies (Krishnamurti 1978). Such changes can be said to be taking place at the phonemic level and have led Wang and Cheng (1977) to postulate that most sound change is lexically gradual and phonetically abrupt.

A lexically abrupt sound change would affect all lexical items at the same time, while one that is lexically gradual moves through the lexicon affecting individual items or groups of items in sequence. A phonetically gradual sound change takes place in very small increments, moving gradually through phonetic space, while a phonetically abrupt change takes place in a single large, discrete step. If the phonological units of the lexicon are phonemes or generative underlying representations, a sound change that affects words differentially must be phonetically abrupt, since small phonetic increments do not exist in the structuralist or generativist lexicon. Thus the changes reported on in Wang (1977) are changes affecting phonemes, such as Chinese tones, final nasals, and English stress as used in diatone pairs (*récord, recórd*).

Similarly, Labov (1981, 1994) proposes that some sound changes exhibit lexical diffusion while others are 'Neogrammarian' changes, that is, they are regular in the sense that they affect all lexical items with appropriate phonetic conditioning at the same time. The changes that exhibit lexical diffusion, according to Labov (1994: 542–43), are phonetically discrete, bringing about phonemic changes in particular words. Labov further proposes a typology of Neogrammarian vs. lexical diffusion changes: The latter, Labov proposes, are found in shortening and lengthening of segments, diphthongization of mid and low vowels, changes of place of articulation of consonants, metathesis of liquids and stops, and deletion of obstruents. Regular sound changes occur in subsystems of vowels, including vowel shifts and the diphthongization of high vowels; also regular are changes in the manner of articulation of consonants, vocalization of liquids and deletion of glides and schwa. Such changes are most often phonetically gradual and lexically regular.

Phillips (1984) does not accept Labov's claims, arguing that his dichotomy is too simplistic, as many changes affecting subsystems of vowels and the manner of articulation of consonants show evidence of lexical diffusion. Phillips implies that lexical diffusion is much more widespread than previously thought, and, based on Hooper (1976), provides a distinction between two types of lexical diffusion. In one the direction of diffusion is from the most frequent to the least frequent words, while in the other, the opposite direction of change is found. High frequency words are affected earlier by vowel and consonant reduction or assimilation processes (Fidelholz 1975, Hooper 1976, Leslau 1969). Phillips characterizes this type of change as "motivated by physiological factors, acting on surface phonetic forms" (320). Changes that affect the least frequent words first are more likely motivated by conceptual factors. These include grammatical conditioning, as in analogical leveling and diatone formation, as well as changes affecting the sequential constraints of the language.[2]

This paper concerns only the first type of change—phonetically-motivated change. Change of this type usually appears to be lexically regular once the change is complete, but evidence presented here shows that such changes affect lexical items at different rates while the change is in progress. Using *t/d*-deletion as the example, it will be argued that sound change can be both lexically gradual and phonetically gradual. The consequences of this finding for lexical representation is that lexical entries for words undergoing gradual change must include detail about the range of phonetic variation associated with each word.

1.2 Word Frequency in Lexical Diffusion

There exists a considerable body of evidence showing that phonetically-conditioned sound change proceeds through the lexicon, gradually working from high frequency words to low frequency words. The effects of frequency have been shown for vowel reduction and deletion in English (Fidelholz 1975, Hooper 1976), and for the raising of / a / to / o / before nasals in Old English (Phillips 1980), for various changes in Ethiopian languages (Leslau 1969), for the weakening of stops in American English and vowel change in the Cologne dialect of German (Johnson 1983), for ongoing vowel changes in San Francisco English (Moonwomon 1992), and for tensing of short *a* in Philadelphia (Labov 1994: 506–07).

Some of these changes are both lexically gradual and phonetically gradual. For instance, the schwa deletion process discussed in Hooper (1976) gradually reduces a schwa following the stressed vowel and preceding a sonorant, preferably / r / or / l /. This reduction is more advanced in higher frequency words. Thus high frequency *memory, salary, summary* and *nursery* have a more reduced penultimate syllable than low frequency *mammary, artillery, summery* and *cursory*. Of course all of these words have multiple variants in actual use, but their ranges of variation differ systematically.

No Schwa	Syllabic [r]	Schwa + [r]
every (492)	memory (91)	mammary (0)
	salary (51)	artillery (11)
	summary (21)	summery (0)
	nursery (14)	cursory (4)
evening (149) (noun)		evening (0) (verb + *ing*)

Table 1. Words Undergoing Reduction at Differential Rates due to Word Frequency (frequency figures from Francis and Kucera 1982)

