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The social life of phonetics and phonology

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Abstract

In this article we define and illustrate sociophonetic variation within speech, highlighting both its pervasiveness and also the relatively minor role it has played in the development of phonetic and phonological theory. Reviewing evidence from studies of adults and children, we suggest that cognitive representations of words combine linguistic and indexical information, and that both types of information are present from the first stages of acquisition. We suggest that an exemplar-based model of phonological knowledge offers the most productive means of modeling sociophonetic variation. We discuss some of the characteristics of an exemplar-based account of sociophonetic variability and highlight some strands of investigation which would facilitate its further development.

1. Introduction

Variability is one of the defining characteristics of human speech. No two voices are identical, no two utterances the same. Variability in speech is not, however, wholly random or chaotic. Rather, it results from a number of specific sources and may form rule-governed patterns.

Much research in phonetics and phonology has been concerned with identifying these patterns and their sources, with a view to furthering understanding of central issues within these fields. Explaining systematic variation in speech may yield insights into the operation of the speech production and/or perception mechanisms, or it may help in distinguishing phonological knowledge from natural phonetic processes. It has been shown, for example, that phones may differ in their intrinsic properties: Close vowels have a higher f0 than open vowels (Shadle, 1985; Whalen & Levitt, 1995), voice onset time durations and stop release bursts vary as a function of both place of articulation and the quality of adjacent vowels (Liberman, Delattre, & Cooper, 1952; Westbury, 1983), articulatory gestures tend to be longer and 'stronger' when in stressed contexts or preceding major prosodic boundaries (Kelso, Bateson, Saltzman, & Kay, 1985; Shattuck-Hufnagel, & Turk, 1996), and faster speech tends to produce more articulatory undershoot (Lindblom, 1963; Perkell, Zandipour, Matthies, & Lane, 2002). Such sources of variation are largely explicable with reference to articulatory constraints and/or the natural laws of aerodynamics and acoustics operating within the vocal tract (Ohala, 1983; Shadle, 1997; Stevens, 1998). By contrast, other variable patterns appear to be language

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specific and thus represent part of the phonological knowledge acquired by speakers of the language. English, e.g., displays contextual allophony such that voiceless stops are aspirated in initial prevocalic position, but not when in onset clusters preceded by /s/. Similarly, language-specific morphophonological alternations yield variable patterns illustrated by *act* [−t] versus *action* [−ʃ−] and *elect* [−t] versus *election* [−ʃ−].

While these examples show that certain types of variability have been studied extensively in phonetics and phonology, other types have been the subject of rather less attention. 'Sociophonetic' variation is a case in point. This term is one that has come to be used extensively in the last few years, referring usually to variation in speech that correlates with social factors like speaker gender, age, or social class. It is still something of an exception, though, to find experimental phonetic or phonological studies that include such social dimensions in their methodology, or to find reference to sociophonetics in textbooks, university course descriptions, or conference announcements.

There are several reasons why sociophonetic factors have remained peripheral to phonetics and phonology. Above all, the dominance of particular theoretical models and methodological traditions has meant that social factors have been partitioned de facto from the 'purely linguistic'. The emphasis in the generative tradition, e.g., has been on describing the linguistic knowledge of the "ideal speaker–listener, in a completely homogeneous speech community" (Chomsky, 1965, p. 3). Differences *between* speakers of a given language have thus been less of a concern.

In this article, our aim is to assess the potential for sociophonetic variation to inform theoretical modeling in phonetics and phonology. We begin with an exploration of what is meant by 'sociophonetics' and 'sociophonetic variation' (Section 2), since these terms have not been particularly well defined. We also offer several illustrations of sociophonetic variation, drawing especially on the findings of our own research on non-standard varieties of British English. In Section 3, we examine the relationship between the sociophonetic and linguistic properties of speech from the perspective of a child acquiring a first language. We present data from studies of child-directed speech (henceforth CDS) and from children's speech production in which identifying sociophonetic variation was a principal aim. The findings of these studies form the basis for a discussion of the relevance of sociophonetic issues for phonetic and phonological theory (Section 4). In particular, we question whether the marginalization of sociophonetic factors is sustainable in the construction of a comprehensive account of the long-term storage of information about sounds and sound structure, and how that information is accessed in the on-line processes of speech production and perception. We suggest that an exemplar-based model is the most promising candidate for offering a unified account of how sociophonetic as well as linguistic material might be learned and stored. We also explore the implications of the findings of our sociophonetic studies for exemplar models. Finally, in Section 5, we highlight a number of important issues for future research in sociophonetics.

2. Sociophonetic variation

2.1. The scope of sociophonetics and sociophonetic variation

The definition of 'sociophonetics' is somewhat vague. The term has a reasonably long history (tracing back at least to Deshaies-Lafontaine, 1974), but it has been neither widely nor consistently used. There is, for example, no reference to it in the Oxford English Dictionary (second edition, 1989), or in popular linguistics glossaries such as Matthews (1997) or Trask (1997). In Crystal's (2003) *Dictionary of Linguistics and Phonetics*, it makes its first appearance in the fifth edition. It has had its widest currency among phoneticians, who have used it to refer especially to descriptive accounts of speech production across different dialects, speaker groups or speech styles (e.g., Esling, 1991; Henton & Bladon, 1988). In sociolinguistics, it has come to be used as a near-synonym for work carried out in the variationist tradition pioneered by Labov. Such work focuses on the interrelationships between phonetic/phonological form and social factors such as speaking style and the background of the speaker, but with a particular interest in explaining the origins and transmission of linguistic change (e.g., Labov, 1994, 2001).

Early references to sociophonetics are invariably in the domain of speech production. Since the mid-1990s, though, the denotation of the term has broadened rapidly to cover an eclectic field with an expanding agenda. Sociophonetics now includes investigations of the impact of variation on speech perception (as witnessed by

the contributions to this volume by Johnson, and Hay and Warren; see also Clopper & Pisoni, 2005; Thomas, 2002); the implications of variation for linguistic as well as sociolinguistic theory (e.g., Nagy & Reynolds, 1997); the effects of variation on first and second language acquisition (e.g., Khattab, 2002; Khattab, in press; Lively, Logan, & Pisoni, 1993); and applications of descriptive accounts of variation to fields such as forensic speaker identification (e.g., Nolan, 1997).

Given the diverse fields of reference of sociophonetics, it is important to specify precisely what is meant by sociophonetic variation. In our interpretation, it refers to variable aspects of phonetic or phonological structure in which alternative forms correlate with social factors. These factors include most obviously those social categories which have been examined extensively by sociolinguists and dialectologists: speaker gender, age, ethnicity, social class, group affiliations, geographical origin, and speaking style. Correlation may be with more than one social category simultaneously, and variation may be observable within the repertoire of an individual speaker or across groups of speakers. In cases of sociophonetic variation, then, variable forms can be said to index some or other social category.[1]

Precisely *which* social categories are indexed in speech, and how to define those categories, are key questions in sociolinguistics (see, for example, Ash, 2002 on class; Cheshire, 2002 on gender; Eckert, 1997 on age; and Schilling-Estes, 2002 on style). Style, for example, may cover a wide range of features and systematic variation may result from a number of sources which characterize particular modes of speech. These include the degree of formality, the nature of the topic, the specific audience, the physical setting in which speech is taking place, and the pragmatic demands of a particular type of interaction (see, e.g., Bell, 1984; Eckert & Rickford, 2002; Local, 2003).

In the majority of cases, sociophonetic variation is gradient rather than categorical. That is, variation may be observed such that a given form is used statistically more by one social group than another, or more in one speech style than another. This is the case, for example, with the pronunciation of postvocalic /r/ in some varieties of American English. For example, Labov (1966) showed that in New York City /r/ can either be realized as a rhotic approximant (usually [ɹ]) or it can be given a zero realization, with rates of [ɹ] production correlating with socioeconomic class measures: higher social groups use more [ɹ] than lower social groups. Quantitative distributions of American English /r/ therefore may be an index of social class. Further examples of sociophonetic variation are offered in Section 2.2.

In some cases, including that just described of American English /r/, the category indexed is one that is wholly the product of social construction. Thus, the relationship between linguistic form and social category is arbitrary, and sociophonetic variation represents a pattern of behavior learned by speakers through the experience of using language in social interaction. There is no automatic reason why high rates of [ɹ] production should index high social class. Indeed, in England the indexicality of /r/ shows the opposite polarity: a high rate of postvocalic [ɹ] production is often taken as an indication that a speaker or dialect has a relatively low social status (e.g., Wells, 1982, p. 35).

In other cases, though, indexicality may be of natural categories or phenomena and linguistic variation may be non-arbitrary. For example, it is usually possible to distinguish the voices of adult males, adult females, and children through the gross and direct acoustic consequences of major differences in vocal tract dimensions. Acoustic differences, for example, in relative fundamental frequency and formant spacing, can therefore be used to index the natural biological categories of age and sex. Likewise, physical variation between speakers may yield phonetic differences that index individuals (Laver, 1980; Laver & Trudgill, 1979). There may, however, be no clear dividing line between learned and non-learned behavior or between arbitrary and non-arbitrary phonetic variation. The socially-constructed category of gender, e.g., overlaps considerably with the biological category of sex, and the phonetic cues for gender (such as relatively high f0) may be parasitic on phonetic differences derived from biological differences. There is evidence that male–female differences emerge in children's speech well before the onset of puberty produces large differences in vocal tract size (Günzburger, Bresser, & ter Keurs, 1987; Hasek, Singh, & Murry, 1980; Lee, Hewlett, & Nairn, 1995; Sachs, Lieberman, & Erickson, 1973; Sorenson, 1989). To some extent, then, girls and boys *learn* to use distinct patterns of phonetic

[1]Note that indexicality is used here to describe observable patterns of correlation between linguistic forms and social categories, i.e., what Silverstein (2003) refers to as FIRST ORDER INDEXICALITY. In distinction to this is SECOND ORDER INDEXICALITY, whereby speaker–listeners in a given community show awareness of those correlations, either overtly or tacitly.

realization. In cases like this, it may be impossible in practice to determine whether an indexed category is socially-constructed or not (e.g., gender versus sex). It may also be impossible to distinguish the linguistic effects of learned and non-learned behavior in social indexing. In light of this, we will use the term sociophonetic to cover any instance of variation where the indexed factor is at least *partly* socially-constructed and, therefore, cannot be fully explained by universal principles such as those of acoustics and aerodynamics.

2.2. The transmission of sociophonetic information

Correlations between linguistic forms and social factors can be found at all levels of structure, including syntax, morphology, and lexicon. In phonetics and phonology, this includes variation at the segmental, suprasegmental, and subsegmental levels. In this section, we review examples of sociophonetic variation in order to illustrate both its complexity and its pervasiveness.

2.2.1. Segmental variation

Sociophonetic variation has been documented most extensively in terms of segmental phonetic categories. Wells (1982) establishes four main types of segmental variation for describing differences between accents of English. These can be extended to provide a useful taxonomy of sociophonetic variation more broadly.

First, differences may be SYSTEMIC. That is, there may be variation in the composition of the phoneme inventory. Many Scottish dialects of English, for example, have the phonemes /x/ and /ʍ/, which are not found in most other British dialects. Hence, lexical contrast is established between pairs such as *loch* and *lock*, *whales*, and *Wales*. Systemic differences are not wholly defined on a regional basis, however; social factors may also play a role. For instance, in the dialect of Glasgow /x/ and /ʍ/ are receding in frequency and being replaced by /k/ and /w/. The relative frequency of /x/ and /ʍ/ is therefore indexical of age since older speakers use them more often than younger speakers. There is also evidence that middle class children use more /x/ than working class children do (Lawson & Stuart-Smith, 1999).

A second category of difference concerns the PHONOTACTIC DISTRIBUTION of phonemes. English /r/ is a well-known example. The contextual distribution of /r/ differs across varieties, marking the major division between what Wells (1982) refers to as rhotic versus non-rhotic accents. The latter (including Received Pronunciation and most accents of England) permit /r/ only in prevocalic positions. Rhotic accents, by contrast, allow /r/ to occur in all contexts. As already noted in Section 2.1, variation in rhoticity may index social factors such as class.

