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Vowel Quality

the relation between universal and language-specific factors

Sandra Ferrari Disner

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Vowel Quality:

The Relation between Universal and Language Specific Factors

A dissertation submitted in partial satisfaction of the requirements for the degree Doctor of Philosophy in Linguistics

by

Sandra Ferrari Disner

This dissertation is affectionately dedicated to E. and P.

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S. Disner (1980b). Insights on vowel spacing: results of a language survey. _UCLA Working Papers in Phonetics_ 50:70-92. To appear in I. Maddieson (ed.) _Patterns of Sounds_.

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ABSTRACT OF THE DISSERTATION

Vowel Quality:

The Relation between Universal and Language Specific Factors

by

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Doctor of Philosophy in Linguistics

University of California, Los Angeles, 1983

Professor Peter Ladefoged, Chairman

This dissertation examines some of the similarities and differences between the vocalic systems of different languages, and attempts to place them within the framework of phonological theory.

The theoretical background is presented in chapter 1. This chapter also sets out the limitations of the present study: only the acoustic (as opposed to articulatory or perceptual) characteristics are examined, and only the non-nasalized, non-rhotacized monophthongs of each language are considered here.

Chapter 2 briefly outlines two theories that have been promoted to account for the distribution of vowels in natural languges: dispersion theory and quantal theory. Data from four languages, E. Central Bavarian, Tausug, Italian, and Yoruba, were selected to test the predictions of these theories. It is shown that

neither of these two theories can account for all of the differences between these vowel systems.

Chapter 3 examines a larger group of languages, all genetically related as members of the Germanic family; these are E. Central Bavarian, Danish, Dutch, English, Frisian, German, Norwegian, and Swedish. The vowels that might be expected to be the same across languages -- those transcribed with the same phonetic symbol -- are compared by analysis of variance. Significant differences are indeed found to exist between these similar vowels. A list of the significant cross-linguistic differences in 14 pairs of languages is compiled; those which encompass groups of vowels, or the system as a whole, are distinguished from those which are limited to a single vowel.

Chapter 4 attempts to circumvent the problem of inter-speaker variability by utilizing data from speakers proficient in two or more Germanic languages. Here again, a list of cross-linguistic differences is compiled and the nature of these differences -- system-wide or limited to a single phoneme -- is discussed.

Chapter 5 considers the notion of base of articulation as a means of capturing the significant cross-linguistic differences observed in the preceding chapters. It is possible to relate many, but by no means all, of these differences to particular articulatory strategies such as vigorous lip rounding or tongue raising in one or another of the languages. (This relationship is only inferred, however, and articulatory-acoustic confirmation is called for.)

Since no theory is entirely successful in predicting the phonetic quality of vowels in a given phonetic system,the precise phonetic quality must be specified in the grammar. A format is provided for the sort of phonetic implementation rules needed in such a grammar.

Chapter 1: Introduction

A primary goal of phonological theory is to capture the enormous range of sounds found in natural languages with a finite set of features. These features must at once be capable of showing the oppositions within languages and of marking the phonetic differences between languages -- "all recurrent, patterned phonetic activity that characterizes the spoken language" (Laver 1980:5). For many years interest centered on oppositions within languages; this type of investigation led to important work such as Preliminaries to Speech Analysis (Jakobson, Fant, and Halle 1952) and The Sound Pattern of English (Chomsky and Halle 1968). However, in seeking to clarify which distinctive properties are needed to capture within-language contrasts, researchers left largely tacit the question of how best to represent the language-specific properties of a given system. More recently, there has been a realization that

> "an adequate phonetic theory may have to include [non-contrastive phonetic] features, if the basis for predicting their value in a given utterance can vary from one language to another." (Anderson 1974:8)

A considerable body of research has of late been devoted to filling the gap in our knowledge about between-language differences -- differences which need not function distinctively in any language. This dissertation is part of that effort. It focuses entirely on questions of phonetic vowel quality; its goals are to specify the differences which regularly distinguish vowels of different languages which are often transcribed with the same phonetic symbol, and to determine whether such differences are predictable on the basis of some universal phonetic principle or whether they must be accounted for as language-specific properties. In the latter case, we must ask whether they are applicable to classes of vowels or whether each individual vowel must be specified.