Changes that are both lexically and phonetically gradual create a problem for traditional theories of phonemic or lexical representation: individual words with distinct ranges of variation cannot be represented by a simple set of contrastive phonological units. In the schwa-deletion example, the number of distinct lexical sets is unknown, but there must be at least three: (i) those with the schwa totally deleted, *every, evening* (noun); (ii) those in which the / r / or / l / can be syllabic or non-syllabic, *memory, salary, summary, nursery*; and (iii) those in which the schwa or syllabic resonant is always present, *mammary, artillery, cursory, evening* (verb + *ing*). These three lexical categories range over only two phonemes, since / r / and syllabic / r / are not distinguished phonemically, nor are syllabic / r / and / ´r /. This example shows that lexical items can have subphonemic detail associated with them. The fact that all three classes of words have variable pronunciations suggests that an appropriate model of the lexicon must allow for the representation of ranges of phonetic variation, and these ranges do not necessarily coincide with traditional or generative phonemes. The problem is even more severe if, as is extremely likely, there are not just three classes, but rather there is a continuum of degree of reduction, with each word exhibiting its own range of variation.[3] Moreover, the deletion of schwa and the reduction of the syllabicity of [r] are not separate processes; rather the reduction in all of these words is one continuous process.

1.3 Word Frequency and *t / d*-Deletion

The variable deletion of final / t / and / d / in English has been well-studied in the last two decades (Labov 1972, Guy 1980, Neu 1980). The factors influencing the deletion of final / t / or / d / are phonetic, grammatical and social:

- Phonetic: final / t / and / d / are deleted more often if a consonant follows in the next word than if a vowel follows.
- Grammatical: final / t / and / d / are deleted less often if they function as the regular past tense marker; they are deleted more often if they constitute the past tense suffix in words that also have a vowel change (*told, kept*).
- Social: final / t / and / d / are deleted more often by younger people, males and members of lower social classes (Labov 1972, Neu 1980).

The data analysed for this study was generously supplied by Otto Santa Ana from his study of phonological variation in Chicano English speakers of Los Angeles (Santa Ana 1991). The speakers used in this study were all native speakers of English. The values for final / t / and / d / were transcribed by Santa Ana from recordings made in interviews. For the present study, 2000 tokens of final / t / and / d / from forty-one speakers were used. The speakers ranged in age from 13 to 62 years; approximately half were male and half female.

No evidence of lexical diffusion or a general frequency effect has been reported for *t / d*-deletion, despite the fact that it is a well-studied example of phonological variation. However, in studies of *t / d*-deletion the words *and, just* and *went* are often excluded because of their high rates of deletion. These words are clear examples of lexical diffusion conditioned by high token frequency, leading us to suspect a more general effect of word frequency on the diffusion of this change.

In order to test for the effects of word frequency on deletion, for each word that potentially ends in a / t / or / d / following a consonant, we recorded the text frequency as listed in Francis and Kucera (1982). *Just, went* and *and* were excluded because of their very high frequency and high rate of deletion. All other words were divided into two groups: a high frequency and a low frequency group. The cut-off point of 35 per million was chosen, because a number in this range is used in the psycholinguistic literature when frequency effects are measured. Particularly relevant to our analysis of past tense forms is the fact that Stemberger and MacWhinney (1988) report that a frequency of 35 per million divides English inflected forms in half: half the tokens of inflected forms in Francis and Kucera (1982) have a frequency greater than 35 and half have a frequency of less than 35.

Dividing the current corpus in this way, 20% of the tokens fall in the low frequency group and 80% in the high frequency group. Table 2 shows the deletion figures for the entire corpus by frequency grouping.[4]

	Deletion	**Non-Deletion**	**% Deletion**
High Frequency	898	752	54.4%
Low Frequency	137	262	34.3%

Chi-squared: 41.67, $p < .001$, df = 1

Table 2. Rate of *t / d*-deletion for Entire Corpus by Word Frequency

As the table shows, word frequency is a significant factor in the variation in *t / d*-deletion. It will be shown below that frequency has a general effect even when verbs are separated from nouns and adjectives. Before discussing the data on verbs and their inflections, however, let us examine the implications

of phonetically and lexically gradual sound change for phonological representation.

1.4 Discussion: Phonetic Variation in Lexical Representation

Genuine lexically-determined variation cannot be represented in a variable rule, it must be represented lexically, especially if it affects all or most of the words of a particular phonological shape. Trying to build such variation into a variable rule would require repeating the contents of the lexicon in the rule.

If memory for words resembles memory for other types of sensory input, then we would not expect that words are stored with details removed, but rather that even redundant features of words contribute to the formation of a prototype structure for the phonological representation. The fact that speakers consistently produce *every, memory* and *mammary* with three distinct ranges of variation, means that more distinctions than those that are strictly considered phonemic exist in the lexicon.

One way of accounting for the continuous nature of such sound changes and the frequency effect they show in lexical diffusion is to assume that sound changes affect words opportunistically each time they are used. The sound change 'rules' apply in real time, so that a frequent word has more exposure to the sound change than an infrequent one. If the effects of the sound change are cycled back into the lexicon, as the speaker monitors his/her own speech and the speech of others, the lexical representations for the words gradually adjust to the new productions (Moonwomon 1992). One reason that frequent words are affected at a higher rate than infrequent ones is because they have more exposure to the pronunciation pattern. However, there are two other factors that enhance change in high frequency words when that change is reductive:[5] First, low frequency words occur less often in casual speech and thus have even less exposure to the reductive processes. Second, words repeated in the same discourse are shorter than in their first mention (Fowler and Housum 1987). Thus, given the model of sound change outlined here, words that are repeated often within a discourse, which would also be words that have a high overall frequency, undergo sound changes at a faster rate.