Wells' third category concerns the LEXICAL DISTRIBUTION of phonemes. Accents may differ in which phoneme is used in a given lexical item. In England, both northern and southern accents contrast /a/ and /ɑː/, but they differ in terms of which vowel is used in a particular word. Northern varieties usually have the short vowel in, e.g., *path*, *class*, and *Iraq* while the long vowel is used in the south. The choice may be constrained by social factors as well. Because /ɑː/ is used in the standard accent, RP, northern speakers may shift to using it if in a particularly formal situation. The choice of vowel may therefore index style as well as geographical origin.

Finally, the most widespread type of variation occurs at the level of ALLOPHONIC REALIZATION. We will offer a detailed illustration of such variation from our own research on the English of Newcastle upon Tyne, the largest city in the north-east of England. These observations are supported by fieldwork carried out with 32 speakers, sampled from two class-stratified neighborhoods (labeled for convenience 'working class' and 'middle class'), two age groups (15–27 and 45–67), and with equal numbers of males and females. Unscripted interaction was recorded from the subjects in self-selected pairs (the majority being same-sex) in their homes with minimal fieldworker involvement. In total, 26 hours of vernacular speech were obtained. Subjects also read a phonologically-balanced word-list and text, designed to elicit a more self-conscious, formal register. Several consonantal and vocalic features were analyzed using both auditory and acoustic methods, revealing socially-correlated patterns in variant usage (see further Docherty & Foulkes, 1999; Docherty, Foulkes, Milroy, Milroy, & Walshaw, 1997; Watt & Milroy, 1999).

Particularly complex patterns of variation can be found for /ptk/ in word-medial intersonorant contexts (as in *happy*, *water*, *baker*, *winter*, *bottle*, *button*, *metro*).[2] Speakers from Newcastle (and the surrounding areas)

[2]The relevant contexts can be specified more fully as intersonorant and foot-internal (Carr, 1991). Laryngealized variants can also occur across a foot-internal word boundary (e.g., *bake it*), although these are not discussed here.

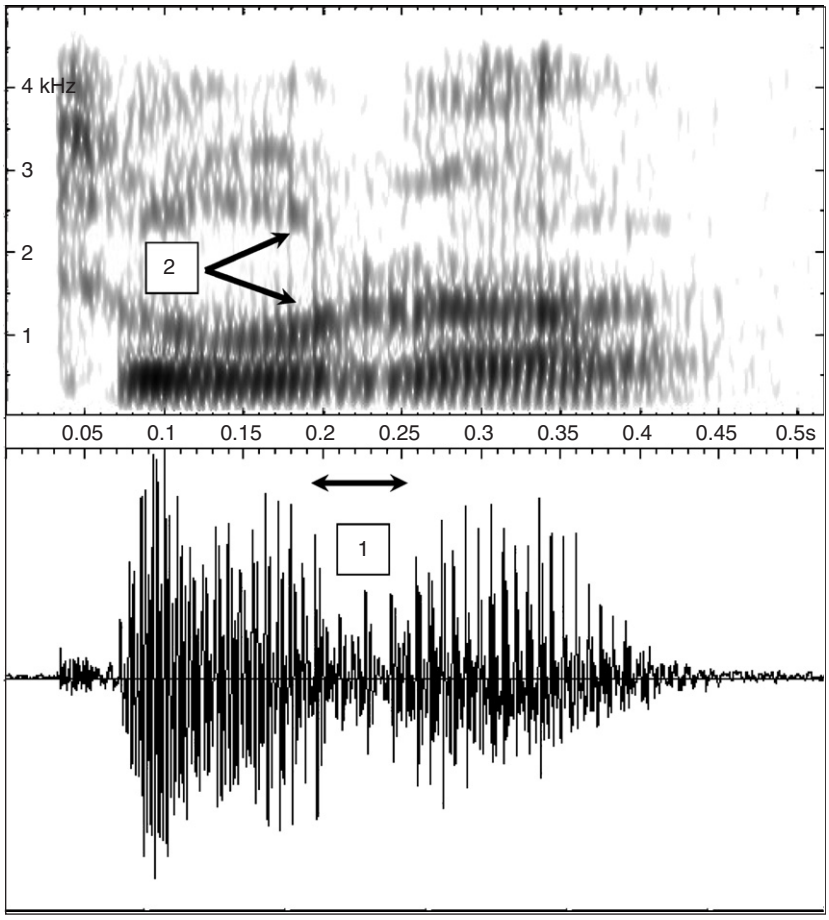

Fig. 1. Spectrogram and waveform of *daughter* (speaker: young male). Arrows identify [1] lenited stop with creaky phonation, [2] formant transitions indicative of alveolar gesture.

use a particularly distinctive realization of these medial stops. A typical example is shown in Fig. 1. Here the medial /t/ is produced as a lenited stop with laryngealized or creaky phonation. There is no period of voicelessness and no complete stop closure or release burst. In most tokens, evidence of an oral gesture is provided by formant transitions into and/or out of the laryngealized portion. In a minority of tokens (particularly before syllabic /l/ or /n/), no oral gesture is present. (A fuller account of the acoustic patterns is given in Docherty & Foulkes, 1999, 2005.) These laryngealized forms are acoustically and auditorily quite different from the canonical forms [ptk] used in standard English, and also from the glottal stops used in many other British dialects. They are very salient to the ears of locals and outsiders, and as such have the status of local, geographically-defined stereotypes (in the sense of Labov, 1994, p. 78).

In our data from unscripted interaction, the laryngealized variants were much the most common forms found, accounting for 71% of the tokens. However, all 32 speakers displayed non-categorical variant usage. Moreover, the data also showed social and stylistic constraints on variant choice, as illustrated in Figs. 2 and 3. Fig. 2 shows the proportional usage of variants by each social group in conversational data. Data for /ptk/ are combined, as similar patterns were found for each stop individually. Fig. 2 shows that the laryngealized forms are not equally distributed across the social groups. For six of the groups the laryngealized forms are the most frequently used variant. However, the older women (the two leftmost bars in the figure) displayed a strikingly different pattern of variant usage, preferring plain oral variants by a ratio of between 1.8 and 3:1. Use of laryngealized forms was higher in all male groups when compared with the corresponding female group, matched for age and class.

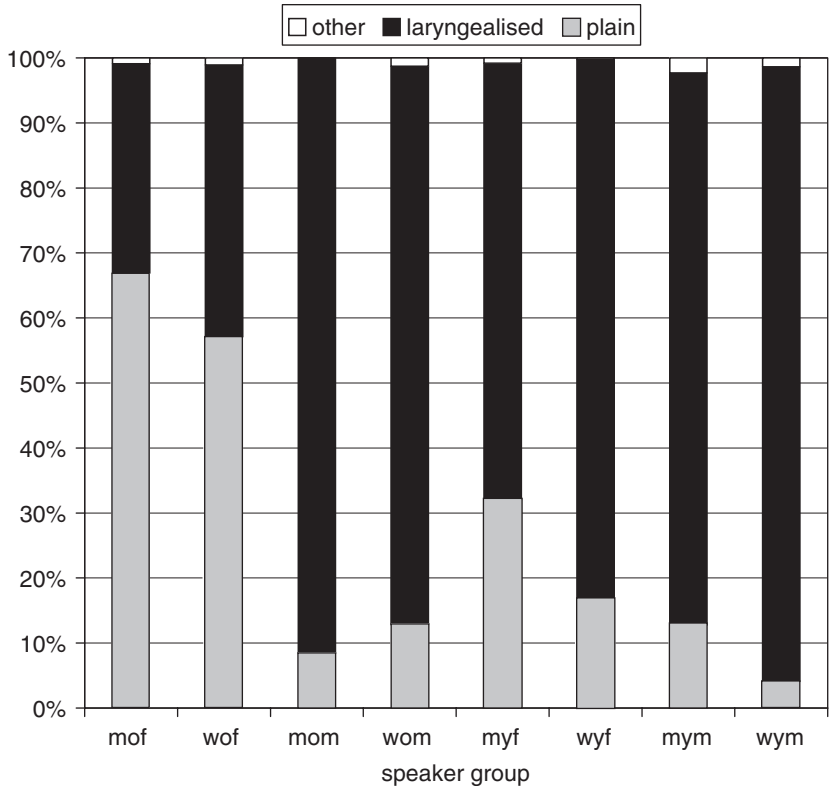

Fig. 2. Proportional usage of variant types by Newcastle speakers, conversational data, /p t k/ in word-medial intersonorant position. Social group abbreviations: mof, middle class older females; wym, working class young males, etc. Total $N = 3392$ (mof = 450, wof = 550, mom = 478, wom = 390, myf = 366, wyf = 398, mym = 392, wym = 368).

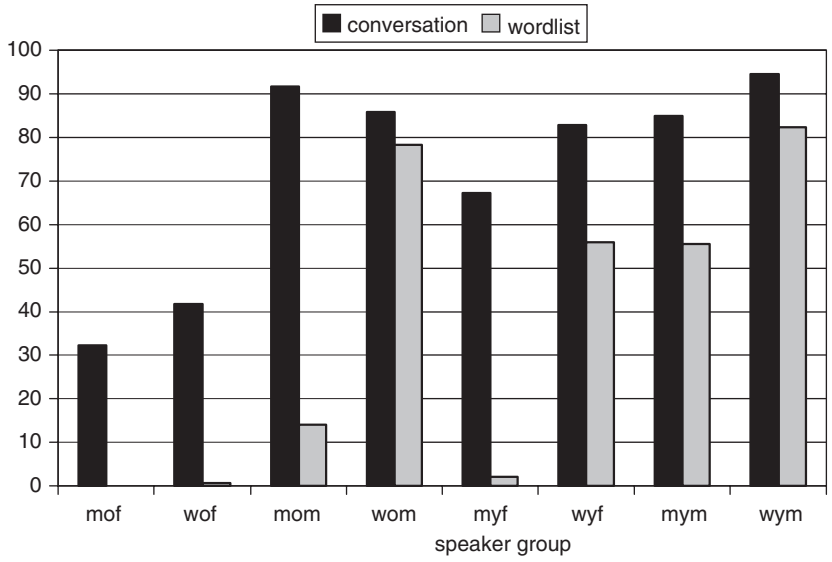

Fig. 3. Proportional usage of laryngealized variants by Newcastle speakers as a function of speech style, /p t k/ in word-medial intersonorant position. Social group abbreviations: mof, middle class older females; wym, working class young males, etc.

Fig. 3 compares the proportional use of laryngealized forms in conversational speech and word-list readings. All groups used significantly fewer laryngealized forms in the more formal word-list readings (mof: $\chi^2 = 61.4$, df = 1, $p < .001$; wof: $\chi^2 = 85.8$, df = 1, $p < .001$; mom: $\chi^2 = 342.8$, df = 1, $p < .001$; wom: $\chi^2 = 4.4$, df = 1, $p < .05$; myf: $\chi^2 = 175.4$, df = 1, $p < .001$; wyf: $\chi^2 = 41.1$, df = 1, $p < .001$; mym: $\chi^2 = 51.5$, df = 1, $p < .001$; wym: $\chi^2 = 18.9$, $df = 1$, $p < .001$). The style effect was almost categorical for the older women and the middle class girls, who barely used any non-standard variants in the word-list material. The gendered pattern was again apparent across all groups, with males using more laryngealized forms than females of the same age and class. This example therefore reveals quite complex sociophonetic patterns: variant use is constrained by a combination of speaker age, sex, class, and speaking style.

2.2.2. Suprasegmental variation

Structured variation has also been found in analysis of suprasegmental features. Intonation patterns, for example, may show regional variation. While most varieties of English use falling contours to mark declarative statements, in some regional dialects rising or high level contours are used instead. These include the traditional dialects of Newcastle, Liverpool, and most of Ireland (Cruttenden, 1997, pp. 128–; Douglas-Cowie, Cowie, & Rahilly, 1995; Knowles, 1978; Local, Kelly, & Wells, 1986).

