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The costs and benefits of phonological analysis

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1. Introduction

This year we mark the 20th anniversary of the publication of Chomsky and Halle's *The Sound Pattern of English* (SPE), one of the important events in recent linguistic history and one that influenced the lives and practice of virtually all phonologists. The work put us firmly on the track of studying language for what it would reveal about "the nature of mental processes" (SPE: viii). Although there has been a virtual explosion of activity in phonology stimulated by SPE I would venture the opinion that none of it has brought us any closer to a true understading of the mental processes serving language. The problem, simply put, is this:

> ...sooner or later...it is going to be necessary to discover conditions on theory construction [in linguistics], coming presumably from experimental psychology or from neurology, which will resolve the alternatives that can be arrived at by the kind of speculative theory construction linguists can do on the basis of the data available to them. That is, there will come a point, no doubt...where one can set up alternative systems to explain quite a wide range of phenomena. One can think that this or that system is more elegant and much more deep than some other, but is it right?
>
> ...it seems to me that in phonology that point may have been reached.
>
> (Chomsky 1967: 100)

The dismaying thing is that this quite sensible assessment of the state of phonology was made 21 years ago and was ignored then and has been ignored since. What we have instead is a kind of Brownian motion through the possible theoretical space. We should continue to spin theories, of course, but in order to be able to select among them we must evaluate or

test them, especially by experimental means. As Chomsky suggests, to evaluate theories of the mental structures underlying language, experimental psychological techniques should assist us. We should not, however, take this to mean that we should let the people in psychology test our theories for us; we ask the questions, so we are responsible for getting acceptable answers to them using whatever methods work, whether these are borrowed from other fields like psychology or whether we have to devise our own. (See also Ohala and Ohala 1974; Ohala and Jaeger 1986; Ohala 1970, 1983, 1986a,b, 1988.)

In this paper I propose to give a rather discursive review of some of the issues surrounding the psychological aspects of phonology, i.e., what native speakers know about the sound patterns in their language and especially what is in their lexicon. The following is a brief "road map" of the paper. In Section 2. I suggest that speculations on how phonological knowledge is represented in speakers' brains should be done using a "cost-benefit" analysis, i.e., finding how speakers could best do what they need to with the sound patterns in their language given all the constraints they operate under. Estimating the simplicity of rules or grammars by itself doesn't satisfy this. In Section 3. I offer some speculations and some experimental results which suggest that many speakers of English would have considerable difficulty constructing a phonology like that outlined in SPE because: morphemic constituents of polymorphemic words may be hard to find, general phonological patterns may be hard to detect due to exceptions, mere exposure to general patterns doesn't mean people will recognize them, and the payoff from constructing an SPE-like phonology is too poor to justify it. Cut-and-paste rules will handle the crucial task of extending existing sound patterns to novel derivations.

2. In evaluating the cost of proposed phonologies, simplicity isn't enough

In traditional generative phonology the only method, if it could be called that, for evaluating competing hypotheses or theories was to attempt to gauge their relative simplicity. The assumption was that only true generalizations would merit representation in the grammar; particularizations would simply be listed in the lexicon, the compendium of all idiosyncratic information about the language. The generality of a description should correlate with its simplicity which could be measured in turn by counting the

number of elements in the description. I do not reject simplicity as a valid criterion to apply in the evaluation of candidate hypotheses, but my view differs from the generative view in important ways.

2.1 *Simplicity is only part of the evaluation of grammars*

First, I assume that simplicity is just *one* aspect contributing to the initial evaluation of competing hypotheses. This is especially true when one deals with the behavior of purposive, teleological systems. Examples of such would include: the animal whose goal is to survive and reproduce itself given its genetic and environmental resources, the computer engineer whose goal is to make a machine that can perform in a specified way given economic and technical constraints, and, of course, the human whose goal is to communicate via speech.

Consider a simple example. Imagine you wanted to make a computing device that could generate the integer series in (1) and you had further determined that you didn't want to do it by simply storing a large number of the elements of the series as a list because you expected the device to produce any member of the series.

(1) 1, 3, 6, 10, 15, 21, ...

As is well known, there are at least two algorithms for generating this series, those in (2) and (3).

(2) nth member of series = $\sum_{i=1}^{n} i$

(3) nth member of series = $(n+1)*(n/2)$

Which algorithm one implements in the machine will depend on a number of things. If simplicity is desirable, where this is measured by the number of elements and operators in the algorithms, then (2) would be optimal. For large n it would be slow, though, since n additions would be necessary. If speed were important then (3) would be best. If the complexity of the operations mattered, the fact that (3) required the mathematical operations of multiplication and division would make it less preferable. In computers these require shift registers, an extra expense, whereas the cheaper comparators, accumulators, and the like would be all that the machine imple-

menting (2) would require. In real life the purchase or design of a computer system requires taking into account ease of input and output, the rate of obsolescence of the machine, its compatibility with previously-written software, cost, size, energy consumption, and a host of other factors. Simplicity is one criterion out of many that are considered — and then not necessarily the dominant one.

In the biological domain sexual reproduction is a prime example of living systems solving a problem in a way that rejects simplicity. Obviously it would be much simpler to reproduce asexually: only one parent is required, no courtship, etc. Considerations other than simplicity must predominate.