In the case of *t / d*-deletion, I am not suggesting that each word has an index of deletion probability related to its frequency. Rather, I propose that deletion takes place very gradually as the shortening of the coronal gesture and this shortening is represented lexically. (For measurements of this shortening, see Losiewicz 1992, discussed below). I also propose, following

Moonwomon, that phonological processes, such as the weakening of final /t/ and /d/, apply in real time and have an effect on the words to which they apply. Thus when a word with a final coronal stop is used, that articulatory gesture is usually compressed and shortened. The output of that process is registered in memory through self-monitoring and decoding the speech of others. Thus small changes may be periodically made in the prototype representation for each word. The more a word is used, especially in contexts that are appropriate for reduction, the more reduced the word becomes. In this way, the effect of word frequency on the propagation of a change through the lexicon is explained.

Proposing that variable rules affect the lexicon is not as radical an idea as it may sound. Harris (1989) discusses the increasing 'lexical depth' of variable rules, which he regards as a natural consequence of the development of a rule. In his view, as rules develop they progress both phonetically and lexically. His examples involve phonemic change. Guy (1991a, 1991b) proposes that *t/d*-deletion, usually considered postlexical, applies at the deep levels of Lexical Phonology, again an indication that the variable process has penetrated the lexicon. (Below I will give evidence for representing *t/d* weakening in the lexical entries rather than in the lexical rules.)

The proposal that words have their own ranges of phonetic variation rather than being composed of units that belong to a (systematic) phonemic set, specifiable for each language, would seem to allow an infinite range of phonetic representations for the words of a language. Why is it that the phonetic properties of words are strictly controlled by language-specific constraints rather being infinitely variable? The reason is that what goes into the lexicon is regulated by the phonetic processes or pronunciation patterns whose function it is to automate the production of phonetic strings. The efficiency of such patterns depends upon their producing a regular and highly constrained inventory of phonetic strings. Eventually these phonological processes carry sound changes through to completion and regularize lexical representations.

Phonemes, then, do not exist in the representations of words; they are not units of lexical representation. Instead, phonemes are abstract patterns that emerge in the phonological organization of the lexicon (see Langacker this volume). To the extent that distinct phonetic units are grouped together into more abstract units, this is done on the basis of the phonetic implementation schemata, and is not a strict matter of complementary distribution, as can be seen from the examples presented so far.

1.5 Phonetic Gestures

The phonetic representations and mode of phonetic implementation that best accommodate the workings of sound change that I am trying to characterize here is gestural phonology. I am considering phonological representations to be sets of commands to the articulators and phonetic output to be a series of partially overlapping articulatory gestures (Browman and Goldstein 1990, Pagliuca and Mowrey 1987). This conception provides an explanation for the phonetic conditions that favor *t/d*-deletion, i.e. the presence of a following consonant.

Browman and Goldstein (1990) traced the articulatory gestures in the phrase *perfect memory* to see what happens to the coronal gesture in the /t/.[6] They found that the lingual gesture was present, but the preceding velar and following labial gesture overlapped the coronal one, obscuring it entirely. It would thus be perceived as deleted, even though articulatorily it is still present. This does not mean that deletion is a myth; it does mean that there is no variable rule of *t/d*-deletion. Rather there is a gradual process of shortening or reducing the lingual gesture (for which we will see evidence just below). As the gesture shortens, the likelihood that it will be overlapped and thus acoustically obscured by surrounding gestures increases. Thus in words of higher frequency, where the coronal stop is shorter, perceived deletion is more likely.

Perceived deletion leads to actual deletion, that is, loss of the coronal gesture. This loss is ongoing, but at a much slower rate than the perceived deletion. Perceived deletion leads to the restructuring of underlying forms and proceeds item by item. Actual deletion occurs because preconsonantal and prepausal environments are three times as common as prevocalic ones. If lexical representations are prototype representations of all input variations, the final coronal stop in a lexical entry will shorten and gradually move towards deletion.

This particular sound change has articulatory, perceptual and lexical dimensions. Articulatorily a gestural reduction is taking place. At the same time, the perception of the reduced consonant is masked by surrounding consonants. Lexical entries containing a final coronal stop are gradually accommodating to the changing input, and will gradually restructure, losing the stop entirely. Thus there are three sources of the surface variation: the articulatory change is gradually reducing the gesture involved; the phonetic environment conditions whether or not the gesture can be perceived, and the lexical items themselves have different degrees of reduction.

