Usage-based phonology
Daniel Silverman

Phonologists must contend with two incontrovertible facts:

(1) Phonological systems consist of *discrete* psychological categories
(2) Phonological categories emerge from *variable* speech tokens

An approach to phonology may be characterized as "usage-based" to the extent that it investigates the nature of—and formulates compelling hypotheses about—the interaction of these two aspects of phonological structure. This search for explanation in phonology is usually undertaken in one or both of two arenas: (1) the psychological and physical world of the individual, in the form of laboratory investigations, and (2) the social world of language transmission, in the form of quantitative field studies that, broadly construed, include corpus studies, frequency studies, dialectal variation, and the intimately related area of sound change. Indeed, two of the modern progenitors of usage-based phonology have established their research niches accordingly. Ohala's research program focuses on using the laboratory as a quasi-time machine, sometimes inducing physical and perceptual conditions that may reflect slow-going natural sound changes in "speed-up" form. It has spawned the burgeoning field of experimental phonology. Labov's research program involves the study of real-world sound change in the form of longitudinal and dialectal quantitative analyses of speech. It has spawned the field of quantitative sociolinguistics.

This chapter is divided into two sections. The first section consists of a survey of early (19^{th} to mid-20^{th} century) observations that may be interpreted as prefiguring the modern, quantitative research programs pioneered by Ohala and Labov. Among the most important authors to be discussed are Kruszewski, Baudouin de Courtenay, and Martinet. The second section outlines the research programs of Ohala and Labov, and further discusses the work of a number of researchers who have been directly or indirectly influenced by these two major contributors to phonological theory, and have written at length on the subject.

1. Precursors to modern approaches

The Kazan School

The Kazan School of linguistics, headed by Baudouin de Courtenay and Kruszewski, may be seen as the historic reflex of several strains of linguistic theorizing that have come to prominence in more recent times. As will become clear, the influence on these early thinkers (and, indeed, on contemporary scholars as well) of Darwin's theory of evolution by means natural selection, cannot be overestimated. Kruszewski and Baudouin de Courtenay both reference Darwin in their writings, but even if they had not, the mark of the Darwin revolution is writ large in their theories of linguistic sound structure, with their emphasis on slow-going diachronic pressures that may shape and re-shape the linguistic system, due to specific patterns of use and disuse.

In his master's thesis of 1881, Kruszewski outlines his proposals on the origins and properties of sound alternations. He divides sound alternations into three types, each with its own constellation of phonetic and functional properties.

The first type of sound alternation consists of regular phonological alternations admitting of no exceptions. For example, as exemplified in (1), "When Modern German **s** is followed by a vowel, and, at the same time, preceded by a sonant or by zero, it necessarily becomes **z**. This is exceptionless" (1881:11). (The examples in (1) do not, in fact, exemplify alternation. It is curious that Kruszewski chose these forms when alternating forms are readily available.)

(1)	**zeele**	**haus**
	unzer	**ɔks**
	gewezen	**ist**

Another example, from Russian, involves the automatic palatalization preceding **e** and **i**, e.g., **t** → **t^{j}**.

(2)	**sveta**	of the world	**svet^{j}e**	in the world
			t^{j}eksas	Texas

Kruszewski claims that such patterns are fully explicable in articulatory terms. In such alternations, (1) the causes can be immediately identified, (2) the alternation is exceptionless, and (3) the alternating sounds are usually articulatorily similar.

Regarding the origins of such changes, Kruszewski's remarks in 1883 make it clear that he sees language structure as intimately connected with language use, prefiguring subsequent theorizing on, more generally, Ohalaian and Labovian approaches to sound change and more specifically for current purposes, listener-based exemplar modeling and probability matching (discussed in detail in Section 2):

> In the course of time, the sounds of a language undergo changes. The spontaneous changes of a sound depend on the gradual change of its articulation. We can pronounce a sound only when our memory retains an imprint of its articulation for us. If all our articulations of a given sound were reflected in this imprint in equal measure, and if the imprint represented an average of all these articulations, we, with this guidance, would always perform the articulation in question approximately the same way. But the most recent (in time) articulations, together with their fortuitous deviations, are retained by the memory far more forcefully that the earlier ones. Thus, negligible deviations acquire the capacity to grow progressively greater… (1883:85)
>
> As an example, let us take the sound **k^{j}**. Let us imagine its domain as a line; on one end the sound **k^{j}**, will have the slightest palatal nuance (**k$^{j}_{1}$**), and on the other

end a very significant palatal nuance ($\mathbf{k^j_n}$): the intermediate points ($\mathbf{k^j_2}$, $\mathbf{k^j_3}$, $\mathbf{k^j_4}$) will designate the articulation between $\mathbf{k^j_1}$ and $\mathbf{k^j_n}$...

$$\mathbf{k^j_1 \ldots k^j_2 \ldots k^j_3 \ldots k^j_4 \ldots \ k^j_5 \ldots k^j_6 \ldots k^j_7 \ldots k^j_n}$$

Let us imagine that, while pronouncing $\mathbf{k^j}$, we have articulated $\mathbf{k^j_2}$. Which articulation will we perform the next time we pronounce the same sound? Each of the articulations is directed by the unconscious memory of similar articulations performed on previous occasions; therefore, we can perform the same articulation of $\mathbf{k^j_2}$. However, our memory retains only an approximate picture of the previous articulation, and our organs perform only approximately the same operation which we make them perform. Therefore, it is much more likely that the next time we will perform the articulation not of $\mathbf{k^j_2}$, but of one of its neighboring articulations $\mathbf{k^j_1}$ or $\mathbf{k^j_3}$. Let us assume that we have performed the articulation of $\mathbf{k^j_3}$. Which articulation will we perform the third time? Our characteristic, unconscious memory of the articulation of sound $\mathbf{k^j}$ should be a complex recollection of all articulations of $\mathbf{k^j}$ which we have performed. But not all of these articulations are arranged equally in the memory. For this reason, after performing the articulation of $\mathbf{k^j_3}$, the chances of performing $\mathbf{k'_4}$ are much greater than they are for $\mathbf{k^j_1}$, etc". (1883:65-6)

Kruszewski's second category of sound alternation is exemplified by German **s-r**: **wa<u>r</u> - gewe<u>s</u>en**. Such patterns (1) have many exceptions, and thus cannot be stated in purely phonological terms, (2) Possess causes and conditions that require a paleophonetic and etymological investigation, (3) are typically associated with only certain morphological concatenations (or concatenation classes), but not necessarily exhaustively, (4) often have triggers that are unclear, in the sense that the (natural) cause of the alternation has been obscured by historical changes, and (5) involve phonetically dissimilar alternants.

Kruszewski's third category consists of morphologically-conditioned alternations. He again employs examples from German and Russian. First, consider German umlaut.

(3) German umlaut

ha<u>u</u>s	**hæ<u>u</u>s-er**	**hæ<u>u</u>s-lein**
ʀa<u>d</u>	**ʀæ<u>d</u>-er**	**ʀæ<u>d</u>-lein**
lo<u>x</u>	**løx-er**	**løx-lein**
bu<u>x</u>	**by<u>x</u>-er**	**by<u>x</u>-lein**

Such patterns (1) require a paleophonetic investigation, (2) are productive (apply to nonce forms), (3) are exceptionless within the paradigm in which they are present, and (4), are morphologically conditioned.

Consider also the **k** - **tʃ** alternation in Russian.

(4) Russian **k** - **tʃ** alternation

prərok̲	**prərotʃit**
prorok̲	**prorotʃit**

All **k**-final nouns have corresponding verbs with **tʃ** as the stem-final consonant. As with German umlaut, this alternation is limited to particular grammatical category changes, and thus serves a morphological function.

While "[a]ll of the phenomena which we have been discussing result from physical processes called combinatory and spontaneous sound change, and from unconscious psychical processes..." (1881:19), the grammatical uses towards which particular alternations are put have consequences for their diachronic trajectory. For example, Type-1 alternations involve exceptionless physically-based correlations (**s : s$_1$**). Over time, **s$_1$** may now become another sound, **z**, and a new correlation **s : z** is introduced. Such **s : z** patterns admit exceptions, since the alternation is not causal or automatic. A Type-1 pattern may thus diachronically evolve into a Type-2 pattern. Type-2 patterns, in turn, may be further subject to "psychical" pressures such that (sub-) regularity is re-introduced. A pattern might level such that it limits itself to particular paradigms, and morphological conditioning becomes possible. This is Type-3.