Simplicity, then, is only one of many factors relevant in the selection of an optimal algorithm and an optimal grammar. Linguists have not spent much time trying to find out what the various "costs" are when humans construct grammars. In particular, they have not really faced what the speaker uses phonological knowledge for. Costs cannot be assessed independently of the goal — the payoff, the benefit — motivating the expenditure. Is computation (rule extraction or generalization) costly? Or perhaps rule implementation, or memory size, or time to retrieve data from memory, or flexibility (the possibility of changing the items in storage or the form of the rules)? Anecdotal evidence suggests that memory is often cheap in comparison with computation. Consider, for example, the colored bands on electrical resistors that code the numerical value of the resistance in ohms, where red equals "2" and orange equals "3", etc. Various mnemonic jingles exist (usually somewhat racy) to help the electronics engineer remember the code. Experienced engineers know these jingles for their entertainment value but do not use them; through long familiarity with various resistors they have simply memorized the color pattern for hundreds of resistor values. Similar anecdotes exist regarding librarians and the hundreds of call number types which categorize books. The relevance of this to grammar construction is not clear but it does indicate that generalizations or rules, which bring some order into what would otherwise just be long lists of entries, are not always optimal psychologically.

In a great many other behavioral sciences "cost-benefit" analysis has already been successfully introduced. Two key aspects of this new approach are that, first, systems are often treated quantitatively; models are constructed and their behavior compared with that of the living systems they are supposed to represent. Second, these investigators impose no artificial or a priori standards of "correct" or optimal behavior but simply try to discover the internal logic of the behavior of their subjects: what are their resources?, what are their goals?, can the behavior be understood in terms of these? Accordingly, ethologists and anthropologists explore the "payoff" of altruistic behavior, deceptive behavior, even of self-destructive or anti-social behavior such as anorexia nervosa, suicide, aggression, and cannibalism.

In linguistics, especially in phonology, I think we are imposing on our subjects, the native speakers of languages, norms of behavior that are essentially are those appropriate for linguists (see also Derwing 1977). With few exceptions we have seldom asked what speakers want to do and need to do with their language, what their resources are and how they accomplish their goals within these constraints. At this stage in our knowledge of what speakers do with their phonology we should probably not characterize our statements as anything more than informed speculation but we should nevertheless make some start on this problem. Lindblom (1983a,b 1986) has begun such work, attempting, in his words, to "derive spoken language from non-language", that is, from bio-mechanical considerations.

2.2 *Testing must follow any cost analysis*

The second way I differ from generative phonologists in the use of simplicity is this: Even though simplicity may play a part in helping us select from among competing hypotheses the hypothesis we may want to give initial *tentative* allegiance to, simplicity and the other measures contributing to cost can never by themselves determine whether that hypothesis is better than any of the others. The only way to do this is by testing. It was considerations of simplicity (and tradition) that led early astronomers to posit circles underlying the planetary orbits. This was reasonable as a first choice from among the infinitude of possible orbital shapes. As we know, though, subsequent work showed this first choice was wrong.

3. The epistemology of phonology

The lexicon is assumed to be the store of all idiosyncratic information about words or morphemes. This includes, of course, all words derived or inflected if either the meaning, pronunciation, or any other necessary detail, e.g., connotation, usage, spelling, etc., cannot be predicted from the

simple concatenation of its constituent morphemes. Thus *extremity* would be listed because some of its meaning and connotation cannot be derived from the constituents *extreme* and *ity*. Presumably the simple fact that a given derivation has been made (coined) with a specific word would merit its separate listing if the same derivation is not automatic with all eligible words. Thus even though the meaning and usage of *oddity* seems fairly predictable from the meanings of its constituents, the fact that *oddity* exists but any number of other adjectives' derivation with *-ity* do not (**pality* < *pale*, **pristinity* < *pristine*) would have to be registered. Even perfectly regular plurals like *corpuses* and *indexes* may be stored since one needs to know that they are viable alternatives to the irregular plurals *corpora*, and *indices* (which, of course, would also be stored).

The issue is: what other information does the lexicon have? In particular, does it include information about the systematic *phonological* relationship between say, *extreme* and *extremity*?[1] *Yes* is the answer given by generative phonology and every major school of phonology that followed from it. A fragment of such a lexicon might be something like that in (4).

(4) /ɛk'strim/ [ɪk'stɹĩm] //ĕkstrēm//
(plus: meaning, connotations, gram. class, spelling, usage.)

/ɛk'strɛmɪti/ [ɪk'stɹɛ̃mɪɾi] //ĕkstrēm + ĭtĭ//
(plus: meaning, etc.)

/ɪti/ [ɪɾi] //ĭtĭ//
(plus: meaning, etc.)

The relationship between the pronunciation and the underlying form (marked by double slashes) would be motivated by the existence of phonological rules in the grammar — e.g., vowel laxing and vowel shift. In fact, the underlying forms (insofar as they differ in any detail from the surface pronunciation) and the phonological rules must be constructed simultaneously since neither would have any motivation without the other. Henceforth I will refer to this type of posited mental construction as an "SPE phonology" but apply this as well to many more current phonological approaches since they operate under the same assumptions.

Relatively little attention has been given to how this knowledge is obtained (however, see Derwing 1976, 1977, 1979; Derwing and Baker 1977; Derwing and Nearey 1986) but it is possible to establish the following sequence. In order to construct underlying forms and phonological rules it

is necessary to recognize a general phonological relationship between words; to do this one has to first suspect that the words are related and to do that one has to be able to detect the constituent morphemes and the morpheme boundaries. I'll explore each of these in turn.

3.1 *Recognizing derivational relationships between words*

As Derwing and his co-workers have remarked, in order for a native speaker to even conceive that two words are related by rule it is plausible that the two words should be phonetically and semantically similar. Thus *teach*, *teacher* would meet both criteria but *dog*, *puppy* and *lathe*, *lather* only one (different ones), and *quick*, *bio(logy)* neither (even though the latter pair are in fact historically related). Derwing's evidence suggests that semantic similarity counts for more than phonetic similarity and that the degree of similarity in both parameters must be very high in order to obtain a confident judgment from subjects that words are related.

