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Editors' introduction
Cognitive processing as a bridge between phonetic and social models of sound change

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The seven papers in this special edition are derived from the 2nd Workshop on Sound Change held at Kloster Seeon, Germany, in May 2012. The purpose of the workshop was to bring together scientists approaching the question of sound change and its relationship to synchronic variation in speech from many different disciplinary perspectives that we believe are necessary for understanding this complex relationship. The publications in this special issue are a reflection of this breadth and cover a wide range of issues, such as the influence on sound change of child speech, dialect contact, social differences, coarticulatory variation, and imitation. The studies draw upon several languages (Mandarin Chinese, English, German, Khmer, Korean, Spanish) and employ diverse experimental techniques for relating synchronic variation and diachronic change, including ultrasound measurements of the tongue (**Lin et al.**), acoustic and perceptual analyses of multilingual corpora (**Beckman et al.**), measurements of oral and nasal airflow in combination with the perceptual analysis of aerodynamic variation (**Solé**), and computational modelling (**Kirby**).

It has been convenient in the literature so far to draw a distinction between the conditions that give rise to sound change as opposed to those that are concerned with its spread through the community (e.g., Ohala 1993). A classic issue within the first of these is phonologization (Hyman 1976), which can often be related synchronically to a change in the way that the multiple features which cue a phonological distinction are parsed in the speech signal. Four papers in this special issue address this issue.

In **Kirby's** study, phonologization arises when laryngeal features (primarily fundamental frequency) and/or voice onset time take over from a trill in distinguishing pairs such as /kru:, ku:/ in the colloquial Phnom Penh variety of Khmer. The phonetic basis of this change is likely to be a drop in fundamental frequency

that is a consequence of /r/-fortition and concomitant voicelessness of the trill. Kirby draws a parallel between this type of sound change and the development of phonological nasalization and loss of post-vocalic nasal consonants (e.g., Latin *manus* → French *main*) that has been extensively investigated experimentally by Beddor (2009).

Beckman et al. make use of a real-time investigation of data taken from studies spanning some 60 years as well as acoustic and perceptual measurements in order to investigate the forces underlying the change from VOT to fundamental frequency as the basis for the contrast between phrase-initial lax and aspirated stops in the Seoul variety of Korean.

Solé's concern is with the phononologization of so-called implementational features which function to enhance a contrast: in her analysis, the implementational feature is leakage of nasal airflow, which reduces the supraglottal pressure, thus facilitating vocal fold vibration as the basis for the voiced-voiceless contrast in Spanish oral stops. She provides perceptual evidence to show how this nasal leakage can become phonologized as a nasal consonant. Solé also argues that implementational features are inherently variable (across speakers and languages); as a consequence, they may be especially prone to sound change because of listeners' difficulty in parsing such features with the source that gives rise to them.

Lin et al. take on the challenge of relating coarticulation, hypoarticulation, and phonologization. Their study is concerned with the vocalization of preconsonantal /l/ in English preceding labial (*help*) and velar (*milk*) stops. They use ultrasound methods to show that that the tongue tip is lenited to a greater degree than in corresponding words with an alveolar cluster. They also show that these differences are not just a matter of overall hypoarticulation, given their other findings that tongue-tip lenition is not correlated with a lenition of the tongue dorsum (as it might be in an overall more hypoarticulated production). On the basis of an acoustic analysis, they make the interesting suggestion that the articulatory-acoustic change may be quantal, in which the very small tongue-tip lenition causes an approximation of the first and second formants such that they become perceptually integrated. Thus the sound change may be likely in such contexts because a small articulatory change produces quite a marked perceptual effect. Finally, they show that these apical lenitions are more likely in high- (e.g., *milk*) vs. low- (e.g., *ilk*) frequency words, but again not in a way that is predictable from the degree of lenition of the tongue dorsum. Such a finding provides for the first time physiological evidence that is compatible with the idea expressed in, e.g., Bybee (2006) and Wang (1977) that, contra the Neogrammarian hypothesis, high-frequency words may undergo sound change ahead of low-frequency words.

The way that sociophonetic variation can give rise to sound change is another issue that is taken up in some of the studies. **Clopper's** concern is with establishing a relationship between perceptual speech processing, the listener's experience with dialects, and dialect levelling. She shows how knowledge of a dialect can increase the speed and accuracy of lexical processing in that dialect. The further issue she considers is the effect of such a processing advantage for those listeners having had exposure to multiple dialects, especially when one of these is a standard variety. The results from her various studies suggest that exposure to a standard may facilitate lexical processing irrespective of the listener's dialect background, but that such exposure can come with the cost of causing local dialect attrition. Whether or not local dialects are levelled depends (at the level of the individual and for the community), she argues, on a number of factors, including the individual listener's experience with different varieties, the need to maintain phonetic distinctiveness between two varieties, and on other factors such as the perceived prestige and the solidarity amongst interlocutors.