An example of the evolution of changes in alternation types comes from a case of paradigm leveling in Eastern Slavic. Note that an automatic, phonetically explicable pattern of palatalization has become removed from its phonetic origins in Russian, such that the two sounds in question no longer bear a "physical" or "psychical" relationship to one another. Subsequently, sub-regularity is reintroduced through paradigm leveling: the alternation levels towards different values in a Russian dialect and in Ukrainian. In the Russian dialect, the entire paradigm has leveled towards **k**, while in Ukrainian, it has leveled toward **ʒ**.

(5)

Standard Russian:	Russian dialect:
pʲek̲u	**pʲek̲u**
pʲetʃoʃ	**pʲekʲoʃ**
pʲetʃot	**pʲekʲot**
pʲetʃom	**pʲekʲom**
pʲetʃote	**pʲekʲote**
pʲek̲ut	**pʲek̲ut**
	Ukrainian:
mog̲u	**moʒu**
moʒeʃ	**moʒeʃ**
moʒ̲et	**moʒe**
moʒ̲em	**moʒemo**
moʒ̲etʲe	**moʒete**

mogut mozut

Regarding the evolution of a Type-3 pattern from a Type-2 pattern, the ~~–u~~nconscious and psychical principle" may "come to the rescue of the…alternation by endowing it with a new function. Were it not for this function, the alternation would be destined to irrevocable extinction." (1881:22) "…[C]haos, as we observe it in the domain of anthropophonic phenomena, is only *temporary*. Everything that was once, but is no longer, absolutely necessary from the anthropophonic view is exposed to the effect of *unconscious*, *psychical factors*…[which] *strive to impose complete order and simplicity on language*" (1881:20; throughout, italics within quotation marks are in the original).

Baudouin de Courtenay's writings on this same topic were intended as a challenge to the Neogrammarians' proposal that sound change is "law-governed" in the sense that we can, with sufficient data, predict diachronic endstates: "[b]etween the starting and ending point of historical change (such as the transition from an original **k** to **tʃ**, or **ei** to **i**) there is no relationship that could be interpreted as a law of evolution…[A]ny conditioned combination falling under the concept of "law" belongs to the field of imperceptible [at the time of his writing –D.S.] microscopic differences. Genuine laws of causality are *hidden in the depth*, in the intricate combination of the most diverse elements" (1910:272, 276).

Baudouin de Courtenay's wrote that the *genuine* law-governed primitives that operate on linguistic patterns derive not from the observation of superficial linguistic patterning, but instead from four main sources: (1) "the psychological world of the individual" [cognition –D.S.], (2) "the biological and physiological world of a given organism" [articulatory phonetics –D.S.], (3) ~~–t~~he external, physical world" [acoustic phonetics –D.S.], and (4) ~~–t~~he social world (the transmission of linguistically expressed ideas from one individual to another [psychological matches and mismatches between speaker and hearer –D.S.]" (1910:261): ~~–T~~he complexity and causes accounting for the emergence and preservation of alternations must ultimately be ascribed to communal life and the physical (anatomico-physiological) and psychological make-up of the members of a speech community."

The post-Kazanians

The interacting pressures of phonetic variation (~~–t~~he physical"), cognition (~~–t~~he psychical") and also the inevitable psychological mismatches between speaker and hearer (~~–T~~he social world"), is similarly taken up by other 19th century scholars. Consider the writings of Paul (1890:44), who additionally considers the important role that *frequency and recency of usage* may have on linguistic structure:

> …[V]ariability of production, which remains unnoticed because of the narrow limits in which it moves, gives the key to our comprehension of the otherwise incomprehensible fact that a change of usage in the sounds of a language sets in

> and comes to its fulfillment without the least suspicion on the part of those in whom this change is being carried out.
>
> If the motory sensation were to remain always unchanged as a memory-picture, the insignificant deviations would always centre round the same point with the same maximum of distance. In fact, however, this sensation is the product of all the earlier impressions received in the course of carrying out the movement in question, and, according to a common law, the impressions, not merely those which are absolutely identical, but also those that are imperceptibly different from each other, are fused into one. Correspondingly to their difference, the motory sensation must be somewhat modified with each new impression, to however insignificant an extent. It is, in this process, of importance that the later impressions always have a stronger after-influence than the earlier. It is thus impossible to co-ordinate the sensation with the average of all the impressions during the whole course of life; rather, the numerically-speaking inferior may, by the fact of their freshness, outbalance the weight of the more frequent…There thus gradually arises, by adding together all the displacements (which we can hardly imagine small enough) a notable difference…

Schuchardt (1885:57-58) in his challenge to Neogrammarian doctrine writes in similar terms, and specifically implicates *token frequency*, and its interaction with *recent* versus *remote* speech acts, as important factors in certain forms of sound change:

> The change of a sound, its progress in a certain direction…consists of the sum of microscopic displacements. It is, therefore dependent upon the number of repetitions. If **x** requires 10,000 repetitions to become **x'**, these repetitions are to be counted within individual words, nevertheless. An **x** spoken one time each in 10,000 different words would not become **x'**. I will not deny that a word that has been spoken 10,000 times can favor the development of the sound **x** to **x'** in a word spoken only 8000 times, etc. The greater or lesser frequency in the use of individual words … is … of great importance for their phonetic transformation … Rarely-used words drag behind; very frequently used ones hurry ahead…They have been compared to small coins that, as they pass from hand to hand rapidly, are soon worn thin.

Such ideas have never died away. Among 20th century scholars, consider Hockett's musings on the subject (1958:443):

> [If] some speaker of English, over a period of years, were to hear a relatively large number of initial /t/'s with unusually inconspicuous aspiration…the location of the frequency maximum would drift, and his own speech would undergo the same modification. We would not, of course, expect any *single* speaker of English

> to have such an experience. In general, individuals who are in constant communication with each other will experience essentially parallel changes in their…articulatory habits. It is just this sort of slow drifting about of…distributions, shared by people who are in constant communication, that we mean to subsume under the term —sound change".

Hockett further elucidates a *wundt-curve*-like model of leveling vis-à-vis frequency of usage (1958:396-397):

> Other things being equal, irregular forms of high frequency are less apt to be replaced than are rarer ones…[If] an irregular form is frequently used, a child learning his native language will hear it many times, and may never come out with any analogically produced regular alternant. Even if he does, he probably already knows the inherited irregular form and may reject his own innovation…For a rarer irregular form this argument applies in reverse…Under some circumstances, extreme rarity may preserve an irregular instead of helping to lose it. The process, however, is quite different. The word *spake* (past tense of *speak*) and *beholden* still occur from time to time; it would seem that the rarity and irregularity of the forms constitute an integral factor in their peculiar archaic flavor, and it is because of the latter that the forms are used.

Martinet (1952) adds an important new ingredient to the general recipe of usage-based phonological change. While readily acknowledging the importance of phonetic and cognitive pressures on patterns of sound change, as well as the effects of frequency of usage, Martinet ascribes special import to the issue of *lexical semantic confusion*: all else being equal, certain diachronic developments—specifically, sound mergers—are more likely to proceed if the *functional load* of the relevant phonological opposition is low. That is, if a given opposition is responsible for a large number of minimal pairs, a merger of the two values is less likely to proceed.

According to Martinet, the tendency toward merger of an opposition is favored to the extent that: (1) The values in opposition are phonetically similar, (2) The number of minimal morpheme pairs that the opposition is responsible for is low, (3) The number of minimal pairs within a correlated opposition is low (or the opposition is uncorrelated, where *correlation* refers to the Trubetzkoyan notion of a sound series that is opposed to another by one feature), (4) The minimal pairs belong to different syntactic categories, (5) The token frequency of one or both members of the minimal pairs is low, and (6) The presence of additional morphological markers serves a disambiguating function.

Martinet is thus moving towards a more holistic functional approach to usage-based phonology, one that, in theory at least, incorporates the role that lexical semantic confusion on the part of the listener might play in the diachronic trajectory of sound systems. As we discuss in

Section 2, the role of lexical semantic confusion features prominently in Labov's proposed mechanism of usage-based sound change.

