Quantitative Reasoning in Linguistics

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The study of linguistic variation requires a familiarity with both the basic tools of qualitative linguistic analysis and quantitative methods of for pursuing that analysis to deeper levels. This presentation will assume a basic familiarity with both sets of tools, and focus upon how they are used to address the major questions of linguistic structure and linguistic change. Given the output of quantitative analyses, we ask, what good are they? what inferences and implications can be found in these numbers that justify the time and energy needed to produce them? What are the principles of quantitative reasoning that allow us to pass from the measurement of surface fluctuations to the underlying forms and principles that produce them?

1. Variation: the central problem of linguistics

It will be helpful to begin with the general considerations that lead us to the study of variation. From one point of view, linguistics is as diverse as the languages it studies; from another, linguistics centers upon a common problem: variation. If every yes-no question were related to the corresponding declarative in a uniform way, no linguist would be needed to describe the system or tell new learners how to use it. But when a question is asked sometimes in one way and sometimes in another, sometimes with inversion and sometimes without, or sometimes with a final rise in pitch and sometimes a fall, a linguist is called for.

Thus the central task of linguistics is to eliminate variation by discovering the exact conditions that produce one variant or the other on the surface. This is usually done by establishing *complementary distribution* of the variants. But the analysis of variation often results in an approximation to complementary distribution: a given variant may appear 90% of the time in one environment but 10% of the time in another. In the *categorical view* shared by structural linguistics and generative grammar., this proportion cannot be reported as a linguistic fact. In this framework, there are only three statements that be made about the existential status of a given rule, constraint, process: that it always applies, never applies, or is optional. There is nothing theoretically intelligible to be said about how often a variant occurs, or the degree to which a process determines the output.[1]

The consequences of this theoretical stance is that linguists are driven to find 100% solutions to the problem of defining complementary distribution. Exceptional

[1]In actual practice, linguists often do use quantitative predicates in describing languages. Thus in Mattina's account of Alaskan Eskimo, the phoneme /u/ is said to have the rounded and fronted allophone [y], which "occurs often after [t], [s] and [l] and varies freely with [u]" (1970:44). It seems that this account was more satisfactory to the author than to say "[y] varies freely with [u] after [t], [s] and [l]."

cases that violate the pattern must be disposed of as the result of dialect mixture, performance errors, co-existent systems, or simply ignored. Otherwise there is no finding to report, no dissertation to be written, no paper to be published. The rest of this paper is devoted to the alternative approach that accepts variation as a significant linguistic fact.

FUNDAMENTAL CONSIDERATIONS

The *fundamental fact of phonetics* is that no two utterances are alike. Utterances vary in unlimited ways: in their segmental phonology and prosody as well as their syntax and pragmatic context. It is not really possible to say the same thing twice.[2]

The *fundamental postulate of linguistics* is that some utterances are the same,[3]When someone answers the telephone, we learn a great deal from the many ways he or she has of saying "Hello," and yet it is the same morpheme {hello} with the same phonemic realization /helow/.

The contradiction between the fundamental fact of phonetics and the fundamental postulate of linguistics is that, from a linguistic point of view, some differences do not make a difference. They are in *free variation*. Free variation is the then obverse of the fundamental concept of linguistic 'same' and without free variation there can be no linguistic structure.

The existence of free variation within a linguistic category is equivalent to saying that the occurrence of any one token of a category is a *random event*: that is, an event whose outcome cannot be predicted with certainty. This event may be the choice among a discrete number of options, or the realization of a continuous variable.

The study of linguistic variation begins with the introduction of the further concept of the *linguistic variable*. It differs from elements of free variation in the distribution of its variants is of linguistic interest. This presentation is an attempt to define what that interest is.

DEFINITION OF THE LINGUISTIC VARIABLE

The definition of a linguistic variable is the first and also the last step in the analysis of variation. It begins with the simple act of noticing a variation—that there are two alternative ways of saying the same thing.[4]

A first attempt to define envelope of variation searches for the largest environment in which this variation occurs, in order to apply the *principle of accountability*: that reports of the occurrences of a variant must be accompanied by

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[3] Or more precisely, some utterances show partial morpho-semantic identity (Bloomfield 1926).

[4] It should be noted here that the converse is also included in the study of variation: situations where there are alternative meanings conveyed by the same form (e.g., Labov 1984). Cases have been much discussed in which the social variants are not clearly equivalent in meaning (Lavandera 1978, Romaine 1981).. The overwhelming majority of these are in the domain of tense and aspect particles. Sankoff and Thibault (1981) show that these are primarily cases of "weak equivalence." Nevertheless, there are clear cases of co-variation of form and meaning, as shown in Myhill's studies of the development of the strong obligation system in American English (1995,1996).

reports of all non-occurrences.. The definition of a linguistic variable then requires establishing a closed set to which the axioms of probability theory apply.

More precise definitions of the variable are achieved by locating and setting aside *neutralizations:* environments in which it is not possible to distinguish all variants of the variable.[5] We also note *exclusions:* individual items that behave differently from other members of their class.[6]

Once this defining envelope is established for the dependent variable, the major task is to locate and define the independent variables to be included in the study. These are the *constraints* on the variable, sets of sub-categories which may or may not differ significantly in the frequency in which the variants of the dependent variable.are found.

One approach to the selection of constraints is to search for every possible category that can affect the dependent variable in a significant way, or include every category that has been found to be significant in past studies.. Many interesting and valuable results have been found by following this procedure. For many variables there are now fairly clearly guide lines to a relatively small set of social and linguistic categories that are prime candidates for examination. Nevertheless, it seems to me that inserting into the analysis all of the constraints that have appeared in the literature leads to the proliferation of studies with no clear termination and no necessary connection to the broader problems of linguistics. In the approach to follow, it is the social or linguistic problem that dictates the choice of independent variables.

2. Exploring single dimensions of variation.

The most common first step in selecting constraints for quantitative analysis of a linguistic variable is the binary division of the population (of speakers or utterances) into salient groups: men vs. women, middle class vs. lower class, pre-consonantal final clusters vs. pre-vocalic clusters, and so on. The result may be a significant difference in the frequency of variants; yet these differences are often hard to interpret, even if they are quite large since there are many possible explanation for the observed effect.

The observed difference may be an artifact of some other difference, a third variable, which is unevenly distributed across the binary division chosen. A finding of difference in gender may turn out to be due to a difference in education, if the distribution of educational levels is not uniform across men and women. This type of error is resolved by using one or another form of multivariate analyses which correct for such skewing of the data by taking into account the simultaneous effect of all relevant independent variables. Multivariate analyses are strongly preferred for most complex situations, although cross-tabulations and scattergrams will often give clearer view of the distribution of data and the degree of independence of the intersecting variables. The discussion from this point on will apply equally to univariate and multivariate analysis of linguistic data.

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[5] Thus coronal stop deletion (TD) is neutralized before words beginning with coronal stops or affricates..

[6] For coronal stop deletion (TD), the word *and* shows a deletion rate that is idiosyncratically higher than other words of the same structure (Neu 1980). For (ING), we find that *Reading* and *Flushing* never occur with the apical variant.

