PHONOLOGICAL EVIDENCE FOR EXEMPLAR STORAGE OF MULTIWORD SEQUENCES

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Phonological evidence supports the frequency-based model pro-
posed in the article by Nick Ellis. Phonological reduction occurs ear-
lier and to a greater extent in high-frequency words and phrases
than in low-frequency ones. A model that accounts for this effect
needs both an exemplar representation to show phonetic variation
and the ability to represent multiword combinations. The maintenance
of alternations conditioned by word boundaries, such as French liai-
son, also provides evidence that multiword sequences are stored
and can accrue representational strength. The reorganization of pho-
netic exemplars in favor of the more frequent types provides evidence
for some abstraction in categories beyond the simple registration of
tokens of experience.

Ellis's review article paints a very different landscape for linguistic knowledge
from that provided by structural theories of language. In this landscape, fre-
quency of use is not a constraint added to an otherwise structural or genera-
tive architecture (as in Hammond, 1999), nor is it just invoked when the facts
do not yield entirely to structural analysis (see, e.g., Kaisse, 1985, p. 59). Rather,
the picture that emerges from the array of studies that Ellis cites is one in
which linguistic knowledge is based firmly on experience with language, and
frequency of use is a foundational determinate of grammatical properties of
language. The article demonstrates that there is a major convergence of re-
search from many different perspectives—corpus-based analysis, computational
linguistics, discourse, cognitive and functional linguistics, and psycholinguis-
tics—that all point to a new theory of grammar with its attendant theory of
language acquisition.

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Ellis's review focuses on morphosyntactic processing and cites primarily experimental evidence for memory-based processing of morphosyntactic chunks. Many of the same principles can be applied to phonology even beyond the phonotactic evidence that Ellis cites (Bybee, 2001b). In this paper, the role of frequency in phonological reduction is discussed. I also argue that phonological alternations provide evidence for the size and nature of morphosyntactic chunks. Finally, the phonological shape of words provides some evidence that categorization is not completely exemplar based, but rather involves some abstraction resembling the construction of a prototype.

PHONOLOGICAL REDUCTION

The emphasis in Ellis's article on the importance of practice in language acquisition reminds us that phonological production is neuromotor behavior. Neuromotor behavior becomes more fluent with practice (Boyland, 1996). This fluency that comes about by automatization speeds up processing just as representational strengthening does. Most phonological alternations are the result of changes taking place in the sequences of articulatory gestures that reduce muscular activity by reducing the amount of displacement from a neutral position or by reducing the temporal dimension by overlapping consecutive gestures (Browman & Goldstein, 1992; Mowrey & Pagliuca, 1995).

It is notable that more articulatory reduction occurs in words and phrases that are more frequent. Studies of the way in which a sound change diffuses across the lexicon show that reductive sound changes affect high-frequency words earlier and to a greater extent than low-frequency words. This effect has been found in English schwa deletion, as in *memory* versus *mammary* (Hooper, 1976), Old English vowel changes (Phillips, 1984), American English *t/d*-deletion (Bybee, 2000b), and Spanish intervocalic *d*-deletion (Bybee, 2001b). Additionally, in high-frequency phrases we often find special reduction or assimilation. Bybee and Scheibman (1999) showed that *don't* reduces the most in the phrases in which it occurs the most often: The vowel in *don't* reduces to schwa only when preceded by *I*, which is the most frequent item to precede *don't* in the conversational corpus studied, and only before the verbs that most frequently follow *don't* (e.g., *know, think, have, want*, and *care*). Bush (2001) showed that the palatalization of /tj/ and /dj/ sequences in English conversation occurs only between pairs of words that occur together most frequently in the corpus studied (e.g., *did you, don't you, would you, that you, told you, last year*). In both of these cases of special phonological fusion between words, analysis in terms of purely structural factors fails: The class of verbs before which *don't* reduces is not definable in any way except by frequency of occurrence with *I don't*; the pairs of words conditioning palatalization, such as *would you, that you, told you*, and *last year* are not structurally parallel on any analysis.

These facts are accounted for by an exemplar model that includes the memory storage of words and of frequently occurring sequences of words.