Boundary signals and prosodies

The role of juncture cues should certainly be included in any discussion of usage-based approaches to phonology: aspects of phonological structure can be harnessed by users to assist them in parsing the speech stream into its constituent parts. As Trubetzkoy (1939) notes, "In addition to the phonological means serving to distinguish individual units of meaning (sememes), each language has a number of means that effect the delimitation of such individual units of meaning…[E]ach language possesses specific, phonological means that signal the presence or absence of a sentence, word, or morpheme boundary at a specific point in the sound continuum". Trubetzkoy calls these "boundary signals", and continues with a helpful analogy: "They can probably be compared to traffic signals…It is possible to get along without them: one need only be more careful and more attentive. They therefore are found not on every street corner but only on some. Similarly, linguistic delimitative elements generally do not occur in all positions concerned but are found only now and then. The difference lies only in the fact that traffic signals are always present at particularly dangerous' crossings, whereas the distribution of linguistic delimitative elements in most languages seems to be quite accidental. This is probably due to the fact that traffic is artificially and rationally regulated, while language shapes and develops organically." In all, Trubetzkoy taxonomizes boundary signals by noting that (1) they may be contrast-expressing or contrast-suspending, (2) they may be positive (cueing a boundary) or negative (cueing a non-boundary), (3) they may be phonemic or non-phonemic, and (4) they may be individual signals (a single segment) or group signals (a segment sequence).

For example, in Barra Gaelic the aspirated occlusives are found only in word-initial position, and the long vowels, the central vowels, and the nasalized vowels are only found in word-initial syllables. These are contrast-expressing boundary signals, rather than contrast-suspending ones, though it must be emphasized that their role as contrast-expressing boundary signals is a consequence of contrast-suspension in other positions. Another example: in Japanese **g** occurs only word-initially, and **ŋ** occurs only intervocalically (word-medially). Since the two are not responsible for minimal pairs, we are dealing not with a phonemic boundary signal, but rather with a non-phonemic one. Such cases can be multiplied any number of times: elements in complementary distribution, one of which is conditioned by proximity to a boundary, always serve this demarcative function.

Firth's (1948) discussion of prosodies has many parallels to Trubetzkoy's boundary signals. The primary phonological distinction Firth attends to is that between *sounds* and *prosodies*. *Sounds* are components of phonological structure that do not play a syntagmatic role. Sounds occur in *phonematic systems*, and possess solely paradigmatic functional relevance, manifested by "sound subsititutions". Employing the cover terms **C** and **V**, a phonematic system of sounds may occupy a **C** or **V** position and, as such, sounds function contrastively, but impart no syntagmatic

information (apart from their being limited to either a **C** position or a **V** position). *Prosodies*, by contrast, are exactly those elements that *do* impart syntagmatic information. This is not to say that some phonetic value cannot be both a sound *and* a prosody in the same language. In such cases, instances of this value are still regarded as phonologically distinct from each other in contexts where they play distinct—paradigmatic or syntagmatic—roles.

In many ways, prosodies are comparable to Trubetzkoy's boundary signals, though Trubetzkoy adheres to a segmental (or segment-sequential) notion of boundary signals, whereas Firth's prosodies are not comparably limited in shape. Employing conventional terminology for the moment, a prosody may consist of a "segment"-sized element, a "sub-segment"-sized element, or a "supra-segment"-sized element. But it's misleading to relate prosodies (or sounds) to segments at all, as the prosody-sound distinction is based solely on whether the (sub-) system plays a syntagmatic or paradigmatic role; simply stated, if a value is predictable with respect to its distribution in some domain, it qualifies as a prosody; if a value is not predictable with respect to its distribution in some domain, it is a sound. And though Firth does indeed talk in terms of consonants and vowels, it is clear from his exposition that these are mere terminological expedients.

Robins (1957a) makes a partially-successful attempt to elucidate the sound-prosody distinction:

> Phonematic units refer to those features or aspects of the phonic material which are best regarded as referable to minimal segments, having serial order in relation to each other in other structures. In the most general terms such units constitute the consonant and vowel elements or C and V units of a phonological structure. Structures are not, however, completely stated in these terms; a great part, sometimes the greater part, of the phonic material is referable to prosodies, which are, by definition, of more than one segment in scope or domain of relevance, and may in fact belong to structures of any length…A structure will thus be stated as a syntagmatic entity comprising phonematic or segmental units and one or more prosodies belonging to the structure as a whole.

Robins emphasizes that the phonetic exponence of prosodies need not pervade their domain of association: as already noted, a prosody may be "segmental", "sub-segmental", or "supra-segmental" in its phonetic exponence, its status as a prosody being a consequence of its predictable distribution within some domain:

> Broadly speaking [prosodies] come about in two ways. (1) In the first case a feature may be spread or realized phonetically over a structure, such as a syllable, as a whole…(2) In the second case may be mentioned features which are not realized phonetically over the whole or large part of a structure, but which nevertheless serve to delimit it, wholly or partly, from preceding or following

structures, thus entering into syntagmatic relations with what goes before or after in the stream of speech. By virtue of their syntagmatic relations in structures, such features may be treated as prosodies of the structures they help to mark or delimit…" (indices added).

Regarding the functional value of prosodies Firth's analysis only partially succeeds. Its success is due to the boundary-signaling function of certain prosodies. Considering only these sorts of prosodies.

As discussed in Section 2, modern investigations of the functional value of boundary signals/prosodies fall under the rubric of so-called *transitional probabilities*.

(2) Modern currents in usage-based phonology

The flame carried by 19th century scholars who may broadly be considered ~~"u~~sage-based phonologists" dimmed to a mere flicker in the post-war period. Nonetheless, usage-based approaches have survived and, starting with the pioneering scholarship of Ohala and Labov in the 1970s and 1980s, have begun to flourish once again. Implicit in both these research programs (overtly embraced by Labov, though not explicitly discussed by Ohala), is a role for exemplar modeling, discussed in detail by Bybee, among others.

Exemplar modeling

Bybee's usage-based approach to phonological structure (e.g. 2001, 2006a, 2006b) has been greatly influenced by her 19th century predecessors, especially, Kruszewski and Schuchardt. According to Bybee, linguistic categories and their clumping into larger units emerge as a consequence of patterns' frequency of occurrence and co-occurrence. When elements frequently pattern together, they are likely to emerge as independent functional units of language. Many sound changes are the result of phonetic processes that apply as a consequence of actual language use, and consequently, those words that are used more frequently are more likely to undergo phonetic processes. This is exactly the proposal of Schuchardt, over 100 years previous.

Bybee (2001) provides many case studies—most from English, Spanish, as well as a detailed discussion of French liaison—illustrating how sound changes may begin with words and phrases of the highest frequency, and then may gradually diffuse through the lexicon. For example, whereas frequent words like *camera* and *every* have lost their medial schwas, less common words with comparable structure like *mammary* and *homily* retain these schwas. While frequent words are more likely to lead the way in certain phonetic reductions and assimilations, they are also more likely to resist leveling processes. For example, high frequency strong verbs like *kept* have resisted the regularization that has affected less frequent past tense forms such as *wept* → *weeped*; exactly the scenario presented by Hockett.

Bybee proposes that the lexicon is fully specified with phonetic detail, and is highly structured, with interconnections among phonetically and semantically parallel structures. The more similar that lexical entries are in terms of their structural properties, then (1) the more

likely that the morphological structures of these words will emerge, and (2) the more likely that the words will be subject to the same phonological processes.

Speaker knowledge of phonotactic regularities is claimed to be an emergent consequence of frequency of type occurrence. Bybee cites studies which indeed show that listeners' acceptability of sound sequences that are embedded in nonce forms correlates highly with these sequences' type-frequency in real words, and with their overall similarity to real words. Acceptability judgments here are gradient, showing that more familiar structures are more acceptable to listeners, and less familiar structures are less acceptable. Comparable work on Arabic by Frisch and Zawaydeh (2001), Frisch (2004), and Frisch, Pierrehumbert, and Broe (2004) is fully conisistent with bybee's findings: speakers possess stochastic knowledge of the phonotactic regularities of the language, knowledge that is statistically nuanced in the sense that speakers can make gradient judgments on the ~~"n~~aturalness" of nonce forms that parallel the prevalence of such patterns in their lexicons.

Such proposals support a specifically *exemplar*, *episodic*, or *multiple-trace* approach to lexical organization. First introduced to phonology by Johnson (1997), exemplar-modeling has its origins in the classic categorization study of Shepard, Hovland, and Jenkins (1961), which in turn influenced a number of further important studies on categorization of similar and dissimilar sensory items, among then Tversky (1977) Tversky and Gati (1978, 1982), Medin and Schaffer (1978), and Medin (1983). These researchers observe that items may be regarded as more similar or less similar to each other based not only on their physical attributes, but also on the contexts in which items are placed, and the functional role that items play. The application of these ideas to phonology seems an obvious next step: surely, allophonic relatedness presents a scenario in which physical distinctness is clearly overridden by the functional role that the objects play in the linguistic system (Silverman 2006).