1. *Discovering the constituent morphemes*

But there must be other prerequisites to constructing a lexicon like that in (4) and the accompanying grammar. The vast majority of derived and inflected words, like those in (4), are created by the concatenation of morphemes. Speakers must know that such forms consist of two or more morphemes (recurring phoneme strings which have the same or similar phonetic and semantic characteristics) and they must recognize where the boundareis of those morphemes are. The more that phoneme strings differ phonetically and have meanings not completely determined by the concatenation of the candidate parts, morphemes will be harder to recognize. I think the difficulty that the native speaker faces in discovering the full range of morphemes in a language like English has been seriously underestimated (however see Henderson 1983) — primarily because those making the identification of the constituent morphemes of complex words are:

(a) linguists
(b) highly educated, and
(c) literate

We must keep in mind, however, that none of these characteristics are essential prerequisites to being a native speaker of a language (see Derwing 1977).

The problem of phonetic dissimilarity between the "same" morpheme would affect some forms more than others. For example, in the case of the stem morpheme in *conclude*, *conclus-ion* (phonemically /kʌn'klud/, /kʌn'kluʒ-/) there is only one out seven phonemes different (14%) but in *type*, *typ-ify* (phonemically /tɑjp/, /tɪp-/) there is one out of three (33%), a much larger percentage of the whole.[2] The relationship of the latter pair, then, should be harder to recognize than the former.

Much has been written about how the meaning of complex derived words cannot always be determined from the meanings of their constituent morphemes. The examples in (5) are ordered approximately according to increasing opacity of the meaning of the derived word with respect to the meaning of its constituents.

(5)

divinity	(cf. divine)
nationality	(cf. nation, national)
extremity	(cf. extreme)
community	(cf. commune)
cupidity	(cf. cupid)
authority	(cf. author)

It is not surprising that the pronunciation and/or meaning of derived words can wander from those of its constituents; this is one of the marks of a lexical item. But when this happens it reduces the payoff of the speaker's efforts to try to puzzle out the constituent morphemes. (I would wager that one would get an "aha!" or "gosh! I never thought about that" response from a majority of English speakers for at least two of the word pairs in (5).)

Another circumstance which reduces the payoff of morphemic parsing is the extent to which the language presents "false leads", that is, offers apparent opportunities for morphemic decomposition of words only to have such efforts lead to nothing. These are well known and have been systematically catalogued in every work on morphology but the significance of the vast quantity of false leads in the language has not been fully appreciated. Due to limitations of space, however, I will only be able to give a few examples of this.

First, the existence of polysemy[3] in words discourages speakers from expecting recurring phoneme strings to have any connection that might be useful to them. Polysemy is rampant in most languages. Some innocent and some egregious examples from English are given in (6).

(6)

chapter (of book)	chapter (of organization)
/bitʃ/ 'beach'	/bitʃ/ 'beech'
/hæv/ 'have'	/hæv/ 'halve'
spit (saliva)	spit (skewer)
	spit (land jutting into water)
lash (of eye)	lash (to whip)
/hoŭ/ whole (i.e., everything)	/hoŭl/ hole (i.e., nothing)
/reĭz / 'raise', i.e., elevate	/reĭz/ 'raze', i.e., bring down

To compound the problem, polysemy in English is especially evident on the "small" frequently-occurring words like /hæv/ and /hoŭl/.

Another cause of disappointment to the would-be morpheme hunter is extractable word parts that do not have any meaning separable from that of the whole they appear in. These are the well-known *cranberry* morphs and their ilk, e.g., *cran-*, the part that remains after the recognizable part *berry* is factored out of the word. They are profuse in the English lexicon and those of many other languages; some examples are given in (7).

(7)

capac-ity veloc-ity	given the potential extractability of *-ity* from forms like *density* and *serenity*
med-ian pedestr-ian	given the potential extractability of *-ian* from forms like *librarian* and *Parisian*
top-ic ep-ic fabr-ic eccentr-ic	given the potential extractability of *-ic* from forms like *historic* and *symmetric*

These examples cover cases where a historical analysis might reveal recognizable morphemes, e.g., the stem of *eccentric* as *ex* + *center* or *fabr-* recurring in *fabricate*. But this is little consolation to the language learner who lacks the expertise to conduct internal reconstruction.

There are, in addition, cases where similar phoneme strings recur due to chance where not even a historical analysis would find a useful relationship; examples are given in (8).

(8)

syntax	=	sin tax
migraine	=	my grain
antique	=	Ann teak
fanfare	=	fan fare (or fair)
kitchen	=	kit chin
crocodile	=	crock o' dial

Jaeger (1986) reports that her 3-year old daughter formed the candidate morpheme /ɛrɪkən/ which recurred in the two expressions *Eric 'n Lorell* and *air-conditioner*. No doubt she eventually learned that her efforts at morpheme extraction in this case were not rewarded.

Although punsters and fans of the New York Times' cryptograms may take joy in the dissimilarity of meanings of similar phoneme strings, to language learners who are trying to simplify their lexical and morpheme storage, polysemy can only appear unseemly.

The point is that *exceptions and false leads add to the cognitive cost of formulating generalizations*. They don't necessarily invalidate the generalization but they may inhibit the language learner from attempting to find them.

2. *Recognizing morpheme boundaries*

There is another difficulty confronting the speaker attempting to make a grammar and lexicon resembling that outlined in SPE. In some cases even though the presence of two or more morphemes in a derived or inflected word may be clear, it is not always transparent where the morpheme boundaries are. Nevertheless, the accurate location of morpheme boundaries is essential for an SPE phonology. The problem is that inevitably many morphophonemic variations take place at the junction between morphemes and therefore obscure their boundaries by reducing the portion of the phoneme string that repeats or recurs; examples are given in (9).