There is little doubt that similar vowels in different languages sound different from one another. (Foreign language learners who overlook this fact -- by attempting to substitute the vowels of their native language for the corresponding vowels of a second language -- are almost always recognized as having a "foreign accent".) Phoneticians have identified many vowels which, though they fall into the same classificatory category in their respective languages, nevertheless display reliable and consistent phonetic differences. A few examples are the high front [i] vowels of English and Danish, which differ in height (Fischer-Jørgensen 1972), and the front rounded [y] vowels of German and Swedish (Lindau 1978), which differ in the degree and manner of rounding. However, observations of this sort are usually not systematic, and are often based on impressionistic data. This dissertation will meet the need for reliable data by systematically identifying and quantifying the cross-language differences among the vowels of one group of related languages, using acoustic measurements. It will also establish guidelines for incorporating phonetic differences into the grammar. These goals are intended primarily as a contribution to phonological theory, to aid in linking the formal representation of an utterance with its physical (phonetic) realization. Certainly, no theory can be considered "complete" until it succeeds in making this final linkage. By the same token, the goals of this study will be of use to those in applied sectors of phonetic science, such as speech synthesis. Indeed, the great majority of research in the field of speech synthesis has centered on a few languages, such as English, Swedish, French and Japanese, and the question of how generalizable these findings may be to other languages has not received adequate attention.

The selection of the vocalic domain for this investigation was influenced in part by the availability in the phonetic literature of a large body of acoustic data for vowels of different languages, and also by the wealth of evidence directly linking the acoustic data with psychoacoustic parameters of vowel quality. Joos (1948) showed that the phonetic quality of any vowel can be specified by reference to the frequencies of its three lowest formants. This point was made independently by Fant (1962). As it happens, the lower formants are among the most robust of acoustic indicators, quite easily measurable and largely resistant to distortion under the sorts of conditions that often plague phonetic field studies.

The data presented in these chapters are exclusively acoustic in nature. They are also limited to the monophthongs of each language, despite the fact that diphthongs are common in eight of the eleven languages considered here. It is certainly true that the rich system of diphthongs developed by many Germanic languages is an important part of the phonetic framework, and well worth detailed study in its own right. However, data on diphthongs is difficult to use because they must be represented by measures taken at several different points in time and yet be compact enough for use in feature specification. Moreover, acoustic data on diphthongs are virtually unavailable, while acoustic data on monophthongs are quite plentiful.

It should also be pointed out that the Germanic languages convey a rather unrealistic impression of the role of diphthongs in the vowel systems of natural languages. Though diphthongs function contrastively in all eight of the Germanic languages discussed in these chapters, they are in fact rather rare in other language families. Among the representative sample of 317 genetically diverse languages in the UCLA Phonological Segment Inventory Database (UPSID) (Maddieson 1981), diphthongs are used contrastively in only 23, or 7% of the total. There are other parameters along which vowel sounds can differ which also are exploited relatively little in natural languages. For example, contrastive nasalization is present in the vowels of 20% of the UPSID languages, and contrastive rhotacization is extremely rare among the UPSID languages (<1%), despite its familiarity in American English.

The formant frequency values cited in this study thus are drawn from monophthongal, oral, non-rhotacized vowels. In those languages with contrastive length, the long variant is selected over the short when the phonetic quality of the two is identical; both variants are selected when the phonetic qualities are different. The formant measurements are made at a steady state portion in the center of the vowel, as far removed as possible from the formant transitions. In my own investigations (ch.2 and 4) I was usually able to locate a steady state in the vowel, although not all the formants reached a steady state simultaneously. In such cases, the steady state of the lowest formant was given preference over the higher formants. The strategies for formant measurement employed by the other linguists cited (ch. 3) are not always described, but they probably do not differ greatly from mine.