2. Morphological Effects on Sound Change and Lexical Diffusion

2.1 Past Tense of Verbs and *t/d*-Deletion

Studies of *t/d*-deletion consistently find that the final coronal stop is less likely to delete if it is the Past tense morpheme than if it is part of a monomorphemic word (Labov 1972, Guy 1980). Moreover, a consistent difference is found between the regular Past, as in *walked* and *learned*, and the Past suffix on verbs that also have a stem change, such as *kept* and *told*. This difference is consistent with an account that attributes the lower rate of deletion of Past tense *t/d* to the need to retain the information encoded in this morpheme. In the verbs with vowel change, that information is not lost. In the discussion that follows, we will see that this 'information preservation' assumption explains only part of the data.

In the data examined for the current study, it was also found that regular Past tense and Past participle forms (which were grouped together) had a lower rate of deletion than nouns and adjectives in the same frequency range. Regular *-ed* verbs in our corpus had Francis and Kucera frequencies ranging from 0 to 403 per million. The rate of deletion for all words with frequencies of 403 or less is 45.8%; the rate of deletion on *-ed* verbs is 22.6%, as shown in Table 3.

	% Deletion
All words	45.8%
-ed verbs	22.6%

Table 3. Rate of Deletion for Regular Past Tense Compared to All Other Words of Comparable Frequency (403 or less)

Guy (1991a, 1991b) offers an interpretation of *t/d*-deletion in the context of Lexical Phonology (Kiparsky 1982). Guy proposes that the variable rule of *t/d*-deletion applies at all levels of a Lexical Phonology: it applies at the base level to non-derived forms, it applies after Level 1 affixation, and again after Level 2 affixation, assuming only two levels for the purposes of his analysis. Thus monomorphemic words have three chances to undergo *t/d*-deletion; irregular Past forms, such as *kept* and *told*, have two chances—one at Level 1 after affixation occurs and again after Level 2 affixation. Regular Past tense forms are only exposed to the rule once, after Level 2 affixation. Guy proposes that the rule applies at a constant rate and that the different rates of deletion in the three categories of words is an exponent of the number of exposures the word has had to the rule.

Guy's analysis demonstrates a very interesting point: certain words are behaving as though *t/d*-deletion has applied to them more than once. In his analysis, this variable rule has penetrated the lexicon and is treating words differentially according to their morphological structure; words that have higher rates of deletion can be thought of as undergoing the rule repeatedly. Note, however, that Guy's hypothesis refers only to morphological structure and cannot explain the overall effect of word frequency on deletion rates.

The proposal being made here, that *t/d*-reduction applies in real time and has a permanent effect on the phonological shape of words in the lexicon, achieves approximately the same result. If a word already had a weakened [t] or [d] and then underwent further reduction when that word was used again, the chances that it would be perceived as deleted (preceding a consonant) would be increased. Furthermore, Guy (1991b) shows that the effect of the environment preceding the [t] or [d], which is internal to the word and thus always present, increases the rate of application of deletion in words subject to multiple applications, while the following environment does not increase the rate of application in words subject to multiple applications, because the following conditioning environment is only present in the last application of the rule, the postlexical application. The same result is predicted for the model in which rule application has a permanent effect on the lexicon, but for different reasons. The preceding environment has a stronger effect on the lexical representation because it is present each time the word is used. The following environment—a following consonant—is an 'alternating environment' and affects the lexical representation more slowly since it is not always present when the word is used (see Timberlake 1978 and Bybee 1998 for other examples of variable processes that apply less often or to a lesser extent in alternating environments).

In many ways, then, the two models make similar predictions. The difference is that the Lexical Phonology interpretation attributes differential rates of rule application to structural differences among words, while the usage-based interpretation attributes much of the differential reduction to word frequency. In the following I will show that word frequency is a significant factor in *t/d*-reduction, even inside of morphological classes. These facts support the usage-based account over the Lexical Phonology account, since the latter has no way of describing differential application based on word frequency. The following discussion will be situated in the model proposed in Bybee (1985, 1988), which makes certain predictions for the application of *t/d*-reduction to morphologically complex words.