The phonetic form of each token of experience is recorded in the exemplar representation, providing a range of variation for each word or phrase. High-frequency words and phrases have a greater range of variation, being subject to more reduction both because of the greater automatization of highly practiced sequences and because of the greater predictability of high-frequency items (Jurafsky, Bell, Gregory, & Raymond, 2001). Thus, phrases such as *I don't know, don't you*, and *last year* are stored in the lexicon, and phonetic changes that accrue as their production is automated are registered there. Therefore, words that occur in frequent phrases may have multiple phonetic variants. *Don't* in *don't you* is palatalized but not reduced, whereas *don't* in *I don't know* has a reduced vowel and reduced consonants.

The reduction of *don't* and the palatalization of certain /t/s and /d/s before /j/ are major changes that produce highly salient variants. However, more subtle phonetic changes also suggest the storage of sequences of words that have been experienced before. Gregory, Raymond, Bell, Fosler-Lussier, and Jurafsky (1999) studied words ending in /t/ or /d/ in the phonetically transcribed portion of the Switchboard corpus, a corpus of telephone conversations among speakers of American English. They examined deletion of final /t/ or /d/, tapping of these same consonants, and overall word duration. They found that the frequency with which the word containing the final /t/ or /d/ occurs with the next word, divided by the individual frequencies of the words in the corpus (a measure they call mutual information), has a high degree of association with the occurrence of deletion, tapping, and a shorter duration for the words studied. In word pairs that occur together frequently, such as *Burt Reynolds, Grand Canyon, acute illness, but I*, or *twilight zone*, deletion and tapping are more common, and in general the words are shorter.

Gregory et al. (1999) argued on the basis of these results that speakers are aware of collocational probabilities among words that lead them to reduce predictable words more than unpredictable ones. It follows that experience with collocations must be registered in memory. It also seems likely—though Gregory et al. did not take a stand on this issue—that previously experienced collocations are processed as a single neuromotor unit and that the phonetic reduction evident in such collocations is due to the automatization that comes from repetition of neuromotor sequences. Thus, reduction conditioned by preceding or following words provides further evidence that much of the production of fluent speech proceeds by selecting prefabricated sequences of words. In fact, by Erman and Warren's (2000) count, about 55% of both spoken and written texts consist of prefabricated sequences.

EVIDENCE FOR CONSTRUCTIONS AS STORED UNITS

Phonological changes that occur and then are fossilized in multiword chunks also constitute evidence that chunks of words are processing units. Some examples are the phonological alternations in English determiners that occur according to whether the following noun or adjective begins in a vowel or

consonant—for example, *a pear* versus *an apple* or [ðə] *pear* versus [ði] *apple*. English auxiliary verbs contract with preceding pronouns and in some cases nouns, and the auxiliary also contracts with the negative element. These conventionalized contractions reflect the high frequency with which such combinations occur (Krug, 1998).

A more pervasive phenomenon involving alternations conditioned by word combinations is French liaison. Not only was the development of liaison conditioned by the frequency of certain word combinations, but its gradual disappearance, which I will comment on here, shows that word combinations are stored lexically and gain in representational strength due to frequency of use.

French liaison refers to the alternation between the presence and absence of a word-final consonant in certain word combinations, usually in certain constructions. A common locus for liaison is between the determiner and the following noun or adjective, where the consonant appears before a vowel or glide, as in (1a) and (2a), but not before a consonant, as in (1b) and (2b) (Tranel, 1987).

(1) a. *un oiseau*   [ɛnwazo]   "a bird"
    b. *un livre*   [ɛ̃livr]   "a book"

(2) a. *les amis*   [lezami]   "the friends"
    b. *les coquillages* [lekɔkijaʒ] "the seashells"

The contexts in which liaison occurs, besides those in (1) and (2), include clitic pronouns and verbs, verbal inflections, plurals in noun-adjective and adjective-noun combinations, prepositions with nouns, and certain fixed phrases. Two relevant points can be made about such forms. First, they are all of relatively high frequency, especially in the constructions or phrases in which the liaison consonant appears. Second, they all occur in very specific grammatical constructions. No liaison consonant appears independently of a specific construction.