(9)

critic	criticize
[k]	[s]
diplomat	diplomacy
[t]	[s]
formula	formulaic
[ə]	[ej]
act	actual
[t]	[tʃ]
Thom	Thompson
[m]	[mp]

Accordingly, subjects have much more trouble identifying the morphemic constituents in words like *criticize* than they do in words like *explanatory* (Ohala 1986a). A few novel derivations attest to the same difficulty. *Witticism*, according to the OED, was introduced by Dryden who apparently took the ending *-cism* from words like *criticism* or *skepticism*, thus showing confusion about the placement of the morpheme boundaries in such words. One might also speculate that such mistakes also originate from an expectation that morpheme boundaries should coincide with syllable boundaries (which are generally agreed to favor CV over VC as syllable onsets). This would help to explain derivations like *Congolese* which, according the Malkiel (1966), was modeled after *Angolese* (or, strictly speaking, the French words from which these were borrowed), where the morpheme boundary was erroneously placed before the *l*. The consonants intruding just after the stem morpheme in *tobacconist*, *egotist*, and the like, may have the same explanation. Related to this is my experience that linguistically naive English speakers are rather surprised to learn that words incorporating Greek morphemes such as *helicopter*, *amnesia*, *agnostic*, contain the morphemes *-pter*, *-mnes-*, and *-gnost-*, respectively. The reason may be that these are not legal syllable onsets in English.

Relevant to this is a psycholinguistic experiment conducted by Esper (1925) in which groups of English speakers were required to learn the *names* of objects which could have different shapes or different colors. Subjects could readily discover "morphemes" hidden in names such as those in (10a) where syllable boundaries would coincide with the recurring phoneme strings (yielding the "morphemes" /nas/, /weč/, /liŋ/, /deg/, which correlated with Color 1, Color 2, Shape 1, and Shape 2, respectively), but had great difficulty doing that with names such as those in (10b) where this was not true (yielding corresponding "morphemes" /lgɛn/, /zgub/, /nu/, /pe/).

(10)

a.

	Color 1:	Color 2:
Shape 1:	naslin	wečliŋ
Shape 2:	nasdeg	wečdeg

b.

	Color 1:	Color 2:
Shape 1:	nulgɛn	nuzgub
Shape 2:	pelgɛn	pezgub

3.2 *Recognizing the generality of sound patterns*

A second thing necessary to detecting a phonological relationship between words like *extreme*, *extremity* is to notice that the relationship is a general one, i.e., that it is found in many word pairs. Taking the identical vowel alternation, there are examples such as those in (11a) and, if one claims that

all tense-lax vowel alternations represent the same pattern, there are scores more, some examples of which are given in (11b).

(11)

a.		b.	
serene	serenity	divine	divinity
obscene	obscenity	sine	sinuous
supreme	supremacy	type	typify
exegesis	exegetical	sign	signify
ethos	ethical	cone	conical
academe	academic(al)	sane	sanity
meter	metric(al)	ramus	ramify
peter	petrify	profound	profundity
Venus	venery, venerate	rate	ratify

This prerequisite stems from the very fundamental notion that the rules of grammar are generalizations; they are supposed to bring some order or simplicity into what would otherwise be just a long list of independent items. Particularizations, that is, abstracted patterns manifested on only one or a small number of word pairs, e.g., that on *pope*, *papal*, would not simplify the representation of words but would just complicate it.[4] This leads us to the hypothesis that speakers should see a closer derivational relationship in word pairs exhibiting a common sound pattern (one with lots of similar examples) than in pairs exhibiting an isolated pattern (one with few similar examples). Ohala and Ohala (1987) tested this.

In their experiment[5] which was adapted from that of Derwing (1976), they first gathered 20 word pairs exhibiting a common phonological pattern (see 12a) and another 20 exhibiting an isolated pattern (see 12b). For ease of reference, I'll call these the "extremity" and "papal" words, respectively.

(12)

a. *Common Patterns*	b. *Isolated Pattern*
extreme / extremity	pope / papal
particle / particular	thumb / thimble
substance / substantial	strong / stringent
resume / resumption	applaud / plausible
abstain / abstention	peace / pacify
regal / regicide	nose / nuzzle
comprehend / comprehensive	slay / slaughter
erode / erosion	price / precious
permit / permission	mouse / muscle
proper / propriety	toad / tadpole
secret / secretary	confer / confession
Peter / petrify	live / liver
magnet / magnesia	linger / lingerie
vine / vinegar	page / pageant
fable / fabulous	promise / promiscuity
glass / glacier	tame / timid
vocal / vociferous	leap / leopard
marine / marinate	male / malicious
slipper / slippery	risk / rescue
sect / section	haste / hassle

As in the Derwing experiment, these words, randomized and supplemented by other "filler" word pairs that were not of interest for the sake of this study, were presented individually and orally to 16 native speakers of English, educated members of the University of California, Berkeley, community who had had no linguistic training. On the first run through the list subjects were asked to estimate the likelihood that the two words were historically related, that is, had both been derived from a common source. (Admittedly, this is not exactly what generative phonologists mean when they posit a connection between words by way of a common underlying form, but we were unable to discover any other way to express the notion of this connection which would make sense to linguistically naive subjects.) They gave their estimate in terms of a five-point scale, where 1 = very unlikely and 5 = very likely. After obtaining these derivational judgments, the same list was run through and subjects asked to rate the degree of semantic similarity, also using a five-point scale. Finally, the same list was presented and subjects were asked to rate the degree of phonetic similarity. Before each run we offered and discussed a smaller practice set of different word pairs whose ratings would not be controversial, e.g. *parasol / umbrella*, *lamb / lamp*. Subjects were told that their judgments would help us select items that would be used in an aptitude test for high school students and that their answers should simply reflect their intuitions as educated adults.

