7 Instrumental Phonetics

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1 Instrumental Phonetic Studies in Sociolinguistics

Since the appearance of Labov, Yaeger, and Steiner's *A Quantitative Study of Sound Change in Progress* (1972), instrumental phonetic studies have gradually taken up a larger and larger portion of the quantitative sociolinguistic research on phonetic variation. This growth is encouraging to acousticians. Sociolinguistics is far ahead of phonology, another theoretical discipline that deals with pronunciation, in incorporating instrumental methods. However, much remains to be done. Most instrumental sociolinguistic work has been restricted to a few research issues and methods. It has been concentrated on variation in vowels; variation in consonants, prosody, and voice quality has received little acoustic analysis. In addition, much of the instrumental inquiry has focused on investigating the phonetic or phonological motivations for sound change. Instrumental methods could be applied more widely to a variety of other issues, ranging from ethnic relations to phonetic variation as an indicator of the mental representation of sounds. The greater part of the corpus of instrumental studies of phonetic variation presently consists of studies of speech production. Perceptual studies still represent a largely untapped potential, though they are becoming more common.

Certainly, then, instrumental analysis could be applied much more extensively than it has been thus far. It is not, of course, practical for all studies of phonetic variation. Some variables, such as *r*-lessness (e.g. production of *four* and *here* as [foə] and [hiə]), are more easily approached impressionistically. Lindblom (1980) reminds his readers that acoustic measurements are useful only in so far as they reflect linguistically relevant factors, and for *r*-lessness, it can be argued that what is important is whether listeners perceive [ɹ] or [ə]. In any case, the phonetic attributes of *r*-fulness and *r*-lessness – the threshold and rate of the fall in F_3 (the third formant) necessary for perception as [ɹ], the effect of the phonetic context, the effect of duration, etc. – are complicated and have yet to be worked out (though they would make for fascinating perception experiments).

1.1 Measuring the effects of phonetic context

However, there are many issues for which instrumental techniques are more appropriate than other methods. One example is measurement of the effect of consonantal context on vowel realizations. This issue has been important in studies of vowel change because vowel shifts are often conditioned by particular contexts. Experimental studies have demonstrated that perceptual processing of vowels normalizes the effects of consonantal context (Lindblom and Studdert-Kennedy 1967, Ohala 1981a: 179 ff., especially 181, where he cites other studies; Ohala and Feder 1994, Nábělek and Ovchinnikov 1997). Ohala (1981a) terms this process "corrective rules." For example, a given vowel will ordinarily have a lower F_2 (second formant) in the context of labial consonants than in the context of coronal consonants, but listeners will hear the two variants as "the same." Phonetic training does not enable scribes to escape the effects of context entirely (Nairn and Hurford 1995). For that reason, impressionistic transcriptions of vowels in different contexts do not reflect the actual production of the vowel by a speaker as much as they reflect the scribe's perception. In most studies of the role of consonantal context in sound change, however, the ostensible focus is on production, not on perception (and especially not on scribal perception). Instrumental measurement, naturally, is not affected by "corrective rules." Thus impressionistic transcription is poorly suited for examinations of contextual effects, while instrumental measurement is well suited for it. Nevertheless, impressionistic transcription has often been used for contextual studies, in large part because it produces the discrete data necessary for the popular VARBRUL statistical analysis package while acoustic measurements produce data that are continuous and also require inter-speaker normalization.

1.2 Ethnic identification

Another example for which instrumental techniques are more appropriate than other methods involves the perception of a speaker's ethnicity. Speech synthesizers allow researchers to investigate what cues listeners use for ethnic identifications. Without synthesis, researchers are limited to using recordings of speakers, either of natural speech or, following Lambert's (1967) matched-guise experiment, of some sort of performance speech. A number of studies have demonstrated with stimuli that were not synthetically modified that American listeners are able to distinguish African-American voices from white voices (Roberts 1966, Tucker and Lambert 1969, Lass et al. 1979, Bailey and Maynor 1989, Haley 1990, Trent 1995, Baugh 1996). These studies were incapable of determining which features listeners used for their identifications, though Roberts (1966) asked her subjects for subjective guesses about the features they used.

One method of ascertaining what features are utilized for ethnic identifications was employed by Walton and Orlikoff (1994), who took careful measurements of voice quality features in their stimuli and correlated them with the accuracy of ethnic identifications of the stimuli by listeners. However, speech synthesizers allow researchers to conduct perception experiments in which the different phonetic attributes are varied. Although a talented impersonator might be able to produce passable manipulations of particular phonetic attributes, it would be impossible to calibrate the manipulations precisely and the impersonator might unintentionally modify other features, too. Synthetic manipulation can be calibrated exactly and without affecting other features. Graff et al. (1986) used synthetic manipulation to show that Philadelphians could base their identifications of a speaker's ethnicity on whether the nuclei of /o/ and /au/ were fronted (for whites) or not (for African Americans). Hawkins (1993) used both natural and synthetically modified voices. After finding that listeners could identify the ethnicity of unmodified voices most of the time, even after hearing only isolated vowels, she synthetically altered the F_0 (fundamental frequency) of voices and found that listeners tended to identify voices with lower F_0 as African-American and those with higher F_0 as white. Because the correlation was not the same across listener groups, she speculated that stereotype, not physiology, was the cause. (In contrast, Walton and Orlikoff 1994 suggested that physiological differences might account for the voice quality differences that they found.) Lass et al. (1978) found that playing signals backward and compressing the time adversely affected ethnic identifications. In a follow-up study, Lass et al. (1980) found that listeners could identify the ethnicity of lowpass-filtered voices, suggesting that intonation was an important cue. Foreman (1999) conducted a similar experiment involving lowpass-filtered samples of read speech. She found that listeners with extensive exposure to speakers from both ethnicities identified the voices better than those with extensive exposure to only one group and that stimuli exhibiting prosodic contours and pitch ranges typical of only one of the ethnic groups were most accurately identified.

2 Instrumental Studies of Variation in Production

Labov et al. (1972), the study that popularized the use of instrumental techniques in sociolinguistics, focused on vowel shifting in dialects of English as evidenced by patterns of the first two formants (F_1 and F_2). Although they included a few small-scale perception experiments designed to investigate near-mergers and cross-dialectal misperception, they concentrated on speakers' production. Most other sociolinguistic researchers have followed their lead, so, not surprisingly, the largest share of instrumental sociolinguistic work since then has involved the study of vowel shifting in production, based on F_1 and F_2 patterns. Instrumental analyses of consonantal variation (Docherty and Foulkes 1999), prosodic variation (see, e.g., Britain 1992: 102–4, Jun and Foreman 1996, Yaeger-Dror 1997), and variation in voice quality (Walton and Orlikoff 1994) are scarce. Consonants, prosody, and voice quality remain, for the most part, in the realm of impressionistic phonetics. The vocalic inquiry has been centered on the study of stressed vowel nuclei; unstressed vowels and the glides and structure of diphthongs have received much less attention. Furthermore, the focus on diachronic shifts has overshadowed other issues for which instrumental analysis would be useful.

2.1 *Studies of vowel variation and change in production*

Labov et al. (1972) and Labov's subsequent works on the topic of vowel shifting (particularly Labov, 1991, 1994) discussed acoustic analyses of vowel configurations in several dialects in the United States and the British Isles. Their most often cited result was that they found two shifting patterns associated with particular dialects: the "Northern Cities Shift" in the Great Lakes region of the United States and the "Southern Shift" in the American South. Both of these shifts are described below. Comparing their results with a survey of shifts reported in the historical linguistics literature from a variety of languages, they discovered four recurring patterns of vowel shifting. From these recurring patterns, they derived several principles, e.g. in chain shifts, tense nuclei rise along a peripheral track; lax nuclei fall along a nonperipheral track; tense vowels move to the front along peripheral paths; low nonperipheral vowels become peripheral; etc. (Labov 1994: 176, 200, 280). Further testing of the universality of these principles is warranted (see Cox 1999).