Clopper's study and **Jannedy and Weirich's** study contribute to the idea that linguistic experience accumulated during a lifetime is in itself a potential source of sound change. Jannedy and Weirich take up this issue through their demonstration that perceptual categorizations in speech can be altered by exposure to visual primes (see also, e.g., Hay and Drager [2010] for a similar demonstration with respect to Australian/New Zealand English differences). More specifically, a fronted pre-palatal fricative is characteristic of a variety produced by younger speakers from multi-ethnic neighborhoods and is perceptually distinct from the palatal fricative (in words like *i<u>ch</u>*) that is more typical both of a standard and (in Berlin) of a more middle-class variety of German. Exposure to a visual prime (the written names of one of two Berlin suburbs that typify these two varieties) was shown to shift responses along a fricative continuum varying in place of articulation for some listeners. The strong influence of listeners' expectations of a variety, their increasing exposure to youth German, and the relative scarcity of palatal fricatives in the world's languages are some of the reasons that the authors propose for the sound change in progress in Berlin by which the palatal fricative is becoming increasingly fronted.

Imitation or accommodation has been suggested as one of the factors that contribute to dialect convergence (Bloomfield 1933) and to the development of colonial dialects such as Australian and New Zealand English (Trudgill 2004, 2008) in models that are more closely concerned with conditions that bring about the spread of sound change. The present study by **Babel et al.** extends numerous recent empirical findings demonstrating imitation in modified isolated words (Nielsen 2011) and in conversational interaction (Pardo et al. 2012) as well as the

way that imitation can be constrained by social preferences (Babel 2012). In the present study, Babel et al. show that listeners across both genders most readily accommodated to novel voices that were gender-atypical, while only females' but not males' accommodation was influenced by how attractive the voice had been judged to be. For Babel et al., the main role of accommodation in sound change is that it is one of the main mechanisms by which variation is disseminated. They also invoke a type of sociophonetic regulator of the kind proposed by Lindblom et al. (1995) that blocks variants from being imitated if they have pejorative social meaning.

The results from both **Clopper** and **Jannedy and Weirich** are consistent with many others in showing that the perception of phonetic detail is listener specific and highly idiosyncratic depending on listener experience. If so, then listeners must imitate phonetic detail somewhat imperfectly; they might, for example, produce a slightly different mapping between phonology and speech production in the manner suggested by **Solé**. Imperfect imitation would imply that there is a constant stream of novel phonetic forms which could provide the fuel for further imitation, assuming an extension of **Babel et al.'s** finding towards a general propensity to imitate forms that are phonetically novel. Taken together then, these three studies suggest that sound change may be an inevitable outcome of the combination of idiosyncrasy acquired through listener experience coupled with different parsings of the speech signal (imperfect imitation).

Some of the studies bring to bear experimental evidence on the role of male/female differences in the spread of sound change. This issue of how gender is associated with sound change is complicated by whether, in Labov's terminology, the sound change is from above or below. When the sound change is from above, women tend to produce more socially prestigious variants, lagging behind men who are more inclined to produce non-standard forms (principle Ia in Labov 1990). But when the sound change is from below (principle II), women are typically a generation ahead of men and introduce innovative changes (i.e., in sound change from below, men tend to be more conservative and women more likely to produce phonetic variants that deviate from the standard). **Babel et al.** interpret their finding that females tended to accommodate to more attractive voices as a consequence of females' greater attunement to the possible prestige associated with these voices. Their findings might therefore form the basis of a synchronic link between Labov's principle Ia and accommodation. The evidence for principle II comes from **Beckman et al.'s** reanalysis from numerous studies over a 60-year period to show that women led the sound change from below by which pitch is taking over from VOT as the primary cue for lax vs. aspirated stops in Seoul Korean. They further validate this female-led change by showing that lis-

teners' perceptual judgements of lax vs. aspirated stops in this variety of Korean are swayed primarily by pitch cues when listening to women but by VOT when listening to men. Finally, **Clopper** seeks to reconcile the gender paradox that women are at once more conservative in sound change from above but innovators in sound change from below in terms of the type of social network theory that is also aired in **Jannedy and Weirich**. That is, a change from above reflects women's greater use of linguistic variation to signal power and group affiliation, but women may also lead changes from below because they have weaker network ties than men (and are therefore more susceptible to take up phonetic variants from beyond the social group).

The explanation advanced by Labov (1990, 2007) for women leading sound change from below is that children tend to learn their first language from women as their primary caregivers. For this reason, "boys and girls will hear relatively advanced forms from their female caregivers. . . . The asymmetry of the caregiving situation will therefore advance female-dominated changes and retard male-dominated changes" (Labov 1990). Against this backdrop, **Beckman et al.** take up the difficult challenge of demonstrating a different pattern of acquisition in two groups of young children exposed respectively to sound change from below and sound change from above. The first of these is the data already discussed for Seoul Korean that show all the hallmarks of a sound change from below including being led by women. Beckman et al. show that this sound change is now so advanced for young Seoul Korean women that their distinction between lax and aspirated stops is cued entirely by pitch. However, they go on to show that young children still make use of VOT for effecting this distinction because their caregivers from which the distinction is acquired are likely to be somewhat older and therefore incrementally less advanced in the progression of the sound change than the younger women who make use almost entirely of pitch. Beckman et al.'s analysis of sound change from above is taken from the Songyuan variety of Mandarin, which has developed a contrast between retroflex and dental sibilants as a result of contact with the Beijing dialect of Mandarin (in which the phonological opposition occurs). This change from above in Songyuan may also be precipitated by learning to speak what is considered to be the more educated or cultivated Putonghua standard. Their further evidence of a sound change from above that has been abruptly borrowed within one generation is that younger but not older Songyuan adults cleanly separate dental from retroflex fricatives in their productions. In addition, Songyuan children master both the borrowed apical [s] and the native apical [ʂ], just like the children in Beijing Mandarin, which would not be expected if this were an incremental sound change from below.