Lists such as those in (12) are not easy to make and one or another pair may have special associations for some subjects. The relationship between *Peter*, *petrify*, for example, is generally known to those who have read the Bible carefully (given Christ's pun on St. Peter's name); those unfamiliar with the Bible would probably react to this in about the same way as they would to *magnet*, *magnesia*. Also, in (12b) not all the word pairs are actu-

ally related historically, namely those from *confer*, *confession* to *haste*, *hassle*. We as linguists know this but it is not clear that linguistically naive subjects would. (As it happened, some of the historically unrelated pairs, e.g., *tame*, *timid* got higher derivational ratings than some of those which are historically related, e.g., *strong*, *stringent*.) What we tried to do was to include in both lists pairs that would be likely to span as full a range as possible of judgments on semantic and phonetic similarity. It is appropriate to the test that some pairs get high ratings and some get low ratings on one or another of the parameters tested.

In analyzing the data we were interested in the value of the derivational judgment as a function of both the semantic and the phonetic judgments. Our hypothesis, recall, was that the derivational rating would be higher for the "extremity" words than the "papal" words (given comparable semantic and phonetic ratings). In agreement with Derwing's earlier findings, it turned out that the phonetic judgments contributed very little to the prediction of the derivational judgment, that is, accounted for very little variance, 4.4%, so we conducted the rest of our analysis based only on the derivational vs. semantic ratings. Using the least squares method we found a logarithmic function that accounted for the most variance, 32.5%, that is, of the derivational judgments on all 40 word pairs as a function of the semantic judgment; this is the solid line in Figure 1. The broken and the dotted lines on the same figure show the same function for the 20 "extremity" pairs and the 20 "papal" pairs, respectively. The regression lines show that the 20 "extremity" words have higher derivational ratings than do the "papal" words but it turns out that dividing the words into these two smaller groups does not account for significantly more variance than the original regression line for all 40 words as a single group. Therefore we concluded that there was no significant difference in the behavior of the two groups of words. Of course, it would be worthwhile to re-do the experiment with more subjects and, conceivably, with some modifications in the word list, instructions, etc. Pending such revisions of the experiment, it is safest to infer that a systematic phonological relationship does not enhance the apparent derivational relationship of word pairs; speakers are as likely to see such relationships in word pairs with a general pattern as those with an isolated particular pattern.

One reason why speakers may find little reward in paying attention to general phonological patterns such as those exemplified on *extremity* and *particular* is that, first, there are exceptions to these patterns and, second,

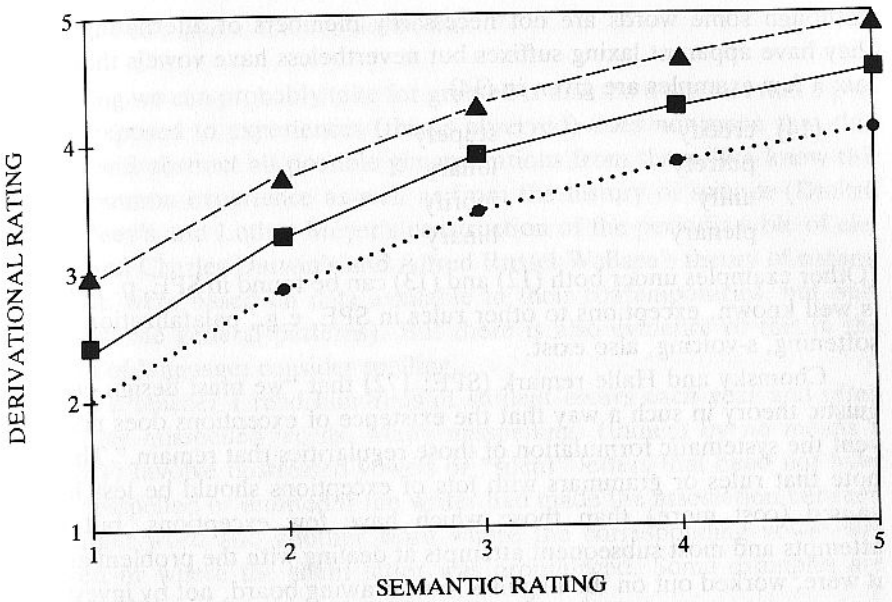

Figure 1. Logarithmic regression lines obtained by least-squares method showing subjects' derivational rating (abscissa) as a function of their semantic rating (ordinate) for various word pairs; dashed line/triangles: 20 pairs of the type *extreme / extremity*, dotted line/circles: 20 pairs of the type *pope / papal*, solid line/squares: all 40 pairs. (From Ohala and Ohala 1987.)

words that one would expect to exhibit the pattern do not. Examples of exceptions to the vowel laxing rule are given in (13).

(13)

obese, obesity	crude, crudity
probe, probity	nude, nudity
immune, immunity	note, notify, notary
between, betweenity	prose, prosify
cube, cubical	psyche, psychical
cherub, cherubical	muse (music), musical
anecdote, anecdotical	speech, speechify
grain, granary	prime, primary
bean, beanery	accuse, accusatory
chicane, chicanery[6]	explode, explosible

Although some words are not necessarily members of alternating pairs, they have apparent laxing suffixes but nevertheless have vowels that don't lax; a few examples are given in (14).

(14)

crucify	stupefy
putrefy	lunary
unify	lubrify
plenary[7]	binary

(Other examples under both (12) and (13) can be found in SPE, p. 181.) As is well known, exceptions to other rules in SPE, e.g., palatalization, velar softening, s-voicing, also exist.