The basic proposal of exemplar theory is that categorization proceeds from *experience* with actual sensory objects: perceptual categories emerge from *repeated exposure* to similar sensory events, where, as just noted, similarity is not determined solely on physical grounds, but also by the context in which items are placed, and the functions to which items are put. In general, the more often a sensory event is perceived, the more likely it will come to emerge as a categorical component of the system. Nosofsky (1986, 1989), and Goldinger (1996, 1998) further explore the role of categorization within a specifically exemplar model of categorization. Nosofsky proposes that perceptual stimuli are categorized based on their degree of similarity to stored exemplars. Goldinger suggests that an ~~"e~~pisodic" model of word learning (and memory in general) obviates the need for learners to match perceived speech to idealized templates or prototypes in a normalization procedure. He discusses a number of lines of evidence supporting the claim that humans have a remarkable memory capacity, one that is capable of storing richly detailed information about both linguistic and nonlinguistic perceptual stimuli.

As applied to phonology, the sensory events in question are speech tokens, and the categories that may emerge are those components of the speech stream that are repeated over and over again. In this approach, phonological categories are the emergent consequence of language

use. Bybee (2006a:717) discusses several advantages of the exemplar approach: ―(1) Exemplar representations allow specific information about instances of use to be retained in representation, (2) Exemplar representations provide a natural way to allow frequency of use to determine the strength of exemplars, and (3) Exemplar clusters are categories that exhibit prototype effects. They are organized in terms of members that are more or less central to the category, rather than in terms of categorical features."

Note that Bybee's approach need not embrace the segment as a phonological primitive. Given that repeated patterns are of many shapes and sizes, the phonological units that might emerge may consist of articulatory routines of varying length and complexity. In Japanese for example, the single tongue blade gesture in the sequence **ʃi** is argued to historically derive from **si**, which is claimed to have involved a sequence of blade gestures. Due to the frequency of their co-occurrence, this gestural sequence gradually merged in terms of tongue position, culminating in the single articulatory gesture in evidence today.

Since the pioneering work of Johnson, the exemplar model has been harnessed to varying degrees of rigor by a number of researchers. Steels (2000) and de Boer (2001), computationally model vowel systems as self-organized complex dynamic systems; Plug (2005, 2009) investigates certain discourse patterns of phonetic reduction from an exemplar theoretic and usage-based perspective. The exemplar model has been applied to phonological patterning by several other scholars, including Pierrehumbert (2001), Liberman (2002), Silverman (2002, 2006a, 2006b), Wedel (2004, 2006), Yu (2004, 2007), Ernestus (2006), and perhaps most compellingly by Labov (1994).

Semantic misperception

Labov's proposed mechanism of sound change (discussed in detail in Labov 1994) is firmly exemplar-theoretic in orientation, and furthermore, is a direct descendent of Martinet's functional account, though applied with a great deal more rigor. Consider first an example case of a shift in usage: in French, plural **s** has been lost (except when a vowel follows), and thus, for example, the plural article (earlier, ***las** in all contexts) runs the risk of being homophonous with the singular, i.e. **la**. However, the plural is now (usually) signaled by a change in vowel quality: ***las** → **le**. As Labov asserts, ―[This] show[s] how long-range changes in the French phonological, morphological, and syntactic systems compensated for sound changes, in ways that suggest a causal link" (1994:570).

Comparable patterns exist in any number of systems, including Boston Puerto Rican Spanish (Hochberg 1985): plural **s** is variably absent, but deletion is more often encountered in inherent plurals, and less often encountered when the loss of **s** would result in semantic ambiguity, thus **las plantas** (*the plants*; cf. **la planta** *the plant*) but **mutʃa planta** (*many plants*). Consider further the pattern in (6). Note in particular the distinction between 2nd sg. and 3rd sg. verb agreement; 2nd person is marked by **s**, whereas 3rd sg. lacks this **s**.

(6)

	Sg.	Pl.
1st	(**jo**) **estudio**	(**nosotros**) **estudiamos**
2nd	(**tu**) **estudias**	

3rd (ɛl, eja, ustɛd) ɛstudia (ejos, ejas, ustɛdɛs) estudian

The s in the 2nd sg should delete the least often, since it is the sole marker of the 2nd-3rd contrast. In fact, the 2nd sg. s drops more often than the overall average. However, pronoun use increases in the context of this s-drop, thus morphologically salvaging the phonologically neutralized contrast. Interestingly, among educated Madrid speakers, in which s is not undergoing attrition, pronoun use is significantly lower. Pronoun use increases upon switch-reference, however (when a new subject is introduced) (Cameron 1992).

As Labov writes, ―If speakers do not consciously or unconsciously adjust their sentences to maximize the transmission of meaning, then we need to find some other mechanism that accounts for the systemic adjustments that maintain informational content" (1994: 585). His proposed mechanism is *probability matching*: animals (including humans) show the capacity to replicate observed frequencies of events in their behavioral responses. Studies indicate that certain of these behaviors must be the result of perception and calculation rather than reward, since animals may adjust their behavior even without having been actually reinforced. So-called ―variable rule learning" may thus easily be seen as proceeding in the same fashion: the statistical distribution of speech tokens within the phonetic space is calculated by language learners, and, most remarkably, is largely matched in their own speech productions.

Labov applies probability matching and exemplar modeling to aspects of sound change. As stated, the basic idea is that language users are especially adept at matching in their own productions the variation that they perceive, such that variation is conventionalized in the speech community. However, as Labov writes (1994: 586), ―It is not the desire to be understood, but rather the consequence of misunderstanding that influences language change. This mechanism implies a mismatch between producer and interpreter: the type of built-in instability that we would expect to find behind long-term shifts in language behavior." For example, if the word ―drop" is produced as dræp, it might be understood correctly, since it is unlikely to be confused with another word (there is no English word ―drap"). No matter how small such an effect, repetition may come to shift the pool of exemplars in terms of its phonetic properties. Consequently, such interlocutions may, over time, lead to an overall fronting of the low back vowel. Alternatively, dræp might not be understood, and the token may simply be thrown out, having no effect on the exemplar pool, thus inhibiting any change. In a fashion comparable to this latter scenario, if a token of ―block" is produced as blæk, there is a greater likelihood of misunderstanding since both ―blok" and ―black" are actual words. Again, the role of these misunderstandings is to *inhibit* sound change, since such tokens will not be pooled with the listener's store of exemplars for the word ―block". The vowel qualities—as a passive consequence of language use—may enjoy a comfortable perceptual buffer zone.

Phonetic misperception

Like several 19th and early 20th century scholars before him, Ohala (e.g. 1975, 1981, 1983, 1989, 1993) suggests that variation in speech is the fodder for many sound changes. Harnessing modern experimental techniques, Ohala expands upon these earlier proposals in his use of the laboratory to

show how certain phonetic (pre-) conditions may give rise to particular sound changes. He further gets much mileage out of the proposal that listeners, as opposed to speakers, are progenitors of sound change, thus harkening back to Baudouin de Courtenay's (1910) discussion of lapsis auris. According to Ohala, four major scenarios may play themselves out over time as a consequence of the interplay between the acoustic signals that speakers produce and the interpretations of these signals by listeners: (1) correction of acoustically unclear signals, resulting in diachronic stability, i.e. no sound change, (2) confusion of acoustically similar sounds, (3) hypo-correction, and (4) hyper-correction.

Hypo-correction involves listeners interpreting a context-dependent phonetic effect (often coarticulatory or assimilatory) as context-independent. For example, the nasalization present on vowels in the context of a following nasal consonant may be (–~~n~~is-") attributed to the vowel, rather than as a context dependent feature of the nasal consonant. Listeners may thus fail to correct for a predictable feature of the speech signal. Once a listener interprets the nasalization on the vowel as primary, the nasal consonant itself may be interpreted as context-dependent, in time withering to zero, thus, **VN** > **$\tilde{V}$N** > **$\tilde{V}$**. Note that the endpoint of such a sound change is incipient in its starting point, in the sense that low level phonetic variation involving vowel nasalization provides the necessary fodder for the initiation of the change.