Labov (1991, 1994) treats tenseness as a phonological abstraction and prefers to account for his descriptions of vowel shifting patterns in terms of peripherality, which, he observes, usually but not always corresponds with tenseness. He seems less interested in the phonetic correlates of tenseness other than relative peripherality in F_1/F_2 space and length. However, in order to explain the diachronic shifting patterns exhibited by vowels, it is necessary to examine all the phonetic attributes closely. Labov does offer a plausible articulatory explanation for the fronting of tense back vowels (Labov 1994: 261–4), though it is not the only possible explanation (see Ohala 1981b). He also offers perceptual explanations for some vowel shifts (e.g. Labov 1994: 332). Even so, the phonetic explanations for many of the shifting patterns remain unclear. Why, for example, should peripheral vowels tend to rise? Additional instrumental investigation would shed light on this issue. Tenseness is manifested as a bundle of phonetic attributes, as Labov et al. (1972: 41) acknowledge. Tense vowels are generally breathier than lax vowels, more diphthongal, produced with the tongue body higher, and produced with advancement of the tongue root, as well as being more peripheral in F_1/F_2 space and longer (Lindau 1978, Kingston et al. 1997). Raising of the tongue body and advancement of the tongue root both contribute to lengthening the pharyngeal cavity, which lowers F_1, thus effecting the raising of tense vowels. Viewing one phonetic attribute, e.g. peripherality, in isolation from the others may obscure some of the answers. Investigations of why the different phonetic attributes of tenseness co-occur and how consistently they do so could go further to explain why vowel shifting follows certain patterns. For example, why do pharyngeal cavity lengthening and breathiness develop when a vowel becomes durationally lengthened, how general is this process across dialects, and is lengthening of duration the first step?

2.2 *Instrumental studies of vowel variation in individual dialects*

Since the appearance of Labov et al. (1972), acoustic inquiry into vowel variation and change has grown at a healthy pace. As Docherty and Foulkes (1999) note, however, virtually all of this inquiry has focused on comparisons of F_1 and F_2 values. Other components of vowels have received almost no instrumental attention from sociolinguists. Di Paolo and Faber (1990), Di Paolo (1992), Faber (1992), and Faber and Di Paolo (1995) found that phonation could be used to preserve vowel distinctions in Utah English that were no longer maintained by differences in formant values. A few other studies have examined vocalic duration. Feagin (1987) and Wetzell (2000) discussed the "Southern drawl," the lengthening of stressed vowels associated with the American South. In Thomas (1995), I correlated durational variation with truncation of the /ai/ diphthong, as in *tide*. Scobbie et al. (1999) examined the effects of the "Scottish vowel length rule." Nevertheless, F_1 and F_2 remain the primary focus of instrumental vowel analysis. The following paragraphs survey this research; I have limited the survey to studies of English, though F_1/F_2 studies of other languages exist (e.g. Sabino 1996, Yaeger-Dror 1996).

The description of the Northern Cities Shift is one of the most important results of Labov's instrumental research. The Northern Cities Shift consists of a chain of vowel shifts. /æ/, as in *cat*, is raised to [ɛə~eə~iə]. /ɑ/, as in *cot*, is fronted to [a], perhaps approaching [æ]. /ɔ/, as in *caught*, is lowered and often unrounded to [ɑ]. /ʌ /, as in *cut*, is backed and may be rounded to [ɔ]. /ɛ/, as in *bed*, may be lowered toward [æ] or backed toward [ɜ ~ʌ]. Finally, /ɪ/, as in *bid*, tends to be somewhat lowered or, more often, centralized (though centralization of /ɪ/ is actually rather widespread in American English: see Thomas 2001). Analyses of the Northern Cities Shift based on acoustic measurements are found in Labov et al. (1972) and Labov (1991, 1994), as well as in Veatch (1991) and Labov et al. (2001). Ito and Preston (1998) and Ito (1999) used acoustic analysis to examine the spread of the Northern Cities Shift on a more local scale, in small towns in Michigan. Acoustic analysis of Northern Cities Shift vowels is also found in Hillenbrand et al. (1995), albeit not by the authors' intention.

Labov's Southern Shift consists of several developments. One set involves diphthongs. /oi/, as in *boy*, is raised to something approaching [ui]; /ai/, as in *by*, may be backed to [ɑi~ɒi] or monophthongized to [a:]; /e/, as in *bay*, may be widened to [ɛi~ɜi~æi~ai]; and /i/, as in *bee*, may be widened to [ei~əi]. In England, these shifts – except for monophthongization of /ai/ – have been termed the "Diphthong Shift" (Wells 1982). In a similar fashion, /o/, as in *coat*, may be widened to, e.g., [ɐu], and /u/, as in *coot*, may be widened to [əu] or something similar. Other components of the Southern Shift are the fronting of /ɪ/ and /ɛ/ to positions peripheral in the vowel envelope, roughly [i] and [e], respectively, and shifting of /ɔ/ by either raising to [o] or diphthongization to [ɔo~ɑo]. Besides the general discussion of the Southern Shift in Labov et al. (1972) and Labov (1991, 1994), other acoustic analyses are found in Habick (1980, 1993), Feagin (1986), Veatch (1991), Labov and Ash (1997), Fridland (1998, 2000), and Thomas (2001). Schilling-Estes (1996), Schilling-Estes and Wolfram (1997), Wolfram et al. (1999), and Wolfram et al. (2000) included some acoustic analyses of the vowels of speakers from Smith Island, Maryland, and the Pamlico Sound region of North Carolina. In these areas, /ai/ shifts to [ɑi~ɒi] and /ɔ/ to [o], unlike other parts of the South, where /ai/ is monophthongized in some or all contexts and /ɔ/ is diphthongized.

Other dialects have been studied using spectrographic analyses of vowel formants, too. Labov et al. (fc.) is a continent-wide dialect survey based on acoustic analyses of telephone interviews that charts the geographical distribution of numerous vowel variables. Thomas (2001) is a continent-wide and cross-ethnic acoustic survey of vowel variation. Hindle (1980), Kroch (1996), Labov (1980), and Roberts (1997) examined various aspects of the Philadelphia vowel configuration. Herold (1990) included some acoustic analysis in her study of the merger of /ɑ/ and /ɔ/ in the Scranton/Wilkes-Barre region of Pennsylvania. Additional instrumental studies include Habick (1980, 1993) and Thomas (1996) on communities in central Illinois and central Ohio, respectively; Ash's (1996) study of the fronting of /u/ in the Great Lakes region; two studies of Texas English, Thomas and Bailey (1992) and Thomas (1997); and studies of the dialect of Vancouver, British Columbia, by Esling (1991) and Esling and Warkentyne (1993). Thomas (1991, 1995) and Niedzielski (1996) examined "Canadian raising," which involves raising of the nuclei of /ai/ (as in *sight*) and /au/ (as in *out*) before voiceless consonants, in the Great Lakes area. Instrumental dialectal analyses from other parts of the English-speaking world are not numerous, though see the formant plots from the British Isles in Labov et al. (1972) as well as those from New Zealand in Maclagan (1982), from Scotland in McClure (1995), and from Australia in Cox (1999).

Minority dialects have recently begun to attract some instrumental analysis. Acoustic analyses of the vowel formants of African Americans have appeared in Graff et al. (1986), Denning (1989), Deser (1990), Bailey and Thomas (1998), Thomas and Bailey (1998), and Wolfram et al. (2000). Acoustic analyses of the vowels of Jamaican creole appear in Veatch (1991) and Patrick (1996). Analyses of the vowels of Mexican Americans are found in Godinez (1984), Godinez and Maddieson (1985), Thomas (1993, 2000), Fought (1997). Anderson (1999) analyzed the diphthongs of North Carolina Cherokees. Thomas (2001) includes analyses and discussion of the vowels of African Americans, Mexican Americans, and a few Native Americans. Other minority groups, particularly Asian Americans and non-Chicano Hispanics, have been neglected.