2.2 Morphology as Lexical Organization

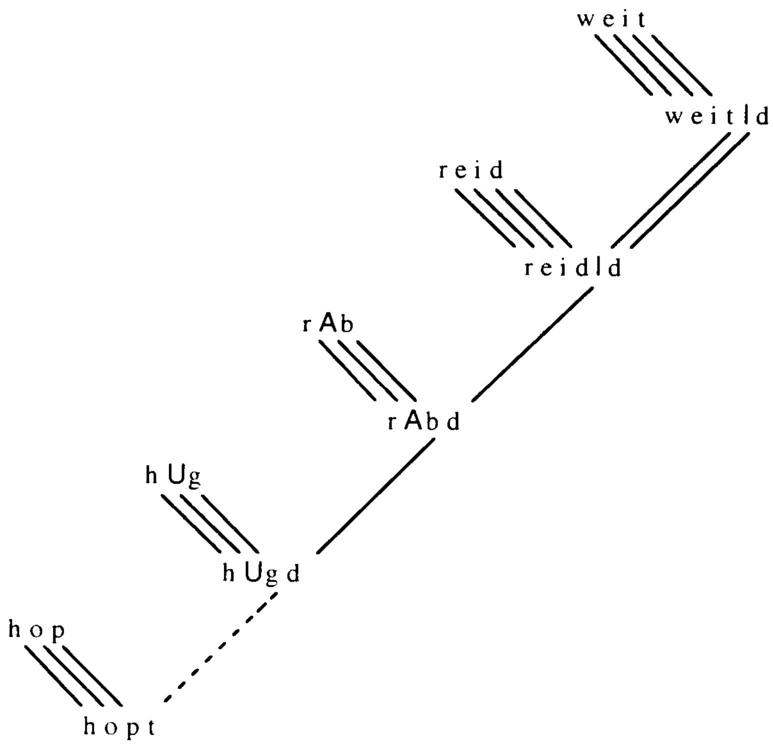

Figure 1. Emergent Morphological Structure and the Regular Past Tense Schema

In Bybee (1985, 1988) it is proposed that the lexicon consists primarily of words, and even words that are morphologically complex may have lexical storage. It is also argued that token frequency has an effect on the way words are stored and processed, as words have varying lexical strength according to their frequency of use. Even at resting levels, high frequency words have stronger representations in memory, making them, among other things, easier to access. Morphologically complex words of high frequency are more likely to maintain their irregularities because they have a stronger representation in memory, and lower frequency words are more likely to be replaced by those formed on a regular pattern. Irregular forms are stored in the lexicon and to the extent that they form classes with other forms, patterns of similarities based on prototype structure create lexical schemas (Bybee and Moder 1983, Prasada and Pinker 1993).

Figure 1 illustrates the relevant portion of the proposed lexical network. Similarities among words are shown as lexical connections, which can be phonological or semantic. Parallel phonological and semantic connections, such as those shown in Figure 1, constitute morphological relations if they are repeated across items. A dotted line indicates similarity but not identity.

It follows from the premise that frequency of use determines representation in the lexicon, that even regular morphological formations of sufficient frequency are represented lexically. The internal structure of morphologically complex words derives from the connections made with other words. Thus the Past tense morpheme emerges from the patterns of lexical connections as a schema. Because of its high type frequency, this schema is very powerful, leading to its high productivity (Bybee 1995).

$$\ldots \text{(i) alveolar stop]}_{\text{past tense}}$$

Very low frequency verbs may not have their Past tense forms represented in memory, or they may not be represented with sufficient strength for easy retrieval. In that case, the base verb is supplied with a Past tense inflection by the general schema. This means that there are two ways of processing regular Past tense verbs—selecting them whole from the lexicon and deriving them by applying the schema to a base.

Losiewicz (1992) tested the hypothesis that high and low frequency regular verbs are processed in these two ways. She started from the finding that consonants that are parts of monomorphemic words are produced with shorter acoustic duration than those that constitute morphemes, that is, the / s / in *lapse* is shorter than the one in *laps* (Walsh and Parker 1983). She found that the same situation holds with respect to Past tense [t] and [d], that is, in word pairs such as *swayed* and *suede* the *-ed* suffix is on average 5 msec. longer than the nonmorphemic [t] or [d]. The interpretation of this durational effect given by Walsh and Parker and by Losiewicz is that segments that are represented in the underlying form as part of the word tend to be shorter than those added in morphological processing. Losiewicz reasoned that if lexically represented consonants are shorter than added ones, and if high frequency Past tense verbs are stored as units but low frequency verbs are constructed by applying a schema to the base, then the Past tense [t] or

[d] on high frequency verbs should be shorter in acoustic duration than the same consonants on low frequency verbs.

Losiewicz constructed eight pairs of rhyming, regular Past tense verbs in which one member of the pair had a frequency of 100 per million or greater and the other had a frequency of 10 or fewer per million. Some examples are *called, mauled*; *covered, hovered*; *needed, kneaded*; *expected, inspected*. The stimuli verb pairs were presented in sentences which differed only in the verb. (For example, *The workers expected/inspected all the mail at noon every day.*) Each subject read only one of each pair of stimuli sentences. Subjects read the sentences into a recorder and the length of the consonants in question was measured from the waveform. The results show that on average the *-ed* suffix on low frequency verbs is 7 msec. longer than on high frequency verbs. Losiewicz concludes that high frequency multimorphemic verbs are represented as unitary wholes in the lexicon, while low frequency multi-morphemic verbs are processed as stem + affix.

A difference in the length of the final [t] or [d] suffix varying with the frequency of the verb is predicted from the interpretation of the lexical diffusion process for *t/d*-reduction given above. Among verbs of sufficient frequency to have their Past tense represented lexically, we would expect that higher frequency verbs will have undergone more reduction than lower frequency verbs. Thus a frequency difference even within lexically listed verbs is predicted, in addition to the length difference found by Losiewicz. The results of the test of this hypothesis are given in the next section.