Social divisions may also be indexed by contour types. Rising contours in declaratives have begun to emerge recently in English dialects where they are not traditional features, a phenomenon variously referred to as 'uptalk' or 'high rising terminal' (see Cruttenden, 1995, 1997). This innovation has been observed in the USA (Arvaniti & Garding, 2005), Australia (Guy, Horvath, Vonwiller, Disley, & Rogers, 1986), New Zealand (Britain, 1992; Warren & Britain, 2000), and England (Cruttenden, 1997). In most locations, it is characteristic mainly of young speakers. In the USA, Australia, and New Zealand it is also most common in lower class and/or female speech, but by contrast it seems to be associated with the upwardly mobile in England. There is furthermore evidence that the rises are more prevalent in certain styles of speech since they play a number of different discourse roles, such as acting as a turn-holding mechanism in narratives.

Similar regional and social differences have been found with other suprasegmental features including pitch accent realization (Grabe, Post, Nolan, & Farrar, 2000), tonal alignment (Nolan & Farrar, 1999), voice quality and vocal setting (Esling, 1991; Henton & Bladon, 1988; Stuart-Smith, 1999), rhythm (Deterding, 2001; Low, Grabe, & Nolan, 2000), and stress placement (Wells, 1995).

2.2.3. Subsegmental variation

The predominance of auditory analysis has led to sociophonetic variation being cast most commonly as an alternation between segmental categories. However, instrumental techniques have demonstrated that sociophonetic variation can also be manifested in fine-grained subsegmental aspects of speech, in terms of the relative duration, strength or temporal coordination of articulatory gestures.

Nolan and Kerswill (1990), e.g., investigated a range of connected speech processes including consonantal place assimilations at word boundaries. Their subjects were 14-year-old children from three schools in Cambridge, England. The schools were selected to represent different social classes. Electropalatographic data revealed a continuum in the degree of assimilation. Some tokens showed complete assimilation (e.g., [gɹ iːm pɑːk] for *green park*), some showed none at all, while others had partial assimilation involving an incomplete alveolar gesture. Nolan and Kerswill furthermore found that assimilation rates differed significantly across their speaker sample. Children from the lower status school produced more assimilated forms than did those from the higher status schools.

Similar subsegmental patterns have been reported in several other studies, showing that subtle phonetic variation may index regional and/or social categories. Examples include Fourakis and Port (1986), Kerswill and Wright (1990), Di Paolo & Faber (1990), Thomas (2000), Stuart-Smith (in press), and Scobbie (2005).

We have also observed subsegmental sociophonetic variation in our work in Newcastle. In Section 2.2.1, we described word-medial laryngealized variants of voiceless stops. Acoustic analysis revealed systematic variation within this phonetic category. We examined spectrographically the 549 laryngealized tokens that

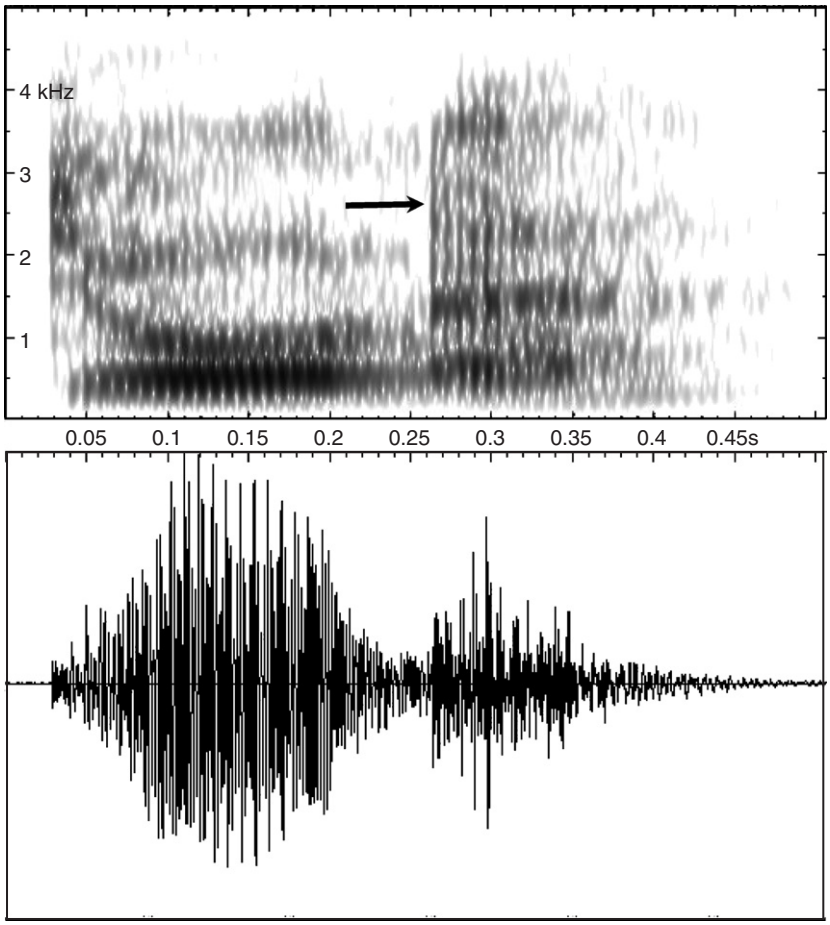

Fig. 4. Spectrogram and waveform of *daughter* (speaker: older male). Arrow identifies transient indicating release of oral closure.

were found in the word-list readings (Docherty & Foulkes, 2005).[3] Our analysis revealed that laryngealized stops displayed acoustic variation suggestive of differences in gestural magnitude and/or temporal coordination. Although most tokens could be described as lenited stops with laryngealization, 26% of tokens contained an acoustic transient indicating release of a complete oral closure. An example is shown in Fig. 4.

The tokens with visible release were not randomly distributed across the speaker sample, however. They were more frequent in the speech of the older men (accounting for over 40% of their tokens) than any other group (between 11% and 23%). This may suggest therefore that older males produced more complete oral closures than other speakers. It may also be that they were timing their oral and laryngeal gestures such that the former lagged behind the latter (making the release audible), whereas the laryngealized variants produced by other speakers generally had the oral release masked by a sustained glottal gesture.

A final example can also be cited from our work on stops in Newcastle English (Docherty & Foulkes, 1999). In prepausal contexts, /t/ displays a range of forms. It is possible to find glottal stops in this context, but they are rare in this dialect (unlike most other British varieties). Newcastle speakers instead tend to produce released oral stops without laryngealization, but these realizations show systematic variation in the relative

[3]The word-list tokens were analyzed in preference to the conversational material for two reasons. First, they provided a controlled set of lexical items for all speakers. Second, acoustic analysis was more difficult with unscripted speech because of occasional background noise, overlapping speech, etc.

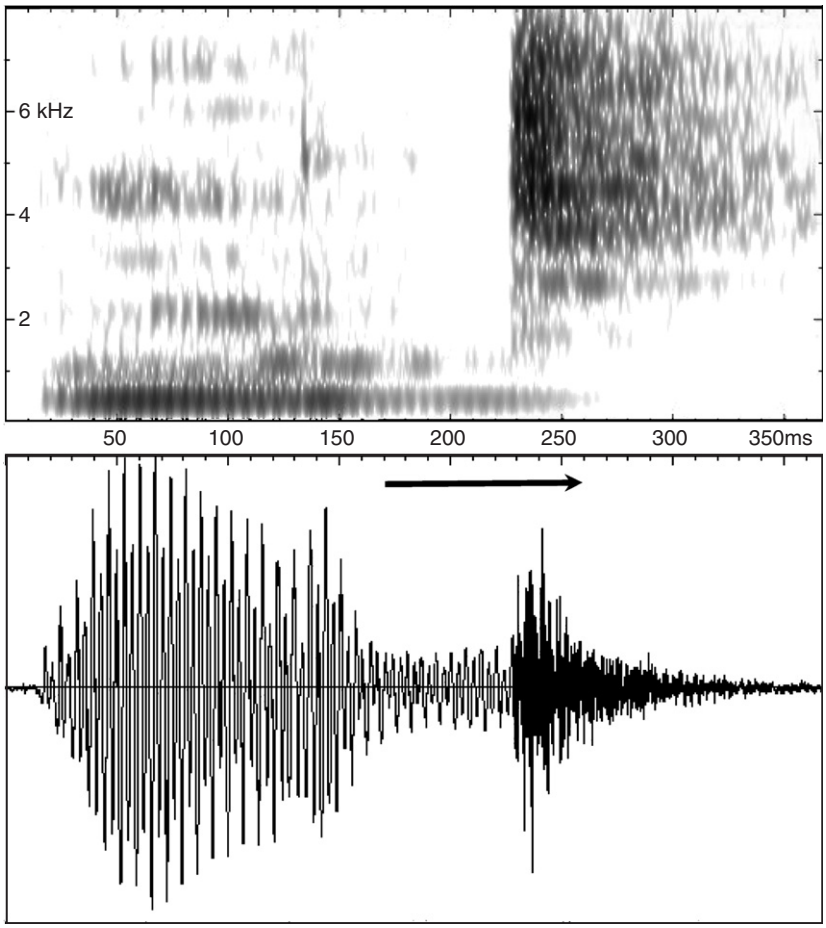

Fig. 5. Spectrogram of *boot* showing extended voicing (speaker: older male). Arrow indicates voicing throughout stop closure and into release of stop.

timing of oral and laryngeal gestures. In some tokens, as illustrated in Fig. 5, voicing from the preceding vowel extends as far as the release burst of the stop or even into the postburst fricative energy.

In other tokens, a period of fricative energy can be seen prior to the stop closure. In some cases, this fricative energy is similar to that found in [h], being diffuse, spanning a wide frequency range and sometimes displaying formant structure (as illustrated in Fig. 6a). In other cases (Fig. 6b), the fricative energy is clearly the product of oral constriction, appearing in the higher frequency ranges and similar to the fricative energy after the release burst. Still other cases show a combination of the acoustic patterns shown in these two illustrations. We have used the term "preaspiration" to cover the range of forms illustrated in Fig. 6, as similar acoustic variation can be found in languages like Faroese where preaspiration is a lexically-contrastive feature (Helgason, Stölten, & Engstrand, 2003). In most preaspirated tokens voicing appears to halt relatively early, before the stop closure has been completed. As discussed in Docherty (in press), given the general absence of prepausal laryngealization in Newcastle English, we infer that the cessation of voicing is effected by glottal opening rather than closure. Glottal opening allows greater airflow into the oral tract, which may in turn result in the production of frication. Fricative energy might be produced at the glottis or in the whole oral tract in the case of [h]-like tokens. Alternatively, if there is sufficient airflow and a suitably narrow oral constriction, the fricative noise source may be generated at the oral constriction being made for the stop.

Once again, though, these variant patterns were not found in random distribution in our sample. Acoustic analysis was undertaken of 360 word-final /t/s in the word-list data. The extended voicing pattern (Fig. 7) was found around twice as often in male speech than female speech (with no marked effects for age or class).