Regarding hyper-correction, listeners may over-correct a component of the speech signal, misinterpreting a context-independent property as context dependent. For example, in Latin **kwiŋkwe: > *kiŋkwe:, assuming a degree of labiality persists through the first vowel, a listener may mistakenly conclude that the labiality of the first vowel is simply an automatic –~~s~~pillover" from the second velar release, so they –~~u~~ndo" it, (–~~n~~is-") attributing it solely to the second **k**. The result of such a hyper-corrective sound change is dissimilation.

Though not overtly discussed by Ohala, this notion of –(~~n~~is-) attribution" on the part of listeners is predicated on a specifically segmental approach to phonological structure. Blevins approach (2004, 2006a, 2006b), essentially the same as Ohala's, overtly embraces the segment as a phonological primitive, typologizing certain sound changes as the result of –~~a~~mbiguous segmentation" due to (1) change, (2) chance, or (3) choice.

Sound change due to change involves the phonetic signal being –~~m~~isheard by the listener due to perceptual similarities of the actual utterance with the perceived utterance" (2004:32). For example, **anpa** may be misheard as **ampa**.

Sound change due to chance involves a phonetic signal that is —~~a~~ccurately perceived by the listener but is intrinsically phonologically ambiguous, and the listener associates a phonological form with the utterance which differs from the phonological form in the speaker's grammar" (2002:32). For example, a speaker may say **ʔa̰ʔ**, and a listener may recover the signal accurately, but does not faithfully reproduce the speaker's mental representation of the utterance: the listener constructs /**aʔ**/ where the speaker constructs /**ʔa**/. Clearly, like Ohala before her, Blevins assumes the existence of both segments, as well as the generative-theoretic notion of underlying representations (Chomsky and Halle 1968).

Sound change due to choice is characterized thus: ―Multiple phonetic signals representing variants of a single phonological form are accurately perceived by the listener, and due to this variation, the listener (a) acquires a prototype or best exemplar of a phonetic category which differs from that of the speaker and/or (b) associates a phonological form with the set of variants which differs from the phonological form in the speaker's grammar" (2004:33). For example, a speaker may say **ka'kata kă'kata kkata** for /**kakata**/, while the listener hears **ka'kata kă'kata kkata** but mentally constructs /**kkata**/. Thus, ―choice" too crucially relies on the notion of underlying representations.

The listener's role: interpreting speaker intent, or matching speaker behavior?

Ohala and Labov clearly entertain different hypotheses regarding the listener's role in certain aspects of sound change. Recall that, in general terms, Ohala proposes that listeners are intent on interpreting the *phonetic* intentions of speakers, and that certain types of sound change are a consequence of listeners' sporadic ―incorrect" conclusions about these phonetic intentions. Labov, by contrast, proposes that listeners are, rather, exceptionally talented in interpreting the phonetic signal produced by speakers, as evidenced by the fact that they are able to match the very variation they perceive, in a form of probability matching. For Labov then, certain sorts of sound change may be a consequence not in listeners' sporadic misinterpretation of the *phonetic* signal, but rather, a consequence of listeners' sporadic misinterpretation of the *semantic* content that rides on this phonetic signal.

Consider the findings of Öhman (1966) and Manuel (1990, 1999) in light of these two competing accounts. These authors investigate patterns of coarticulation: Öhman investigates cross-linguistic patterns of vowel-to-vowel coarticulation through intervening consonants (**VCV**), and Manuel investigates cross-linguistic patterns of vowel coarticulation due to consonantal context (**CVC**). Both find that different languages possess different patterns of coarticulation in these contexts, and further, that at least a certain amount of the observed language-to-language difference in coarticulation may be attributable to the language-particular system of contrastive values. Öhman, considers **VCV** coarticulation in Swedish, English, and Russian. This last language, unlike the first two, has a series of palatalized consonants that seems to curtail the degree of coarticulation such that palatal contrasts are recoverable in the speech signal: ―[I]n Swedish and English, the stop consonants seem to coarticulate relatively freely with the vowels….there are languages, such as Russian, in which the instructions for the stop consonants are made…as in English or Swedish but with the additional feature that the vowel channel must simultaneously receive exactly one of two fixed commands [palatalization or velarization]". The data discussed by Manuel (1987, 1990) and Manuel and Krakow (1984) are also consistent with the idea that coarticulation is influenced at least in part by the distribution of contrastive values in the phonetic space, and that coarticulation may be curtailed to the extent that it (at least sometimes) does not jeopardize these contrastive values. Manuel and Krakow find that there are be larger V-to-V coarticulation effects in languages with smaller vowel systems, and smaller coarticulatory effects in languages with larger vowel systems. For example, Shona and Swahili, with five vowel systems, may display more vowel coarticulation

than in a language like English: on the one hand, because the vowels in English are more crowded in the articulatory/acoustic space, the range of production for each one would be rather small so as to maintain distinctions among them; on the other hand, as the vowel qualities of Shona and Swahili are more spread apart, they could presumably tolerate larger ranges of production without running the risk of encroaching on each other‘s distinctive space.

These studies, along with quite a few others that investigate system-influenced patterns of conventionalized (co-) articulatory routines (among them Clumeck 1976, Beddor, Krakow, and Goldstein 1986, Recasens 1987, Recasens, Pallarès and Fontdevila 1998, Beddor and Krakow 1999, Beddor, Harnsberger and Lindemann 2002) are consistent with Labov‘s proposal that variation in speech is conventionalized within speech communities. Note further that probability matching in language is found in domains that are surely not explicable in physiological terms, including variable morpheme usage both in real-world settings (for example, Poplack), and in laboratory settings, in which subjects were exposed to variable patterns in a contrived mini-language during a learning phase, and came to reproduce this variation in their own speech patterns during a testing phase. For example, Hudson and Newport (1999) taught subjects a contrived mini-language in which nouns were variably marked with a determiner. Subjects were divided into groups which differed in the extent to which the nouns they heard possessed this marker: one group was exposed to nouns, 75% of which had the marker, and another group was exposed to nouns, 25% of which had the marker. In the testing phase, subjects largely matched their usage to their exposure. That is, subjects in the 75% group produced about 75% of their nouns with the marker, and subjects in the 25% group produced about 25% of their nouns with the marker.

Such findings support the proposal that certain so-called ―low-level" or ―phonetic" effects may in fact be the result of deep, systemic pressures many times removed from the physical systems that proximally underlie speech. That coarticulation is limited in just those contexts where lexical contrasts would otherwise be jeopardized is readily explainable in the diachronic scenarios envisioned within a Labovian account. Such patterns lend themselves less readily to an account in which listeners are formulating hypotheses about the phonetic intentions of speakers. Under this latter account, it is either a pure coincidence, or is due to a rather circuitous chain of events, that speech variation is conventionalized on a language-to-language basis, depending especially on the system of contrasts semantic content on which lexical semantic content is dependent. It would further be purely due to coincidence that aspects of morphological variation pattern in just the same as do aspects of phonetic patterning.

Near-mergers and near neutralization

Labov‘s discovery of *near mergers* and *near neutralizations* (e.g. Labov 1966, Labov, Yeager, and Steiner 1972, Labov, Karen and Miller 1991) has had great success in explaining many previously ill-understood sound changes, and has inspired a significant amount of work as well. (See, for example, Dinnsen and Charles-Luce 1984, and Charles-Luce 1993 on Catalan, Port and O‘Dell 1985, Port & Crawford 1989 on German, Slowiaczek & Dinnsen 1985 on Polish, Pye 1986 on Russian, Warner, Jongman, Sereno, and Kemps 2004 on Dutch, Gerfen and Hall 2001, and Bishop

2007 on Andalusian Spanish.) Near-merger occurs when there is significant token-to-token phonetic overlap of two (or more) phonological values, such that language users may not be aware of the phonetic distinction that is variably in place. Note that listeners are clearly sensitive to these values' nearly-merged status, since they recapitulate the pattern in their own speech (in a form of probability matching), but they may lack conscious awareness of their persistent small degree of difference. Indeed, it emerges as a corollary to a specifically usage-based phonology that *speaker intuitions* should perhaps play no role whatsoever in linguists' proposals about the structural components of language.