Chomsky and Halle remark (SPE: 172) that "we must design our linguistic theory in such a way that the existence of exceptions does not prevent the systematic formulation of those regularities that remain." They do note that rules or grammars with lots of exceptions should be less highly valued (cost more) than those which have few exceptions, but their attempts and most subsequent attempts at dealing with the problem are, as it were, worked out on the linguists' own drawing board, not by investigating the behavior of native speakers. The issue is not whether linguists can make theories of language which accommodate generalizations mixed in with exceptions; we know they can. The issue is what do language users do. We have at present no way of knowing whether the level of exceptions presents serious difficulties to the language learner, especially when this is added to the difficulties discussed above in identifying morphemes and their boundaries.

No doubt, whether a native speaker imagines a relationship between two words is probabilistic, the probability being a function of the speaker and the words involved. Zimmer (1969) found that Turkish speakers in his study showed a clear awareness of a major morpheme structure condition (MSC) in Turkish but many showed little awareness of a minor MSC that affected some 56 words (some of them common, frequently occurring words). Jaeger (1984) and Wang and Derwing (1986) review previous work and present original data showing that English speakers' awareness of the alternations covered by vowel shift is not equally strong for all vowel alternations. The method of repetition priming employed by Stanners et al. (1979) and more recently with refinements by Fowler, Napps, and Feldman (1985) (and Feldman, this volume) appears capable of providing behavioral evidence relevant to this issue.

3.3 *"You can lead a horse to water, but..."*

One thing we can probably take for granted is that the mere fact that a person is exposed to experiences (things observed) does not mean that that person will abstract all possible generalizations from them. We know this from common experience as well as from the history of science (Dmitrii Mendeleev's and Lothar Meyer's construction of the periodic table of elements and Charles Darwin's and Alfred Russel Wallace's theory of natural selection were based on data available to their contemporaries, but only they saw the general patterns). But there is also evidence of this in the domain of language: consider spelling.

As a teacher I read hundreds of student essays each year and often encounter misspelled words. Many misspellings (though by no means a majority) involve unstressed vowels or "silent" letters that need not have been misspelled or omitted if the writer had made the association between the target word and another word where the corresponding vowel was stressed or where the silent letter was pronounced. Some examples are given in (15).

(15)

target word:	*misspelling:*	*related word:*
separate	seperate	pare
preparation	preperation	prepare, pare
aromatic	aramatic	aroma
complement	compliment	complete
definite	definate	finite
	defenite	
accommodate	accomadate	commode
	accommadate	
collaborate	collaberate	labor
laboratory	labratory	labor, laborious
mnemonic	nemonic,	amnesia
	numonic	
exhibit	exibit	inhibit
recommend	reccom(m)end	commend
solemn	solem	solemnity
radiance	radience	radiate
dominant	dominent	dominate

I presume (without direct evidence) that these writers knew and would cor-

rectly spell the words in the third column. Why don't they make the connection, then, between the target words and these other words? In most cases they are semantically related and to a large extent graphemically similar. But is this such a completely different situation from that found with spoken words? Why is it almost invariably the case that even among linguists one can elicit a laugh by mentioning the connection — supposedly a regular one — between *suppose* and *suppository*?[8] No doubt this is partly due to the character of suppositories but it is also due to the novelty, the unexpectedness of the relationship. Both words were present in speakers' vocabularies but the connection had never been reflected upon. I would speculate that the great popularity of books on etymology (in 'the romance of words' genre) derives in part from the "aha!" feeling the readers get from them: the discovery of previously unrecognized relationships between well-known words.

Ehri (1984, forthcoming) reports that some children's skill at reading before they have had any formal training in it consists of recognizing the "envelope" of the orthographic representation of the word, i.e., the location of ascenders and descenders, the relative length of the word, etc., such that *clay* and *stag* would be confused. She points out that with a limited lexicon (plus context) this is not a completely unsuccessful strategy and only fails when these children are forced to increase their recognition reading vocabulary. The point is that even though they have had relatively extensive experience with individual letters shapes and how these letters are concatenated into words, the children fail to assimilate this data, relying instead on the somewhat more easily extracted word shapes or envelopes.

Teachers who are called upon to verify the knowledge or competence of their students certainly realize that just because students have been exposed to certain material it cannot automatically be assumed that they have mastered it, assimilated it. Rather, some behavioral evidence — acceptable performance on tests, writing an original paper — is required. Phonologists would do well to maintain the same skepticism regarding what native speakers of languages know.

3.4 *What is the payoff from constructing SPE-phonology?*

An interesting aspect of Ehri's analysis of her young "pre-readers"' strategy is that she could show how it satisfied their limited goals, i.e., they learned what they needed to and no more. What is the payoff from making an SPE

phonology? What does it benefit a speaker to know the special phonological relationship between *type* and *typify* and similar such pairs? There are a number of possible advantages.

We should first acknowledge that different pronunciations of the same morpheme, i.e., allomorphy, are largely nonfunctional and are rather to be viewed as an unfortunate but inevitable consequence of the ravages of sound change. It would serve the goal of communication better if there were a one-to-one mapping between pronunciation and meaning. Nevertheless, by knowing the systematic phonological relationships between words, an individual can to some extent compensate for the effects of sound change and get some initial idea of the meaning of one member of an allomorphic pair if the meaning of the other is known. For that matter, this would apply to recognition of cognates cross-dialectally and even cross-language. Hearing [mus] from a speaker of Scots English, one can figure that this corresponds to *mouse* if one knows of the similar correspondence affecting words like *house*, *South* etc. Likewise, knowing that the German words *Wasser* and *Fuss* correspond to English *water* and *foot*, respectively, one can deduce the correspondence: (some) German /s/'s = English /t/, and thereby figure out that German *Nuss* must be cognate to English *nut*. But however useful this skill is, it is dispensable. Many people never develop it or fail to develop it fully and still go on to live happy and productive lives. By far the most common way to learn the meaning of new words is by deducing their meaning from context or by explicit instruction. As far as the end result is concerned, it is the same when one learns that *shep-* in *shepherd* is cognate with *sheep* by using the phonological clues as when one learns that *ovine*, *mutton*, etc. are related to *sheep*, where phonological clues are of no help.