2.3 *t/d*-Reduction in Regular Past Tense

For the test of the effect of frequency on *t/d*-deletion among regular *-ed* verbs, we control the phonological environment, taking only those that favor deletion—non-prevocalic conditions. Dividing the regular verbs into two groups—those with frequencies of their *-ed* forms of 35 or fewer per million and those with frequencies over 35 per million, we find a significant effect of frequency, as shown in Table 4.

	Deletion	Non-Deletion	% Deletion
High Frequency	44	67	39.6%
Low Frequency	11	47	18.9%

Chi-squared: 5.00313, $p < .05$, df = 1

Table 4. The Effects of Word Frequency on *t/d*-deletion in Regular Past Tense Verbs (non-prevocalic only)

The results in Table 4 present strong confirmation of the hypothesis that regular verbs of higher frequency have lexical listing. If the *-ed* suffix were always added to the verb by morphological rules, there would be no reason for the length of the suffix to be affected by the token frequency of the whole unit, i.e. the Past tense verb form. The fact that the frequency of the whole unit affects the deletion rate of the suffix [t] or [d] can best be accounted for by listing the units in the lexicon and allowing gradual phonetic change to affect the lexical entries.

These data also argue against the dual processing model proposed by Pinker (1991), in which irregular forms have lexical listing, but regular ones are produced by a rule that is independent of the lexicon. In Pinker's model all regular verbs are formed in precisely the same way, and there is no way for the token frequency of the whole unit to affect the phonetic shape of the suffix.

2.4 Double-Marked Past Tense Verbs

Studies of the effects of morphology on *t/d*-deletion consistently show that double-marked Past tense forms such as *kept, found, told*, etc. have a higher rate of deletion than regular Past tense. In our data, the rate of deletion for these verbs is 42.8%. This high rate of deletion is consistent with the fact that most of these verbs have relatively high token frequency. All but two of them which occur in our corpus have frequencies over 35 per million in Francis and Kucera.

In Guy's treatment of *t/d*-deletion in Lexical Phonology, the Past tense of these verbs is formed at Level 1. After they are formed, *t/d*-deletion is available to apply to them (variably) at Level 1 and then again (variably) at Level 2. Because the variable rule has two chances to apply to these verbs, they have a higher rate of deletion than the Past tense forms derived at Level 2, which only have one chance to undergo the rule. Thus Guy's treatment claims that the different rate of deletion is due to a structural difference in the derivation of irregular and regular Past tense.

However, it is entirely possible that the different rate of deletion is due to the high frequency of these verbs and not to a structural difference between them and other verbs. If a structural difference governs the rate of deletion of these verbs, then we would expect the rate to be similar across the different lexical verbs. However, if it is frequency that conditions the rate of deletion, we would expect to find differences even among the double-marked verbs conditioned by frequency. The latter is what the data show: the higher frequency verbs of this class undergo deletion at a higher rate than the low frequency verbs, as shown in Table 5.

Total Tokens	Verb	# of Deletions	% Deletions
32	told	22	68%
9	felt	5	55%
8	left	2	25%
6	kept	4	66%
4	sent	1	25%
4	built	0	0
3	held	0	0
3	heard	0	0
2	slept	1	50%
2	lent	0	0
1	found	0	0
1	lost	0	0
1	meant	0	0

Spearman rank order correlation: p = .696
Significant at the .01 level (two-tailed or one-tailed)

Table 5. Double-marked Pasts Ordered by Frequency in our Data, with Ties Ordered by Francis and Kucera Frequency

Table 5 shows a strong effect of word frequency among the words of this class, with high frequency verbs generally showing deletion at a higher rate than low frequency verbs. The data also suggest conditioning by phonological factors: a labial stop preceding the / t / favors deletion since the labial gesture can overlap and obscure the perception of the / t /. This explains why *kept* and *slept* have a higher rate of deletion than some of the other more frequent verbs.

The frequency effect among the words of this class cannot be accounted for in the structural account that proposes that these words are derived at Level 1 and have a higher rate of deletion because the rule has two chances to apply to them. If this account were correct, the rate of deletion for each verb would be approximately the same. I conclude, therefore, that the primary factor that accounts for the higher deletion in this class is word frequency.

2.5 Modeling

We have seen that the facts of *t / d*-deletion are consistent with the hypothesis made by the usage-based model that high frequency words are represented in the lexicon even if they are morphologically complex. The facts also support the hypothesis that sound change occurs in real time, with its effects being registered in the lexicon as small incremental changes, such that words that are used more often will undergo change at a faster rate.

With these two points now established it is possible to turn to a consideration of the question of why the Past tense suffix / t / and / d / reduce more slowly than non-suffixal / t / and / d /. The factor traditionally invoked to explain the conservatism of morphemic / t / and / d / is that the information value of the Past tense / t / and / d / is greater than that of nonmorphemic / t / and / d /. Past tense marking is often redundant; however, in cases where it is carrying some information crucial to the discourse, speakers are quite capable of slowing down their speech and adjusting junctures in such a way as to make the / t / or / d / perceptually salient. Suppression of the reduction and coarticulatory overlap will also serve to retard reduction of the phonetic substance of the lexical schema for Past tense / t / and / d /.

