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CHAPTER 13

CHANGES IN REPRESENTATIONS

THE NATURE OF HISTORICAL CHANGE
IOANA CHITORAN

THE RELATIONSHIP BETWEEN SYNCHRONIC VARIATION AND DIACHRONIC CHANGE
JONATHAN HARRINGTON

MODELING EXEMPLAR-BASED PHONOLOGIZATION
ROBERT KIRCHNER

This chapter addresses the nature of historical change, focusing on how the motivations and mechanisms for language change are informed by experimental work. Chitoran frames these issues by reviewing the question of the source(s) of "naturalness" in phonology. Harrington discusses the role of synchronic variation in setting the stage for diachronic changes. Kirchner introduces an exemplar theory-based model of change, explaining processes of "phonologization."

13.1 THE NATURE OF HISTORICAL CHANGE

Ioana Chitoran

13.1.1 Introduction

The nature of historical change is one of the earliest concerns of experimental approaches to phonology. "Why" sound change happens and "how" are key questions that, by the nature of the object of study, invited an experimental perspective, and inspired researchers to incorporate in their approach increasingly sophisticated methods of experiment design, technological advances, and computational models. Since linguistic change can rarely be observed and studied directly, an alternative is to replicate it in the laboratory or to model it, and these endeavors have proven fruitful. This body of work reminds us that the establishment of the Laboratory Phonology conference series in 1987 was the foundation of a research program, rather than its inception.

This section deals with the representation of historical change. This section addresses three issues. In Section 13.1.1 I review proposed sources of sound change in phonetic variation stemming from speech production and perception, and I discuss their implications for representations. In Section 13.1.3 I discuss the relationship between synchronic and diachronic systems, focusing on the development of phonologization models and on the related controversy surrounding the issue of naturalness. In Section 13.1.4 I outline promising new directions in experimental work on sound change.

13.1.2 Listener-perceived vs. speaker-produced variation:
Implications for representations

Approaches to sound change are primarily structured along the major distinction between the initiation and the propagation of change. The discussion will be limited
to the first aspect, which is directly relevant to the issue of representations. All models agree that sound change happens because variation in speech exists. Where they differ is in determining the relative importance of a particular type of variation: the phonetic variation inherent in the signal produced by the speaker (production-oriented change), or the variation perceived by the listener (perception-oriented change).

Two models of phonetic variation have been influential in explaining sound change: Lindblom’s H&H theory (Lindblom 1990; see Harrington, this chapter) and Ohala’s phonetic listener-based model. Both are built on extensive experimental work and have defined the main issues and research questions regarding sound change.

Ohala (1979, 1980, 1990, 1992, 1993, 1994) asserts the crucial role of the listener in initiating certain sound changes, citing similar intuitions of early phoneticians in this respect (e.g. Sweet 1874; Durand 1995). For Ohala, the main source of sound change is the misperception of the signal by the (possibly inexperienced) listener. Under this view sound change takes place in the acoustic-auditory domain rather than in articulation. Ohala argues that phonetic variation in speech is found in articulation, but for a sound change to actually take place, a cause must be in the source that is not sufficient. The auditory system of the listener is needed to process the signal in such a way it extracts crucial information from it. In arguing that variation in speech production is not (yet) sound change, Ohala points out that much of this variation is phonetically predictable, and consequently factored out by the experienced listener. This type of variation cannot trigger sound change unless a listener fails to compensate for it, takes the signal at face value, and thus produces a new form, different from the one intended by the speaker. This is the scenario that Ohala labels hypercorrection. The listener fails to correct the phonetically predictable variation. A large body of experimental work has confirmed that listeners regularly compensate for phonetically predictable variation, and fail to do so when the variation is not predictable (Mann and Repp 1980, Beddor et al. 1986; more recently Harrington et al. 2004). This last study shows that the ongoing fronting of /ɪt/ in Southern British English can be traced to the effects of a preceding anterior consonant, but that younger speakers fail to compensate for this coarticulation, thus triggering a shift in the boundary of the /ɪt/ category. This is observed in both their production (the /ɪt/ is more fronted than that of older speakers) and in perception (the /ɪt/ category boundary is shifted towards /ɪ/). The result is a generally fronted /ɪ/.