Like Beckman et al., **Kirby** is also concerned with modelling how sound change might spread across generations. In order to do so, he makes use of

Bayesian classifiers and a computational model to explain his data showing that /r/-loss has given way to pitch cues as the main differentiator of /CrV/ from /CV/ and /C^{h}V/ in the Phnom Penh variety of Khmer. Kirby builds a multidimensional Gaussian mixture model based on four acoustic parameters for each of the above three categories from his production data. In an initialisation stage, the data for a number of so-called teachers are created by randomly sampling the marginal distributions associated with the three category labels /CrV/, /CV/, and /C^{h}V/. The teachers estimate the parameters of the distributions and send samples from these estimated distributions to a number of learners. New learners then receive samples from this first generation of learners and so on. This iterative random sampling ensures that there must be a slightly different association between the categories and data for any learner in any generation (because new learners must infer the category labels). Kirby first shows how there is stability in this iterative system, that is, the relationship between the three categories and the four sets of cues that differentiate them remains largely unchanged across successive generations. But F_0 is shown to emerge as a more important cue for distinguishing /CrV/ from the other two categories in a second simulation in which the duration of /r/ is reduced in the training stage and added to VOT. In a third and final simulation, F_0 emerges as an even more marked differentiator of /CrV/ from the other two categories when /r/-duration is reduced but without adding its duration to VOT. Thus, Kirby's learning algorithm models his data by which pitch cues have become phonologized with the loss of /r/ in Phnom Penh Khmer /CrV/ words.

Many studies in this special issue are founded on the accumulation of evidence in the last decade that categorization emerges from experience and that social and speaker attributes of speech are cognitively represented (Pierrehumbert 2002, 2003). This increasing shift towards developing models of the relationship between phonetics and phonology that incorporate sociophonetic information has numerous consequences for the study of sound change that are to a certain extent reflected in the approaches and conclusions in this special issue. One of these is that there is an increasing blurring of the boundaries between phonetic models that are more directly concerned with the conditions that give rise to sound change and those with a stronger tradition in sociolinguistics that deal more directly with how sound change spreads through the community and/or the lexicon. This is evident in **Kirby's** model in which phonologization is modelled as an emergent aspect of probabilistic classification across successive generations of agents, and in the analysis of **Lin et al.**, which is concerned with how articulatory and acoustic patterns contribute both "to the initiation and lexical diffusion of historical /l/ lenition". Another consequence is that the association between the perception (and possible mis-perception) of context and

sound change is broadened to include not only phonetic factors as in **Solé** and **Lin et al.**, but also many others such as gender (**Beckman et al.; Clopper**), dialect (**Clopper**), and visual primes associated with youth speech (**Jannedy and Weirich**).

Yet another way in which the studies in this special issue contribute to a new way of looking at sound change is that they take up the challenge of understanding not just how age and social factors correlate with sound change as typified in the type of sociolinguistic approach pioneered by Labov, but also how such changes emerge from the cognitive processing of social information in speech communication. This is evident in several studies of the special issue, in particular **Clopper's** analysis showing a link between a listener's experience of dialects and dialect-levelling and **Babel et al.'s** demonstration of how sound change that develops from imitation is constrained by novelty and other types of social information. Topics that have mostly been debated in sociolinguistics, such as the relationship between sound change from above and below or the sigmoidal progression of sound change, are, as the studies of **Beckman et al.** and **Kirby** testify, fully integrated into models of sound change based on speech processing.

Studying sound change in the 21st century requires, in the spirit of laboratory phonology, a synthesis of diverse approaches. The diversity is evident in the association between physiology, perception, sound change, and phonological typology in **Solé**; in the linking of physiology, acoustics, and lexical frequency in **Lin et al.;** in the association of sound changes in progress with the effect of visual primes (**Jannedy and Weirich**); and in the computational modelling of sound change in progress (**Kirby**). Perhaps the most dramatic demonstration of diversity in methods comes from **Beckman et al.,** who introduce evidence from variation across both gender and age groups and the perceptual processing of that variation, considering both incremental vs. abrupt change, and also sound changes in progress in languages (Korean, Mandarin Chinese) that are very differently structured compared with the far more frequently studied European languages. Just this type of plural approach that integrates methods and experimental techniques from different disciplines will be essential in the future for shedding further light on questions that are fundamental not just to sound change but also more generally to laboratory phonology in order to understand the forces that can push the association between speech communication and categories between stable and unstable states.

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