The first quantitative sociolinguistic study was Fischer's report on the use of (ING) in a small New England town (1958). As an anthropologist, Fischer was interested in gender differences, and he therefore calculated the difference in the use of the /in/ variant for boys and girls. He found in this small study that boys use more of the /in/ variant than girls with a p value (chi-square) of less than .05. Many parallel studies have since shown that this was an instance of the general finding that for stable sociolinguistic variables, males show a higher use of stigmatized variants behavior than females (Labov 1990).[7] The next step taken by Fischer shows how an investigator can go beyond the limitations of a binary division of the population. From his other observations of the community, he reasoned that the crucial difference between boys and girls behavior was in differences in their conformity to established norms. Rather than treating males as a homogeneous group, he divided them into two types along this dimension. His analysis was limited to two boys: a "model" boy, who conformed perfectly to the behavioral pattern endorsed by adults, and a "typical" boy, who did not. The model boy used /in/ once out of 39 tokens, while the typical boy used it 10 out of 22 ($p < .001$)..

The procedure suggested by Fischer's brief exploration is to use another independent variable—conformity—to subdivide the gender dimension and thus create a more finely graded dimension: girls/model boys/typical boys. This is parallel to the strategy adopted by Eckert in her study of the Northern Cities Shift in a Detroit suburb (1999). For the backing of (^) in *lunch, bust, etc*., the Burn-Out youth were in advance of the Jocks, and female Burn-Outs even more so. Eckert designated a sub-class of "Burned-Out Burn-outs" who exemplified the norms of the Burn-Out group more clearly than the others, and their backing of (^) was even more extreme. Thus our confidence in the relation between Burn-out norms and the backing of (^) is considerably reinforced.

THE INCREMENTAL PRINCIPLE

The general strategy here may be termed the *Incremental Principle*. Confidence in the relationship between variables A and B is highest when it can be shown that each increment in A is accompanied by an increment in B. If A is temporally prior to B and can be shown to influence B, a causal relationship is inferred. This is the basis for our confidence that smoking is a cause of heart disease and lung cancer: it has been shown that each increment in smoking, no matter how small, is associated with an increase in the incidence of these diseases.

The study of coronal stop deletion (TD), the first constraints selected were binary: a following consonant vs. a following vowel,[8] and monomorphemic vs. bimorphemic (past tense) clusters. An understanding of how these environments affected (TD) was achieved by a more fine-grained sub-division. The effect of the initial segment of the following word formed the series (from most to least deletion): obstruent, liquid, glide, vowel. This is the well-known sonority hierarchy (Saussure 1959): the more sonorous segment following a cluster, the less likely it is to be

[7] Further investigations showed that this applies only when both men and women have full access to those norms (Nichols 1976).

[8] Some investigators grouped a following pause with obstruents (Labov et al. 1968), and others with a following vowel (Wolfram 1969). This issue was later resolved (see below).

simplified. This in turn was attributed to the greater possibilities for resyllabification of coronals with following sonorants and glides (Guy 1991).[9]

A similar development occurred in the exploration of internal constraints on the variable (ING). It was found that the velar variant is strongly favored by the progressive, and the apical variant by nouns (Labov 1989, Houston 1985). This appears to be the result of long-term continuity with the O.E. participle *–i/ende* and the O.E. verbal noun *–i/ynge*.[10] This proposal receives support from more fine-grained divisions of the grammatical dimension: in order of decreasing use of [in], we find participle, adjective, gerund and noun. nouns show the least [in], gerunds (Houston 1985).

Many studies of the social class hierarchy are carried out with binary divisions, such as middle class vs. working class. Our confidence that there is a causal link correlation between social class position and the use of a given sociolinguistic variable is increased when the number of divisions of the social class hierarchy is increased from 2 to 4 or 5 (Weinberg 1974, Wolfram 1969, Trudgill 1974). This leads to the well established principle that stable sociolinguistic variables are associated with monotonic functions of social class.(Labov 2000, Ch. 5).

Monotonic functions of this type are not necessarily linear. In fact, a great deal of information is obtained by observing the nature of departures from linearity. Thus the relatively sharp social stratification in England is shown by the clustering of middle class and working class sub-groups, and a wide gap between them (Trudgll 1974). In Philadelphia, negative concord (NEG) is more sharply stratified than (ING): (NEG) shows relatively low values for middle class sub-groups, and relatively high values for all working class sub-groups (Labov 2000, Ch. 3).

3. The comparison of several dimensions

So far, we have been considering the relationship between one dependent variable and a single independent variable—sometimes elaborated by intersection with a second. A great deal can be learned from the patterns formed by mapping the linguistic variable against several constraints, or mapping the paths of several variables together.

3.1. INFERENCES FROM INDEPENDENCE.

The most striking results of are found in the joint mapping of social and stylistic stratification of stable sociolinguistic variables: New York City (Labov 1966), Detroit (Wolfram 1969), Norwich (Trudgill 1974), Bahia Blanca (Weinberg 1974), Glasgow (Macaulay 1978), Ottawa (Woods 1979), Teheran (Modaressi 1980), Lopez 1983, Copenhagen: (Gregerson and Pedersen 1991). The surprising regularity of these patterns had considerable influence on those who had believed that linguistic variation in large cities was chaotic and unmanageable. These displays, replicated for many

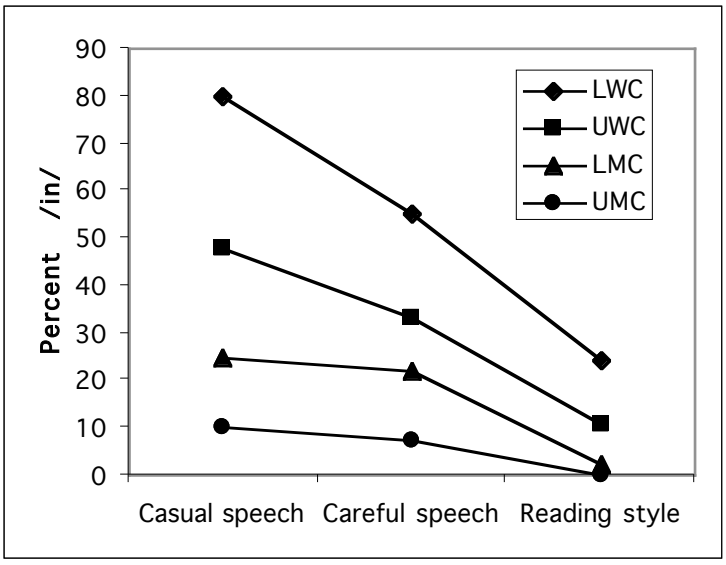
[9] A proposal supported by the further finding that following /l/ was associated with a much higher probability of deletion than following /r/. However, an even further division of the continuum showed that /w/ favors deletion as much of an obstruent, while /y/ behaves like a vowel (Labov 1997). It seems likely that perceptibility plays a larger role here than production.

[10] By the well recognized processes of sound change, [in] is the regular reflex of *–inde*, and [iN] is the regular reflex of *–inge*.

different speech communities, show that the community is highly differentiated: with stable sociolinguistic variables all social classes are stratified in each stylistic context. On the other hand, they show that the community is remarkably uniform: each social class follows a parallel path of style shifting.[11]

Figure 1 displays the fact that members of the speech community share a set of values that are correlated with their use of linguistic variables. It is the same consensus that is found in the uniform results of matched guise tests (Anisfeld and Lambert 1964, Lambert 1972, Labov et al. 1968, Labov 1972): the negative evaluation of stigmatized features is shared by those who use them rarely and those who use them frequently. Some students of sociolinguistics, wishing that the facts were otherwise, oppose these conclusions as reflecting an ideology that approves of the situation, sometimes called a "consensus theory" of societ y. However, the consensus reflected here is not an inference or a theory, but simply an observed phenomenon.