If we assume that genuinely merged values cannot be undone—unmerged—by linguistic means (this is Garde's Principle, after Paul Garde 1961), then the existence of near mergers offers a compelling explanation for patterns that have been (mistakenly) analyzed as having merged in the past, only to unmerge at a later point in time. The doctrine of Uniformitarianism (originally applied to geological strata) states that the laws governing the patterning of natural phenomena are equally valid across all space and time, and thus, "knowledge of processes that operated in the past can be inferred by observing ongoing processes in the present" (Christy 1983). Consequently, as Labov writes, we might use the present to explain the past. The existence near-mergers today is good evidence of their existence in the past. More particularly, if we find near-mergers in the present in exactly those cases that purportedly underwent complete merger in the past, then we may conclude that the values did not, in fact, completely merge at all; rather, they merely nearly merged in the past, and this near merger has persisted to the present.

The contemporary evidence for near-mergers may thus provide a compelling explanation for putative cases of historic "unmergings". For example, In Middle English "meet", "meat", and "mate" possessed distinct vowel qualities: eː, æː, aɪ. During the sixteenth century, the vowels æː and aɪ purportedly merged toward ɛː, but during the seventeenth century they purportedly unmerged, with (historic) æː and eː merging toward iː (and historic aɪ rising to eɪ). Labov reports, that, in fact, certain contemporary Belfast dialects possess the near-merger of æː and aɪ. That is, the vowel qualities that purportedly merged—and then purportedly unmerged—in the past are, in fact, nearly-merged today. Labov proposes that the values never really merged at all. Instead, they engaged in a near-merger that, quite remarkably, has persisted for several hundred years: "The overlap [in the distribution of the two vowel qualities] has not prevented the distinction between the two classes from being maintained for almost three hundred years…It follows that speakers are capable of tracing the frequency of occurrence of the two classes…and that this differential distribution is a part of their fundamental knowledge of the language…"; a compelling instance of long-term probability matching in language use.

Some of Labov's most famous research investigates near-mergers in North American English. For example, consider New York "source" and "sauce". In so-called "r-less" dialects, the non-prevocalic ɹ found in other dialects typically corresponds to a schwa-like offglide here. Since these same dialects possess ɔə in words like "sauce", the pronunciation of these two words—"source" and "sauce"—is nearly identical, their meager difference more often encountered in recitation speech, less often in spontaneous speech

Another case: in Albuquerque, a high school student was found who nearly merged the vowels in ―fool" and ―full". Despite a slight though persistent difference in their phonetic properties, this student felt that all the relevant words possessed but a single vowel quality. He was recorded reciting a list of ―fool"-―full", ―pool"-―pull" words. When this recording was played to speakers who possessed a better separation of the vowel qualities, they correctly identified the words 83% of the time.

Charles-Luce (1993) reports on a study of a related phenomenon, near-neutralization in Catalan. Her results show that the tendency towards neutralization is indeed affected by semantic factors, just as suggested by Labov's ―consequences of misunderstanding" proposal: ―[T]he perception and production of spoken words is affected differentially by the presence and absence of higher levels of linguistic information and…the degree of precision of articulation is inversely proportional to the presence of semantic information." She finds that a Catalan voicing alternation is more likely to be nearly-neutralized (as opposed to completely neutralized) in contexts that would otherwise be semantically ambiguous. As Charles-Luce concludes, ―[T]here may be some on-line assessment by the speaker as to the degree of biasing information present [that] may be quite automatic and learned through experience…".

Charles-Luce's findings may also be viewed as supporting Martinet's earlier claims regarding pressures that might militate against merger: as an emergent outcome of sporadic semantic misinterpretation, there may, under certain conditions, be a passive social pressure against values' merging and neutralizing.

Many excellent longitudinal and latitudinal studies have been inspired by Labov's pioneering work in quantitative sociolinguistics, among them Poplack 1980a,b, on Caribbean Spanish, Eckert 1988, Guy 199. Docherty, Foulkes, and colleagues (for example, Docherty and Foulkes 1999, Docherty, Foulkes, Tillotson, and Watt 2006, Foulkes, and Docherty 2007, Foulkes, Scobbie, and Watt 2010) have presented detailed sociophonetic investigations Tyneside English, focusing in particular on ―socially structured variation". These authors consider many aspects of speech variation that are partially delineated by social setting, including social class differences, age-based differences, sex differences, child-directed speech, etc.

Natural selection as metaphor

Silverman (2006) is directly inspired by Labov's work on probability matching, Ohala's proposals regarding the phonetic preconditions for sound change, and Martinet's proposals regarding the role of functional load in the tendency toward merger. In keeping with his strictly functional approach to phonology, Silverman typologizes synchronic *sound substitutions* into three logical/functional categories: (1) *contrastive* (meaning-changing), (2) *neutralizing* (which are re-defined as exclusively homophone-inducing alternations), and (3) *allophonic* (meaning-preserving). Employing an exemplar-theoretic approach to lexical organization, Silverman argues that morphemes are not broken down by language users into smaller-sized sound units unless there is evidence from alternation to do so. He applies Darwin-like evolutionary principles to patterns of sound change, proposing—like Kruszewski and Baudouin de Courtenay before

him—that the explanation for synchronic patterns of usage resides in phonetic and functional pressures that interact across generations of language use.

The basic components of his approach are Darwin-inspired, including (1) speech variation (cf. mutations), (2) communication from speaker to listener (cf. reproduction), and (3) the increased likelihood of semantically unambiguous speech tokens being stored and recycled as listeners become speakers (cf. natural selection). As discussed by Labov, variation in speech can sometimes lead to semantic confusion for listeners (as when one word is confusable with another due to their phonetic similarity), and this confusion may, over generations of speakers, lead to the better separation of phonological categories. Under this view (as in the Kazan School) allophonic alternants are viewed as the culmination of a series of small, natural changes to the system that takes place over generations of speakers. In more recent work, (Silverman 2010, *in prep*.), he investigates the proposal that neutralizing patterns (according to the term‘s traditional definition) are tolerated to the extent that they do not derive excessive homophony, a là Martinet and Charles-Luce.

Unlike Ohala, Silverman argues that listeners in these scenarios are not formulating hypotheses about speakers‘ phonetic intentions. Rather, in the spirit of Labov‘s exemplar-theoretic/probability-matching approach, listeners are primarily engaged in reproducing the very variation that they perceive in the incoming speech signal. On this view, certain sound changes are not a consequence of sporadically misinterpreting the phonetic content of the speech signal (as in Ohala‘s and Blevin‘s segment-based approach), but rather, are a consequence of either correctly or incorrectly interpreting the semantic content that rides on this phonetic signal (as in Labov‘s approach, which need not invoke the segment as a linguistic primitive).

Wedel (2006) also assumes this strong version of functional, Darwin-styled phonology, discussing three pressures on sound change that derive directly from theories of evolutionary biology: (1) *pruning of lines of inheritance*, which involves the slow memory decay of individual speech tokens—including outliers—and their subsequent replacement by more recent tokens, (2) *blending inheritance*, which involves the averaging of multi-modal distributions, resulting in a winnowed uni-modal distribution, and (3) *natural selection* (much like Silverman‘s proposal). Wedel runs various computer simulations that demonstrate how each of these pressures may lead to a naturalistic distribution of sound categories in the perceptual space.

Transitional probabilities

Trubetzkoy‘s and Firth‘s work on boundary signals and prosodies respectively—that is, their role in serving as an aid to parsing—has, in recent years, been experimentally studied by a number of scholars who are focusing on the functional value of so-called *transitional probabilities*. These scholars are investigating the utility of transitional probabilities in both adult and infant learning of contrived mini-languages, finding that, indeed, statistically rare sound sequences found at "word" boundaries (of course, in these experiments they are not real words) serve to cue these boundaries. The necessary flipside to this finding is that statistically more prevalent sound

sequences—those involving neutralization or contrast suspension within some domain—may function as negative boundary signals, that is, they may cue a non-boundary.

Saffran, Newport, and Aslin (1996) provide a nice cross-modality illustration of what they intend to investigate: ―[O]ne might discover words in the linguistic input in much the same way that one discovers objects in the visual environment via motion: the spatial-temporal correlations between the different parts of the moving object will be stronger than those between the moving object and the surrounding visual environment."

Formulaically, the transitional probability of **y** given **x** is shown in (7):

(7) $\frac{\text{frequency of pair } \mathbf{xy}}{\text{frequency of } \mathbf{x}}$

If this ratio is high, the presence of **x** is a good predictor of a following **y**; such sequences might thus serve as negative boundary signals—Trubetzkoy's "green light"—increasing the likelihood that the sequence is word-internal. However, if this ratio is low, then the sequence **xy** may serve as a positive boundary signal.