2.3 *Vowel normalization*

A problem faced by many of the above-mentioned acoustic studies of vowel production is that speakers' mouth sizes differ, which results in differing formant values for "the same" vowel uttered by different speakers. As a result, quantitative comparison of vowel formant measurements from different speakers requires normalization. Disner (1980) states that normalization should reduce interspeaker variance but should preserve linguistic (and by implication, dialectal) differences. Other goals of normalization include keeping separate the contrasting vowels of a language or dialect and perhaps reflecting how human vowel perception operates. Numerous formulas for vowel normalization have been developed; all require F_1 and F_2 measurements, many require F_3 and/or F_0, and a few require other data, such as formant bandwidths, formant amplitudes, or F_4. Reviews of some of these methods can be found in, e.g., Hindle (1978), Disner (1980), and Syrdal and Gopal (1986). The fact that male and female formants are not scaled in exactly the same way (see, e.g., Fant 1966, Yang 1992) complicates normalization. All normalization techniques have drawbacks; choosing one is a matter of deciding which drawbacks are tolerable for the study at hand.

Labov (1994: 54–72) used a method developed by Nearey (1978) for his studies of vocalic change in Philadelphia. This method involves computation of a scaling factor for F_1 and one for F_2 based on the entire range of F_1 and F_2 values – or at least part of the range – produced by a given speaker. It reduces interspeaker differences effectively and discriminates contrasting vowels of a dialect, so it is suitable for comparisons of speakers of the same dialect, as Labov used it. However, because differing vowel configurations skew the scaling factors, it does not preserve linguistic and dialectal differences well. That is, for a dialect in which /o/, /ʊ/, and /u/ are fronted, the scaling factor for F_2 would be skewed toward higher F_2 values, while for a dialect with backed /o/, /ʊ/, and /u/ it would be skewed toward lower F_2 values, and the two dialects would not be comparable. Thus, it is inappropriate for cross-dialectal comparisons. Another disadvantage of this method is that it does not reflect human speech perception, since listeners are capable of normalizing a single vowel without hearing another vowel by the same speaker; even hearing point vowels has little effect on identification (Verbrugge et al. 1976). In Thomas (1996, 1997), I used a normalization formula developed by Iri (1959) that uses F_1, F_2, and F_3 and can normalize based on a single vowel. Iri's method has its own weaknesses, e.g. it is highly sensitive to perturbations of F_3 and the normalized values of the three formants are not mathematically independent of each other.

Syrdal and Gopal (1986) model human vowel perception by computing the F_1–F_0 distance (in Bark units) and the F_3–F_2 distance (in Barks) and suggest that this method could be used for vowel normalization. A third measure that they discuss, the F_2–F_1 distance (also in Barks), could be added or substituted to resolve differences that the other two measures do not (e.g. [e] vs. [ɪ] or [i] vs. [ü]). Variations in F_0, such as from intonation, individual voice quality differences, and aging, can disrupt the height (F_1–F_0) dimension, but this problem can be circumvented by using the F_3–F_1 distance in place of the F_1–F_0 distance. Syrdal and Gopal's method appears to fulfill all of the goals of normalization listed above.[1] Figure 7.1 shows the mean measured F_1 and F_2 values of the vowels of a married couple, both lifelong residents of Johnstown, Ohio, and both born in 1959. Figure 7.2 shows their vowels normalized by the Syrdal and Gopal method (using F_2–F_1 instead of F_3–F_2), demonstrating that this method indeed reduces interspeaker differences.

2.4 *The mental representation of sounds*

Most of the studies of dialectal variation cited above are concerned with linguistic variation and change. In fact, one issue – the forms and causes of sound change – is a focus of the majority of them; discerning why language change has always been a mainstay issue of sociolinguistics. Some of those studies used instrumental techniques to address other issues, of course. Several investigated how identity with social groups is manifested in vowel production (e.g. Habick 1980, Fought 1997, Schilling-Estes 1996). The role of gender variation is intertwined with the issue of what causes diachronic shifts (Fridland 1998, Schilling-Estes 1996). Several of the studies that investigated ethnic dialects used instrumental analysis to investigate ethnic identity (e.g. Anderson 1999, Fought 1997, Wolfram et al. 2000). Stylistic variation is addressed as well (e.g. Hindle 1980, Schilling-Estes 1996). Language variationists could employ instrumental methods far more extensively on these matters. However, the causes of change and variation represent only one group of issues that variationists could address using instrumental techniques. As noted in the opening paragraph, another important group of issues that variationists could address – even though they have largely conceded it to phonologists and phoneticians in recent years – is that of the mental organization of sounds.

Research on the relationship between phonetics and phonology has indicated that the mental representation of sounds is far more complex than simply contrasts and phonological features (e.g. Keating 1990, Ohala 1981a). This fact,

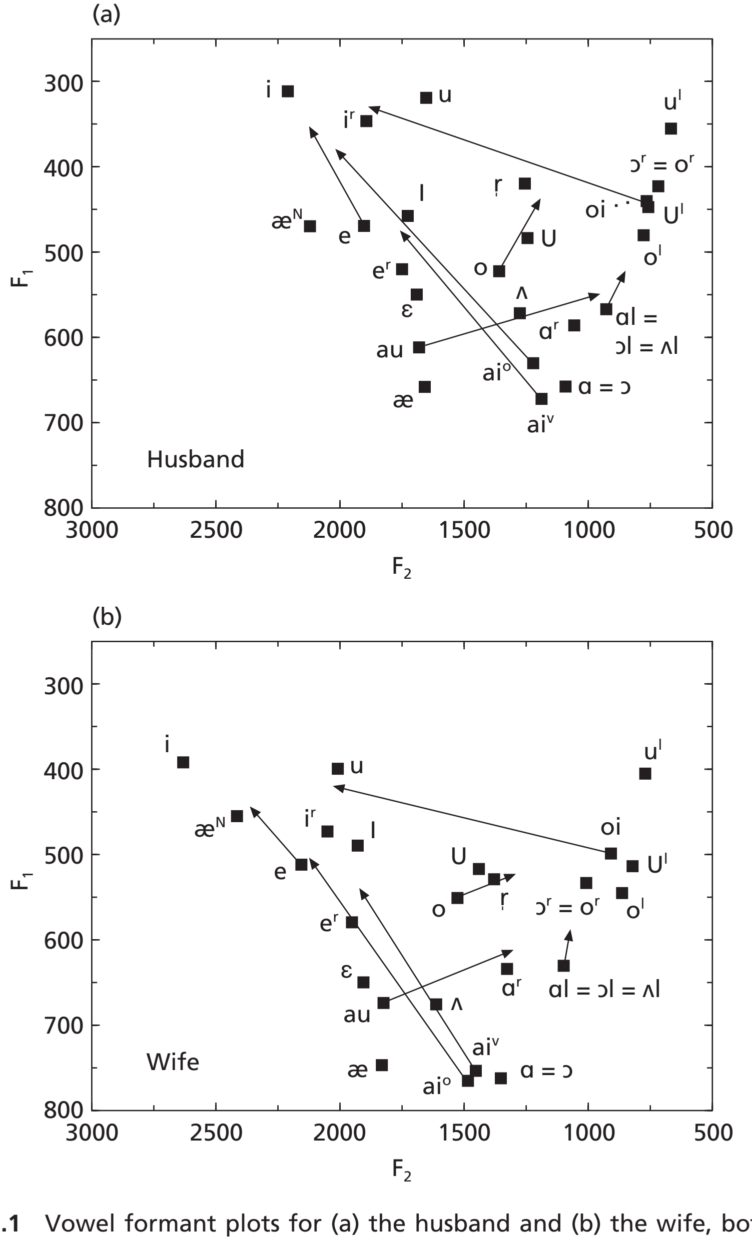

Figure 7.1 Vowel formant plots for (a) the husband and (b) the wife, both born in 1959, from Johnstown, Ohio