Figure 1. The social and stylistic stratification of (ing) in New York City.



The cross-tabulations that produce these displays are a direct display of the *independence* of style and social class as constraints on the linguistic variable. The effect of style is independent of social class, and is replicated for each social class[12]

The mathematical independence of social and stylistic stratification does not mean that they are unrelated. On the contrary, their parallel effects may be due to the fact that one is derived from the other. This is the inference put forward by Bell (1977) and Preston (1991n). In supporting the view of style as audience design, Preston pointed out that the range of stylistic stratification in such displays is always less than

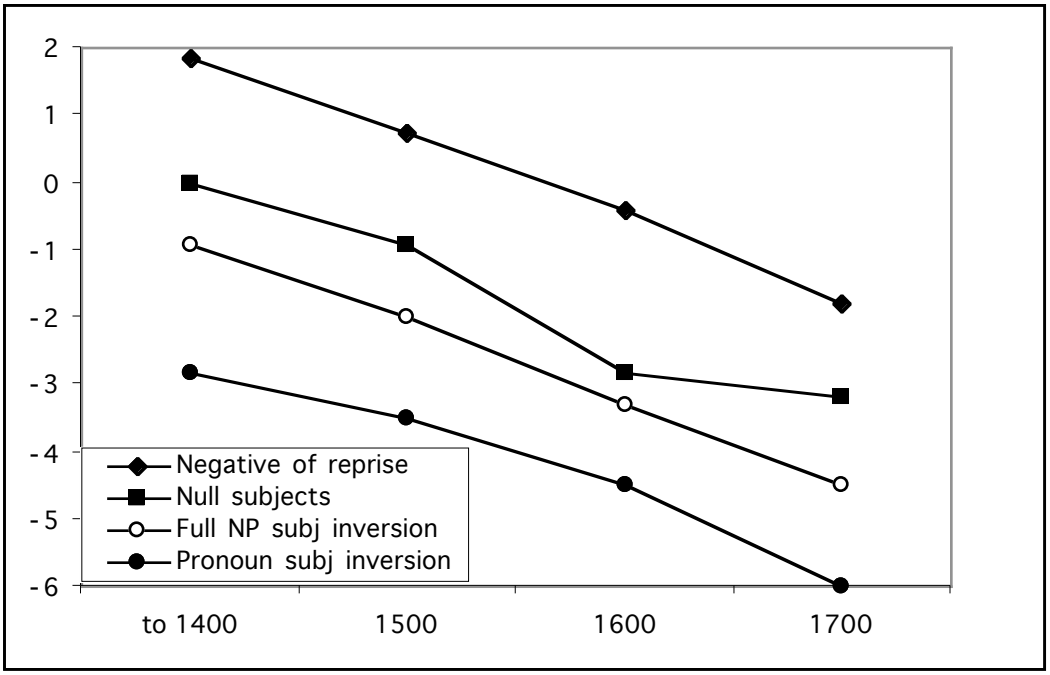
[11] This is independence that is assumed—but not displayed—by the Varbrul program. Many other programs for multivariate analysis facilitate the tracking of departures from independence (ANOVA), but independence cannot be directly displayed except by such cross-tabulation.

[12] Figure 1 may also allow us to infer the presence of covert values, which explain the fact that the system is stable over long periods of time, and that people do not speak in the way that conforms to their formally endorsed norms (Labov 1966). Direct evidence for such covert norms is sparse, however.

the re=ange of social stratification, and argue that the former is therefore derived from the latter.

A different form of independence is found when several linguistic variables are mapped together in the same context. In Kroch's study of long-range historical change, strong conclusions are drawn from displays of two to five different dependent variables with time as the horizontal axis, and frequency (or logit frequency) on the vertical axis. Figure 2 shows how the decline in subject inversion and null subjects is accompanied by a rise in left dislocation (shown here as the negative of "reprise").,The eye can directly observe the parallelism of these curves and calculations show that the slopes are not significantly different. The inference is then drawn that these different variables are the product of a single, more abstract variable: in this case, the decline of the verb-second constraint in French.[13] This is the basis of Kroch's characterization of variation as "competing grammars." From the standpoint of our initial discussion of the linguistic variable, it represents the final re-definition of the variable, responding to the imperative to find the largest linguistic phenomenon that varies in a uniform way.

Figure 2. Decline of inversion and null subjects accompanied by the inverse of the rise of left dislocation (reprise). Source: Kroch 1989, Fig. 5.



The "Constant Factor" principle that also flows from much of Kroch's work is the product of a similar mapping of sub-cases of what can be seen as the same variable. In the case of do-support, it is affirmative questions, negative declaratives, negative questions, and so on. The striking finding of this work—that the logistically transformed curves are parallel throughout the course of the change—leads to the

[13] Left dislocation gradually replaces topicalization, since as verb-second constructions decline, the subject position into which topicalized elements move is regularly filled. With left dislocation constructions, the verb can be seen as occupying the third position.

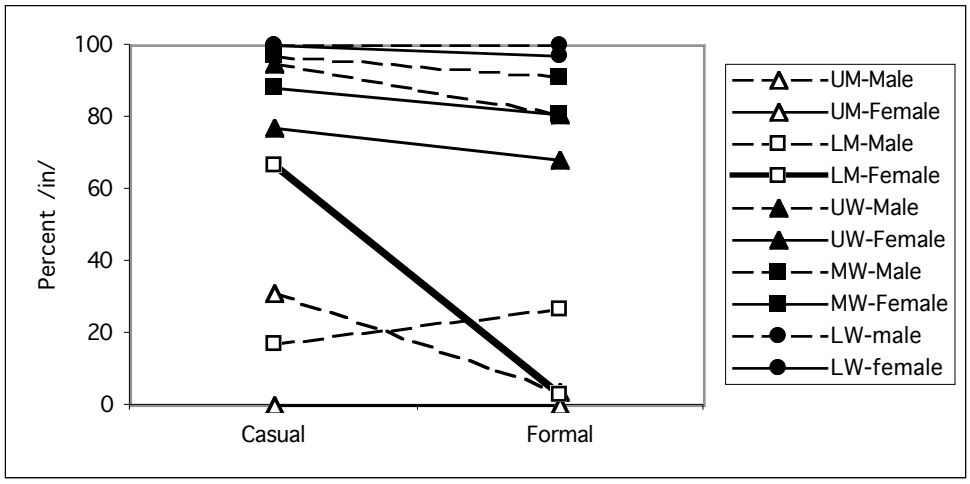
conclusion that the object which changes over time is more abstract than any of the observed structures. Thus the Constant Factor and Competing Grammar principles both embody the major thrust of quantitative reasoning: to characterize surface variation in terms of the largest (and most abstract) set of objects that vary in the same way. Once thjs goal is achieved, the task of discovering the cause of the change, and its relation to other changes, begins to come within reach.