A smaller category of sound change falls under the scenario that Ohala calls hypercorrection, whereby the listener performs an unnecessary, inappropriate correction of the signal, and ends up producing a new form. Hypercorrection often results in dissimilation. An example is vowel backing after a palatal glide in Slavic (Ohala 19917: /stiʃj+/ /stʌ/) becomes /stiʃ+i/, because listeners mistakenly attribute the frontness of the final vowel to the preceding front glide, and correct it by backing the vowel. The general scenario underlying both of these sound changes can be characterized as “misunderstanding in sound change,” in the words of Labov (1994), implying a mismatch between production and perception.

Ohala’s model of sound change assumes rich phonetic representations, incorporating details of acoustic-articulatory relations, aerodynamic principles, and principles of how our auditory system extracts information from the acoustic signal. This phonetic model necessarily assumes that language learners have direct access to phonetic detail. At the same time, however, work by other researchers suggests the need to further enrich representations by accommodating symbolic aspects such as hierarchical structure (cf. Pierrehumbert 1990), based for example on ample evidence that the phonetic realization of segments is differentially affected by different levels of prosodic structure (Keating et al. 2003, among others; see Bougerol 1999 for a review). The question of representations more generally is currently one of the most exciting ongoing debates in the field, fueled by several interesting and strikingly different models. Some of these are discussed in the course of this section.

A major difference between Lindblom’s and Ohala’s models is their (non-)teleological aspect. For Lindblom sound change results from the interaction of two goals: articular economy and enhancement of perceptual contrast. For Ohala the initiation of sound change is instead non-optimizing and non-teleological, although he agrees that its spread may well be. Both models have been subsequently integrated by Blevis (2004) in a model which classifies sources of sound change into three categories: change, chance, and choice. In Blevis’s CCC model the categories change and chance derive from Ohala’s model, and refer to sound change via misperception and misapplication of a phonetics-phonology mapping. The category of choice follows Lindblom’s model and refers to change stemming from synchronic variation along a continuum of careful to casual speech (hyper- to hypoarticulation). Blevis maintains Ohala’s non-teleological view, except for instances of choice. His argument is simply that the articulatory and perceptual goals are redundant as an explanation, and therefore cannot be definitively proven. It has been proposed, for example, that the common change from palatalized velars to palatals is motivated by the goal of maximizing a phonological contrast phonetically. But Gairson (1999) demonstrated, in a series of production and perception studies, that velars before front vowels are easily confusable with palatovelar affricates, more so than with velars before back vowels. This invites then the
simple explanation that this sound change is due to purely perceptual conditioning, eliminating the need to refer to a principle of maximizing contrast, which in turn would require further exploration.

So far the emphasis here has been on the listener as a source of sound change. But other phonetic accounts of sound change have placed more emphasis on production. Goldstein (1981) examines common patterns of vowel shift, explaining how patterns of variability consistent with this type of sound change may emerge from the resonance properties of the vocal tract under essentially random articulatory variability. This hypothesis is tested in a simulation using the Haskins Laboratories articulatory synthesizer (Rubin et al. 1981). The proposal is consistent with the difference between stable and unstable regions identified in Stevens’s (1972, 1989) quantal theory.

Building on such earlier studies, the model of Articulatory Phonology subsequently developed by Browman and Goldstein (1986, 1990) includes detailed accounts of sound change. Even though the theory is not developed specifically as a theory of sound change, it has contributed insightful explanations and makes clear predictions about the way in which patterns of speech production can change a phonological system. Specifically, Browman and Goldstein (1991) propose that many cases of sound change can be analyzed consistently with Ohala’s model, as well as with their dynamic definition of articulatory gestures as shared primitives (“common currency”) in characterizing both phonological patterns and phonetic actions. For example, in Brown and Goldstein’s model, reductions in gestural magnitude can account for lenition phenomena, and variable gestural overlap accounts for assimilation and deletion patterns.