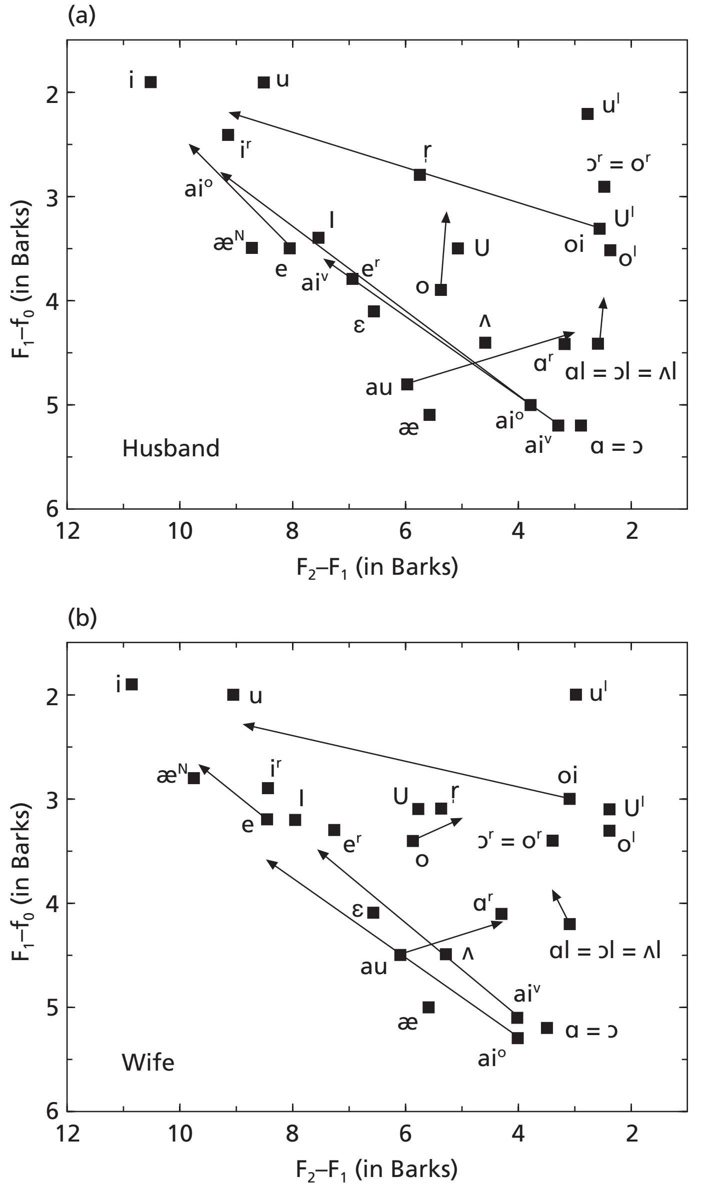

Figure 7.2 Vowels of (a) the husband and (b) the wife from Johnstown, Ohio, normalized with the method described in Syrdal and Gopal (1986)

of course, lay behind the notion of "variable rules" (see Fasold 1991). Recent phonetic work has discussed the degree to which different phonetic processes are automatic phonetic effects or are learned. Lectal variation can shed light on this issue simply because processes that show such variation cannot be automatic phonetic effects, but must be learned and therefore must be represented mentally. In fact, because lectal variation is such a valuable clue as to whether a process is automatic or not, variationists may be in a better position to study these processes than experimental phoneticians are. In the following paragraphs, I discuss four types of phonetic processes for which variationist approaches would illuminate the extent of mental representation.

The first type of phonetic process involves the means by which contrasts are made. The various phonetic cues used for the tense/lax vowel distinction were discussed previously. The realization of these cues differs from dialect to dialect. It is well-known that tense vowels are more diphthongal than lax vowels in many dialects of English, but not in all lects, e.g. those of parts of Ireland and Scotland and for many speakers in northern and western England or in Minnesota and adjacent states. Diphthongization is often viewed as a phonological process, but could as easily be viewed as a phonetic correlate of certain contrasts. Another example is the finding of Di Paolo and Faber (1990), Faber (1992), and Faber and Di Paolo (1995) that phonation may remain as a cue when formant values no longer differentiate tense and lax vowels. Sociolinguistic studies could say a great deal about how much the realization of the tense/lax contrast varies.

Perhaps the most extensively researched example in the phonetics literature is that of how the voicing of stops is distinguished. Lisker (1986), for example, lists 16 phonetic cues that may distinguish medial /p/ and /b/ in trochees, such as the duration of the closure, the duration of the preceding vowel, and the contours of F_0 and F_1 before and after the closure. Other phonetic cues occur in initial and final positions. Kingston and Diehl (1994) discuss the cues used to differentiate "voiced" and "voiceless" stops in several languages and find that the sole cue used by all the languages was that F_0 was lower after "voiced" stops than after "voiceless" stops. The fact that such differences occur among languages implies that they could also occur among dialects and individuals and perhaps among speaking styles. One of the cues that Lisker mentioned, the duration of the preceding vowel, has attracted an especially large amount of attention from phoneticians (e.g. House and Fairbanks 1953, Denes 1955, Peterson and Lehiste 1960, Chen 1970, Waldrip-Fruin 1982). Generally, vowels are longer before phonologically voiced obstruents than before phonologically voiceless obstruents. Keating (1985: 120–4), drawing on various studies, reports that some languages realize this difference to a greater degree than others. Laeufer (1992), comparing French and English, suggests, however, that the reported cross-linguistic discrepancies may be artifacts of the various designs of the studies. Davis and Summers (1989) find that the situation is more complicated in that the difference is realized in stressed syllables but perhaps not in unstressed syllables. Certainly, variationist studies could enable researchers to make sense of the contradictory evidence about vowel length before voiced and voiceless stops (see Scobbie et al. 1999).

A cue used to discriminate the voicing of final stops, and one that is not contrastive by itself, is the release burst. Many speakers are inconsistent in their production of releases; furthermore, dialects differ in their rates of production. In Thomas (2000), I find that white Anglos from central Ohio and Mexican Americans from southern Texas differ considerably in their rates of production of /t/ and /d/ releases. Not only do they differ in their overall rates – the Ohioans produce them much less often – but they also differ in whether /t/ or /d/ was released more often, with the Ohioans releasing /d/ more often and the Texans /t/. These results suggest not only that the production of releases is learned, but also that the importance that phoneticians often place on releases as a perceptual cue should be reevaluated.

The second type of phonetic process is duration-dependent reduction (Lindblom 1963). Vowels tend to become more schwa-like or to show more coarticulatory assimilation with neighboring sounds at short durations than at long durations. Lindblom proposed that phonetic vowel reduction, which he termed "undershoot," was entirely due to differences in the duration of vowels. In subsequent years, researchers have discovered that undershoot also varies according to the stress level of the vowel (Delattre 1969, Engstrand 1988, Harris 1978, Nord 1986, van Son and Pols 1990), the particular phoneme (Flege 1988), the individual speaker (Flege 1988, Kuehn and Moll 1976), the speaking style (Lindblom 1990), or the particular language (Delattre 1969). Individual and stylistic differences, as well as cross-dialectal differences (implied by the cross-linguistic differences that Delattre, 1969, reported) fall within the realm of sociolinguistics. For that reason, undershoot could serve as a useful variable for sociolinguistic studies. Beyond that fact, however, sociolinguists are well-suited for determining the extent to which undershoot is a learned process. In Thomas (1995), I examined duration-dependent truncation of the onset of the /ai/ diphthong, a process closely related to undershoot. When the duration of /ai/ is short, the onset of the diphthong is truncated and, as a result, the nucleus becomes more like the [i] glide in quality. Figure 7.3 shows plots of the data for F_2 of the /ai/ nucleus, plotted against the duration ot the diphthong, for four sixth-grade girls from Johnstown, Ohio, who were included in the study. All four plots show data for the girls' readings of the same words from a story and minimal pairs. The *y*-axis is scaled so that the lowest value is the mean value of /ul/, as in *pool*, and the highest value is the mean value of /i/, as in *eat*. Although all four speakers show similar forms of /ai/ when its duration is long, each one shows a different regression slope, indicating that they are affected to different degrees by the truncation process. These differences may represent projections of individual identity, but they also appeared to be part of a shift in progress in Johnstown.