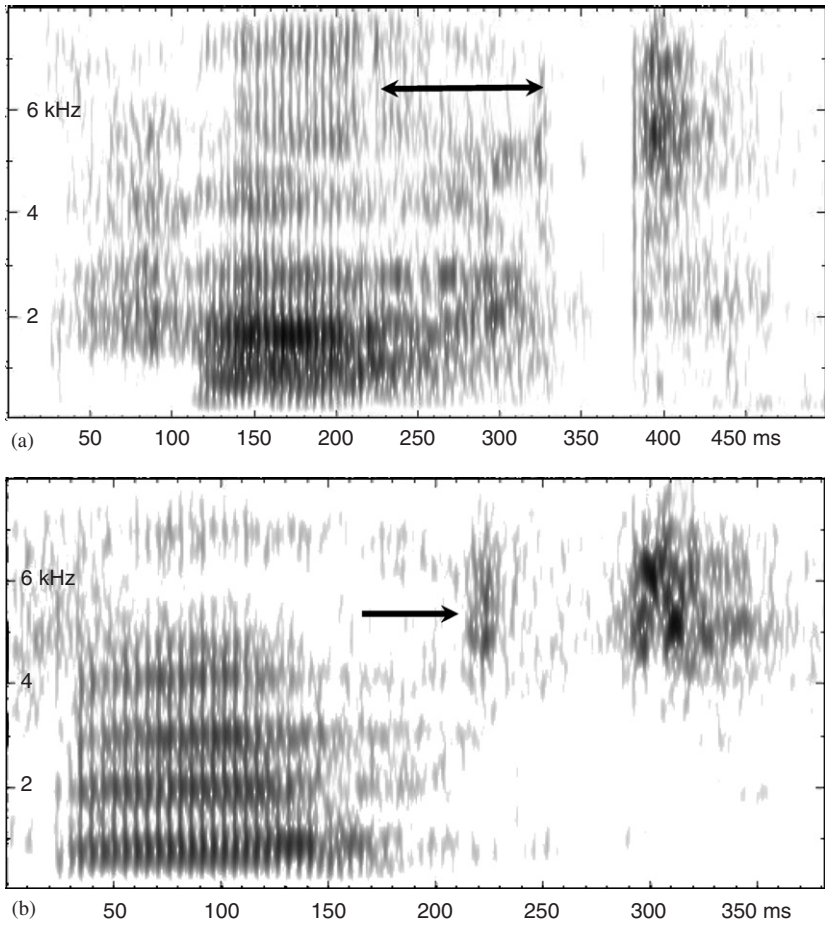

Fig. 6. Spectrograms showing different forms of preaspiration. (a) *Hat* (speaker: young female). Arrow indicates preaspirated section (see text for further details). (b) *Bet* (speaker: young female). Arrow indicates preaspirated section (see text for further details).

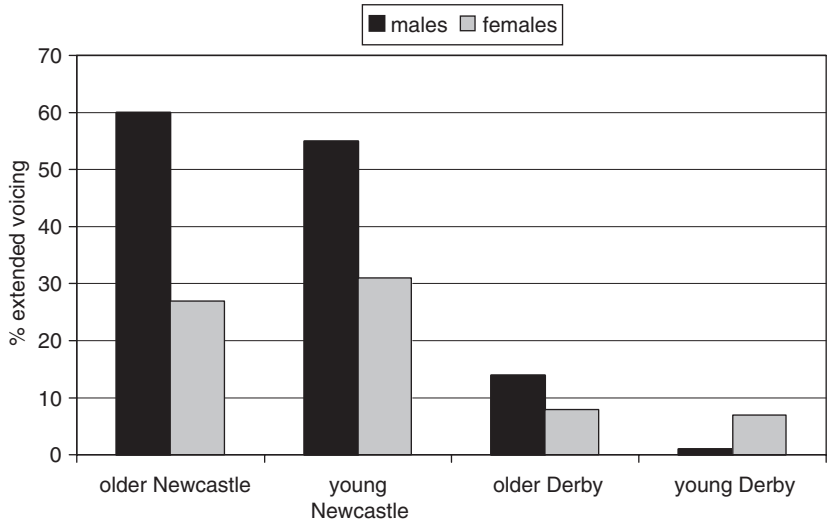

Fig. 7. Distribution of tokens of word-final prepausal /t/ with extended voicing, by speaker group (adapted from Docherty & Foulkes, 1999).

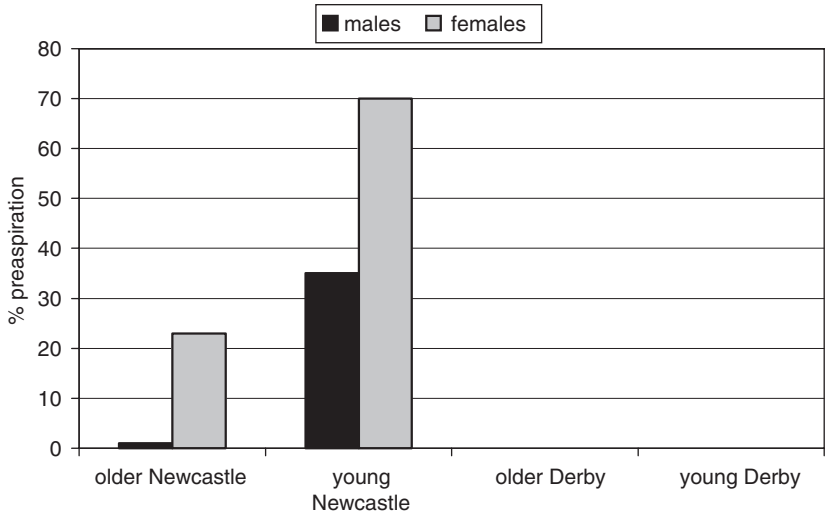

Fig. 8. Distribution of tokens of word-final prepausal /t/ with preaspiration, by speaker group (adapted from Docherty & Foulkes, 1999).

Preaspiration, by contrast, was correlated with both age and sex (Fig. 8). For young women of both social classes it was the most frequent form in use (70% of the 90 tokens analyzed overall, 27/43 for the working class and 36/47 for the middle class).

Figs. 7 and 8 include comparable data for speakers from Derby, a city in the English Midlands. These data were collected from 32 informants, sampled with the same design as the Newcastle speakers (Docherty & Foulkes, 1999). The Derby results were quite different from those for Newcastle, showing that the acoustic patterns found in Newcastle were not simply the automatic consequence of physiological differences between males and females that happened to correlate with the independent variables. Preaspiration was not found at all in Derby, while extended voicing was much lower in frequency than in Newcastle and showed no clear social effects.

2.3. *Summary*

Although the examples discussed in Section 2.2 were drawn from English, similar patterns have been found in abundance in all languages that have been approached with sociolinguistic methods (see, e.g., Dressler & Wodak, 1982; Kissine, Van de Velde, & van Hout, 2003; Sankoff, Blondeau, & Charity, 2001). It is clear that sociophonetic variation has a wide range of sources, and its effects are probably found at all levels of phonetic and phonological structure. Complementary evidence from studies of speech perception shows that sociophonetic differences are also perceptible (Thomas, 2002), and that they may influence the operation of linguistic processes such as phoneme recognition and lexical access (Hawkins, 2003; Strand, 1999). Indeed, the interweaving of sociophonetic and linguistic information in speech is so complete that no natural human utterance can offer linguistic information without simultaneously indexing one or more social factor.

3. A child's perspective on sociophonetic variation

Given the pervasiveness of sociophonetic variation it is perhaps surprising that it has not played a more prominent role in phonetic and phonological work. Sociophonetic variation clearly reflects acquired knowledge about speech sounds, and sociophonetic information is conveyed through precisely the same medium as propositional information. Nevertheless, a clear account is still lacking of how sociophonetic information is represented cognitively. In particular, it is not clear how it is stored and processed in relation to other types of information.

In this section, we outline another series of findings that bear upon this issue. A productive way to examine the representation of sociophonetic material is to investigate how such information comes to be learned during the course of language acquisition. There is of course a rich literature on children's speech production and the acquisition of phonology. However, as is the case with phonetics and phonology more broadly, sociophonetic variation has only rarely been central to acquisition studies. A handful of sociolinguistically-oriented studies have been undertaken of children's speech and these are discussed below. Our main set of findings, though, are derived from our own studies of children in Newcastle upon Tyne (Docherty, Foulkes, Dodd, & Milroy, 2002).

3.1. Fieldwork with children in Newcastle

Our data are drawn from 53 children and their mothers. All the subjects were recruited from the same working class neighborhood of Newcastle that had been investigated in the earlier study of adults (Section 2.2.1). Forty children were sampled according to a cross-sectional design, with four boys and four girls at ages 2;0, 2;6, 3;0, 3;6, and 4;0 (± 1 month). The other 13 children were followed longitudinally over all or part of the same 2-year age range. The children were all first-born, to minimize the linguistic impact of older siblings. The mothers were in all cases the child's main caregiver, to establish (as far as is practicable) that the mother's speech was the primary source of input for the child. Recordings were made at the subjects' homes using Sony digital audio equipment and Trantec radio lapel microphones. Activities included free-play sessions between the children and mothers, and the elicitation, using picture books and toys, of particular lexical items containing key phonological variables. Several vowels and consonants have been analyzed in the data using both auditory and acoustic methods. The data referred to here are all drawn from the cross-sectional study. One recording proved unsuitable for analysis, leaving 39 mother–child pairs as the main speaker sample. (Further details of the fieldwork and data analysis are given in Docherty, Foulkes, Tillotson, & Watt, 2005; Foulkes, Docherty, & Watt, 2005.)

3.2. Sociophonetic variation in input to children

It goes without saying that children's linguistic knowledge is in part based on their analysis of the ambient language, or input. It is furthermore self-evident that input is riddled with variation. Most children receive input from a number of individual talkers and will thus hear tokens of words and sounds spoken by very different voices. No two children are ever likely to experience precisely the same input.

Quantitative data from Newcastle support this point. Word-medial /t/, as we saw in Section 2.2.1, is typically realized as a lenited and laryngealized voiced stop, although a standard oral [t] is also possible. In our sample of CDS from 39 mothers, some women used the laryngealized forms categorically, while others used [t] categorically. Twenty-six individuals used both forms in varying proportions. Thus, even within this tight-knit group of subjects drawn from a single neighborhood, the phonetic composition of the input may vary markedly from child to child.

The phonetic variability in the input is not purely idiosyncratic, however. Some variability provides language-specific information that must be acquired as part of grammatical knowledge. This would include morphophonological alternations and contextual allophones, for example. It is also clear that input is likely to contain socially-conditioned phonetic variation. Roberts (1997) and Labov (2001, p. 420) observe that children's input typically comprises speech from a range of different interaction styles. Speech in situations of instruction or discipline may differ in its linguistic composition from that found in more informal situations such as play and intimacy. As with adult speech, phonetic features may vary as a reflex of this range of styles, with standard variants usually present in higher frequency in the more formal styles. From an early age, then, children will experience linguistic variation correlating with style.

It should not be assumed, however, that input simply represents a scale model of the language as used in mature interaction. This is very clear when we examine the properties of CDS (or 'motherese'), which may differ substantially from the properties of mature speech. For example, CDS is typically characterized by simpler syntax and vocabulary, shorter utterances, more repetition, slower speaking rate, longer pauses, and common words may be adapted to fit a CVCV structure (Snow, 1995). Phonetic patterns in the input may also

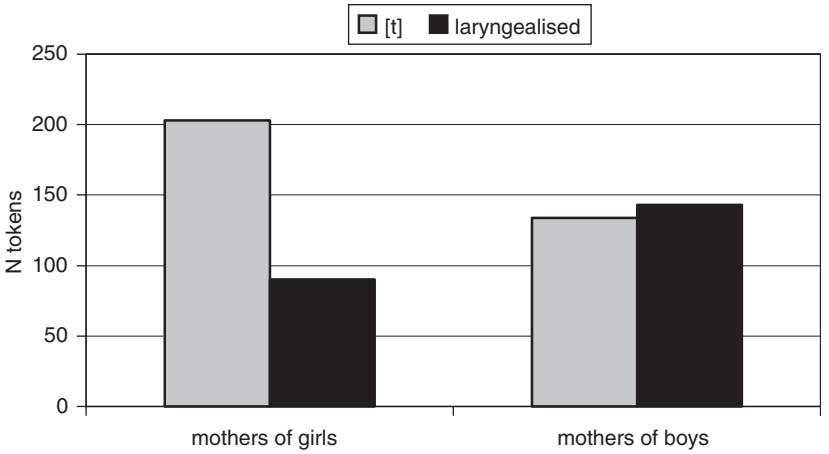

Fig. 9. Mothers' use of laryngealized variants of medial /t/ as a function of sex of child.

differ, most notably perhaps with respect to intonation. It is common, e.g., for adults to use higher average fundamental frequency and an extended pitch range when they speak to children (e.g., Fernald et al., 1989). Segmental properties have been the subject of less research, but it has been argued, e.g., that parents exaggerate some phonological contrasts when speaking to their children (Kuhl et al., 1997; Malsheen, 1980). The phonetic correlates of these contrasts may thus be different from those in mature speech.[4]

Our Newcastle data also revealed some stark differences in the distribution of sociophonetic variants in speech from mothers to children compared with the patterns we had observed in our study of adult speech. The clearest illustration is provided by comparison of the findings for voiceless stops in word-medial position. In inter-adult speech (henceforth IAS), laryngealized variants were by far the most frequent for all but the older women (Fig. 2, Section 2.2.1). Young working class women—i.e., the same demographic group as the mothers in the child study—produced 81% laryngealized forms. When considering /t/ alone, 90% of tokens were laryngealized, with plain [t] accounting for less than 10% of tokens. For the mothers speaking to their children, by contrast, only 36% of tokens of /t/ were laryngealized. Plain [t] was much the most frequent variant in CDS, used in 59% of cases (see further Foulkes et al., 2005). Statistical differences in variant usage in CDS and IAS are also reported by Shockey and Bond (1980), Bernstein Ratner (1984a, b), and Roberts (2002).