But the more interesting cases are still the perceptually based sound changes. In a gestural model these involve reassignment of gestural attributes among temporally overlapping gestures, and mispairing of articulatory movements. Gestural reassignment captures the listener’s failure to correctly identify the source of a particular property of the signal, as in Ohala’s model. Once of Brown and Goldstein’s examples of such a failure is the historical change of /ai/ to /ii/ in words like cough and tough, pronounced [kotix] [lortix] at the stage when the consonantal change took place (Browman and Goldstein 1991). Given increased overlap between the second element of the diphthong /ei/ and the velar fricative /x/, the lip-rounding gesture of the former co-occurs with the friction of the velar gesture. If the frication is attributed by the listener to the labial gesture rather than to the tongue body (velar) gesture, then a labial fricative is more likely to be perceived. The shortening of the diphthong into a monophthong also follows from this analysis, as the narrow labial gesture for rounding is no longer attributed to the diphthong.

Gestural mispairing can also explain cases that involve the apparent insertion or deletion of a gesture. An example of the former is the “spontaneous” vowel nasalization in Hindi, in the absence of a nasal consonant (Ohala and Adobe

1981): Sanskrit bāsa ‘breath’ > Hindi [s]. The acoustic and perceptual account attributes the change to the high air flow volume through the open glottis for the fricative, reinterpreted by the listener as nasalization. The alternative gestural account relies on the finding that velum height for oral constriction gestures varies directly with the constriction degree (Bell-Berti 1980), so that in a sequence [a] the velum lowers rapidly from consonant to vowel. This rapid velum lowering may be misinterpreted as an intended velum-lowering gesture, and misattributed to nasalization. Note that the two accounts are not entirely equivalent, because the gestural one assumes an articulation that is already present (rapid velum lowering) rather than being a perceptual mirror.

The opposite case, mispairing with a deletion effect, is also attested, for example in Shona buna ‘kunywa’ > kunywa (Ohala 1981a). The labiality of [w] can be entirely attributed to the preceding [n], factoring it out and keeping only the velar component. This analysis is entirely equivalent to Browman and Goldstein’s gestural one. Two successive labial gestures for [mw] result in a very similar overall lip movement as a single labial gesture. The listener can thus attribute this pattern to a single gesture instead of a pair.

By and large, these models are similar in that they agree on the necessity of rich phonetic representations to capture the phonetic variation identified as the source of the change. Where they can differ is on the issue of speaker-produced vs. hearer-perceived variation. It appears to be harder, in a gestural account, to accommodate those less common cases where an exclusively perception-based explanation has been proposed. This invites concrete experiments targeting the specific nature of the phonetic representations proposed—acoustic or articulatory—that are best suited for a model of variation and sound change. This particular issue, in turn, is especially relevant for understanding the process of phonologization, discussed next, whereby phonetic variation becomes part of the grammar. The question of representation is non-trivial in this respect, since phonologized patterns require symbolic representation.

13.1.3 Relationship between synchronic and diachronic systems: Phonologization and phonetic naturalness

All models agree that sound change has its source in synchronic variation, and its effects can cause not just differences in pronunciation, but changes in the phonological patterns learned by the listener. For this reason, many models of sound change have focused crucially on the process of phonologization. I start from a schematic definition of phonologization: the shift from high phonetic variability to low variability, followed by the development of a new contrast. Most models agree on these basic elements (e.g. Hyman 1978; Kiparsky 1995; Hajek 1997; Blevins 2004; Kirchner et al. 2010; Kirchner, this chapter).
The most widely cited and explicitly formulated model of phonologization is Hyman (1976). The process involves two steps: phonetic variation leading to phonological variation (phonologization), and phonological variation leading to distinctive variation (phonemicization). Hyman's model clarifies and reconciles the production vs. perception perspective: "Phonological change is perception-oriented, even though the seeds for a change may be articulatory" (Hyman 1976: 416).

Hyman's model has the clearest predictive value. Blevins (2004) mistakenly criticizes it for predicting that the evolution of a new contrast always implies the loss of former contrasts, but Hyman does not actually make this claim. What is crucial to this model and the reason why it works, are its three steps, schematized below:

1. \( \text{intrinsic phonetic variation} \)
2. extrinsic distinctive variation
3. phonemic stage

If we follow the three steps in the classic example of the bifurcation of Southeast Asian tone, they correspond to the following changes:

- **Step 1**: Voiced and voiceless consonants determine \( f0 \) perturbations on following vowels;
- **Step 2**: \( f0 \) perturbations are exaggerated, and no longer attributable to universal phonetics. A rule develops: \( a \rightarrow \text{[voice]} \).