The third type of process concerns the relative timing of articulatory gestures. Fourakis and Port (1986) compared epenthesis of [t] in words such as *dense* in Midwestern American English and South African English. The Americans

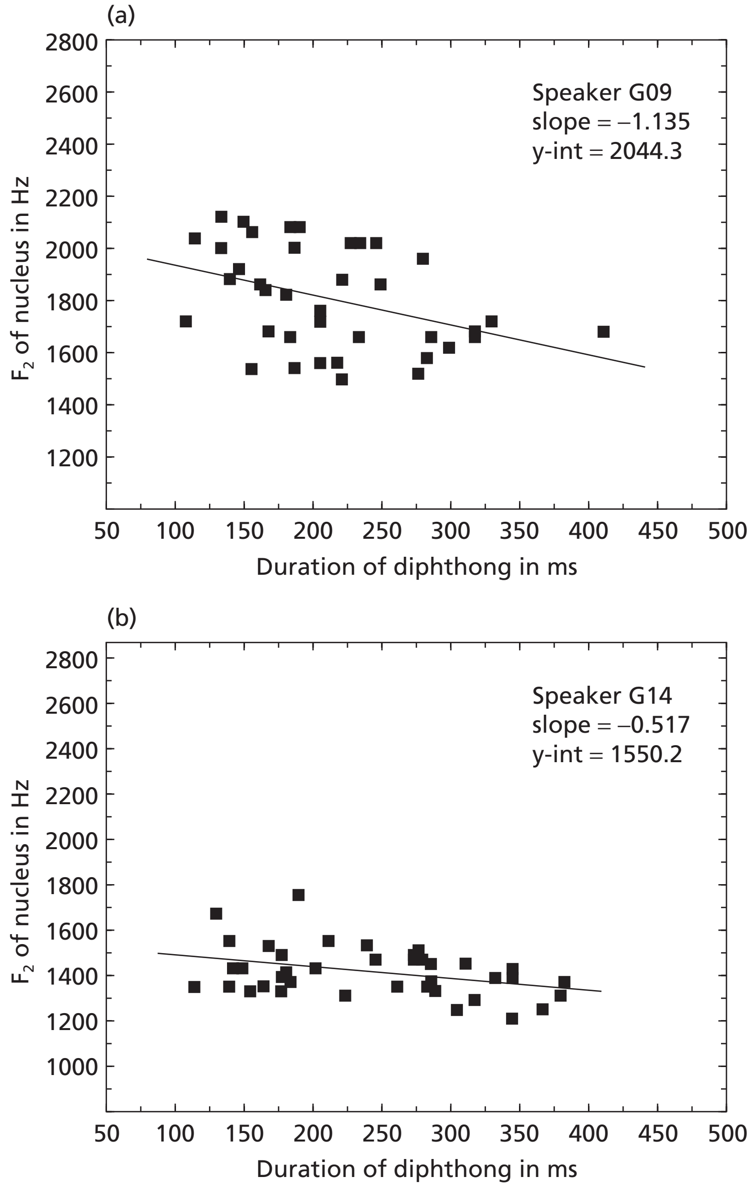

Figure 7.3 F_2 values of /ai/ nuclei plotted against diphthong duration for sixth-grade girls from Johnstown, Ohio

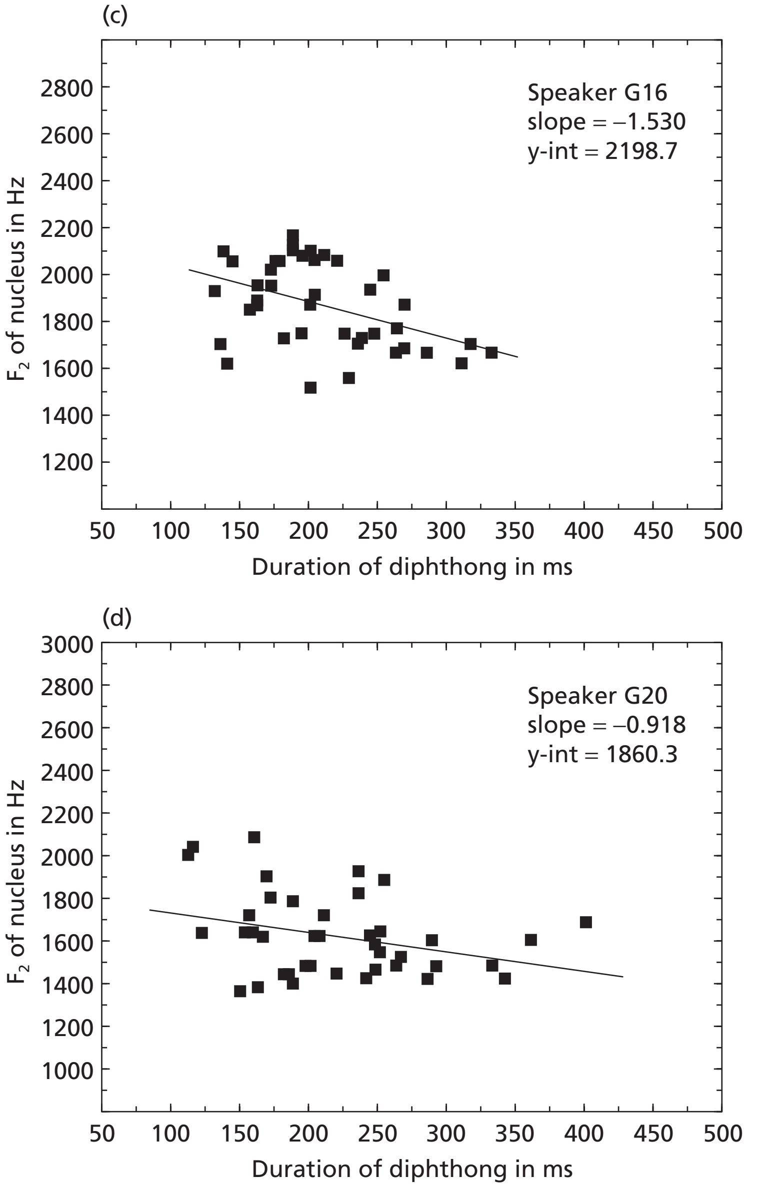

Figure 7.3 (*cont'd*)

generally produced an epenthetic [t], e.g. *dense* [dɛnts], whereas the South Africans did not. Fourakis and Port attributed this dialectal discrepancy to a difference in the phasing of gestures: the Americans ceased vocal fold vibration before commencing frication, while the South Africans did not. They suggested the term *phase rule* for such processes. There are undoubtedly many other dialectal variations involving differential phase rules. For example, I have observed that some speakers seem to begin unrounding before fronting for the /oi/ diphthong (indicated by a rise and subsequent fall of F_1), while other speakers show the opposite sequence. Additional examples of differences in phasing of gestures are discussed in Browman and Goldstein (1991).