There is furthermore evidence that input may vary with respect to a child's age and sex. It is probably obvious that features of CDS change as a child grows up. The extreme features of CDS give way gradually to mature speech forms. Relatively few studies have examined changes in segmental properties of CDS, although our Newcastle data showed systematic differences in variant usage correlating with the children's age. Speech to younger children contained more standard phonetic forms than speech to older children (e.g., plain oral variants of word-medial stops). Speech to older children contained higher rates of local vernacular forms (see Foulkes et al., 2005 for full discussion).

The sex of the child was also a significant factor in accounting for variant usage by the mothers, as illustrated by the results shown in Fig. 9 which arise once again from /t/ in word-medial position. Mothers of boys used approximately equal proportions of laryngealized and plain variants. By contrast, plain [t] is more than twice as frequent as the laryngealized forms in the speech of girls' mothers ($\chi^2 = 25.75$, df $= 1$, $p < .0001$).

More radical changes in input for all children take place when their social environment is changed. Children may be subject to abruptly different linguistic influences if their family moves home to another region, for example (Chambers, 1992; Payne, 1980). More generally, all children experience the social event of entering school. Once in school children begin to spend far more time with their peers. Thus, they come to experience

[4]It should also be noted that there is variation across cultures in the structure and extent of CDS, and more generally in the nature of interaction between adults and children. In some societies, for example, adults barely speak to children at all until the children are able to produce recognizable words (Ochs & Schieffelin, 1995, p. 77).

more linguistic input from other children. That input may of course be very different in nature from the input received in the home (for a particularly clear example see Kerswill & Williams, 2000).

3.3. Sociophonetic variation in children's speech production

Children's speech production is even more notable than adult speech for its variability. Changes can be observed almost daily in the speech development of any child, and lexical items may be produced with a wide range of different forms by individual children. Much of this variability can be attributed to factors such as immature motor skills, imperfect mapping of adult targets, or carry-over effects from babbling preferences (Menn & Stoel-Gammon, 1995).

Variation in children's speech may also reflect different learning opportunities provided by different input patterns. Most obviously, a child learns a particular language or variety because it receives a predominance of input in that language or variety. A number of sociolinguistic studies have tracked the development of variety-specific features, or features subject to ongoing sound change, including Payne (1980), Roberts and Labov (1995), and Roberts (1997). Children seem to be capable of acquiring complex patterns of sociolinguistic variation at least as young as 3 years, although there is some evidence that across-the-board patterns are acquired more readily than those involving complex contextual or lexical constraints. Roberts and Labov (1995), for example, focused on the acquisition of /a/ in Philadelphia. This vowel undergoes tensing in closed syllables, thus yielding a difference between *plan.et* (tense vowel) and *Ja.net* (lax). Children between 3;2 and 3;10 showed evidence of distinguishing such pairs in production, but the polarity emerged much more clearly for children aged 3;11 to 4;11. Payne (1980) studied a number of variables in the speech of 34 children who were in-migrants to Philadelphia. Few children acquired the tensing pattern for /a/, whereas across-the-board patterns were learned within a year or two of arrival in the city.

Within a dialect community, subtle differences in input may yield subtle differences in children's own productions. Hewlett, Matthews, and Scobbie (1999) examined acquisition of the distinctive vowel length pattern found in most Scottish dialects of English. Their subjects were seven 6–9-year olds all of whom were judged to speak with a Scottish accent. In standard English, a vowel duration difference is found depending on whether a following consonant is phonologically voiced or voiceless: The vowels of *brute* and *Bruce* are shorter than those of *brood* or *bruise*. In Scottish dialects, the pattern is more complex, with short vowels also appearing before voiced stops. *Brood* therefore has a short vowel. Hewlett et al. found that the Scottish pattern was learned most readily by children who had at least one Scottish parent, presumably because their linguistic input contained consistent exemplification of the pattern. The pattern was less readily acquired by children of non-Scottish parents.

Data from Newcastle further suggest that variability in children's performance may be linked to individual variability in input. Analysis of prepausal /t/ showed that children's use of variants correlated with that of their mothers. Fig. 10 summarizes variant usage by mothers and children in the form of a scatter plot. The horizontal axis represents the proportion of the children's tokens that were classified as preaspirated. The vertical axis represents the mothers' use of preaspiration. Six mother–child pairs were removed from the overall sample because of low token counts by one or both speaker(s), leaving 33 pairs shown in Fig. 10. The overall correlation reaches significance at the 5% level ($r = .366$, $df = 31$), and is particularly clear if we ignore a number of apparent outliers (circled). Note that these are all children who used high rates of preaspiration but whose mothers did not. Perhaps of greatest interest, however, is that the reverse pattern was not found, suggesting that if the mother produces preaspiration the child is likely to follow suit.

Mother–child correspondences were found with other variants analyzed in the Newcastle data, including glottal stops for /t/ in prepausal context, and [ɹ] where /t/ is word-final and followed by a vowel-initial word (e.g., *shut up* produced as *shu*[ɹ]*up*). As noted in Section 2.2.3 glottal stops are possible but rare in prepausal context. However, four mothers produced relatively high rates (40–70%). Three of these also had children who used glottal stops frequently, including the two highest scorers in the sample. The variant [ɹ] is only possible in a small set of lexical items, mainly common monosyllabic verbs and non-lexical words (*get*, *got*, *put*, *that*, *not*, *but*, *what*; Wells, 1982, p. 370). Its overall occurrence in the mothers' speech was low (6.3%), although a number of individuals used it with considerable frequency. The low usage of [ɹ] was mirrored in the children's speech (6.8%), but the mother with the highest score also had the child with the highest score.

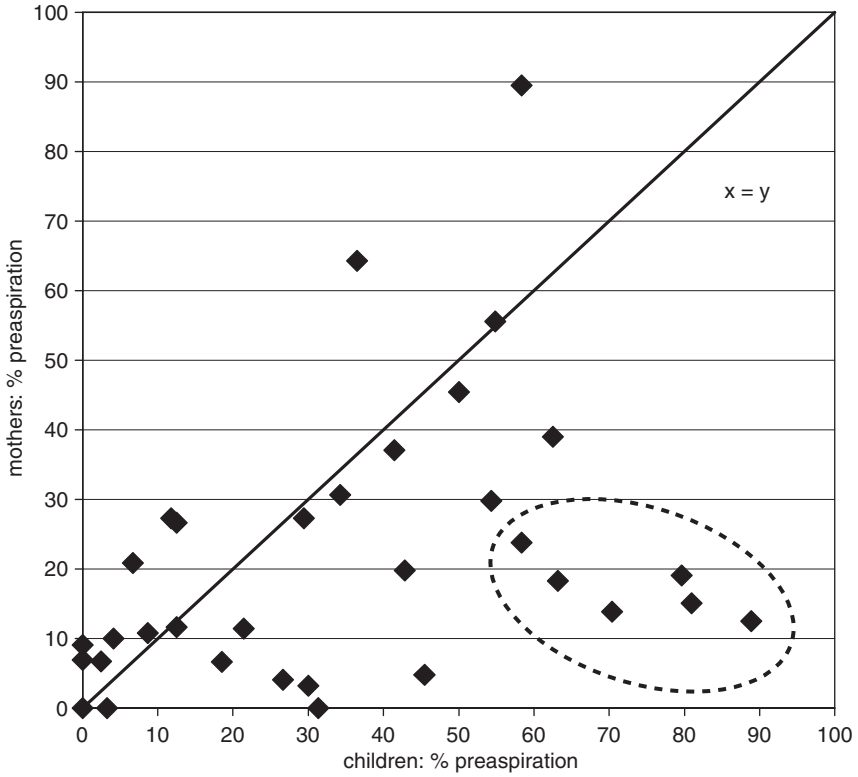

Fig. 10. Use of preaspiration for word-final /t/ by mothers and children. The ellipse identifies apparent outliers (see text for further discussion).

Evidence can also be found to show that children's production undergoes changes over time in line with changes in input. A striking example is given by Kerswill and Williams (2000), based on their research in the town of Milton Keynes. This was designated a "new town" in 1967, and subject to massive expansion as a commuter residence to serve London and other major cities in the south east of England. As the town has grown in size it has seen very high rates of in-migration from a number of different areas, leading to a speech community of adults who speak a very wide mix of regional dialects of English. Kerswill and Williams have tracked the linguistic development of children in this dialect 'melting pot'. Their research focused on three age groups of children and their parents: 4-year olds, who were still cared for predominantly in the family home, and two groups of school children aged 8 and 12. Their analysis of a number of phonological variables showed that the youngest children's speech production was closely linked to that of their parents, with considerable variability throughout the sample reflecting the mix of dialect models available in the community. Older children, however, had received considerably more input from their peers than the 4-year olds had. The 8-year olds showed much more homogeneity as a group, and there was far less evidence of minority forms they had experienced via the home model. The 12-year olds showed almost no reflexes of home dialects. Furthermore, the children's leveled dialect differed from that of the local area.

In the Newcastle study, we were also interested to discover whether children's speech would display the same sort of social correlations that had been observed in the adult community. We focused in particular on whether boys and girls would manifest gender differentiation in their use of variants that index gender among adults (Docherty et al., 2005). With preaspiration, for example, our adult study showed a particularly strong preference for this form by young women. We have already seen that preaspiration was overall quite variable in the speech of the mothers, and that this variation was paralleled in the children's speech. It was also apparent, however, that gender differentiation was emerging for the older children, as illustrated in Fig. 11.

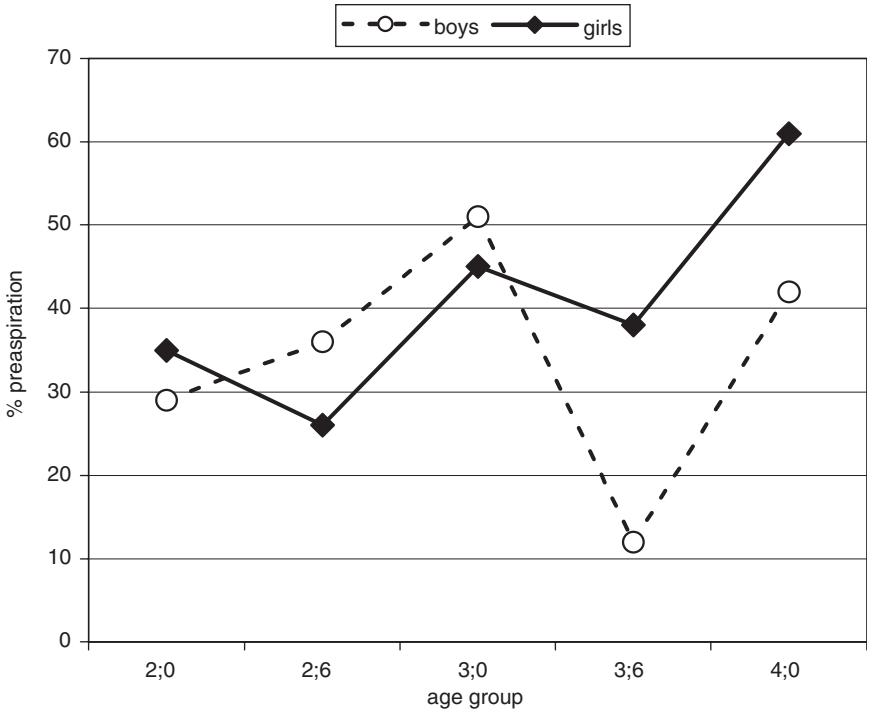

Fig. 11. Children's use of preaspiration as a function of age and sex (adapted from Foulkes et al., 2005) (adapted from Docherty et al., in press).