Bybee (2001a, 2001b) argued that the liaison consonant is a part of the construction in which it appears and that there are two variants of constructions that involve liaison—one with and one without the consonant. The situation is similar to a verb having two alternate stems, as in *weep, wept*. In the case of irregular verbs regularizing, there are two effects of token frequency: (a) The form of the stem that is less frequently used will be lost, and the more frequent form will remain (Bybee, 1985); and (b) the less frequent verbs will regularize, whereas the more frequent ones (e.g., *keep, kept*) will retain their irregularities. Both of these effects can be accounted for by registering all forms of a verb in the lexicon and allowing them to accrue lexical strength due to the frequency of use (Bybee, 1985). The stronger forms will remain, whereas the weaker ones have a tendency to be lost over time.

The same effects of frequency are found in the case of French liaison. If we view the two forms of the construction—one with and one without the liaison consonant—as comparable to the irregular verb forms, then we would expect

Table 1. Number of instances of liaison for the finite forms of the verb *être* ending in *-t*

Verb forms	Liaison	No liaison	Total	% liaison
est (3rd Sg. Pres. Ind.)	2591	77	2668	97%
sont (3rd Pl. Pres. Ind.)	242	38	280	86%
était (3rd Sg. Impf.)	272	95	367	75%
étaient (3rd Pl. Impf.)	36	21	57	63%
serait (3rd Sg. Fut.)	17	24	41	41.4%
soit (3rd Sg. Pres. Subj.)	22	32	54	40.7%

the less frequent alternate to be lost. This is just what happens. Given that consonant-initial words are two to three times more common than vowel-initial words, the alternate with the consonant is less frequent and therefore tends to be lost. We would also expect the loss of liaison to occur in the less frequent constructions; again this is precisely what happens. The determiner-noun and clitic pronoun-verb constructions retain the liaison alternation, whereas other constructions are variable or have lost liaison entirely. The following is just one example of the effects of frequency on the loss of liaison.

The copular verb *être* "to be" has numerous inflected forms that end in *-t* and exhibit liaison. However, even when these inflected forms are in the same construction, the extent to which they exhibit the liaison consonant before a vowel varies with their frequency of use. Table 1, based on spoken data from Ågren (1973), shows this variation. The fact that frequency of use is a strong determinant of the maintenance of liaison provides evidence that constructions are stored in memory and can accumulate representational strength that protects them from change (Bybee & Thompson, 2000). The fact that a phonological element, such as the liaison consonant, can be maintained due to frequency provides evidence that explicit phonological material is contained in constructions, even those involving multiple words (Bybee 2001a, 2001b).

EXEMPLAR OR PROTOTYPE CATEGORIZATION?

A final phonological phenomenon that provides evidence for the structure of the theory that Ellis outlines in his paper bears on the issue of whether categorization is purely in terms of sets of exemplars or whether a more abstract prototype is constructed based on the stored exemplars. As mentioned previously, a theory of representation in which tokens of experience are registered in memory is a good fit with the fact that sound change is phonetically gradual and affects different words at different rates (Bybee, 2000a; Pierrehumbert, 2001). Each word would have a range of phonetic variation associated with it, but because words occur in many different phonetic environments, phonetic variants of a word might proliferate. For instance, in many dialects of Spanish, word-final /s/ is weakened to /h/ when a consonant follows. At first

the /s/ is preserved if a vowel follows. Thus, every word that ends in /s/ would have two quite distinct variants, for example, *entonces, entonceh* "then" or *más, máh* "more." However, this situation is not maintained for long. In more advanced dialects, the more frequent preconsonantal variant spreads to prevocalic position, narrowing the range of variation for each word. Only words that occur with /s/ before a vowel in high-frequency constructions, such as determiner-noun, maintain two alternates for a word (cf. the contexts in which French developed the liaison alternation; Bybee 2000a, 2001b).

This suggests that speakers are not simply recording and reproducing phonetic variants, but rather that the more frequent variants dominate the category formed from the exemplars and come to be used in a wider range of contexts, whereas the less frequent variants take on a more marginal status and are eventually lost. Thus, although the gradualness of sound change suggests attention to particular exemplars, the extension of frequent variants suggests a gradual and probably continuous restructuring of categories around the most frequently occurring members. It remains to be seen whether or not other linguistic categories undergo the same type of restructuring.

CONCLUSION

These comments are intended to reinforce the clear implication of Ellis's article that a new theory of language is emerging as a convergence from many different research paradigms. Evidence from phonology rounds out the theory, demonstrating that every aspect of language can profitably be reexamined in light of the important frequency effects. Naturally, it follows that the implications of this new linguistic theory for our understanding of first and second language acquisition will be profound.

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