3.2. INFERENCES FROM INTERACTION.

The converse of independence is interaction, where values of a variant along one dimension differ according to the values of another dimension. The elegance and simplicity of the independent mapping in linguistic variation may lead us to think that interaction is a less systematic phenomenon, and that constraints that interact with each other give us less insight into the organization of the system. Thus social variables typically interact with each other, so that the differences between men and women vary from class to class and from style to style. This may be true for a single case of interaction, but when the same pattern of interaction emerges on repeated studies, the inferences we can draw are even more powerful than in the simpler pattern of complete independence.

One of the first examples of interaction was the "cross-over pattern" found in the social distribution of (r) in New York City. In general, the use of the incoming norm of *r*-pronunciation is directly related to social status. But in the most formal style, the second highest status group surpasses the use of (r) by the highest status group, and in general, shows a much steeper slope of stylistic stratification. Further explorations of this situation show a further interaction involving social class, gender and style. Figure 3 shows the variable (ing) in Norwich by social class and gender (Trudgill 1974) . Here it is the women in the second highest status group who show an exceptionally steep slope of style shifting, quite different from any other group.

Fig 3. (ing) in Norwich by social class, style and gender (Source: Trudgill 1974).



This greater sensitivity of lower middle class women to overt linguistic norms has been the subject of much discussion and further reasoning that go beyond the scope of linguistic argumentation. It is sufficient at this point to note that the recurrence of this more complex pattern in various contexts leads to greater confidence in the significance of the result. In general, the more complex the pattern, the less likely that its replication is the result of chance.

A very different type of interaction can be noted when we examine the same variable in a large city and a small city. Modaressi (1978) studied the same variables in Teheran and Ghazvin, a small city 150 Km from Teheran. The variable (AN) represents the raising of /a/ to [u] before nasals: at a high rate in the speech of Teheran, but at a lower frequency in Ghazvin. In Teheran, there is a direct correlation with social status, and a very sharp stylistic stratification where [u] practically disappears in the most formal styles. Modaressi also found that the pattern of social stratification of (an) was reversed in the two cities. In the capitol city, the frequency of [u] was inversely correlated with social class; in Ghazvin it was the directly correlated. How can such a reversal come about? We can infer that diffusion of the Teheran vernacular to Ghazvin was the product of a limited stylistic and social contacts, so that the vernacular of the capitol city was re-interpreted as a prestige form.

One of the most dramatic examples of gender interaction is found in the study of Sydney high school students by Eisikovits (1981). She divided all of the students' utterances into those that immediately followed her own turns of talk, and those that did not. For the girls, she found the expected accommodation to her standard form for eight grammatical variable. However, the boys shifted in the opposite direction for 5 of the 8 variables. This dramatic reversal of accommodation patterns gives us one of the clearest indications of the existence of covert norms opposing the standard norms.

3.3. Reasoning from ambiguity

In the course of coding tokens of a linguistic variable, it often happens that we encounter a case whose status is unclear: it could belong in one of two different

categories, depending on the linguistic analysis. Thus the effect of final pause on (TD) could be seen as similar to the effect of a following consonant: it does not have the opportunity for resyllabification that is available when a vowel follows. On the other hand, final consonants can be released, creating a semi-syllable, and so are more easily perceived than when an obstruent follows. Since there is no unique solution to this problem from general qualitative arguments, the reasonable quantitative strategy is to treat following pause as a separate category. When this was done, the results were surprisingly diverse. For most dialects, following pause behaved like a following vowel; but for others, like a following obstruent (Guy 1980). In general, we can say that if linguists can see two radically different modes of analysis of a structure, then native speakers can too—at least in their unconscious productions.

The same strategy was followed in regard to ambiguous past tense verbs like *kept, told, lost*, etc. Is the /t/ a past tense form? One argument is that it is not, since the vowel change can carry the past tense information. Another argument is that it is, since other is a final /t/ or /d/ cannot be added accidentally to a past tense, and must carry at least part of the past tense information. The solution was to create a separate category of semi-weak or derivational forms, as opposed to the inflectional forms *rapped, rolled, passed*. This was a fruitful decision which led to a long series of profitable findings that illuminated the nature of variation. some are presented below.

3.4. TRIANGULATION

It is not only a constraining factor that may be subject to competing explanations. The linguistic variable itself may be the product of several processes, independently determining the outcome. This is the key to the puzzling situation that confronted Patrick in his first analysis of (TD) for Jamaican Creole English in Kingston (1991). In the initial analysis, monomorphemic forms showed a deletion rate of 71%, and regular past tense suffixes a rate of 80%. This is certainly an anomaly in the light of the consistent findings for AAVE and all other dialects studied previously.

The key to the situation lay in the existence of competing processes. For most American dialects, (TD) is a simple phonological process, which as we have seen, operates upon a consistent underlying form. This may not be the case for young children, who have not yet acquired consistent past tense marking. Patrick believed that it was not the case for Jamaican Creole English, where there is variable past tense marking in addition to phonological reduction of past tense clusters. He undertook to separate these two effects by the strategy that I have here termed *triangulation*: to locate another variable that registers the frequency of only one of the two competing processes. In this case, it is the irregular verbs that do not have final consonant clusters but mark past tense only by ablaut vowel alternation: *give ~ gave, see ~ saw* etc. Using this sub-class and others, Patrick was able to calculate that the rate of past tense marking for all Jamaican verbs was 50%. It followed that only 202 of the 405 verbs that could have been marked with a final past tense suffix were in fact marked in this way as underlying forms. Only 79 suffixes remained on the surface, it follows that these were remnants of a pool of 202 possible deletions, not 405, and that only 123 were deleted, not 326. Thus Patrick was able to calculate that the rate of deletion of the past tense suffix was 123/202, or 61%, considerably lower than the 71% for monomorphemic forms.

Ziqiang Shi undertook a study of the historical development of the Chinese particle *le,* which occurs after the main verb of the sentence to denote relative anteriority (1989). This sentential particle developed from the main verb *liao* in classical Chinese. *Le* grew rapidly in use as an anterior marker from the 12th to the 14th centuries, increasing sevenfold, but Shi was puzzled to discover that *de,* the main item that *le* replaced, declined only in half. *Le* continued to grow in use to reach a maximum in the 17th century, without any marked decline of other competitors. It was possible, of course, that Chinese were marking anteriority more often over five centuries, but it is not likely.

Shi suspected that *le* was essentially a vernacular form, but the texts he was working with were an intimate mixture of Classical Chinese and the vernacular. The steady growth of *le* might then reflect not one, but two processes: replacement of the other competing forms (*que, de*) and the gradual decline of Classical Chinese in the texts. In order to separate these two effects, he located another particle that was used only in Classical Chinese. This was *ye*, a sentence-final copula or interjective marker. By charting the frequency of *ye,* Shi was able to estimate the decline in the proportion of classical characters in texts. He used this to calculate a corrected chart of the growth of *le* and decline of *de*. In these corrected figures, *le* increased only four-fold from the 12th to the 14th century, and *de* declined by roughly the same proportion. Furthermore, it appears in this view ethat *le* reached its maximum in the 14th century, when it had displaced all competitors, and has not increased in frequency since. The original view of a steady increase of *le* over five centuries actually represented a decline in the frequency of classical elements in Chinese texts.