The last type of lect-specific phonetic process to be discussed here is the steady-state pattern of diphthongs. Diphthongs necessarily show transitions in which formants move. However, they may also show steady states, in which the formants are relatively level. Steady states may appear at the beginning or end of a diphthong, or in the center of a triphthong. Lehiste and Peterson (1961) examined the diphthongs of American English. They found that /e/ typically showed one steady state – at the end – while /o/ showed a single steady state at the beginning. They stated that /ai/, /au/, and /oi/ showed steady states at both the beginning and end. Other important papers on steady-state patterns of diphthongs include Gay's (1968) study of American English, Peeters' (1991) perceptual comparison of British English with other Germanic languages, Manrique's (1979) study of Spanish, and Jha's (1985) study of Maithili. However, steady-state patterns have received little attention from either variationists or phoneticians. They exhibit more variation, both allophonic and dialectal, than the above studies suggest. For example, /ai/ may indeed show two steady states when its duration is long. In many American dialects, though, when /ai/ shows only one steady state, it is at the beginning before a voiced consonant, as in *tide*, and at the end before a voiced consonant, as in *tight*. Figure 7.4 shows spectrograms of the minimal pair *tide . . . tight* uttered by four speakers: two from central Ohio, where "Canadian raising" is not prevalent, and one speaker each from northern Ohio and Newfoundland, where

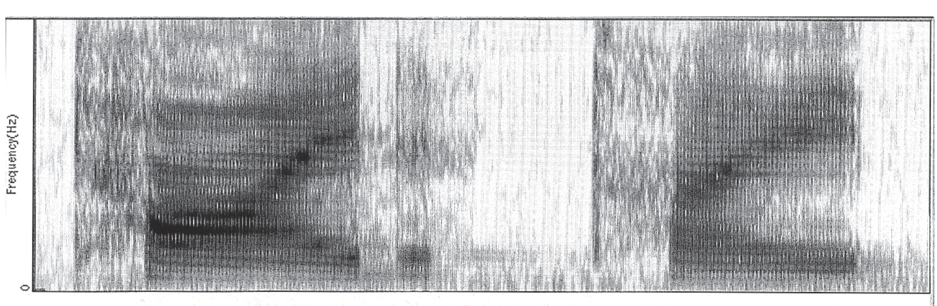

Figure 7.4(a) Spectrogram of the minimal pair *tide . . . tight* uttered by a sixth-grade girl from Johnstown, Ohio

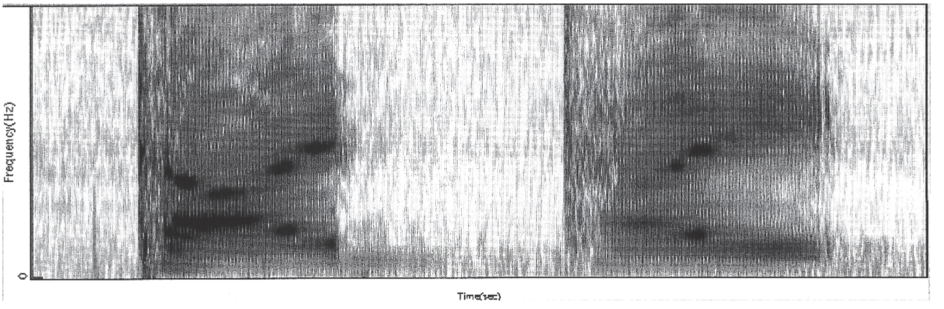

Figure 7.4(b) Spectrogram of minimal *tide . . . tight* uttered by a sixth-grade boy from Johnstown, Ohio

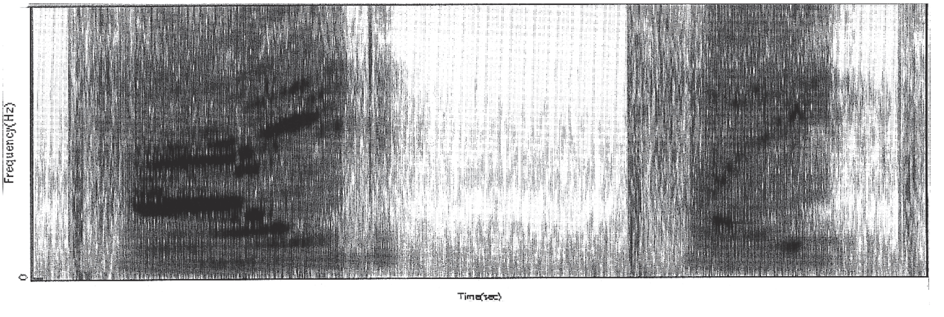

Figure 7.4(c) Spectrogram of *tide . . . tight* uttered by a woman from Euclid, Ohio (a suburb of Cleveland)

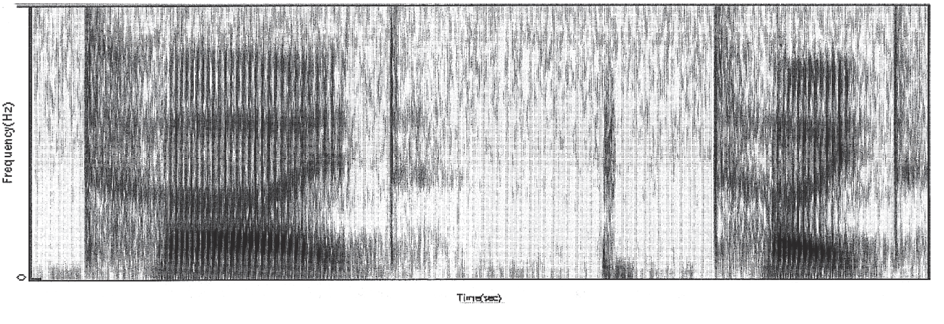

Figure 7.4(d) Spectrogram of *tide . . . tight* uttered by a man from St. John's, Newfoundland

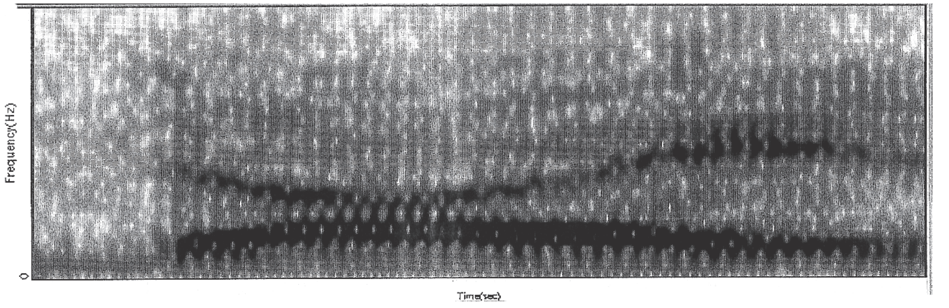

Figure 7.5(a) Spectrogram of *died* uttered by a man, born 1860, from North Truro, Massachusetts

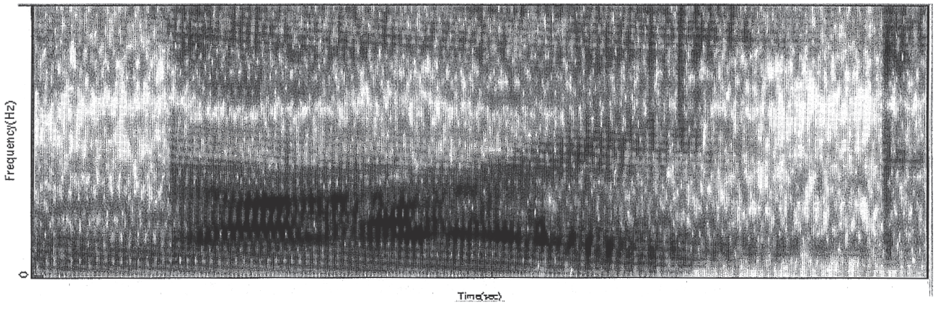

Figure 7.5(b) Spectrogram of *night* uttered by a woman from Swan Quarter, North Carolina

"Canadian raising" predominates. All four speakers show this steady-state pattern, which may be a causal factor for certain mutations of /ai/, including "Canadian raising." Not all dialects show this pattern, as figure 7.5 shows. Some very old Northerners consistently showed offset steady states before voiced consonants, as in the utterance of *died* shown in figure 7.5a. Many Southerners show only an onset steady state before voiceless consonants, as in the utterance of *night* shown in figure 7.5b.