The transition from 1 to 2 marks the phonologization stage, and at this point the system can go either way. It may keep \( [p]\) and \( [b]\) both with the same voicing distinction and the two tones in complementary distribution. This is the predicted outcome if the \( f0 \) and voicing distinctions are perceived to an equal degree. If, on the contrary, the primary distinction perceived is the \( f0 \) rise instead of the consonant-voicing distinction, then the split tones are predicted to survive at the expense of the voicing distinction. This is the attested outcome, and it marks the phonemicization stage (see also Lands 2003), which is the transition from 2 to 3.

- **Step 3**: Distinctive split tone develops, consonant-voicing distinction is lost.

Hyman explicitly states the possibility of the contrast loss: "... accompanying every phonologization is a potential dephonologization" (Hyman 1976: 416).

Hyman's model is the most clear to date, despite being developed over three decades ago. There are, however, several alternatives in representing the details of the phonemicization stage as we rethink the nature of phonological representations and categoriality in trying to capture the shift from higher to reduced variability. Kirchner (this chapter) proposes an exemplar-based phonologization model. Another promising way of modeling reduction in patterns of variation, without recourse to a major change in representation, is the gestural model of articulatory phonology. The model can handle precisely the general scenario discussed here by virtue of its units, articulatory gestures, conceived of as dynamic targets, and thus is well placed to capture changes in variability.

One frequently debated issue related to phonologization is naturalness. All sound change is phonetically plausible because it stems from phonetic variation. In that sense it is natural. At the same time, much of synchronic variation reflects diachronic change, so there is also a sense in which one might expect the same naturalness to play a role in synchronic phonology. The issue of naturalness has received much attention from several generations of linguists, starting with early generativists (Stampe 1979, Donegan and Stampe 1979), and has occasionally steered theoretical approaches toward a more functionalist or reductionist angle. The conclusion reached at this point is that naturalness is relevant in the diachronic dimension, but once a pattern is phonologized it becomes independent of its original articulatory and/or acoustic sources. Lands (2003) proposes in fact the term *dephonemization*, which best captures this particular stage. At this point the pattern may be subject to different principles for which naturalness is irrelevant. This simply means that a debate about the phonetic naturalness or unnaturalness of a phonologized pattern becomes a moot point. Many phonological patterns cannot be directly attributed to phonetic principles such as perceptual salience, ease of articulation, perceptual recoverability (for the most explicit arguments see Hyman 1975, 2001; Anderson 1988).

A series of recent studies have helped clarify this question by examining the loss of the original conditioning environment in phonologization. They show explicitly how phonetically natural as well as unnatural factors interact in phonologization. It is generally understood that exaggeration of production variation severs it from its coarticulatory source. Subsequent loss of the source is taken as an indication of phonologization. Recent studies by Beddor (2007) and Beddor et al. (2009) have shown that the loss of coarticulatory sources is affected by the larger segmental and phonotactic context, which is, of course, language-specific.

Beddor and her colleagues focus on the loss of the nasal in coarticulatory vowel nasalization in VN sequences. They reveal a systematic coarticulation between the duration of the nasal consonant and the extent of nasalization in the preceding vowel: in a VN sequence the shorter the nasal consonant, the longer the extent of nasalization on the vowel. This is expressed as temporal sliding of the velum-lowering gesture toward an earlier onset in the preceding vowel. This coarticulation is in turn conditioned by other phonetic elements in the extended context: (i) the voicing of a consonant following the VN sequence; (ii) the duration of the vowel in the sequence. These patterns are summarized in (1a).

\[(a) \text{Trade-off relations between extent of V nasalization and N duration} \]

<table>
<thead>
<tr>
<th>Example</th>
<th>Short</th>
<th>Long</th>
<th>Voiced</th>
<th>Unvoiced</th>
</tr>
</thead>
<tbody>
<tr>
<td>[spænd]</td>
<td>short</td>
<td>long</td>
<td>voiced</td>
<td>unvoiced</td>
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</table>
A similar pattern is reported for Italian (Ohala and Busa 1995; Busa 2002), involving the presence of a fricative vs. a stop following VN. There are, therefore, clearly identifiable contexts where N shortens systematically, due to articulatory overlap between a vowel and an adjacent nasal.