3.5. COMPETING CONSTRAINTS

The cases just considered concern the separation of influences on the linguistic variable that operate in the same direction. Perhaps the most common type of debate in linguistic analysis is the competition between constraints that have opposite effects. This situation arises dramatically in efforts to test the *functional hypothesis*. This is essentially the proposition that variability can be explained by the tendency of speakers to preserve the semantic information in their messages (Kiparsky 1982). In the case of (TD), the functional hypothesis was immediately advanced to explain the lower percentage of deletion of past tense clusters as compared to monomorphemic clusters. In regular past tense forms, the /t/ or /d/ carries past tense information in itself, and this information is obviously preserved if the cluster is preserved. It has even been suggested that the morpheme will be deleted only when it is redundant—that information is never lost.

Guy (1996) examined this situation with the technique I have called triangulation. He located a form that has the same phonological structure as the past tense clusters but does not share their semantic load. Guy noted that the functional hypothesis predicts that the participial suffix in passives and perfects will be deleted at the rate of monomorphemic forms, since it is clearly redundant. In fact, most studies of (TD) deletion show that it is deleted at the same low rate as preterit clusters (1996, Table 2).

Perhaps the most thoroughgoing exploration of the functional hypothesis was carried out by Poplack in her studies of the aspiration and deletion of /s/ and the

weakening and deletion of /n/ in Puerto Rican Spanish (1979, 1980, 1981). The possible constraints on the variable included two major sets of influences. One set registered the informational status of the variable—primarily dealing with signals of plurality. This included the grammatical status of the segment, the presence of other grammatical signals carrying the same information, other morphological or syntactic configurations that conveyed such information, semantic information from other parts of the discourse, and cultural knowledge that would influence singular or plural interpretations. Another set of constraints registered the mechanics of articulation: the nature of the following or preceding segment. A third type of constraint concerned the position of the grammatical signal in a complex noun phrase. In a three-membered noun phrase of article, noun and adjective, an /s/ signal might be preceded by one or more /s/ signals, or by one or more zeroes. An informationally-based view would predict that the frequency of deletion would be higher after an /s/ that was preserved in the surface structure. Poplack's results showed that just the opposite was true: a preceding /s/ favored a following /s/, and a preceding zero favored a following zero. This finding has been reinforced by a variety of studies that support a strong tendency towards *perseverance* (Weiner and Labov 1983, Sherre and Naro 1991, 1992). It is the equivalent in production of perceptual priming; it appears that language production is facilitated by parallelism of production. Thus the strongest influence on the choice of the passive in subjectless sentences is the choice made in the last token of the same variable—no matter how widely separate in time. (Weiner and Labov 1983). At the same time, one can show that informational considerations also play a part: as in the tendency to place the given first and the new information second..

With such complex sets of constraints, a univariate analysis is not informative. Any one of the competing constraints will show a positive result. A multivariate analysis (in this case, the Varbrul logistic regression) will allow one to see which of effects predominate. In both the passive variable and Spanish/Portuguese inflections, multivariate analyses showed that the mechanical effects were stronger.

3.6. RATIONAL AND IRRATIONAL COnSTRAINTS

One of the major tasks in the study of variation is the identification of underlying forms. Given a fluctuation between the presence and absence of a segment, we must ask whether it is present in the representation in the lexicon and variably deleted, or whether it is variably inserted at some other level of the grammar. If the segment also functions as a separate morpheme, like the past tense /t/ or /d/, we might locate the variation at the phonological level, at the level of morphological realization of the past, or at a more abstract level of variable past tense marking.

The presence of an underlying segment may be inferred from a variety of observable phenomena: from the absence of hypercorrection, uniformity of use among community members, and/or a moderate and systematic slope of stylistic shifting. But the clearest indication of the presence of an underlying form is the existence of phonological conditioning. As indicated above, coronal stop deletion is sharply inhibited by a following vowel, and promoted by a following obstruent. One might well imagine a process of insertion that was sensitive to this factor, but many different studies of variation support the general principle that phonological conditioning

implies the presence of an underlying form on which the conditioning is exerted. This finding is consonant with the modularity of language structure. Phonological spellings are not visible at the level at which morphological elements are inserted.[14]

This situation with (TD) contrasts sharply with the behavior of third singular /s/ in African American Vernacular English. Some of the first studies showed the reverse constraint--/s/ inhibited by a following vowel, and others showed no phonological conditioning at all (Labov et al. 1968). This finding was correlated with the presence of hypercorrection and other indications that subject-verb agreement is not present in the grammar. It was concluded that the variable /s/ that was found in speech was not an underlying form, but the product of a variable process of insertion at the morphological level.

An irrational constraint is one that runs counter to all established linguistic findings and principles. Barale's study of Mandarin VN syllables (1982) hypothesized three variable phonological stages to be accounted for:

1. Nasalization of the vowel of a VN rhyme
2. Loss of the nasal segment
3. Denasalization of the vowel

For stage 1, it was found that nasalization was promoted by the presence of an adjoining nasal syllable. But for stage 3, the opposite appeared: nasalization was favored by conjunction with a syllable headed by an oral vowel. There are no known cases of dissimilating nasalization, and it could only inferred that the three-stage model had to be modified. Closer study detected the presence of a small number of common words that showed almost categorical use of oral vowels. It could be inferred that they had lost the underlying nasal and were represented in the lexicon with oral vowels. When these were removed from the data set, the irrational constraint disappeared.

Thus the detection of irrational constraints discredits the abstract model being considered, and leads the analyst to revise that model. Such a logic is not confined to internal variables, but applies to social variables as well. Here one must be cautious, since there may not be principles of social life as compelling as the uniform principles of linguistic structure that are based on the common physiology of all human beings. Nevertheless, there are sociolinguistic findings that approach such a high level of confidence, where reverse findings are not only surprising but suspicious. One such generalization is that concerning the linguistic nonconformity of male speakers, cited above. In the face of a very large number of studies supporting this finding from many parts of the world, urban and rural, a small number of exceptions appeared in regard to the use of the Arabic *qaf*. In various modern Arabic dialects, the uvular stop /q/ of classical Arabic appears variably as /k/, /g/, /?/ or /q/. Given the prestige of Classical Arabic, it would be expected that men would use less /q/ than women. But in a number of studies,in Jordan, Egypt and other countries, the opposite was found (Abdel Jawad 1981, Al Wer 1991, Schmidt 1974, Salam 1980, Haeri 1996). One explanation advanced was consistent with the caveat given above, that both men and women would have to have equal access to the public norms for the principle to apply (Labov 1982). But Abdel Jawad showed that even upper middle class women in Amman used

[14] Studies of speech production show that this is not merely an abstract schema peculiar to the analyst but a property of the production of speech in real time (Levelt 1989).

less /q/ than men. The situation was resolved by Haeri who pointed out that the model was wrong in assuming that Classical Arabic was comparable to the standard languages of other countries. In any case, the low frequency of /q/ found in colloquial speech is not the result of phonological variation, but rather of borrowings of particular words from the Classical Arabic lexicon. This argument finds strong confirmation in Abdel-Jawad's report that in his Amman data, there is no phonological conditioning of /q/, but only lexical conditioning. Haeri demonstrated in her own study of Cairo Arabic that /q/ was not part of a productive linguistic variable, but occurred in lexical borrowings. The variant comparable to a standard form of modern urban Arabic was the glottal stop, and here indeed, women used more of this variant than men did.