Chapter 2: Dispersion and Quantal Theories

In discussions of how vowel systems may differ, and of what forces appear to underlie the distribution of vowels in the phonetic space, it is often convenient to focus attention on the so-called "point vowels", the high vowels [i] and [u] and a low vowel, usually [a]. These vowels, among which the maximum and minimum values of F1, F2, and F3 can usually be found (although it is not uncommon for [e] or [o] to contain the maximum or minimum F2), define the overall size and shape of the system. They are also the most common vowels by far, present in about 90% of the languages of the UPSID survey; 289 of the 317 UPSID languages have [i], 267 have [u], and 279 have [a]. The implicational hierarchy described by Jakobson (1941) with these vowels before all others, is basically correct, though in need of a slight reordering to show that [u] implies [a] and [a] implies [i]. It is not an unreasonable approach, then, to compare vowel systems by comparing their point vowels, irrespective of what, if anything, lies between them.

Whether, on a phonetic level, the vowels that are commonly transcribed as [i u a] are comparable across languages (and hence whether the overall phonetic size and shape of the vowel systems are comparable) is a matter of considerable debate. It has been suggested, for example, that the distribution of vowels is best accounted for by a principle of maximal dispersion (Martinet 1955; also Jakobson 1941), that is, that they tend to be arranged so as to be maximally far from one another in the available phonetic space.

Liljencrants and Lindblom (1972) first attempted to account in a systematic manner for the distribution of vowels in natural languages with a computer model designed to maximize the distance between vowels. For any number of vowel points selected, the Liljencrants and Lindblom model yields the most widely separated possible configuration within the formant space, with each individual vowel maximally distant from its neighbors. The formant space is a theoretical construct, based on the Lindblom and Sundberg (1971) articulatory model, with F2 and F3 merged into an "effective second formant" to convey both backness and rounding. The vowels predicted in this fashion were assigned phonetic symbols, and these were then compared with some of the then best-known cross-language surveys of vowel inventories (Trubetzkoy 1929, Hockett 1955, Sedlak 1969). From this comparison, the "maximal dispersion" model was found to yield "approximately correct results" for systems of six vowels or less, and a limited number of errors -- notably, a proliferation of vowels between [i] and [u] which is not reflected in natural languages -- in larger systems. That this evaluation process is less than satisfactory has been noted by many commentators, not the least of whom are Liljencrants and Lindblom themselves, who note that the natural-language data are based on phonemic analyses and that the authors "often fail to comment on fine phonetic details." (p. 845).

The importance of such detail has been underscored by Terbeek (1977), who points out that very significant differences between, for example, the Turkish point vowels [i] or [u] and the [i] or [u] generated by the Liljencrants and

Lindblom model remain concealed when comparing the vowel symbols alone. A survey of a larger and somewhat more phonetically detailed corpus of language data, collected by the Stanford University Project on Language Universals and reported by Crothers (1978), shows vowel systems of comparable size to be a good deal more varied than the purely phonemic accounts would lead us to believe. The examination of acoustic data from different languages (Disner 1978) yields evidence of more subtle, but nevertheless consistent differences between vowels which, even in Crothers' phonetically detailed transcription, are given the same symbol. (For example, there is a consistent difference in both height and backness between the high front unrounded vowel of German and of Norwegian, although both are transcribed as [i:] in the Stanford archive.)

Lindblom has since abandoned his principle of maximal dispersion in favor of a more flexible and, from a phonetic point of view, more realistic principle of "sufficient system contrast" (Lindblom 1975, 1979; also Terbeek 1977, Maddieson 1977). This general principle is more consistent with the structure of natural vowel systems than was the earlier principle of maximal contrast. However, the notion of "sufficient" contrast verges on the unfalsifiable. Lindblom attempts to strengthen his claim by hypothesizing that the degree of this contrast is invariant across languages and system size -- an eminently testable corollary to his original hypothesis -- but then retreats to some extent by adding that "the phonetic values of vowel phonemes should exhibit more variation in small than in large systems." (p.29 ms.), a seeming non-sequitur if "invariance" is to be taken at face value.

To support his claim, Lindblom cites empirical data reported by Crothers (1978) regarding the phonetic instantiation of the phonemic point vowels /i u a/ in the largest and the smallest vowel systems; /u/, for example, appears as [u], [ɯ], [ɷ], or [o] in the smaller systems, but only as [u] in the larger.

These patterns of variation become clearer when the shape of the vowel space is taken into consideration.