Learning to read and to spell in a language like English might involve some skills similar to an SPE phonology but only if the words are to be related to the pronunciation. Much allomorphy is avoided in the printed word since the conventional English orthography reflects pronunciations prior to many of the sound changes that led to morphologically-caused variations. Deaf readers or non-English-speaking readers of English who do not need to connect what they read with pronunciation can, if they like, treat the letter sequence 'typ' identically in *type* and *typify*. But again, learning to read and learning to connect the printed form with pronunciation, although highly useful, are complex skills that the majority of native speakers of languages throughout history have not acquired. The motiva-

tion for learning these skills therefore must lie outside the human universal language-using context.

An SPE phonology would be useful in order to derive new words, e.g., to nominalize the adjective *mundane* into *mundanity*. But there seems to be a lot that the speaker can do (and does do) to make new derivations instead of this. First, the vast majority of derivations and inflections involve phonologically neutral affixes such as English *pre-*, *inter-*, *-ness*, *-hood*, *-ing*, *-ish*, *-ly* and thus do not require complex phonological knowledge. Second, even if affixes which are not phonologically neutral in the rest of vocabulary are used, e.g., *-ism*, *-ian*, *-ity*, etc., the linguistically naive speaker of English is most inclined to treat them as if they were neutral. The form *mundaneity* /mʌn'dejnɪti/ has been found by T. Armbruster (per. comm.) and I have heard it myself from an acquaintance; Larry Hyman heard a Los Angeles disc jockey talk of *musicisms* /'mjuzɪkɪzm̩z/. In Ohala (1974) I reported that the majority of responses I obtained from Berkeley students when asked to make novel derivations orally by adding certain non-neutral suffixes to existing stems were of the sort /do^{w}'mɛstɪkɪzm̩/ '*domestic* + *ism*', /su'primɪfaj/ *supreme* + *ify*, i.e., where the patterns evident in the established vocabulary were not extended.

And even in the cases where novel derivations are made that productively extend established sound patterns, e.g., when some of the subjects in the Ohala 1974 study did give responses of the sort /do^{w}'mɛstɪsɪzm̩/ and /su'prɛmɪfaj/, it is still not necessary to assume that they were using an SPE phonology. They could as well make use of what I call "cut-and-paste" rules (also known as "analogy"). Consider, for example, how one might go about making a novel derivation of *obtain* using the suffix *-atory*. As shown in (16) one would first find an existing word sufficiently like *obtain* that also had a derived form with the suffix *-atory*. The latter part of *explain* is like *obtain* and it has the derived form *explanatory*. One then divides the two underived forms into what we can call the common pseudo-affix, /ejn/, and pseudo-stems, /ʌbt/ and /ɛkspl/. *Explanatory* must also be divided into the pseudo-stem it shares with *explain* plus two pseudo-affixes /æn + ətɔri/. The novel derivation for *obtain* is made by concatenating the pseudo-affixes of *explanatory* onto the pseudo-stem of *obtain* (see arrows in (16)). (Although the pseudo-stems and -affixes are contiguous in this example there is nothing preventing them from being discontinuous, e.g., something like /p..tr/ + /ɛ...ɪfaj/ for *petrify*.)

(16)

Pseudo-Stem	Pseudo-Affix	Pseudo-Stem	Pseudo Affix
ʌbt	ejn	ʌbt	ænətɔri
ɛkspl	ejn	ɛkspl	ænətɔri

The principal ways cut-and-paste rules differ from those in an SPE phonology is that they do not require abstract underlying forms (the /æ/ in *obtanatory* did not come from an abstract underlying //ǣ//, it came from a surface vowel, that in *explanatory*) and there is essentially just one rule or one algorithm for all cases where sound patterns are extended productively; long lists of rules applying in sequence — in ordered, unordered, or simultaneous fashion — are unnecessary. Dryden's coinage of *witticism*, discussed above, seems rather transparently to have involved something like a cut-and-paste process where *-cism* was cut out as a pseudo-affix. Without further behavioral evidence (but see Ohala 1974; Reid 1977; Wang and Derwing 1986) we cannot say for sure which way speakers make novel derivations like *domesticism*, *supremify*, and *obtanatory* which productively extend sound patterns — we are faced with the same kind of alternatives discussed earlier with respect to the two ways of generating the integer series in (1).[9] If simplicity is important for the speaker, however, then the cut-and-paste rule will be preferred over SPE rules: the former simplifies the lexicon by eliminating the need for underlying forms common to historically related words and it eliminates the need for the mental equivalent of Chapter 5 in the SPE (the compendium of rules). Assuming the two approaches get the same results, it is difficult to see what the cognitive advantage of an SPE phonology would be for any purpose.

I should not leave this topic without acknowledging that although I seriously doubt the need for an SPE phonology to allow the language user to deal with historically related allomorphs, rules of some sort do seem to be required to enable the listener to factor out predictable contextually-caused phonetic variation. For example, the release of stops before high, close vowels or glides is generally very noisy, often creating in effect an affricated release. This is particularly evident in /t/ before what is in effect the close glide [ɪ] as in 'truck'. Listeners (some listeners, at any rate) are able to factor out this purely physically-caused noise in order to arrive at the plain stop that was presumably intended by the speaker (see Ohala, 1986b, 1989). This would be a form of what communication engineers

would call "error correction" or "normalization" and no doubt something cognitively similar must account for listeners' ability to factor out distortions in the speech signal introduced by room acoustics, background noise, and the like. Although it is not clear yet how this normalization is done there is good evidence that it is done (see, e.g., Mann and Repp 1980, 1981; Ohala 1981; Ohala and Feder 1987; Fowler 1981).