4. Multiplicative effects

Many quantitative studies use elaborate techniques to gather data in a controlled fashion, but ultimately reduce the results to a simple qualitative statement, X is significantly greater than Y in the context Z. The study of linguistic change and variation has been heading strongly in the other direction, and preserving the quantitative output to make the best use of the actual numerical relations involved. This and the following sections will attempt to show what profit is to be derived from working with more precise statements.

A classic problem in variation studies is a linguistic variable with three major variants which may be related either in a hierarchical or unstructured manner. The first of these is the study of the contraction and deletion of the auxiliary and copula in African American Vernacular English [AAVE] (Labov 1969), a topic that continues to grow and expand at the present writing. The analysis began with a the relation between contraction and deletion, It was first observed from qualitative arguments that speakers of AAVE delete or contract the copula only in those environments in which other dialects contract it. The basic conception is that contraction is the removal of an unstressed vowel, and that deletion is the removal of the lone consonant that is left after the vowel is deleted: that is, deletion can apply only to the pool of contracted forms. In their consequences for syllable structure, contraction and deletion are opposed. One of the most important bodies of evidence concerned the phonological conditioning found: the nature of the preceding segment. When the lone consonant is cliticized on a subject with a final vowel, contraction is favored; when the subject has a final consonant, deletion is favored. Both processes then favor the unmarked syllable structure CVC.

Contraction and deletion are parallel processes in regard to the grammatical environment. Both are favored by pronominal subjects, and both show a profile of following grammatical factors in the increasing order: noun phrase, adjective or locative, verb, future (*gonna*). The crucial quantitative argument is that these grammatical effects are intensified for deletion, with greater differences between the environments for deletion. In other words, the syntactic constraints seem to have applied once for contraction, and twice for deletion. This would be a natural results if they were parallel rules with parallel constraints, and deletion was fed by contraction. Figure 4 and Figure 5 show the effect of the following environment on the contraction

and deletion of *is* for the pre-adolescent Thunderbirds and the adolescent Jets. Note that the relative positions of the following predicate adjective and the following locative are reversed for these two groups. This relationship is not stable across groups (but see Cukor-Avila 1999).

Figure 4. Contraction and deletion of *is* by following grammatical environment for the Thunderbirds [N=13]. Slope of contraction: 10.0; slope of deletion:

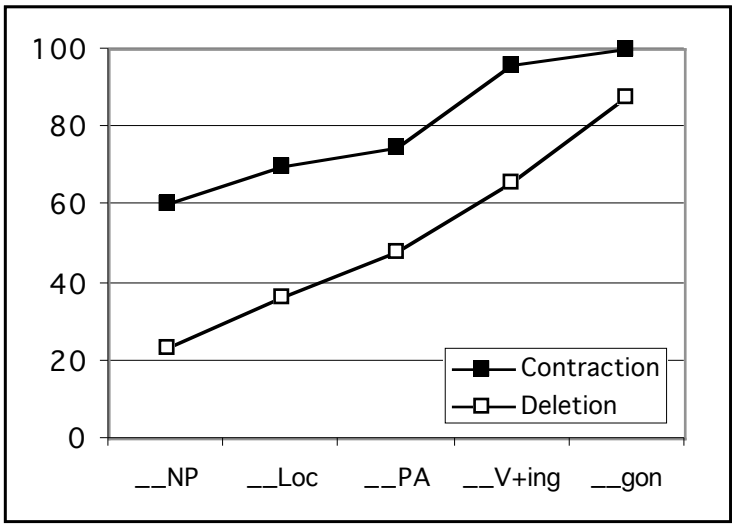
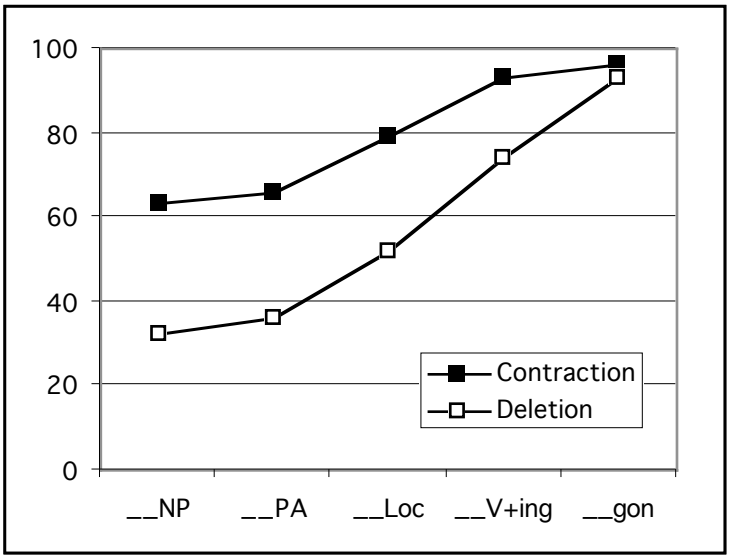


Figure 5. Contraction and deletion of *is* by following grammatical environment for the Jets [N=29]. Slope of contraction: 9.3; slope of deletion: 16.



This type of argument was given a more precise form by Guy in his studies of coronal stop deletion (1991a, 1991b). Guy discovered that the relation between the factors in the grammatical group for (TD) was exponential:

regular past tense clusters	x
semi-weak derivational clusters	x^2

monomorphemic x^3

These results have been supported in a number of studies since then (Santa Ana 1992, Bayley 1994). In the period since Guy's initial publication, I have students in Quantitative Analysis at the University of Pennsylvania carry out tests of Guy's exponential relationship in their own data. In five successive trials, the exponential relation was found the best fit to the data.. Table 1 shows the numbers of tokens and percent clusters retained for the preterit, derivational and monomorphemic sub-classes for each successive year. Below this is the estimate of the probability of retention, calculated as the same as the percent retained for the preterit, the square root for the derivational class, and as the cube root for the monomorphemic class. All of these figures are of course subject to chance deviations. The "best fit" column shows the probability that fits the over-all data best in terms of the minimal chi-square in the last column. This is of course closest to the sub-class with the most data, the monomorphemic class. None of the chi-square figures shown are large enough to register a deviation from the exponential model greater than one would expect by chance. No other mathematical model tested—linear, logarithmic, polynomial--showed a fit of this kind over the whole range of data.

Table 1. Five tests of the exponential relationship in coronal stop deletion, 1991-1997. [Source: Linguistics 562: Quantitative Analysis]

		Preterit	Deriva-tional	Mono-morphemic	Best Fit p_r	Chi-sq
1991						
	N	100	53	539		
	Retained	79	29	221		
	p_r	0.79	0.73	0.74	0.74	0.37
1992						
	N	116	64	583		
	Retained	93	32	250		
	p_r	0.80	0.71	0.75	0.75	0.93
1995						
	N	404	229	922		
	Retained	323	149	496		
	p_r	0.80	.80	0.81	0.82	0.67
1996						
	N	96	82	374		
	Retained	85	62	219		
	p_r	0.88	0.87	0.84	0.84	0.56
1997						
	N	258	90	906		
	Retained	209	71	491		
	p_r	0.81	0.89	0.82	0.82	1.99

The exponential model has then received strong empirical confirmation. How are we to account for it? Guy's reasons that this multiplicative effect nust be the result

of repeated applications of the same constraint, that is, a cyclical effect. Such a cyclic process is found in the framework of Lexical Phonology, where a rule is applied within brackets which are successively erased as new material is added to the construction. Thus the rule would apply to monomorphemic forms alone in the narrowest scope, to monomorphemic forms and semi-weak clusters at the next stage when derivational (Level 1) suffixes are added, and to all three when at the next stage when inflectional (Level 2) suffixes are added.