Based on the trade-off in production, the authors predicted equivalence in perception. Since the overall amount of nasalization tends to remain constant, listeners should not be sensitive to its location (on the vowel or on the consonant). Perception studies were carried out with speakers of two languages with different timing relations: American English (a language with trade-off in production) and Itaklange, where no trade-off relations were found, and where NC is traditionally analyzed as pre-nasalized. Natural English and Itaklange stimuli were edited to co-vary N duration with extent of V nasalization. Listeners of both languages showed sensitivity to the overall amount of nasality, regardless of where it is located in the signal (V or N), supporting the authors’ perceptual equivalence prediction.

English listeners, however, performed significantly worse on stimuli where vowel nasalization had been kept constant, as they were expecting a trade-off relation between V nasalization and N. They showed the same sensitivity to co-variation when the voicing of C in VNC was varied. Many listeners predominantly perceived a nasalized vowel, especially in the VNC contexts, with a shorter nasal.

These results have important implications for dichotomy. The perceptual equivalence of nasality on either V or N predicts that codas nasals are resistant to loss, since N can still be perceived even with relatively little nasality. Cross-linguistically this prediction is borne out in languages where the loss of coda N is known to have been slower than loss of other coda consonants. At the same time, however, co-variation in production between V nasalization and N along with perceptual sensitivity to it, predicts that listeners can predominantly perceive a nasalized vowel and no N in the relevant context. It can thus counteract coda stability. This is the scenario that would facilitate listeners’ (learners’) reconstruction of V for ‘VN’, leading to loss of N as a coarticulatory source.

These studies show convincingly that the loss of the conditioning environment to sound change is not a direct consequence of phonologization, but rather the result of repeated interaction between synchrony and diachrony. Certain phonetic contexts favor shorter nasals and heavier V nasalization, leading to systemic synchronic alternations, which in turn condition a sound change, and a phonological change of introducing contrastive vowel nasalization in the system. At the same time, language-specific timing relations and language-specific phonotactics ("unnatural" factors) can affect the course of the sound change by determining to what extent a given context occurs in a language.

13.1.4 Experimental work on sound change: New directions

The studies presented above illustrate the combined research directions advocated by Ohala (1974: 553): "...there are (.) two types of experiment: that of the man-made controls and that of the nature-made controls." Ohala's own model is built primarily on human-made controls, the nature-made ones being much harder to come by. But whenever these are available they offer a valuable testing ground for hypotheses, allowing the study of historical change in a living laboratory of synchronic variation. These are the types of studies I would like to highlight next.

All are experimental phonetic studies of sound patterns in one language that can inform historical development in that same language or a different one.

The potential of this crossover approach was noted early on by Pierric Delattre (1946) in a paper whose very title heralds Ohala's direction: "Stages of Old French phonetic changes observed in Modern Spanish." The paper is essentially a list of thirty-one well-documented sound changes of Old French for which an equivalent phonetic stage can be found in Modern Spanish, a language that is not a direct descendant. Delattre advocates the study of diachronic change by observing patterns of synchronic variation. At the same time, such studies can answer more general questions about speech production. A relevant example is glide strengthening in initial position: /u/ > /u/ or /u/ (later reduced to a fricative in Modern French) and /el/ > /gel/, as in Gmc [wadla] "wage" > Gallo-Roman [gewa] > Mod. French gage [ga]. Synchronic variation in Spanish reflects this pattern: e.g. [gweis] is frequently heard for hueso 'bone.' Experimental investigations of such patterns can indeed clarify many historical questions. In the case of the Old French palatal glide it is hypothesized that it went through a stage where the affricate was palatalized. If a similar co-occurring palatalization is observed in Spanish, it would strengthen the hypothesis regarding the diachronic change in French. The labio-velar glide raises a question with even broader implications for typology and for speech production. If strengthening involved increased constriction at one end, and there are two ends available (the lips or the tongue dorsum), what makes languages choose one over the other?