The data also reveal another factor that may help explain why the Past tense /t/ and /d/ reduce more slowly than nonmorphemic / t / and / d /. For some reason, regular Past tense /t/ and /d/ occur more often before a vowel than final / t / and / d / in nonverbs. For all words in the corpus ending in / t / or / d /, 22.7% occur before a vowel; of verbs ending in Past tense / t / or / d /, 40.1% occur before a vowel. Since prevocalic position is the most favorable position for / t / and / d / perceptually, their more frequent occurrence in this position would retard the reduction that is conditioned perceptually.

2.6 Theoretical Implications

Two important points for usage-based models are established by the data presented here. It has been argued that sound change, or phonetic change, affects the lexicon gradually by spreading out across lexical items from the most frequent to the least frequent, and by producing small gradual changes in the phonetic representation of lexical items. One important consequence of this view is that sound change permanently affects the lexicon, and that lexical items are not represented in an abstract phonemic notation. A second consequence is the more general point that the phonetic properties of lexical items, like their morphosyntactic and semantic properties, are affected by language use.

"Phonemes" do not exist as units; the phenomena that phonemes are intended to describe are relations of similarity among parts of the phonetic string. These relations of similarity can be captured by lexical connections and schemas just as other relations of similarity are. Complementary distribution, rather than a criterion for deciding on lexical status of a phone, is just a consequence of the fact that articulatory adjustments are conditioned by the surrounding environment. Registering such phonetic variation in the lexicon even if it is predictable provides a means for accounting for the establishment of new phonemes from distinctions that were formerly predictable, such as the [x] – [ç] distinction in German (Bybee 1994).

For most of this century, linguists have assumed the existence of units representing the phonemic status of certain segments. They have also assumed that both predictable and unpredictable phonetic variation is caused by rules acting on static underlying representations. Unaccounted for variation in phonetic strings has either been ignored (as low-level phonetic phenomena) or relegated to unexplained "inherent variation." But just as the study of details of actual language use is yielding surprising and important results in the study of morphosyntax and lexicon, the study of the phonetic details of actual language use will yield a new view of phonological phenomena.

Notes

1. The data used in this paper was generously supplied by Otto Santa Ana. I am also grateful to Valerie Daniel for inputting data, to Greg Thomson who coded and analyzed the data, and ran statistical tests on it, and to Jean Newman who provided input at various points. Thanks are also due to Janet Pierrehumbert who provided many valuable comments and suggestions on a previous version of the paper.

2. Phillips (1981) discusses the case of the diffusion of the loss of the [j] glide in words such as *tune* and *Duke* in the English of Georgia. Phillips attributes this change, which affects the least frequent words first, to a change in sequence structure conditions. I suspect, however, that it is a dialect borrowing or accommodation to the standard dialect. Words learned at the mother's knee, so to speak, would be the most conservative, while the least frequent words would be affected first.

3. Other types of representation run into the same problems. If the three classes of words were represented with different moraic structure, separate variable rules could delete the schwa and delete the mora associated with the syllabic consonants. However, since morae are discrete units, there is a limit on the number of distinct classes that could be represented.

4. The table presents percentages for convenience. The chi-squared value was not computed on the percentages.

5. Probably all phonetic change is due to reductive mechanisms—reduction of gestures and the compression of gestures causing overlap (assimilation) (Pagliuca and Mowrey 1987); however, the surface results in terms of segments may not always seem reductive.

6. When read from a list by the same speaker, *perfect* had a released final $[t^h]$.

References

Browman, Catherine P. and Louis M. Goldstein. 1990. Tiers in articulatory phonology, with some implications for casual speech. In John Kingston and Mary E. Beckman (eds.), *Papers in Laboratory Phonology I: Between the Grammar and Physics of Speech*, 341-76. Cambridge: Cambridge University Press.

Bybee, Joan L. 1985. *Morphology: A Study of the Relation between Meaning and Form* (Typological Studies in Language 9). Amsterdam: Benjamins.

Bybee, Joan L. 1988. Morphology as lexical organization. In Michael Hammond and Michael Noonan (eds.), *Theoretical Morphology: Approaches in Modern Linguistics*, 119-41. San Diego: Academic Press.

Bybee, Joan L. 1994. A view of phonology from a cognitive and functional perspective. *Cognitive Linguistics* 5(4), 285-305.

Bybee, Joan L. 1995. Regular morphology and the lexicon. *Language and Cognitive Processes* 10(5), 425-55.

Bybee, Joan L. 1998. Lexicalization of sound change and alternating environments. In Michael Broe and Janet Pierrehumbert (eds.), *Laboratory Phonology*, Vol. 5. Cambridge: Cambridge University Press.

Bybee, Joan L. and Carol L. Moder. 1983. Morphological classes as natural categories. *Language* 59, 251-70.