For the three youngest age groups there was no difference between boys' and girls' use of preaspiration. For the 3;6 group the girls significantly outscored the boys, suggesting they were reflecting the gender difference in this variant observable among adults. For the oldest group the same trend was apparent, just missing significance at the 5% level. Allen (forthcoming) investigated an older group of Newcastle children, and found robust and significant differences in preaspiration by the age of 9. Romaine (1978) also describes gender differences in the use of /r/ variants by a group of Scottish children aged between 6 and 10. Children's speech production may therefore show signs of recognizing the social indexicality of linguistic forms, although it may take some time for this recognition to develop and be reflected in speech output.

3.4. Implications of variation for emergent phonological knowledge

Examining phonological learning from the perspective of the child learner brings the interwoven nature of the linguistic and the sociophonetic into particularly sharp focus. The findings reported throughout Section 3 suggest that it is essential to take social factors into account when assessing a child's task in acquisition. Linguistic learning cannot be adequately described without reference to the social setting in which that learning takes place, or to the indexical meanings of linguistic forms. What a child learns about language is dependent on linguistic experience. But that experience is shaped by a wide range of social forces, and different social settings may present very different learning opportunities by virtue of shaping linguistic input in different ways (cf. similar conclusions by Ochs & Schieffelin, 1995 with respect to grammatical learning).

The input undergoes constant modification as the child grows up, engages in more mature speech styles, and encounters new talkers. The reference information for the child's linguistic learning may thus contain a number of moving targets. As social experience changes so too do a child's opportunities for learning linguistic forms. We might then expect linguistic representations to change over time as a response to emerging differences in the input. This is indeed what is suggested by Newcastle children's own production of medial laryngeals and even more clearly by Kerswill and Williams's Milton Keynes research. Systematic changes in

children's speech production tuned to systematic changes in input imply that changes are taking place in learned linguistic representations.

We also observed that input may vary for different children as a direct reflex of social categories relevant to a particular society. For medial /t/ Newcastle mothers showed distinct variant patterns according to whether their child was male or female (Fig. 9). This pattern can only be explained with reference to the local indexical values of those variants. As explained in Section 2.2.1, laryngealized forms are stereotypes of the local vernacular. As is typical for stereotype features they show both gender-correlated and stylistic variation in IAS. They are more frequent in male than female speech, and they are used less in more formal styles. In CDS, mothers of boys use more vernacular variants than do mothers of girls, presumably because there are different social expectations in this community about the usage of these variants. Their use by boys is socially acceptable and expected, and boys' mothers are permitted by social convention to use these variants when speaking to their sons. With girls, on the other hand, there is a greater expectation that they will use plain oral variants since these carry sociolinguistic prestige as a consequence of their use in more formal styles, and in standard English more generally. Mothers of girls may therefore use more [t] with their daughters since it is socially appropriate to do so. In short, performance appears to be tuned in line with the developing sociolinguistic identity of their children. As far as we are aware, gender-differentiated usage of segmental properties has not been reported before in the literature on CDS. However, compatible findings have emerged from studies of syntax, discourse structure and vocabulary. For instance, Gleason, Perlmann, Ely, and Evans (1994) found that parents' use of diminutives such as *doggie* was more frequent in speech to daughters than to sons. Parents presumably avoid these forms with boys because their connotations of immaturity are incompatible with boys' assumed development of masculine identity (see further Foulkes et al., 2005). Children do show signs of learning the indexical values of variant forms, as we saw with preaspiration of prepausal /t/ (Fig. 11). However, time may be needed for children to derive specific knowledge of indexical values from their input such that appropriate patterns are deployed in their own production.

A further implication is that, in many societies, patterns indexical of female speech are likely to receive prominence in early input as a consequence of the gender asymmetry of child care (Labov, 1990). All else being equal, most children spend most time in the first few years of life with women, especially their mothers. It follows that they also receive the greatest part of their linguistic input from women. Where a dialect shows gender patterning in variant use we would thus expect children to have greater exposure to the variants which dominate in female speech. We might hypothesis therefore that children are likely to display speech patterns characteristic of a female model, especially in the early stages.

Finally, it is important to bear in mind that the input experienced by any child contains information relevant to both linguistic and non-linguistic issues. Tokens in the input may vary in form as a result of linguistic factors (e.g., contextual allophony) or social factors (e.g., whether the speaker is male or female, and whether the token is embedded in intimate talk or discipline). Crucially, many tokens (perhaps *all* tokens) will encode both linguistic and sociolinguistic information simultaneously. For a child in Newcastle, e.g., the phonetic form of a medial /t/ is relevant for the learning of morphophonological alternation (compare the laryngealized variant in *putting* versus the plain [t] in *put*). The choice of variant, however, also indexes, if somewhat inconsistently, speaker gender, age, and speaking style. The consensus in the acquisition literature is that the child will learn a form that is close to the surface form produced in the input, at least in the early stages of acquisition (e.g., Boersma & Levelt, 2003; Vihman, 1996). If this is so, the first stored form is likely to implicitly incorporate indexical information as well as information relevant for the establishment of lexical contrast or phonological processes. When first experiencing a word like *putting* a child cannot know a priori whether the medial phone represents essential linguistic information, or whether it has indexical meaning, or both. We cannot assume, then, that the child somehow automatically strips away the indexical information in order to focus solely on the linguistic content of the form.

4. Towards an integrated model

In light of these observations on sociophonetic variation, we turn now to a discussion of how such variation might be accommodated within a theoretical framework. In doing so, a specific question is the extent to which

theoretical models can account for the intertwining of indexical and other information within the speech signal.

Many if not all theoretical models of phonetic and phonological structure have mechanisms to cater for variation. For example, within generative phonology variability within a language was accounted for by optional rules or variable rule orderings (Brown, 1972; Newton, 1972). More recently, optimality theorists have invoked alternative constraint rankings or unordered clusterings of constraints (Anttila & Cho, 1998; Boersma, 1998). With respect to speech production models there has been a range of approaches put forward to explain variability in speech performance, including those by Kent and Minifie (1977), Keating (1990), Browman and Goldstein (1992), and Stevens (1998). Even in such models, however, as we highlighted in Section 1, socially-constrained variation has been a marginal concern. Greatest attention has been given to aspects of variability arising from structural, environmental or prosodic aspects of lexical items, typically with an assumption that speaker–listeners map between invariant lexical representations and the complex variation associated with multiple physical realizations of the target.

What this previous work has not achieved is to provide an account from first principles of how sociophonetic variability is produced within speech while also accounting for the questions of how the indexical meaning of sociophonetic variability is learned, interpreted, and represented. For example, Anttila and Cho (1998) formulate an elegant optimality account of dialectal differences in /r/-ø alternation in English. They show how different constraint rankings predict quantitative differences in variant usage. However, their analysis is silent with respect to the indexical values of the variant forms, which are well known to be highly salient sociophonetic markers in many dialects of English (Foulkes, 1997; Wells, 1982, p. 284).

4.1. Exemplar models and sociophonetic variability

Currently, the only theoretical framework that embeds indexicality centrally within phonological knowledge is the exemplar-based model of representation discussed by, amongst others, Goldinger (1997), Johnson (1997), Pisoni (1997), Pierrehumbert (2001, 2003a, b), Lachs, McMichael, and Pisoni (2003), Hawkins and Smith (2001), and Hawkins (2003). The exemplar model takes a very different point of departure from most other models by not assuming that lexical representations are stored solely in abstract and invariant form. Instead, knowledge of linguistic structure is built up by representing in memory the totality of linguistic experiences that an individual has. So, for example, knowledge of the sound patterning associated with the word *cat* is not considered to be reducible to something like a three phoneme string, /kat/. Rather, it consists of a detailed record of all of the exemplars that an individual speaker–listener has encountered of that word. In principle, a lexical representation may therefore include a potentially vast set of detailed acoustic traces based upon tokens an individual has heard, and a parallel set of traces bearing articulatory information about tokens that the individual has uttered.[5] Each exemplar simultaneously encodes non-linguistic as well as linguistic information since the acoustic record contains reflexes of who was speaking and what the speaker's voice sounded like (in terms of segmental features, pitch range, voice quality, etc.).

Thus, the exemplar model intrinsically captures the observation made in Section 2.3 that no natural human utterance offers linguistic information without simultaneously indexing some social factor. Specifically, it predicts that individuals store and can access those aspects of phonological patterning which are crucial in conveying indexical information. Associations are automatically created in memory between linguistic and indexical information conveyed by the speech signal, and, in any particular instance, listeners map phonological patterning not only against the meaning of the word in question but also against other dimensions of that particular token such as the identity of the speaker. Experimental evidence indicates that this does indeed happen, at least in certain communicative tasks (e.g., Hawkins & Smith, 2001; Lively et al., 1993; Nygaard, Sommers, & Pisoni, 1994; Smith, 2004, and other contributions to this volume).

[5]For the present purposes we put to one side the questions of how exactly an exemplar representation is encoded, as well as the extent to which exemplar representations are subject to attrition and other factors intrinsic to long-term memory. Readers are referred to Bowers and Marsolek (2003) for further discussion of these matters. We proceed on the assumption that exemplar-based representation encodes multi-sensory traces which encapsulate the individual's long-term experience.

These features alone strongly differentiate the exemplar-based model from other models of representation, but there is a further element of this approach which strengthens its appeal to those interested in accounting for sociophonetic variability. For many investigators, including all those cited above, exemplar-based representation goes hand in hand with a probabilistic approach to linguistic learning and categorization (see contributions to Bod, Hay, & Jannedy, 2003). Precisely, the same probabilistic mechanism can be extended to account for the emergence of knowledge of the indexical properties of variants.

The probabilistic approach assumes that phonological categories are substance-based, emerging from experience as encoded in stored exemplars. Specifically, as individuals amass exemplars and update their experience of linguistic substance, they appear to develop sensitivity to the statistical properties of that substance. Pierrehumbert (2003a) hypothesizes that phonological categorization is hinged on an ongoing analysis of the "acquired density distribution in phonetic space". That is, listeners encounter substantial variability within phonetic space, but the variability comes to form patterns as experience grows. Over time, exemplars with similar phonetic properties cluster together in memory, and as a result the distribution of phonetic forms develops peaks and valleys. It is from this statistical patterning that individuals' awareness of phonological categories emerges (see Pierrehumbert & Gross, 2003 for further detail and for simulations of the process whereby phonetic categories emerge from variable and noisy input). Pierrehumbert (2003a) further claims that "extreme positional conditioning can create distinct phonetic modes". In other words, if a speaker–listener experiences phonetically distinct forms of a word (loosely-defined), clusters may emerge within the exemplar store for that word. This is likely to occur, for example, as a result of contextual variation (Pierrehumbert illustrates the point with reference to the example of glottal stop as a positional variant of English /t/). The phonetic space occupied by exemplars of a word can therefore be distributed multi-modally. Pierrehumbert's simulations are focused on the emergence of segmental units, but there is evidence that individuals develop awareness of the distributional properties of many other aspects of sound patterning within spoken communication, including those relating to morphophonology and phonotactics (Pierrehumbert, 2001).[6]

In her discussion of multi-modal distributions in phonetic space, Pierrehumbert refers specifically to contextually-constrained allophonic variation. However, when we take account of the full range of structured sociophonetic variability (as outlined in Sections 2 and 3) it is likely that multi-modal distributions of exemplars are anything but the exception to the rule. Indeed, they must be epidemic. Listeners experience systematic variability correlating with many non-linguistic criteria and at many levels of structure. All words are likely to be affected by sociophonetic variation in the exemplar store. At the simplest level, exemplars will be stored from both male and female talkers. Major differences in the vocal tract dimensions of males and females yield many phonetic differences (Section 2.1), which in turn will lead to major disjunctions within the exemplar store on parameters such as fundamental frequency and vowel formant frequencies. Strand (1999) appeals to a similar structuring of phonological knowledge in accounting for her findings that listeners' expectations of stereotypical [s] and [ʃ] productions for male and female speakers impact on their categorization of a synthetic [s]–[ʃ] continuum. At a more complex level, many words will also reflect systematic differences emanating from factors such as speaking style, where the relationship between linguistic form and social meaning is the product of social convention.