A number of phoneticians have responded unwittingly to Delattre's call, through sophisticated experimental studies that have accomplished even harder tasks: contributing to the reconstruction of sound systems whose historical development is much more sparsely documented than that of French. An excellent example is the thorough acoustic analysis of Athabaskan stops by McDonough (2001) and McDonough and Wood (2008), which informs the historical evolution of that
system. In Athabaskan languages the stop series has a three-way contrast: aspirated, unaspirated, ejective—traditionally written d, t, c, k, k'. The authors argue that the aspirated stops are not phonetically aspirated, but are instead affricates with a velar release [ts, ks]. They consider this to be the native, inherited pattern. While this analysis had already been suggested by earlier linguists (Haas 1968; Young and Morgan 1980, 1987; McDonough 2003) acoustic study of Navajo stops and McDonough and Wood’s (2003) investigation of stops in five different Athabaskan languages confirm the analysis experimentally. In these languages aspirated stops are shown to have long, heavily fricated releases. A quantitative analysis of the r
[tx] release spectrum finds it to be no different from that of the velar fricative [x].

The sound change t > k in some Athabaskan languages is therefore best interpreted as [tx] > [kx], as in Navajo [tx'ox] ‘water’. The detailed acoustic analysis of synchronic Athabaskan data thus reveals valuable information about the historical development of the sound system of this language family.

Another successful instance of this approach is Moreton and Thomas’s (2007) instrumental analysis of diphthong raising in American English, which they compare to the better known case of Canadian Raising. Their study challenges the view that the sound change arises from the Great Vowel Shift (GVS). They propose instead that it begins as voicing-conditioned variation in the offglide (rather than variation in the nucleus, predicted by GVS). They hypothesize that voiceless codas favor assimilation of the /t/ nucleus to the offglide, resulting in raising, while voiced codas favor assimilation of the offglide to the nucleus, resulting in lowering. Testing requires a longitudinal study, showing that at some point assimilation to the offglide overtakes assimilation to the nucleus.

While such a study is no longer possible on the Canadian variety of English, the authors used recordings of speakers from Cleveland, OH, where similar alternations are observed. Comparative acoustic analyses of archival and new recordings showed that Pi of nuclear [a] lowers by 2 percent before voiceless codas for speakers born before 1900, and by 14 percent for speakers born after 1905. At the same time, the offglide itself shows a similar rise over time. These results favor the new hypothesis (voicing-conditioned assimilation to the offglide increases over time) over the GVS hypothesis, whereby the nucleus would be primarily affected. The authors have compared phonetic variation in one variety of English to the similar pattern of a completed sound change in another variety. This methodology has led to radical rethinking of a well-known diachronic explanation in light of new synchronic data.

A similar approach is used by Chitoran and Hulke (2007) in comparing pho-
netic variability across five modern varieties of Romance to determine the historical development of vowel sequences and diphthongs—e.g., [pl-a]· [pla]. By interpreting the experimental results in the diachronic context of each language, the authors show that each synchronic variation pattern reflects a different stage within the evolu-
dution of a hiatus-diphthong contrast, so that all varieties are staggered at different points along a hiatus-diphthong continuum. Systematic duration measurements revealed phonetic factors common to all varieties, that are responsible for the variation: initiality effects (vocalic sequences are longest in word-initial position), proximity to stress effects (stressed vocalic sequences are longest, followed by pre-
tonic sequences, and by pre-pre-tonic ones—dilo—diagram—diagonal). The different patterns currently observed in the five Romance languages are shown to follow from the interaction of these independent factors: (i) a general articulatory tendency for hiatus to resolve to diphthongs, due to the relative stability of diph-
thong articulations; (ii) phonetic (prosodic lengthening) effects which inhibit the shift from hiatus to diphthong and (iii) system-internal (lexical attractor) effects of pre-existing diphthongs in a language from different historical sources.

13.1.5 Conclusions

Even though laboratory methods cannot be applied directly to sound change, a significant component of experimental work has directly informed our understanding of the complex relationship between diachrony and synchrony. Replicating sound change in the laboratory, testing hypotheses about sound change in one language against synchronic variation in another language, and computational modeling of sound change, all allow for the investigation of subtle details of diachronic change. These methods have significantly deepened our understanding of change. At the same time, new findings in this area have led to a rethinking of gradience and categoricity as the turning point in the question of representations. Returning to the definition of phonologization as the shift from high to reduced variability, the emerging view is that of categoriality as illusion, while phonological systems evolve by organizing gradience.

13.2 The Relationship Between Synchronic Variation and Diachronic Change

Jonathan Harrington

13.2.1 Introduction

The dramatic effect of sound change on phonology can suddenly be brought into sharp focus by place names in which the relationship between spelling and