In one of their experiments, adult subjects were taught a contrived mini-language consisting of four consonants (**p b t d**) and three vowels (**a i u**). Twelve CV syllables were constructed, which were strung into tri-syllabic sequences constituting the ―words" of the language, for example, **bapuba**, **dutaba** etc.). Transitional probabilities at ―word" boundaries were lower than transitional probabilities within ―words". After a training period, subjects were able to determine word structure at levels significantly better than chance, thus showing that they perform complex statistical calculations over the sound sequences they were trained on.

It should be emphasized that there is no chicken-or-egg problem here: there is no reason—as a matter of principle—to weigh in on the issue of whether, say, learners come to functionally harness certain incidentally beneficial phonotactic patterns as they begin to parse the speech stream (that is, phonotactic patterning drives parsing), or whether the learning process actually comes to shape the phonotactic regularities in a way that makes it easier to parse (that is, learning drives phonotactic patterning). Rather, the complex array of linguistic subsystems is subject to specifically *co*-evolutionary pressures. Properly treating language as a "complex adaptive system" (Steels 2002) that passively evolves as function of its use, the language analyst should not—as a matter of principle—extract one component pressure on language structure to the exclusion of others with which it is necessarily intertwined. Darwin's famous ―tangled bank" passage would seem appropriate to ponder at this juncture:

> It is interesting to contemplate a tangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent upon each other in so complex a manner, have all been produced by laws acting around us. These

> laws, taken in the largest sense, being Growth with reproduction; Inheritance which is almost implied by reproduction; Variability from the indirect and direct action of the conditions of life, and from use and disuse; a Ratio of Increase so high as to lead to a Struggle for Life, and as a consequence to Natural Selection, entailing Divergence of Character and the Extinction of less improved forms. Thus, from the war of nature, from famine and death, the most exalted object which we are capable of conceiving, namely, the production of the higher animals, directly follows. There is grandeur in this view of life, with its several powers, having been originally breathed by the Creator into a few forms or into one; and that, whilst this planet has gone circling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being evolved.

Conclusion

It should not be surprising that Darwin‘s theory of evolution by natural selection has served as a catalyst—either directly or indirectly—for so much research in usage-based phonology, both in the immediate post-*Origin* era, and continuing up to the present day, when technological advances allow for the computational modeling of the self-organizing aspects of complex dynamic systems like language (for example, Liljencrants and Lindblom 1972, Lindblom, MacNeilage, and Studdert-Kennedy 1984, Steels 2000, de Boer 2001, Liberman 2002, Wedel 2004, 2006). There is little doubt that research in speech and language analysis, due to ever-improving technology, will continue to branch and diversify in new and innovative ways that are directly inspired by the Darwin revolution. This author, for one, is quite confident that such research will provide increasingly compelling theories about—and increasingly compelling evidence for— the divergent though intertwined aspects of phonological structure introduced in the opening to this chapter, that is, that phonological systems consist of discrete psychological categories, and that phonological categories emerge from variable speech tokens.

References

Beddor, Patrice S., James D. Harnsberger and Stephanie Lindemann. 2002. Language-specific patterns of vowel-to-vowel coarticulation: acoustic structures and their perceptual correlates. *Journal of Phonetics* 30.591–627.

Beddor, Patrice S. and Rena A. Krakow. 1999. Perception of coarticulatory nasalization by speakers of English and Thai: evidence for partial compensation. *Journal of the AcousticalSociety of America* 106.2868–2887.

Beddor, Patrice S., Rena A. Krakow and Louis M. Goldstein. 1986. Perceptual constraints and phonological change: a study of nasal vowel height. *Phonology Yearbook* 3.197–217.

Bishop, Jason. 2007. Incomplete Neutralization in Eastern Andalusian Spanish: Perceptual Consequences of Durational Differences Involved in S-Aspiration. *Proceedings of the International Congress of Phonetic Sciences XVI*. 1765-1768.

Blevins, Juliette. 2004. *Evolutionary Phonology: the emergence of sound patterns*. Cambridge: Cambridge University Press.

Blevins, Juliette. 2006a. A theoretical synopsis of Evolutionary Phonology. *Theoretical Linguistics* 32.117–166.

Blevins, Juliette. 2006b. Reply to commentaries. *Theoretical Linguistics* 32.245–256.

Blevins, Juliette and Andrew Garrett. 1998. The origins of consonant-vowel metathesis. *Language* 74.508–556.

de Boer, Bart. 2001. *The origins of vowel systems*, Oxford: Oxford University Press

Bybee, Joan. 2001. *Phonology and language use*. Cambridge: Cambridge University Press.

Bybee, Joan. 2006a. *Frequency of use and the organization of language.* Oxford: Oxford University Press.

Bybee, Joan. 2006b. From usage to grammar: the mind's response to repetition. Language 82(4). 711-733.

Charles-Luce, Jan. 1985. Word-final devoicing in German: Effects of phonetic and sentential contexts. *Journal of Phonetics* 13, 309–324.

Cameron, Richard. 1992. *Pronominal and null subjects variation in Spanish: constraints, dialects, and functional compensation*. Ph.D. dissertation, University of Pennsylvania.

Charles-Luce, Jan. 1993. The effects of semantic context on voicing neutralization. *Phonetica* 50, 28–43.

Christy, Craig. 1983. *Uniformitarianism in Linguistics*. Amsterdam and Philadelphia: John Benjamins.

Dinnsen, Daniel. 1985. A re-examination of phonological neutralization. Journal of Linguistics, 21, 265–279.

Chomsky, Noam, and Morris Halle. 1968. *The Sound Pattern of English*. New York: Harper and Row.

Clumeck, Harold. (1976). Patterns of Soft Palate Movements in Six Languages. Journal of Phonetics 4:337-351.

Dinnsen, Daniel, & J. Charles-Luce, J. 1984. Phonological neutralization, phonetic implementation and individual differences. *Journal of Phonetics* 12, 49–60.

Docherty, Gerard J. and Paul Foulkes. 1999. Instrumental phonetics and phonological variation: case studies from Newcastle upon Tyne and Derby, In Paul Foulkes & Gerard Docherty (Eds.) *Urban Voices: accent studies in the British Isles*. London: Arnold, 47-71 1999.

Docherty, G.J., Paul Foulkes, P., Tillotson, J. & Watt, D.J.L. (2006) On the scope of phonological learning: issues arising from socially structured variation. In Goldstein, L., Whalen, D.H. & Best, C.T. (eds.) *Laboratory Phonology* 8. Berlin: Mouton de Gruyter. pp. 393-421.

Eckert, Penelope. 1988. Adolescent social structure and the spread of linguistic change. *Language in Society* 17:183-208.

Foulkes, Paul, Scobbie, James M. & Watt, D.J.L. Sociophonetics. To appear 2010 in Hardcastle, W., Laver, J. & Gibbon, F. (eds.) Handbook of Phonetic Sciences (2nd ed.). Oxford: Blackwell.

Foulkes, Paul and Gerard J. Docherty 2007. Phonological and prosodic variation in the English of England. In Britain, D. (ed.) *Language in the British Isles*. Cambridge: Cambridge University Press. pp. 52-74.

Frisch, Stefan. 2004. Language processing and segmental OCP effects. In Bruce Hayes, Robert Kirchner, and Donca Steriade eds., *Phonetically-based Phonology*, 346–371. Cambridge: Cambridge University Press.

Frisch, Stefan A., Janet B. Pierrehumbert, and Michael B. Broe. 2004. Similarity avoidance and the OCP, *Natural Language and Linguistic Theory* 22.179–228.

Frisch, Stefan and Bushra Zawaydeh. 2001. The Psychological Reality of OCP-Place in Arabic, *Language* 77, 91-106.

Gallistel, Randy. (1990). The Organization of Learning. Cambridge MA, MIT Press.

Garde, Paul. 1961. Réflexions sur les différences phonétiques entre les langues slaves. Word 17:34-62.

Gerfen, Chip and Kathleen Hall. 2001. Coda aspiration and incomplete neutralization in Eastern Andalusian Spanish. Ms. University of North Carolina at Chapel Hill.

Gluck, Mark A., and Gordon H. Bower. (1988). Evaluating an adaptive network model of human learning, Journal of Memory and Language. 27:166-195.

Goldinger, Stephen D. 1997. Words and voices: perception and production in an episodic lexicon, in Keith Johnson and John W. Mullennix, editors, *Talker variability in speech processing*. New York: Academic Press. 33-56.