In this way the exemplar model accounts for emerging knowledge of indexical properties of phonological patterning, without having to invoke any special mechanisms over and above those that apply in phonological learning more generally. As with other types of phonological patterning, a distributional analysis of exemplars provides the basis from which experience with sound patterning can be aligned to the social factors which are significant for a particular individual. It is this capacity that makes the exemplar approach stand apart from others and worth pursuing further to explore its potential for modeling sociophonetic variation. In the following sections, we consider how knowledge of key social-indexical dimensions within spoken communication might emerge, a process for which the exemplar approach offers

[6]This attunement to distributional properties of speech at levels other than the segment is clearly helpful in structuring segmental categorization; e.g., a phonetic difference between *wa*[t]*er* and *wa*[ʔ]*er* where context determines that the meaning of the two words is the same facilitates an association of the two phonetic categories while maintaining their multi-modal distribution and their mapping onto distinct indexical points of reference.

some testable predictions. In doing this, we also highlight a number of aspects of the model that are in need of further elaboration.

4.2. Developing knowledge of social-indexical variation

Applying the principles of the exemplar-based model leads to the prediction that knowledge of the sociophonetic dimensions conveyed within the speech signal will be present from an early stage of phonological acquisition. Assuming that children learn language via input from more than one individual, it follows that all tokens of all words will inherently contain reference to individual talkers. Within an exemplar model, it is reasonable to assume further that exemplars are likely to cluster relatively neatly as a result of stark and consistent phonetic differences across individual talkers. In the early stages of acquisition, when the child has only limited experience and a small exemplar store, it is conceivable that three basic groupings will emerge. These three groups will consist of exemplars derived from adult males, adult females, and children, respectively, based on marked phonetic distinctions that are fundamentally driven by biological differences (f0, formant frequencies, etc.). In the first instance, the child may not be aware of the source of the clustering or the indexical meaning of the differences between the phonetic variants within the clusters, but it is the very presence of such clusters that permits indexical awareness to emerge.

Given this foundation, and sufficient maturity and experience, the child would begin to build an understanding of the correlations between clusters of exemplars and specific features of the immediate environment. For example, recognition of an individual talker is likely to emerge first, in particular of the primary carer, who will be the source of the majority of the early input. Recognition of individual talkers should in turn give rise to recognition of groups of talkers, most readily perhaps the three basic groupings of adult male, adult female, and child. The child may well begin by inferring that the difference resides on a dimension such as mother/father/sibling rather than the more abstract male/female/child, although at some point in development more extensive experience with ambient phonological variability should enable generalizations to be made. Subsequent experience with structured variation, which yields further distinct clusters of exemplars, permits other indexical categories to emerge.

The extent to which the development of awareness of the social-indexical value of phonetic variation is an explicit or implicit process is a matter on which investigators can only be agnostic at this stage. Within an exemplar-based account, associations between clusters of exemplars and particular environmental referents need not be explicit since they would arise as a direct consequence of the associative nature of the representation that is proposed. Nevertheless, adults, and even young children, do demonstrate an explicit awareness of at least some of these associations and can be observed to manipulate them within conversational interaction (e.g., Sangster, 2002, illustrates young adults' explicit awareness and manipulation of the stereotypes associated with their own particular regional variety of English; likewise, Sachs and Devin, 1976, report on children's use of age-appropriate speech-styles in interactions with other children). However, the conditions that lead to the development of such explicit knowledge remain to be investigated experimentally.

If acquiring knowledge of the social-indexical value of phonetic variability is a routine part of phonological acquisition, then a further hypothesis arising from the exemplar-based approach is that awareness of some types of indexical knowledge could emerge more readily than others. Biologically-conditioned phonetic variation is consistent, fairly discrete and pervades many lexical items, which should lead to early awareness of male/female/child differences. Once these differences have been identified and their indexical values learned it is a reasonably short step to identifying those socially-constructed categories for which the linguistic cues overlap those of biologically-determined categories. These will include gender (for which the relevant cues overlap those indexing sex) and age (in social as well as biological terms; Eckert, 1997). Many biologically-determined differences serve also as indices of these social categories, including, for example, f0. They thus form a foundation for learning more arbitrary relationships between linguistic forms and gender or age, which might be hypothesized to pose a greater challenge. These will include variable forms particular to a given dialect or community, such as those we outlined in Sections 2 and 3. A child growing up in Newcastle, e.g., needs to learn the indexical values of the various forms of /t/ such as [ɪ], laryngealized stops and preaspiration, all of which are gender- and/or age-differentiated but which have no transparent grounding in biological

differences, are not used by all individuals in these groups, and which are more restricted in their frequency of occurrence.

An even greater challenge for learning should be found in the case of completely arbitrary sociophonetic relations, such as those pertaining to style,[7] ethnicity, social class, or geography. This learning task is rendered more challenging for two reasons. First, it is likely that some of the key sources of variability may be experienced relatively rarely within the immediate environment. Some children may have very limited exposure to ethnic, social, or regional dialect groups other than those of their family. They are also likely to experience only a limited range of linguistic styles. Relevant exemplars may therefore be available in low frequencies, which we would assume poses an obstacle when it comes to learning the indexical values of these social factors (although novel patterns of course can be highly salient, a factor which could mitigate the dependency on frequency distributions inherent within a probabilistic model of representation). Secondly, even where the exemplars are available, the clustering of relevant exemplars may be much less obvious than is the case with, say, age or sex. Some of the essential cues for indexing age and sex can be gleaned from transparent and consistent phonetic differences which yield relatively discrete partitioning of exemplars. The indexical information for geography, class, ethnicity, and style, on the other hand, is usually encoded more continuously in phonetic space. The salient differences between groups are often no more than small statistical differences in the frequency of occurrence of a given feature (Section 2.1). Thus, the peaks and valleys of the exemplar store may be much less prominent. Making inferences about the indexicality of subtle phonetic differences is likely to be a more difficult task compared with those examples in which the distribution of exemplars is more quantal in nature.

In short, the more transparent the link between phonological variant and social category, the easier it should be to learn. The most transparent case is variation which is a consequence of organic features distinguishing speakers, but other aspects of social-indexical variability have more or less transparency and thereby may be more or less straightforward to learn. The exemplar model captures this because of the way in which multi-modality will emerge in the exemplar store: sex is bimodal for some phonetic parameters, while age might emerge in the same way on a child–adult dimension. Indexing of individual speakers should also be relatively straightforward. Much more arbitrary relationships may take a long time to be learned, or may never be learned at all.

There is some evidence that is supportive of the progression and gradation just envisaged. For example, recognition of maternal voice has been demonstrated in neonates at 3 days (DeCaspar & Fifer, 1980). In Section 3.3, we described a developing gender split in the use of preaspiration by children in Newcastle: 2;0–3;0-year olds of both sexes tended to stay close to the maternal model, but between 3;0 and 3;6 there were indications of an emerging male/female differentiation. By the age of 9 years the differentiation has been found to be clear and robust (Allen, forthcoming). The Newcastle study also revealed the properties of CDS being configured by mothers in a way which would facilitate the identification of indexical patterning (Section 3.2). Other studies suggest that the learning of speech style differences seems to be fundamentally rooted in a child's developing social and linguistic experience. Labov (2001, pp. 437–) suggests that awareness of style differences emerges initially in relation to the linguistic differences between play and discipline contexts in early parent-to-child communication. In a similar vein, Gillen and Hall (2001) report children aged 3;0 demonstrating some of the prominent stylistic aspects of telephone speech in a telephone game played out at nursery. There is also evidence that some aspects of social-indexical patterning are significantly harder to acquire. For example, Nathan, Donlan, and Wells (1998) illustrated the difficulties that 4- and 7-year olds have in recognizing words spoken in an accent to which they have had little or no previous exposure, noting that these are more marked in the younger group of speakers. Clopper's (2004) evidence that adults have

[7]It might be argued that style is not totally arbitrary to the extent that stylistic differences on an informal–formal plane often embody variation along a hypo-/hyper-continuum of speech production (Lindblom, 1990). However, this relationship is far from inviolable. For example, in England many speakers adjust their speech in formal styles toward the standard accent, RP. RP is distinguished from many non-standard dialects in permitting processes such as 'smoothing' of diphthongs, and extensive reduction to /ə/ or complete elision of unstressed vowels (Wells, 1982, p. 286). Formal speech may thus paradoxically engender phonetic forms that are further toward the hypo-end of the continuum than those found in less formal speech. Moreover, we are using the term 'style' here to cover a very broad range of situation-specific phenomena, which may be orthogonal to issues of formality (see Section 2.1).

relatively poor ability to recognize regional or social or ethnic accents with any degree of precision underlines the fact that strongly arbitrary and/or low frequency social-indexical patterning may never be fully mastered.

Findings such as these are promising indications that an exemplar-based account of the acquisition of sociophonetic knowledge may be worth pursuing. The relevant studies, however, are relatively few and far between and there is clearly a need for further empirical data to explore the validity of this approach.

4.3. Mapping to production

While focusing on the potential of an exemplar-based model to account for how individuals develop and continue to develop their awareness of the indexical values of phonological variation, it is important to bring this approach to bear on what we know about indexical variability within speech performance. The exemplar-based model has arisen largely from work on perception and categorization. The question of how exemplar representations relate to speech production has been explored relatively little. Pierrehumbert's (2003b) stance is perhaps the clearest to date. She suggests (p. 186):

> once a label is selected (presumably through a decision to say a word that involves that label), a production goal is established by sampling the empirical distribution for that label. Specifically, an averaged neighbourhood around a randomly-sampled point in the distribution serves as a production goal. Bias terms on the initial sampling and on the computed production goal are available to model systematic shifts in the use of the phonetic space. Such shifts can come about through choices of speech style and historical changes in progress.

Thus, a 'bias' on the sampling of the exemplar space would seem to be a basic mechanism whereby a speaker can generate a target which is sociophonetically appropriate for a given context. So, for example, if in exemplar representation an individual speaker from Newcastle has developed an association between plain and laryngealized variants of /t/ and female/male speakers, respectively, then one simple bias which could be applied at the point of generating a production target would be to match with the speaker's own gender. Likewise, if an individual has developed probabilistic associations between particular styles of speech and particular patterns of phonetic implementation, here too the bias could simply ensure a match for the situation of the utterance to be produced. It is also conceivable that a bias mechanism such as this lies behind the observations of phonological divergence and convergence between participants within a conversation, with the polarity and extent of the bias being driven by the individual participant's evaluation of the social context of the interaction (Bell, 1984; Coupland, 1980; Local, 2003; Pierrehumbert, 2002).

If such bias terms do have a role within a speech production model in governing sociophonetic variability, it is instructive to consider how they themselves might come to be established. While young children may develop associations in memory between particular phonetic patterns and particular speakers (or types of speaker), it is clear that they are restricted in the extent to which they can manipulate this knowledge in their own performance. For simple developmental reasons children simply cannot produce forms which are adult-like in all their acoustic detail. In this situation, it is conceivable that they may attend to a greater extent to exemplars nearest to what they themselves can do—i.e., those produced by women and by other children. This would have the effect of reinforcing the importance of the female model already established through frequency (assuming a female primary carer). As the child's own production begins to develop, more exemplars will be added from the child's own speech and a production bias might emerge as a separate category (cf. Vihman, 1993, who argues that children's patterns of performance seem to reflect the existence of an 'articulatory filter' which reinforces and enhances in phonological representation the recurrent patterns that the child produces and is exposed to). As the child's social world becomes more complex and his/her ability to interpret it becomes more sophisticated, we might also predict that the effect of exemplars from other children will increase in importance as (a) the child encounters more children and experiences more exemplars from them, for example, on starting school, and (b) because other children's exemplars are also closer to what that particular child is capable of generating in production. Thus, divergence from the biases induced by the home model might be hypothesized to emerge both by a frequency effect (of additional exemplars heard from other children) and gradual emergence of indexicality relative to peers versus non-peers, brought about by changes in social circumstances. Kerswill and Williams' (2000) study of children in Milton Keynes revealed precisely

this sort of effect: preschool children adhered to parental patterns of phonetic realization but 12-year olds adopted the innovative variety characteristic of the first generation youth in the town (Section 3.3).