3 Instrumental Studies of Variation in Perception

As noted above, most studies of phonetic variation have concentrated on speech production. Speech perception is equally important, however, and although socio-perceptual experiments are now firmly part of sociolinguistics, much more work is needed. Those studies conducted thus far have focused mainly on a few issues, which the following discussion describes. The emphasis here is on studies that involve instrumental modification of the signal, such as with a speech synthesizer or the use of gating, but perceptual studies using unmodified signals are also included because perception experiments themselves can be considered instruments. Speech synthesis is an invaluable tool for examining perception; even though it can be difficult to ensure that the stimuli sound naturalistic, synthetic modification of signals permits researchers to address certain issues that no other method allows. Sociolinguists could contribute to the understanding of perceptual problems beyond traditional sociolinguistic concerns. For example, the differences between perception in optimal and "normal" listening conditions have hardly been addressed by phoneticians (Kewly-Port and Zheng 1999), but sociolinguistics, for whom attaining "normal" conditions for speech has always been a prime concern, could apply their expertise to that issue.

3.1 Sociolinguistic reactions to linguistic differences

A group of socio-perceptual studies has investigated the sociolinguistic reactions of listeners to recordings of voices. One procedure involves testing listeners' ability to identify the dialect of a speaker. Some of these studies, such as Preston (1993), Wolfram et al. (1999: 129–31), and several of the ethnic identification studies mentioned earlier, involve unmodified recordings. Others involve manipulation of the signals in order to test what features listeners utilize for their identifications. Bush (1967) used stimuli with different filterings to determine how listeners distinguished speakers of American, British, and Indian English. Some ethnic identification studies, such as Graff et al. (1986), Hawkins (1993), and Foreman (1999), have modified different aspects of the acoustic signals. Gooskens (1997) used stimuli that were either unmodified, lowpass filtered to eliminate segmental information, or monotonized to eliminate intonation in order to determine whether listeners relied more on segmental variation or intonation to identify dialects. She found that intonation was more important for identification of English dialects than for identification of Dutch dialects.

Another group of studies has investigated the intelligibility of dialects. These studies, naturally, have involved stimuli that were spliced but otherwise unmodified. Labov et al. (1972: 135–44) and Labov and Ash (1997) tested cross-dialectal perception of vowels in American English. The latter study involved gating the test words, playing them to subjects with minimal, moderate, and extensive amounts of context. Van Bezooijen and van den Berg (fc.) investigated the intelligibility of words in Dutch dialects by asking subjects to identify a word that they heard, with the frame printed for them.

A number of studies have examined listeners' perceptions of the personalities of speakers. Many such studies, such as those using matched-guise technique developed by Lambert (1967), have used unmodified voices (see Brown and

Bradshaw 1985, and Giles and Powesland 1975, for selective reviews; see also Brown et al. 1985). However, a few have employed synthetically manipulated stimuli. Brown et al. (1972, 1973, 1974), Smith et al. (1975), and Apple et al. (1979) variously modified the rate of speech, the mean F_0, and the variance of F_0. Listeners rated the stimuli on personality scales. Van Bezooijen (1988) conducted a similar experiment involving stimuli that were unmodified, lowpass filtered, randomly spliced, or written. Listeners judged the stimuli on personality scales and their judgments were compared with voice quality ratings.

Linguistic stereotypes can also be studied with perception experiments. Niedzielski (1999) examined stereotyping of "Canadian raising" of /au/, as in *house*, in Detroit. Detroit natives listened to a tape of another Detroiter, but half were told that she was a Canadian and the other half that she was a Detroiter. The listeners then matched the /au/ variants on the tape with synthesized tokens. Those told that the speaker was a Canadian tended to identify her /au/ nuclei as higher than those told that she was a Detroiter. Strand (1999) investigated how gender stereotypes are manifested through the "McGurk effect" (McGurk and MacDonald 1976). In the McGurk effect, visual stimuli override auditory stimuli in subjects' perception of speech sounds. Strand, using synthetic stimuli, found that subjects shifted their perceptual boundary between /s/ and /ʃ/ depending on whether they saw a video of a male or a female face producing such a sound. This method could be useful for studying a wide variety of other stereotypes.

3.2 Perception and sound change

Perception experiments can be applied to the issue of what causes sound change. One approach is that of John J. Ohala, who argues that sound change can be modeled in laboratories by finding parallels with results of instrumental perception experiments and production studies. In a number of papers, he has compared historically known shifts with evidence from perception and production (Hombert et al. 1979; Ohala, 1974, 1975, 1981b, 1983, 1985, 1986, 1987, 1989, 1990, and 1993). Foulkes (1997) also takes that approach. Ohala considers misperception, specifically by language learners (Ohala 1989: 186, 1993: 246–7) to be the *most* important factor in sound change (e.g. Ohala 1985). He also argues that sound change is non-teleological, i.e. it does not serve a purpose such as ease of articulation or making speech clearer for listeners. Lindblom et al. (1995) contest those points, citing Lindblom's (1990) model that speakers articulate carefully or sloppily depending on listeners' needs; they assert that speakers deliberately select the resulting variants and that this selection leads to sound change. Much sociolinguistic thought on the spread of changes is also based on the notion that speakers select variants, generally as projections of identity. Browman and Goldstein (1991) take an intermediate stance, agreeing with Lindblom et al. that production, not perception, is primary but with Ohala that change is accidental, not deliberate.

Ohala (e.g. 1993: 238) states that he is attempting to explain only the origin of shifts, not their spread, while Lindblom et al. (1995) attempt to explain both. However, Ohala's model of accidental misperception could be applied to the spread of shifts for two reasons. First, the origin and spread of sound changes may not be distinct: if phonetic conditions are right, many people may independently develop the same innovation at about the same time (Thomas 1995).[2] Second, the spread of changes, as among adolescents, does not have to occur by deliberate imitation. It is conceivable that listeners, exposed to variants in the speech of their friends or others whom they emulate, misperceive those variants as their own and subsequently begin to produce them – a "garbage in, garbage out" means of propagation. Such a process fits with Labov's outline of the mechanism of internally-motivated sound changes as "changes from below," which are "below the level of social awareness" (Labov 1972b: 178). Yet the model of deliberate selection espoused by Lindblom et al. (1995) mirrors the widespread view that speakers manipulate variants as signals of identity. Labov, of course, considers conscious selection to be the major factor in the spread of externally-motivated changes, but what about those that show internal motivation? It would appear that a major empirical issue to be resolved is whether sound changes that are not due to overt prestige occur through deliberate selection of variants, through misperception, or through both. The resolution of this issue will depend on examinations of young sound changes, not just on studies of the more stratified or stereotyped variables on which sociolinguists often focus. More significantly, however, perception experiments will necessarily play a role in the resolution.