A similar model should logically apply to other variables and other languages. Guy is currently examining the reduction of final consonants in Spanish and Portuguese to see if the same logic applies. The status of Lexical Phonology as a theory is now in flux, and it remains to be seen if the cyclical argument will receive other empirical support. Here my focus is on the form of the argument: that multiplicative relations imply such a hierarchical structure.

5. Correlations among linguistic variables

This report has moved from the study of single linguistic variables to the analysis of conjoined and sequential variables. The techniques of analysis and reasoning just discussed carry the linguistic argument to several levels of abstraction beyond the surface data. The simpler technique of correlation can lead to equally strong conclusions when it is applied to a larger number of dependent variables.

Table 2 is an assembly of all possible Pearson product-moment correlations among 12 linguistic variables in the study of change and variation in the Philadelphia speech community. Correlations, above .5, are outlined with black borders; intermediate correlations from .3 to .5 in grey.

Let us first consider correlations among variables of the same type. The highest correlations are naturally found among allophones of the same phoneme. The three /æh/ allophones at upper left have correlations above .8, But the correlation of the two new and vigorous changes /aw/ and /eyC2/ with them and with each other are almost as high. The entire set outlined in black at upper left represents the most heavily weighted among changes from below. Thus the unity of sociolinguistic processes is at the same level as the structural relationship of allophonic identity

A second set are the stable sociolinguistic variables (DH), (NEG) and (ING). They are strongly correlated with each other, as shown in the lower right corner. It is important to note that the indexes of all three are set so that the higher the value, the higher the use of stigmatized forms.

A third set are the four allophones of /ow/ and /uw/. The grey boxes indicate that the are only moderately correlated with each other, and not particularly with any other set of variables. This corresponds with the weak social and age stratification found for these variables in the neighborhood studies.

A great deal is to be learned from examining how these sets are correlated with each other. The grey boxes at lower left indicate that there is a moderate correlation between the stable sociolinguistic variables and the nearly completed raising and fronting of /æh/. In fact, the latter was the only linguistic change in progress to be mentioned by Philadelphians in the field matched guise experiments. The stigmatization of /æ/ raising was used as a test case for normalization: it is so firmly established in fact that any normalization process that weakened it would have to be

rejected (Labov 2000:Ch. 5). Yet these moderate correlations are not found between the stable sociolinguistic variables and the new and vigorous changes /aw/ and /eyC2/. The absence of social stigma with the newer changes is thus clearly demonstrated in the correlation matrix. A set of low negative correlations are found between the stable sociolinguistic variables and the fronting of /uw/ and /ow/. This shows even more clearly that these vowels do not function as sociolinguistic markers, in sharp contrast to the front vowels.

Table 2. Pearson product-moment correlations among 12 Philadelphia variables. aehN, æhS, æh$ = F2 of /æh/ before nasals, fricatives, and apical stops (*mad, bad, glad*); aw = F2 of /aw/; eyC = F2 of checked /ey/; owC, uwC = F2 of checked allophones; owF, uwF = F2 of free allophones; The three sociolinguistic variables (DH), (NEG), (ING) are careful speech values..

	aehN2	aehS2	aeh$2	aw2	eyC2	owC2	uwC2	owF2	uwF2	dhb	N%B	lPGB
aehN	1											
aehS	0.83	1										
aeh$	0.81	0.84	1									
aw	0.72	0.7	0.73	1								
eyC	0.67	0.64	0.62	0.66	1							
owC	0.18	0.12	0.13	0.33	0.23	1						
uwC	-0.1	-0.1	-0.1	0.05	-0.13	0.48	1					
owF	0.13	0.12	0.18	0.25	0.12	0.54	0.39	1				
uwF	0.23	0.12	0.22	0.33	0.14	0.47	0.38	0.5	1			
(DH)	0.23	0.31	0.39	0.21	0.18	-0.3	-0.1	-0.1	-0.1	1		
(NEG)	0.31	0.38	0.35	0.22	0.2	-0.2	-0.1	-0.2	-0.1	0.6	1	
(ING)	0.18	0.37	0.39	0.15	0.09	-0.2	-0.1	-0	-0	0.58	0.49	1

6. The analysis of apparent time

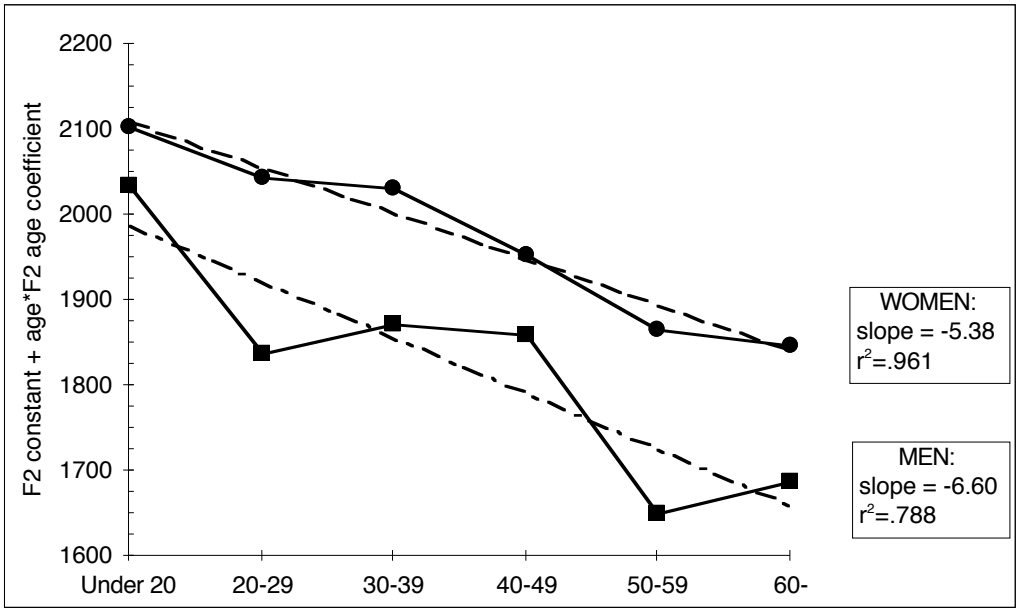
The earliest treatments of change in progress inferred the existence of change from the existence of monotonic functions in age distributions, or *apparent time*. , coupled with auxiliary data from real time studies (Labov 1963, 1966). Some recent comparisons of real time and apparent time data have confirmed the fact that such apparent time functions do reflect change in real time (Bailey, Wikle and Sand 19??). On the other hand, re-studies of the same speakers in real time have regularly shown a mixture of age-grading and community change (Cedergren 1984, Trudgill 1988).