Where would it leave the SPE phonological enterprise if it turns out that it has no place in the speaker's brain? It would not mean that it is without value but rather that it had been misrepresented. Rather than being a synchronic account of sound patterns it would be a diachronic account.[10] Underlying forms common to morphological variants would simply be their parent forms, the phonological rules would be sound changes that applied to these parent forms such that different daughter forms arose. A cyclic phonological rule would be a sound change that applied at different times in the history of a language. Many past and present problems that have occupied phonologists would then disappear. For example, there would be no bar to highly abstract underlying (reconstructed) forms, even those including sounds which are completely neutralized later on, as long as they can be justified using the comparative method and its within-language variant, internal reconstruction, as worked out in the last century by, among others, Schleicher, Grassmann, Verner, and Saussure. Then the practice in CV phonology of employing segments in the underlying form which are intermediate in their concreteness or abstractness, that is phonetically unspecified C's and V's (Clements and Keyser 1983: 67ff), would not seem such a novelty; Saussure pioneered the practice in 1878 in his reconstruction of the IE laryngeals.

It should not be surprising that the bulk of phonological work today would reduce to historical reconstruction. Although the goals of linguistics broadened some 70 years ago with the introduction of structuralism, i.e., to study the underlying structure of language, whether social or psychological, in fact there was no change in methods. After penetrating the new notations and jargon that emerged with structuralism, the methods used by structuralists — and this includes generative and post-generative phonologists — would look familiar to the 19th century grammarians. It is easy to adopt new goals; it is difficult to achieve them if one doesn't have methods to match.

4. Conclusion

It must be repeated that the question of what speakers know about the sound patterns in their language, how they represent them, and how they use them, cannot be determined by purely armchair speculations however plausible they may sound. Evidence based on the behavior of speakers solving the real phonological problems they encounter is necessary. The essence of science is, first, to recognize that our beliefs may be faulty because appearances of things in the universe can be deceiving and, second, to take measures to refine our observations in such a way as to overcome these potential distortions.[11] We should certainly mistrust our subjective judgments about relationships between words in our language, especially phonological relationships. For this task linguists have the misfortune of being literate, highly educated, and, most dangerous, explicitly schooled in the history of languages. This is bound to bias them in their speculations about mental representations of the lexicon and grammar. Psychological experiments such as those reviewed here and others in the present volume make attempts to overcome these subjective biases by making controlled observations on speakers themselves. No experiment is perfect, of course, but detected flaws lead to better experiments and in time to converging results, as demonstrated by Derwing in his paper in this volume.

In this paper I have proposed that we can also improve our speculations about mental grammars by adopting a "cost-benefit" framework. That is, we need to make estimates of what a speaker's cognitive resources are (e.g., storage and processing capacity — looking to experimental psychology for some initial insights on this), what the speaker needs to do with the sound patterns in language, and then evaluate the cost of competing strategies to accomplish these goals within the constraints given. Based on the speculations presented here I offer the tentative conclusion that, as far as phonological relationships between morphological variants are concerned, there are too many words in a language, too many patterns, and not enough time or payoff to speakers to evaluate all of them. Speakers may suspect that *extreme* and *extremity* had a common stem (they could know they are related by using semantic and orthographic clues) but there is little motivation for them to work out a common lexical form for the two words plus the accompanying phonological rules that would derive the variants from it. The productive extension of such a sound pattern to novel derivations can be handled by a cut-and-paste process that operates on purely surface pro-

nunciation. Experimental evidence consistent with this view is starting to accumulate but more is urgently needed.

NOTES

1. Not at issue is whether information on the non-phonological relationships between words is present, e.g., semantic, orthographic; there is much evidence that it is.
2. For the psychological validity of using percent difference in phonemes as estimates of speakers' subjective judgments of phonetic difference between strings, see Vitz and Winkler (1963) and Derwing and Nearey (1986).
3. Homonymy doesn't have to be considered separately since, if we leave knowledge of spelling and etymology out of consideration, homonymy reduces to polysemy.
4. To my knowledge there is just one other common word pair exhibiting the same type of alternation, *nose*, *nasal*.
5. Conducted as a class project by students in my "Methods in Phonological Analysis" class. My thanks to M. Amador, J. Cherry, H. Corcoran, B. DeMarco, D. Feder, R. LaPolla, K. Nikiforadou, J. Wang, and B. Weldon, who collected the data and contributed in many ways to the design of the experiment.
6. For those who, like myself, were unaware of the word *chicane* before researching this, the better-known word *chicanery* would still be a valid example under (14).
7. This also has a variant pronunciation with lax [ɛ].
8. Arthur Abramson's example.
9. Actually, a third possibility exists for how speakers could accomplish this: by using spelling-to-sound rules. For example, in the case of *supreme* + *ify*, one would first encounter the spelling rule that removes final "silent" *e*'s when adding a suffix starting with a vowel. This would yield the letter sequence *supremify*. This would then be interpreted by another rule which would dictate the "short vowel" reading of the letter *e*, i.e., [ɛ], since a "long vowel" reading is no longer supported by a following letter context '__Ce'. The tests reported in Ohala (1974) were conducted orally but there is no way of preventing subjects from forming mental images of the words' spelling.
10. In cultures using conservative orthographies it may also be an account of the spelling-to-sound rules readers must know.
11. The insight that the real truth about the universe may not be evident from the way it appears is one that many great teachers and philosophers have promoted, including Plato, Buddha, Jesus Christ, Freud. It was the lesson of the Scientific Revolution of the 16th century, however, that there are some positive practical steps that one can take to overcome this constraint.

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