One example of the role of perception in sound change that is relevant to many sociolinguistic studies is the perception of word-final stops. Several phonetic studies, e.g. Browman and Goldstein (1990, 1991) and Surprenant and Goldstein (1998), have found that the articulatory gesture for a word-final stop may not produce an audible signal if the following word begins with a consonant, and that coronal stops are more susceptible to this effect than other stops. The effect is due partly to the fact that the stop may be unreleased in this context. It is especially strong when the final stop is part of a cluster, as with the /t/ in *perfect memory*. This perceptual result explains the oft-reported tendency toward consonant cluster simplification, especially when the cluster is followed by another consonant (e.g. Wolfram 1969, Labov 1972a, Fasold 1972, Guy 1980). It also suggests that many tokens that have been classified as instances of stop deletion are cases of imperceptibility, not of deletion in production.

Other approaches to sound change involving perception experiments include following perceptual changes in shifting sounds and examining how contrasts are maintained perceptually. Janson (1979, 1983, 1986), using synthetic stimuli representing phonetic continua, found that vowel shifts in Stockholm Swedish were reflected in perceptual shifts in the boundaries between phonemes. His work raises the question of whether production shifts or perceptual shifts are primary (in time and/or importance), but other researchers have not followed up on his work. Studies of perceptual boundaries between sounds will have to incorporate the fact that misperceptions between sounds are often asymmetrical (Ohala 1985: 462–7) – e.g. [ü] is misperceived as [i] more often than vice versa.

There are a number of dialectal perception studies on how contrasts may be maintained, especially where sound changes have created unusual variants in some dialects or have eliminated some cues used for distinctions. Commutation tests – in which listeners identify words uttered by themselves or by other speakers of their own dialect – involve unmodified speech. Several examples are described in Labov (1994); others appear in Costa and Mattingly (1981), Di Paolo and Faber (1990), and Labov and Ash (1997). Janson and Schulman (1983) took a different approach. They created synthetic stimuli representing a continuum in order to investigate the merger of Swedish short /ɛ/ and short /e/. Subjects were instructed to label each stimulus as a particular Swedish word. The experiment suggested that speakers of a dialect in which the distinction was maintained were unable to perceive it, and Janson and Schulman (like Costa and Mattingly 1981) concluded that distinctions could be lost in perception but maintained in production. However, Labov et al. (1991) argued that Janson and Schulman's experiment was flawed because the task involved labeling of isolated stimuli instead of discrimination in conversations. Using non-synthetic stimuli, they constructed a task in which the interpretation of a narrative rested on listeners' ability to distinguish, in one particular word, vowels that were nearly merged by Philadelphians. The results showed that Philadelphia natives were usually able to perceive the distinction, but that their ability to do so was impaired.

3.3 Perception and mental processing of sounds

Socio-perceptual studies can address issues regarding the mental processing of sounds as well, though few have. The cross-linguistic and cross-dialectal perceptual study of diphthong steady-state patterns by Peeters (1991), mentioned earlier, showed that there is considerable variation in which patterns listeners rate as most realistic. This result suggests that steady-state patterns are language- and dialect-specific and thus part of a person's phonetic knowledge. In Thomas (2000), I found that non-Hispanic whites from Ohio and Mexican Americans from Texas differ in how they perceive /ai/ glides. The Ohioans associated glides closely approaching [i] in quality with a following voiceless stop and those closer in quality to [ɛ] with a following voiced stop. The Texans did so to a lesser extent and confused that distinction with the presence or absence of the final stop. The likely reason was that the Texans may have placed more perceptual weight on the presence of a stop release than the Ohioans and the stimuli, which represented a continuum from *tight*-like to *tide*-like forms, lacked final stop releases.

Sociolinguists could also contribute to the resolution of perceptual issues related to mental processing that are currently debated by phoneticians. For example, Kuhl (1991) proposed the "perceptual magnet effect," i.e. that listeners discriminate formant differences more poorly around a vowel target than away from it. Lotto et al. (1998) contested that notion, arguing that what Kuhl found was simply the effect of the perceptual boundaries between phonemes. A study comparing the perceptual discrimination abilities of, say, speakers of a dialect in which /u/ is fronted and speakers of a dialect in which it remains back could shed light on which theory is correct. That is, are formant differences within "unused" vowel space less apparent if that space is closer to a target? Comparisons of discrimination abilities by speakers who have been exposed to many dialects and those who have not may yield other significant findings about the nature of speech perception.

4 Toward Sociophonetics

Melding of sociolinguistics and phonetics is sometimes referred to as *sociophonetics*, e.g. by Esling (1991). This essay has advocated a greater melding of the two. Integration of sociolinguistics with other disciplines is beneficial, as Docherty et al. (1997) note in their discussion of the links between sociolinguistics and phonology. Experimental phonetics, however, shares a special attribute with sociolinguistics: as Chambers (1995: 26–8) notes, neither adopts the "axiom of categoricity" that linguistic competence is best studied "at some remove from its real-life performance" (1995: 26). Both subfields are focused primarily on observing linguistic behavior directly. Thus, there would seem to be natural links between them.

Each discipline has weaknesses that the other can address. Experimental phoneticians seldom use naturalistic data. They often use small samples of speakers and usually examine subjects' behavior in laboratories. As sociolinguists know well, subjects' linguistic behavior in a formal setting like a laboratory is not always representative of their ordinary linguistic behavior. Phoneticians could benefit from greater sociolinguistic awareness. In addition, more extensive cross-lectal comparisons can shed light on issues that phoneticians usually study. Foulkes and Docherty (1999: 22) point out that many (but not all) phoneticians have been "treating variation as a nuisance" even though it could be a useful tool.

At the same time, sociolinguists too often do not examine closely the phonetic details of the variables they study. For example, a sociolinguistic study of /ai/ in the South may code tokens simply as diphthongal or monophthongal, perhaps categorizing the tokens according to what sort of consonant follows /ai/ or a few other factors, and then move on to the sociological aspects of the inquiry. Glide weakening of /ai/ is actually a gradient process that depends on factors such as duration and steady-state structure that require instrumental measurement. Avoiding instrumental analysis can sometimes lead to erroneous phonetic descriptions and also undoubtedly causes sociolinguists to miss many important variables.

Sociolinguists, furthermore, should avoid becoming too parochial in the phonetic issues that they study. The manifestation of vowel shifting in production has preoccupied sociophonetic inquiry for a generation. Sociolinguists should now nurture other types of phonetic analyses just as much. More instrumental studies of consonantal, prosodic, and voice quality variation are needed. Instrumental analysis can yield greater insights into traditional sociolinguistic constructs such as ethnic or social group identity. Cross-dialectal studies can allow sociolinguists to address issues, particularly those concerning the mental processing of sounds, that they have barely touched in recent years. Perhaps most importantly, the still-nascent field of socio-perceptual inquiry needs to expand and mature. Sociolinguists have already made significant strides in instrumental phonetic analysis. However, for sociolinguistics to remain viable, many more strides into the areas discussed here will be necessary as the twenty-first century progresses.

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NOTES

1 This method reflects human vowel perception in that it requires only a single vowel for normalization. However, it is linked to the assumption by Syrdal and Gopal (1986) that listeners normalize vowels based on steady-state values. Other researchers have argued that listeners identify vowels from formant movements; see, e.g., Strange (1989) and Hillenbrand and Nearey (1999). The issue is still controversial (Pitermann 2000). The F_3–F_1 distance metric can be skewed by contexts with an adjacent /r/. These contexts should be examined separately. One of the original reasons for using the F_1–F_0 value is that high vowels tend to show higher F_0 values than low vowels, thereby minimizing the F_1/F_0 distance for high vowels and maximizing it for low vowels, but this effect is so small that little is lost in not using the F_1/F_0 distance.

2 I do not mean this in the same sense as Weinreich et al. (1968). Weinreich et al. asserted that the origin and propagation of a change are the same because a change is not a change if it involves a single person, but only when it begins to spread (for a critique of this notion, see Romaine 1982: 244f). In contrast, I assume that a change could theoretically involve only one person, but that in real life many people independently and simultaneously show the same innovation. Thus a change has "spread" at the same time that it originates.

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