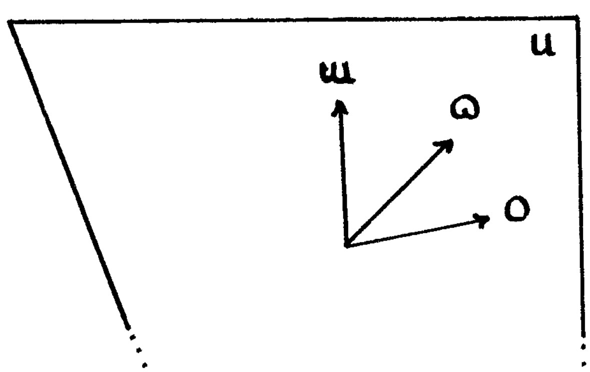

Fig. 2.1 Arrangement of back vowels in a phonetic space

At the same relatively small distance from the center of the vowel system lie the vowels transcribed as [ɯ], [ɷ], or even [o], depending on the angle subtended. At a greater distance from the center there is only the vowel [u]. Thus, even if distances are invariant across system size, as Lindblom claims, smaller systems may have any of the former vowels at their "point", while the larger systems may have only the latter. This expectation is indeed supported by Crothers' data.

However, this point should not be taken as proof of the distance-invariance claim itself. Such proof would require more phonetically detailed data, preferably a large sample of acoustic data drawn from multiple speakers of a wide range of languages.

Another recent improvement over the 1972 Liljencrants and Lindblom model concerns the parameters of the basic vowel space. The earlier model assumed a 2-dimensional acoustic space with F1 and F2' (a weighted average of the second and third formants) along the axes, rendered perceptually more satisfactory by a transformation of the linear frequency scale into mels. In Lindblom's more recent work (1975, 1979) the contribution of the first formant has been increased, and that of the (weighted) second formant decreased, in recognition of the greater intensity of the former. The more intense a formant, the more reliable it is as an indicator of vowel quality, and hence, Lindblom argues, the more important a role it assumes in maintaining perceptual differentiation, particularly under the noisy conditions characteristic of speech communication. The change of scale is also motivated by empirical considerations, chiefly the prediction by the Liljencrants and Lindblom model prediction of too many high vowels in large vowel systems, due to the wide expanse of F2' relative to F1.

The need for a re-scaling of the formant axes was also recognized by Ladefoged (1975), who used formant charts with mel intervals on the F1 scale occupying twice the distance of identical intervals on the F2 scale, in order for the vowels plotted thereon to better match their auditory descriptions. The primacy of F1 is also implicit in phonology: there are languages said to contrast four or even five degrees of vowel height, whereas, to quote Lindau's (1975:13) proposed universal, "[n]o language contrasts more than three horizontal values." By the same token, the phonological framework used by Chomsky and Halle (1968) assumes three levels of height (high, mid, and low) but only two of backness (front and back).

Lindblom's recognition that F1 is more important, perceptually, than the higher formants has not yet yielded a set of accurate predictions of vowel quality. Even his most recently revised model (1979 p.25) yields too many degrees of backness -- e.g. four contrasting high vowels out of systems as small as seven. Evidently, the proper re-scaling factor, based on a thorough understanding of perceptual mechanisms, remains to be discovered.

As an additional refinement, Lindblom advocates the use of the Bark scale (Zwicker 1961; also Bladon and Lindblom 1979) in order to increase the perceptual verisimilitude of the data. This scale is based on the psychoacoustic notion of critical bands, which delimit the masking characteristics of tones of various frequencies. However, Neuburg (1981) has found that this scale does not differ appreciably from the mel scale, used in Lindblom's earlier model, nor, for that matter, from most other frequency scales used in the study of speech, such as the Koenig scale or various scales conceived as the output of filter banks. Neuburg concludes that "there is no reason to choose one rather than another" (p. F22-1).