Fidelholz, James. 1975. Word frequency and vowel reduction in English. *Papers from the 11th Annual Regional Meeting of the Chicago Linguistic Society*, 200-13. Chicago: CLS.

Fowler, Carol A. and Jonathan Housum. 1987. Talkers' signalling of "new" and "old" words in speech and listeners' perception and use of the distinction. *Journal of Memory and Language* 26, 489-504.

Francis, W. Nelson and Henry Kucera. 1982. *Frequency Analysis of English Usage*. Boston: Houghton Mifflin.

Guy, Gregory. 1980. Variation in the group and the individual: The case of final stop deletion. In William Labov (ed.), *Locating Language in Time and Space*, 1-36. New York: Academic Press.

Guy, Gregory. 1991a. Explanation in variable phonology: An exponential model of morphological constraints. *Language Variation and Change* 3, 1-22.

Guy, Gregory. 1991b. Contextual conditioning in variable lexical phonology. *Language Variation and Change* 3, 223-39.

Harris, John. 1989. Towards a lexical analysis of sound change in progress. *Journal of Linguistics* 25, 35-56.

Hooper, Joan B. 1976. Word frequency in lexical diffusion and the source of morphophonological change. In William Christie (ed.), *Current Progress in Historical Linguistics*, 96-105. Amsterdam: North Holland.

Hooper, Joan B. 1978. Constraints on schwa deletion in American English. In Jacek Fisiak (ed.), *Recent Developments in Historical Phonology*, 183-207. The Hague: Mouton.

Johnson, Theodore. 1983. *Phonological Free Variation, Word Frequency and Lexical Diffusion*. Seattle: University of Washington doctoral dissertation.

Kiparsky, Paul. 1982. Lexical phonology and morphology. In In-Seok Yang (ed.), *Linguistics in the Morning Calm*, 3-91. Seoul: Hanshin.

Krishnamurti, Bhadriraju. 1978. Areal and lexical diffusion of sound change: Evidence from Dravidian. *Language* 54, 1-20.

Labov, William. 1972. *Sociolinguistic Patterns*. Philadelphia: University of Pennsylvania Press.

Labov, William. 1981. Resolving the Neogrammarian controversy. *Language* 57, 267-308.

Labov, William. 1994. *Principles of Linguistic Change: Internal Factors*. Oxford: Basil Blackwell.

Leslau, Wolf. 1969. Frequency as a determinant of linguistic change in the Ethiopian languages. *Word* 25, 180-89.

Losiewicz, Beth L. 1992. *The Effect of Frequency on Linguistic Morphology*. Austin: University of Texas doctoral dissertation.

Moonwomon, Birch. 1992. The mechanism of lexical diffusion. Paper presented at the Annual Meeting of the Linguistic Society of America. Philadelphia, January, 1992.

Neu, Helene. 1980. Ranking of constraints on /t,d/ deletion in American English: A statistical analysis. In William Labov (ed.), *Locating Language in Time and Space*, 37-54. New York: Academic Press.

Pagliuca, William and Richard Mowrey. 1987. Articulatory evolution. In Anna Giacolone Ramat, Onofrio Carruba, and Giuliano Bernini (eds.), *Papers from the VIIth International Conference on Historical Linguistics*, 459-472. Amsterdam: Benjamins.

Phillips, Betty S. 1980. Old English *an ~ on*: A new appraisal. *Journal of English Linguistics* 14, 20-23.

Phillips, Betty S. 1981. Lexical diffusion and Southern *tune, duke, news*. *American Speech* 56, 72-78.

Phillips, Betty S. 1984. Word frequency and the actuation of sound change. *Language* 60, 320-42.

Pinker, Steven. 1991. Rules of language. *Science* 253, 530-35.

Prasada, Sandeep and Steven Pinker. 1993. Generalisation of regular and irregular morphological patterns. *Language and Cognitive Processes* 8, 1-51.

Santa Ana, Otto. 1991. *Phonetic Simplification Processes in English of the Barrio: A Cross-Generational Sociolinguistic Study of the Chicanos of Los Angeles*. Philadelphia: University of Pennsylvania doctoral dissertation.

Stemberger, Joseph P. and Brian MacWhinney. 1988. Are inflected forms stored in the lexicon? In Michael Hammond and Michael Noonan (eds.), *Theoretical Morphology: Approaches in Modern Linguistics*, 101-16. San Diego: Academic Press.

Timberlake, Alan. 1978. Uniform and alternating environments in phonological change. *Folia Slavica* 2, 312-28.

Walsh, Thomas and Frank Parker. 1983. The duration of morphemic and non-morphemic /s/ in English. *Journal of Phonetics* 11, 201-06.

Wang, William S.-Y. 1969. Competing changes as a cause of residue. *Language* 45, 9-25.

Wang, William S.-Y (ed.). 1977. *The Lexicon in Phonological Change*. The Hague: Mouton.

Wang, William S.-Y. and Chin-Chuan Cheng. 1977. Implementation of phonological change: The Shaungfeng Chinese case. In Wang (ed.), 86-100.