4.4. It's not all statistics

The exemplar-based framework provides a basis for understanding the integration of lexical and indexical information within memory. However, as alluded to in Section 4.3, it is clear that a full account of the acquisition of sociophonetic information requires a model which can incorporate a dimension above and beyond a probabilistic analysis of the sound patterns within speech. As pointed out by Meyerhoff (2002, p. 527): "Language is understood as but one vehicle by which speakers construct, maintain, or contest the boundaries of social categories and their membership or exclusion from those categories." In other words, a key element in accounting for the sociophonetic properties of speech is to factor in an understanding of how individuals construct their social world and how they use language (phonological patterning in particular) to position themselves within it.

For example, while in very young children probabilistic learning may give rise to an awareness of male/female phonological differentiation, as an individual child's gender awareness emerges this could have the effect of skewing the perceived difference between distributional modes within the exemplar space. It is conceivable that a boy whose gender identity is in the process of emerging may be led to pay relatively greater attention to the tokens produced by other males even though in pure frequency terms he may come across these less often than tokens produced by female speakers. In other words, probabilistic learning will gradually be influenced by the individual's emerging construction of the social world in a way which is not necessarily in keeping with the statistical properties of the input (although how this weighting is implemented within an exemplar framework remains to be determined).

Further examples of this are evident at later stages of development. For instance, many parents observe anecdotally at the onset of schooling a sudden influence of the peer group on an individual child's behavior. In relation to linguistic behavior, it is not the case that the child ceases to be exposed to the patterns of performance modeled by his/her parents/siblings which have been the predominant influences to that point, nor that awareness of these has diminished. Rather, the sudden reconfiguration of the individual child's social world adjusts the balance of importance attached by a child to parents/siblings versus peers, and forces the child to begin to work out how phonological resources can be deployed to convey social indexicality within the broader community. A significant reshaping of the child's social world can thus lead potentially to a rapid shift in the prominence attached to some subsection of an exemplar store. Further evidence of a process of this sort can be seen in studies of children who have relocated to areas with very different dialects (Kerswill & Williams, 2000; Payne, 1980).

The process of attuning phonological behavior to individual social identity is perhaps most transparent during adolescence. It is unlikely to be a coincidence that adolescence, the time at which an individual's self-definition vis-à-vis the peer group is under intense development, is also the time when individual stylistic variability is most strongly apparent in speech production (Eckert, 2000; Mendoza-Denton, in press). Just as other aspects of behavior are geared by adolescents to projecting variable identities to particular audiences, evidence suggests that phonological patterning can be attuned to the same ends.

What these examples from childhood and adolescence suggest is that probabilistic learning and awareness of phonological patterning must be mediated by the fact that individuals are doing more than simply learning how to convey propositions intelligibly to their interlocutors. That is, maintaining lexical contrast may be only one concern, and in some contexts may be a relatively minor one. Crucially, individuals are also learning about how they fit into their own community and about how they can use phonological patterning as a means of achieving and reinforcing this. Furthermore, it is important to emphasize that the social categories which phonological experience is mapped on to are not preexisting or common across all speakers, but are very much a result of how individuals construct their social world based on their experiences as a member of their community or communities. It seems likely then that there is interplay between the probabilistic basis on which phonological experience is interpreted and what Mendoza-Denton, Hay, and Jannedy (2003, p. 136) refer to as the "gradually built up social categories that emerge from the experiences that surround individuals as social actors".

The nature of this interplay has not received significant attention from investigators developing the exemplar model. Critically, however, it is a feature that is fundamentally compatible with an approach based on experiential and probabilistically structured representations. Furthermore, it is a feature that is very difficult indeed to handle within any conventional theoretical framework in phonetics or phonology.

While there is evidence of significant tuning of the social evaluation of probabilistic representation during adolescent years, studies of real-time phonological change in individual speakers (such as that reported by Harrington in this issue) suggest that whatever the mechanisms are that underpin sociophonetic variation, the issues of individual identity/social construction that are so plainly evident in adolescence continue to have a key role throughout later stages of life. Exemplar representations will continue to be updated throughout the life-span with the result that new/innovative mappings in the external environment can be tracked (either those caused by sound change, or more abruptly, those encountered through relocation).

The capacity for the social-indexical value of particular variants to evolve through time is strongly evidenced in a number of studies which show how the same phonetic properties can be redeployed in the same environment with different indexical consequences. Dyer (2002) identifies the 'recycling' of sociophonetic features in her study of the English steel town, Corby. In the 1960s, a large number of Scottish steel workers moved into the town, importing with them a dialect distinct from that of the local area. Many of the Scottish phonological features that characterized the immigrant community have been abandoned by subsequent generations. However, certain features are being maintained but with new indexical values. They no longer act as indices of Scottish ethnicity, but instead mark out the speaker as being from Corby rather than from neighboring towns. Heselwood and McChrystal (2000) offer similar evidence in their study of young English–Panjabi bilinguals in Bradford. Older generations can be identified as L2 English speakers because they transfer Panjabi phonological and phonetic patterns onto their English. Some of these features are being maintained by the young UK-born bilinguals, especially the males, as markers of local ethnic identity.

Finally, the fluidity of social indexicality in speech (i.e., its dependence both on the evolving distributional properties of the exemplar store and on individuals' fluctuating social constructs) would seem to provide the foundation not only for real-time phonological change within the life-span of an individual speaker, but also for many aspects of long-term phonological change. This is strongly reflected in Bybee's work on the role of lexical frequency in sound change (e.g., Bybee, 2001), but it is also implicitly reflected in Trudgill's (2004) discussion of dialect contact and the creation of innovative varieties, particularly in the context of New Zealand English. By and large, phonological features found in low frequency disappear in dialect contact situations in favor of forms that are more widespread among the community. The frequency effect can be overridden, however, if social conventions accord particular social power to a minority group or minority linguistic forms. This is presumably the requisite scenario in cases where innovatory sound changes take place: new forms are, by definition, minority forms. For a new form to spread successfully the form must have some positive social value for those who adopt it.

5. Concluding comments

In Sections 1–3 of this article, we defined and illustrated sociophonetic variation, highlighting both its pervasiveness and also the relatively minor role it has played in the development of phonetic and phonological theory. In Section 4, we outlined a number of ways in which exemplar models hold appeal for modeling sociophonetic variation. This discussion also underlines the fact that, for all the potential that this framework would seem to offer, there is a need for much more empirical work to probe its various predictions. The following areas would seem to be key lines of investigation for shedding further light on the validity of the exemplar approach.

First, in respect of speech production, we need further work to identify which phonetic parameters can carry indexical information. Research to date has been skewed, with a focus on English and relatively little instrumental analysis beyond vowels. There is a clear task to be undertaken to establish the scope that speakers across languages have in deploying their phonetic resources as a social index. It would be valuable, e.g., to understand the extent to which phonetic parameters might be more or less predisposed to act as social indicators across languages. For example, while research on variation in English usually identifies vowels as the main locus of sociophonetic differences (e.g., Labov, 1994, 2001; Wells, 1982), in Arabic, by contrast,

consonants appear to carry the bulk of social information (e.g., Haeri, 1997). Less work has been devoted to the potential indexical role of subsegmental or suprasegmental parameters across languages. It would also be valuable to investigate further the extent to which sociophonetic variables are correlated within speakers' performance. Most sociolinguistic studies focus on variables independently, as our work on Newcastle English has done. Only a few studies have examined the clustering of variables within a community (see in particular Chambers, 1998; Horvath, 1985), and we have little understanding of the effects clustering has on listeners' perceptions of indexical properties.

Indeed, the gaps in our knowledge are in general much more substantial with respect to the perceptual evaluation of sociophonetic features. While some understanding of this is provided by existing studies (e.g., Bennett & Montero-Diaz, 1982; Clopper & Pisoni, 2004; Evans & Iverson, 2004; Gaudio, 1994; Lass, Hughes, Bowyer, Waters, & Bourne, 1976; Purnell, Idsardi, & Baugh, 1999; van Bezooijen & Gooskens, 1999), in general relatively little is known about how and to what extent listeners are able to make judgments about the indexical properties of variability within the speech signal, despite the fact that such judgments are clearly a part of what happens during almost any type of interaction. There are several issues that warrant further investigation. For example, how much material does a listener need exposure to before a confident or robust judgment can be made? What types of judgments can be made? Is there an advantage for some phonetic parameters over others? How do indexical cues carried within speech interact with cues conveyed through other modalities (cf. Strand, 1999)? It is also important to develop an understanding of what factors result in some aspects of sociophonetic variability attaining sufficient prominence that individuals develop an explicit awareness of them (i.e., features are subject to second-order indexicality—see footnote 1). Is this more likely to occur when there is a cluster of variables indexing a particular social characteristic or individual? To what extent is explicit awareness associated with particular social situations or communicative tasks? In pursuing perceptual evaluation, it would also be instructive to investigate the extent to which individuals differ in their capacity to respond to the sociophonetic properties of stimuli. For example, it is regularly attested in forensic phonetic studies that some individuals are substantially more adept than others at identifying speakers or at being able to describe the features of a given speech sample (e.g., Foulkes & Barron, 2000; Yarmey, 2001). Likewise, some individuals appear wholly unaware even of locally stereotyped sociophonetic features (Johnstone, Schardt, Kiesling, Andrus, & Baumgardt, 2004).

We also need to develop a deeper understanding of the range of social meanings that individuals are able to index phonetically. It is now accepted by sociolinguists that social categories such as gender, age, style, and class are all much more complex than has often been assumed. In particular, work by Johnstone and Bean (1997) and Mendoza-Denton (in press), among others, has pointed to the need to investigate in greater depth the notion of speech style and how for individual speakers this migrates from situation to situation as the basis of linguistic social marking.

A final area that is in need of development is the issue of how knowledge of the indexical channel within speech is acquired by children and how this evolves in later life. The findings referred to in Section 3 give some idea of how this issue can be pursued, highlighting the need to focus both on the emergence of sociophonetic features in speech production and on the development of a capacity to interpret the indexicality conveyed within the speech of other people. Studies of this sort are rare and are methodologically very challenging. There is a particular need for longitudinal studies which track children from the preschool years into the first few years of schooling.

It is clear that pursuit of these questions will enhance our understanding of phonological representation and acquisition, speech planning, and perception, and in particular will allow further testing of aspects of the exemplar-based framework for phonological representation. It is also clear that addressing these questions requires a somewhat different overall approach to methodology from that which typically applies in quantitative phonetic research. It is likely that sociophonetic variability is strongly governed by the individual's exposure to the statistical properties of ambient sound patterning and also by how the individual interprets and manipulates his/her social context. Empirical work in this area therefore requires a focus on how *individuals* perform and interpret sociophonetic variability in a range of communicative settings. A corollary of this is that intra- and inter-speaker variability ought to take on greater importance in the analysis and interpretation of quantitative data since these are precisely the indicators that are required to test many of the issues outlined in this article. This focus on intra- and inter-speaker variability should also reflect the

likelihood that the interpretation and representation of phonological knowledge may be less stable, even in adulthood, than is typically assumed. Such a recasting of the object of study is certainly a challenge to fields such as phonetics and phonology, which have typically concentrated on generalizations across subjects and which have made assumptions about homogeneity of groups of subjects on the grounds of shared age, sex, and geographical origin. But studies of sociophonetic variability suggest that such an approach is essential if we are to fully understand how indexical information is channeled alongside linguistic information within spoken communication.

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