The Quantal Theory

A different approach is that of Stevens (1972). He proposes a model which predicts fixed positions in the available phonetic space for the point vowels. He argues that, while articulations and their acoustic output are generally related in a monotonic and linear fashion, there are some notable exceptions. In certain regions of the vocal tract relatively great articulatory variations produce negligible changes in the acoustic signal. These are regions of acoustic -- and hence also perceptual -- stability. The vowels produced in these regions will tend to be favored in natural languages, since they do not require such great articulatory precision as the vowels in neighboring acoustic regions. Stevens argues that the vowels that exhibit such stability are the point vowels, and their frequency of occurrence in the world's languages is just because they are "quantal". Stevens actually makes his case about the point vowels [i], [u], and a more retracted vowel, the [ɑ] of the English word "father", but it is not clear whether the choice of this vowel was intentional or merely an accommodation to English, which has back [ɑ] but no central [a]. In spite of the selection of vowels in English, the vowel [a] is vastly more common than [ɑ] in the languages of the world. In the UPSID language sample, for example, [a] is more than ten times as frequent as [ɑ] (282 languages with [a], versus 26 with [ɑ]).

In his more recent work on the quantal theory, Stevens considers a fourth point vowel, low front [æ], to be quantal (Stevens, pers. comm.). However, this vowel is not much more common in natural languages than is [æ]; it occurs in 44 UPSID languages.

In his 1972 article Stevens suggests that "other vowels" than the point vowels have quantal characteristics as well, "although regions of minimum sensitivity to vocal tract shape are not always so sharply defined" (p. 222); more recently, however, Stevens has retreated from this position and now believes that non-quantal vowels are distributed more or less evenly between the quantal anchors of the vowel system (Stevens, pers. comm.). With this modification, Stevens' model parallels the original principle of maximal dispersion, now abandoned by Lindblom.

With respect to the point vowels, Stevens notes that "[o]ne would expect these configurations to occur frequently in the vowel system of different languages, and indeed, this is the case." (ibid.) There is certainly little doubt that the phonemic point vowels /i u a/ are favored in natural languages. (In comparison to the 90% of UPSID languages with these vowels, only about a third have vowels /e/ or /o/.) However, Stevens' stronger claim -- that these point vowels are in fact acoustically stable -- has lacked convincing proof.

Stevens' and Lindblom's theories make different predictions with respect to the placement of the point vowels in the available acoustic space. Dispersion theory claims that the point vowels assume more or less peripheral positions in the acoustic space, depending on the overall number of vowels in the system, the presence or absence of a series of secondary, nonperipheral vowels such as [y ø œ], and the like. Quantal theory, on the other hand, predicts that the point vowels of most languages will occupy the same optimal positions in the acoustic space, irrespective of phonological pressures from elsewhere in the vowel system.

The differences between these two theories would not be expected to be great for a pair of languages with similar phonological systems. However, the theories make quite different predictions about the acoustic realization of the point vowels in languages with large as opposed to small vowel inventories. In order to maximize the likelihood of encountering such differences, two languages with very different phonological systems were selected for comparison.

The largest vowel system for which various speakers' formant frequency values are available is that of Eastern Central Bavarian (Traunmüller 1982), with thirteen contrasting long vowels, shown in Fig. 2.2:

i y u
e ø o
ɛ œ ɔ
æ ɶ ɒ
a

Fig. 2.2 Schematic vowel system of Eastern Central Bavarian

The dialect represented is that of Amstetten, a small town in Lower Austria, not far from Salzburg. A list of 13 words or syllables of the form [s]V:, each containing a different long vowel, was read by eight male native speakers. This list is reproduced in Table 2.1

E.C.Bavarian	Std. German	English
si:	Sie	you
se:	"	"
sɛ:	es ohnehin	it nevertheless...
sæ:	sei	be (imp.)
sa:	es auch	it too...
sɒ:	Sau	sow
sɔ:	es ab-	de- ... it
so:	so	so
su:	das "u"	the letter "u"
sy:	das "ü"	the letter "ü"
sø:	das Öl	the oil
sœ:	Seele	soul
sɶ:	Seil	rope

Table 2.1 Minimal pairs illustrating vocalic contrasts in Eastern Central Bavarian, with German and English translations. (From Traunmüller, 1982)

Most of these forms are common lexical items or phrases. Two, [su:] and [sy:], are phrases made up of the article and the name of the vowel, which in Standard German would be "das u" and "das ü". Two others, [si:] and [se:] are both Eastern Central Bavarian variants of the first person singular pronoun (Standard German "Sie"); the form with the higher vowel, [si:], is typical of the Amstettner dialect represented here. However, the pronunciation [se:], more typical of Upper Austria, can also be heard in Amstetten, and the speakers were asked to produce this form as well. The absence of a true contrast in these cases is only accidental; the vowels [e:],[u:], and [y:] participate in other contrasts, as shown in Table 2.2. (For a more detailed discussion of the phonetics and phonology of Austrian dialects, see Koekkoek (1955).)