In the discussion of independence and interaction above, it was pointed out that gender and social class normally show strong interaction. This observation holds for stable sociolinguistic variables and for changes from above. However, it does not hold for the new and vigorous changes in progress in Philadelphia that are, like most changes from below, led by women. The difference between men and women in the fronting of /ey/ and /aw/ is independent of social class (Labov 1990). This leads us to believe that the gender differences in changes fom below are due to distinctly different causes than gender differences in changes from above or stable variables.. The independence of the gender effect in changes from below must be associated with a phenomenon that is common to all social classes. One candidate explanation is based

on the asymmetry of language learning. The great majority of children acquire their first language from a female caretaker. It follows that if a linguistic change is more advanced for women, it will be accelerated. On the other hand, if a change is one of the minority that is more advanced among men, the female caretaker will be transmitting a relatively conservative form to children, and the change will be decelerated. The fact that few linguistic changes are male-dominated is consistent with this logic (Labov 1990).

As noted above, the Philadelphia case is far from exceptional. Most studies of linguistic change in progress show that women are ahead of men by about one generation (Gauchat 1905, Labov 1966, Chambers and Hardwick 1986, Haeri 1996,). Moreover, a close examination of the progress of the change shows that the incrementation among women is approximately linear.[15]. Figure 6 shows regression analyses of the fronting of /aw/ by decade for men and women separately. For women, the decade-by-decade analysis is almost linear. A second regression line drawn through these points has an r^2 of .961, indicating that the straight line explains 96% of the differences from the mean. On the other hand, the decade-by-decade analyses for men follow a more step-like pattern. with an r^2 of only .788. The implication seems clear. The linear incrementation among women indicate that they participate in the change beyond the initial impetus given by their mothers. Men do not, and the step-like pattern reflects the increase that occurs as each generation learns their first language from women whose linguistic forms have steadily advanced.

Figure 6. Regressions analyses of the fronting of /aw/ for men and women by decade in Philadelphia. [Source: Labov 2000, Figure 9.5].



[15] All measures given in Figures 6 and 8 are carried out on formant measurements that have been normalized with the log mean normalization (Labov 2000:157-162).

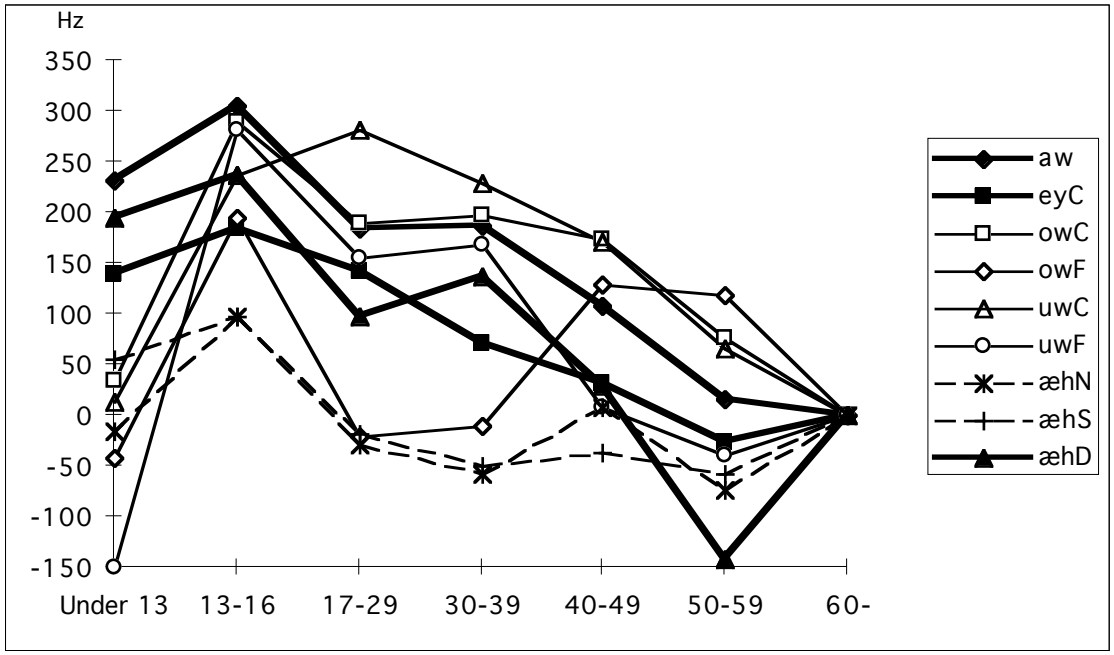
Figure 6 shows the monotonic function of age in apparent time for women. However, the original idea that change in real time would be associated with monotonic functions in apparent time (Labov 1972) does not hold up under closer examination. If children learn their first language forms from their parents, it cannot be the case that the youngest children have the most advanced forms of the change in progress. Linguistic change demands that children must learn to talk differently from their parents, and since most linguistic changes continue in the same direction for a century or more, this re-learning must continue in the same direction across many generations. At the heart of the *transmission problem* there lies the *incrementation problem* (Labov 2000, Chs. 13,14).

It is not likely that incrementation continues throughout the speaker's lifetime, although it may not stop abruptly at some critical age. But whatever model of incrementation we choose will show a peak at some age later than first acquisition—perhaps in early adolescence, or late adolescence, or even in early adulthood. Figure 7 shows a model of incrementation that traces the level of female speakrs for a hypothetical change that began in 1913. Each speaker acquires the change at the level of her mother, and participates in a logistic incrementation process from 5 to 17 years of age. The increase is not linear, but logistic, following the same s-shaped curve as the community. A 9 year old in 1925 would have participated in the change from 5 to 9. A17 year old would have entered into the change 12 years before and participated in it for 8 years. A young woman who was 21 years old in 1925 would have remained at the lower peak that she reached in 1921 at the age of 17. A 29 year-old who was born in 1896 would not have participated in the change at all, since she reached the age of 17 just as the change was beginning. The adolescent peak is clearest in the second generation of 1950. A child at the age of 5 then begins at the level of her mother who was born in 1920, and reached the peak level of 20 units in 1937. This is the generation in which change is most rapid, at the half-way point in the logistic curve. The adolescent peak is much less clear in the 3rd generation, and all but disappears s the change nears completion.

Figure 7. Model of logistic incrementation from 5 to 17 years of age for four generations of female speakers in a hypothetical change that began in 1913 [Source: Labov 2000: Fig. 14.5.ß

This incrementation model approximates the linear pattern for adult women of Figure 6. but only for the 2nd and 3rd generations. It does correspond to the patterns found for youth when speakers from 8 to 17 are examined. Figure 7 shows the age coefficients for the nine linguistic changes in progress led by women that involve changes in F2. Each age group forms a dummy category with a value of 1 for a speaker in that age range, and 0 for all others. Eight age groups show a peak in the 13-16 year age range, and one—the fronting of free /uw/, has a peak in the 17-29 year range. The new and vigorous changes are marked with bold lines, with remarkably similar profiles. All lines converge at 0 for the 60 and over age group, since that is the residual point of reference for this set.

Figure 8. Normalized coefficients for age groups of female speakers for nine linguistic changes in progress led by women in Philadelphia. [Source: Labov 2000:Fig. 14.9].



Summary

This report has presented a variety of different modes of quantitative reasoning using data on linguistic change and variation to answer fundamental questions about language structure and language change. It is of course true that the inferences to be drawn from quantitative data can be no stronger than our confidence that the data is significant and replicable. However, it is the direction of inference and reasoning that justifies the enterprise as a whole.

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