Goldinger, Stephen D. 1998. Echoes of echoes? An episodic theory of lexical access, *Psychological Review* 105.2: 251-271.

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

Harper, D.G.C. (1982). Comparative foraging in mallards: ideal free ducks, Animal Behaviour 30:575-584.

Hochberg, Judith 1986. Final /s/ deletion in Puerto Rican Spanish, in David Sankoff (ed.) *Diachrony and Diversity*. New York: Academic Press. 199-210.

Hockett, Charles F. 1955. *A Manual of Phonology*. Indiana University Publications in Anthropology and Linguistics 11.

Hockett, Charles F. 1967. The quantification of functional load. *Word* 23, 320-339.

Hudson, Carla L., and Newport, Elissa L. (1999). Creolization: Could adults really have done it all?, In Annabel Greenhill, Heather Littlefield, and Cheryl Tano, editors, Proceedings of the Boston University Conference on Language Development, 23. Somerville, MA: Cascadilla Press. 265-276.

Johnson, Keith. 1997. Speech perception without speaker normalization: an exemplar model. *Talker variability in speech processing*, ed. by Keith Johnson and John W. Mullennix, 143–166. New York: Academic Press.

Labov, William. 1966. The Social Stratification of English in New York City. Washington DC: Center for Applied Linguistics.

Labov, William.1994. *Principles of linguistic change, vol. 1: internal factors*. Oxford: Blackwell.

Labov, William, Mark Karen and Corey Miller. 1991. Near-mergers and the suspension of phonemic contrast. *Language Variation and Change* 3.33–74.33.

Labov, William, Malcah Yaeger & Richard Steiner. 1972. A Quantitative Study of Sound Change in Progress. Philadelphia: U. S. Regional Survey.

Liljencrants, J. & Lindblom, B. 1972. Numerical simulation of vowel quality systems: The role of perceptual contrast. Language 48: 839-862.

Lindblom, Bjorn, Peter MacNeilage, & Michael Studdert-Kennedy. 1984. Self-organizing processes and the explanation of language universals. In Brian Butterworth, Bernard Comrie, & Osten Dahl, eds., *Explanations for Language Universals*, Walter de Gruyter and Co., 181-203.

Liberman, Mark. 2002. Simple models for emergence of a shared vocabulary, Paper presented at *Laboratory Phonology VIII*. New Haven, CT.

Lotto, Andrew. 2000. Language acquisition as complex category formation, *Phonetica* 57: 189-196.

Manuel, Sharon. 1990. The role of contrast in limiting vowel-to-vowel coarticulation in different languages, Journal of the Acoustical Society of America, 88:1286-1298.

Manuel, Sharon. 1999. Cross-language studies: relating language-particular coarticulation patterns to other language-particular facts, in William J. Hardcastle and Nigel Hewlett, editors, Coarticulation: Theory, Data and Techniques. Cambridge, UK: Cambridge University Press. 179-198.

Manuel, Sharon and Rena Krakow. 1984. Universal and language particular aspects of vowel-to-vowel coarticulation. Haskins Laboratories Status reports on Speech Research, SR-77/78, 69-78.

Medin, D. L., Schaffer, M. M. 1978. Context theory of classification learning. Psychological Review, 85, 207–238.

Nosofsky, R.M. 1986. Attention, similarity, and the identification-categorization relationship," Journal of Experimental Psychology: General. 115:39-57.

Nosofsky, Robert M. 1988. Exemplar-based accounts of relations between classification, recognition, and typicality, Journal of Experimental Psychology: Learning, Memory and Cognition 14:700-708.

Ohala, John J. 1981. The listener as a source of sound change. Papers from the parasession on language and behavior, ed. by Carrie S. Masek, Robert A. Hendrick and Mary Frances Miller, 178–203. Chicago: Chicago Linguistic Society.

Ohala, John J. 1983. The origin of sound patterns in vocal tract constraints. *The production of speech*, ed. by Peter F. MacNeilage, 189–216. New York: Springer.

Ohala, John J. 1989. Sound change is drawn from a pool of synchronic variation. *Language change: contributions to the study of its causes*, ed. by Leiv Egil Breivik & Ernst Håkon Jahr, 173–198. Berlin: Mouton de Gruyter.

Ohala, John J. 1993. The phonetics of sound change. *Historical linguistics: problems and perspectives*, ed. by Charles Jones, 237–278. London: Longman.

Öhman, Sven E.G. 1966. Coarticulation in VCV utterances: spectrographic measurements, Journal of the Acoustical Society of America 39: 151-168.Martinet, Andre. 1952. Function, structure, and sound change. Word 8.2, 1-32.

Paul, Hermann. 1880. *Prinzipien der Sprachgeschichte*. Halle: Niemeyer. [English translation of 2nd (1886) edition: *Principles of the history of language* (transl. H. A. Strong). College Park: McGrath Publishing Company, 1970.

Pierrehumbert, Janet B. 2001. Exemplar dynamics: word frequency, lenition, and contrast. In Joan Bybee and Paul Hopper (eds.), Frequency and the Emergence of Linguistic Structure. Amsterdam: John Benjamin 137–157.

Plug, Leendert. 2005. –From words to actions: the phonetics of *eigenlijk* in two pragmatic contexts. *Phonetica* 62:131-145.

Plug, Leendert. 2009. Pragmatic constraints in usage-based phonology, with reference to some Dutch phrases. Manuscript.

Port, Robert, & Penny Crawford. 1989. Incomplete neutralization and pragmatics in German. *Journal of Phonetics* 17, 257–282.

Port, Robert, & Michael L. O'Dell. 1985. Neutralization of syllable-final voicing in German *Journal of Phonetics* 13, 455–471.

Pye, S. 1986. Word-final devoicing of obstruents in Russian. *Cambridge Papers in Phonetics and Experimental Linguistics* 5, 1-10.

Recasens, D. 1987. An acoustic analysis of V-to-C and V-to-V coarticulatory effects in Catalan and Spanish VCV sequences, Journal of Phonetics, 15, 299–312.

Recasens, D., Pallarès, M.D.& Fontdevila, J. 1998. An electropalatographic and acoustic study of temporal coarticulation for Catalan dark /l/ and German clear /l/, Phonetica, 55, 53–79.

Saffran, J.R., Newport, E.L., & Aslin, R.N. (1996). Word segmentation: The role of distributional cues. Journal of Memory and Language, 35, 606-621.

Schuchardt, Hugo. 1885 [1972]. On sound laws: against the Neogrammarians, in Theo Vennemann and Terence H Wilbur, *Schuchardt, The Neogrammarians and the Transformational Theory of Phonological Change*.

Silverman, Daniel. 2006. *A Critical Introduction to Phonology: of Sound, Mind, and Body*. London/New York: Continuum Books.

Silverman, Daniel. 2010. Neutralization and anti-homophony in Korean, *Journal of Linguistics*.
Silverman, Daniel. In prep. *Neutralization: Rhyme and Reason in Phonology*. Cambridge University Press.
Slowiaczek, Louisa M., & Daniel Dinnsen. 1985. On the neutralizing status of Polish word-final devoicing. Journal of Phonetics 13, 325–341.
Steels, Luc. 2000. Language as a complex adaptive system, in Marc Schoenauer, Kalyanmoy Deb, Guenter Rudolph, Xin Yao, Evelyne Lutton, Juan Julian Merelo, Hans-Paul Schwefel, editors, Lecture Notes on Computer Science. Parallel Problem Solving from Nature. PPSN-VI. 17-26.
Tversky, Amos. 1977. Features of similarity, Psychological Review 84:327-352.
Warner, Natasha, Allard Jongman, Joan Sereno, & Rachel Kemps. 2004. Incomplete neutralization and other sub-phonemic differences in production and perception: evidence from Dutch. *Journal of Phonetics* 32, 251-276.
Wedel, Andrew B. 2004. *Self-organization and categorical behavior in phonology*. Doctoral dissertation, University of California, Santa Cruz.
Wedel, Andrew B. 2006. Exemplar models, evolution and language change. *The Linguistic Review* 23.247–274.
Yu, Alan C. L. 2004. Explaining final obstruent voicing in Lezgian: phonetics and history. *Language* 80.73–97.
Yu, Alan C. L. 2007. Understanding near mergers: the case of morphological tone in Cantonese. *Phonology* 24.187–214.