E.C.Bavarian	German	English
d̥i:	dich	you (acc. sg.)
d̥e:	diese	this (f. nom. sg.)
d̥ɛ:	Tee	tea
ʃæ:	scheu	shy
ʃa:	Schere	scissors
ʃɒ:	schau	show
d̥ɔ:	da	there
d̥o:	doch	(affirmative particle)
d̥u:	du	you (nom. sg.)
ʃd̥y:n	stillen	to nurse, suckle
ʃd̥ø:n	stellen	to place
ʃd̥œ:n	stehlen	to steal
ʃd̥ɶ:n	steilen	steep (pl.)

Table 2.2 Vocalic contrasts in Eastern Central Bavarian (from Traunmüller, 1982)

Traunmüller carefully monitored the speech for reading pronunciation and had the utterances repeated whenever this, rather than the true spoken form, was produced. Each word was embedded in the sentence frame [ihɛds ___ gsɔkt] (German "ich hätte ___ gesagt"; English "I'd have said ___").

Both LPC and spectrographic analysis were used to obtain the most reliable formant measures. Traunmüller obtained values for F1 through F4, as well as for F0, but only F1 through F3 were utilized for the present study. (See Appendix 1.) Four additional Bavarian speakers were recorded by Traunmüller, but as a number of their formant values were missing from their data, it was decided to omit them from the sample.

To contrast with this large vowel system, data were sought from a language with a very small vowel system (preferably, one with a vowel length contrast such as that of Bavarian). The three-vowel Austronesian languages of the Philippines present themselves as likely candidates; however, most have acquired a complement of mid-vowels, [e] and [o], through assimilation of a number of Spanish and English loanwords. One Philippine language which has been more opaque to foreign loanwords is Tausug, the language of approximately 300,000 speakers in the Sulu region of the Philippines.

Four male speakers of Tausug were recorded in Sulu by Seymour and Lois Ashley in 1981. A larger sample of Tausug speakers would undoubtedly have enhanced the reliability of the data, but no other native speakers were available. (Much of the Sulu region has been outside Philippine Government control since the taping of these four speakers took place.) A Tausug speaker who has been residing in the United States was also recorded but not used, as it was decided that he was likely to have had his native vowel system altered through contact with English.

Each of the four Tausug speakers pronounced a series of words containing the three long vowels of the language. The vowels appear in initial (or post-[h]) position before a dental consonant (or before [h] in one instance). Two words were recorded for each of the three vowels, and all were utilized in the present study. The word list is reproduced in Table 2.3. A different sentence-frame was used for each word.

ha:d	(a period of time)
a:d	(fence)
hi:s	(to push aside)
i:hi	(drive shaft)
u:d	(worm, grub)
u:t	(gap)

Table 2.3 Near-minimal contrasts in Tausug

These data were analyzed with the WAVES analysis system at the UCLA Phonetics Laboratory (Wittenstein & Rice, 1981). As with the Bavarian data, both LPC and spectrographic analysis were used to obtain the most reliable measures for F1, F2, and F3.

After formant values had been obtained for these two languages the results were plotted in a two-dimensional acoustic space. The data for the thirteen long vowels of Bavarian are in Fig. 2.3, and for the three long vowels of Tausug in Fig. 2.4. In these figures the data points have been converted to mels, in order to better approximate the perceived distances in the phonetic space; the values along the axes, however, correspond to the original Hertz values. Ellipses with radii of two standard deviations have been drawn along axes oriented along the principal components of each vowel cluster. These would be expected to encompass nearly all of the scattered data points.

Figure 2.5 shows the three vowels shared by the two languages, long [i: a: u:], plotted on the same graph. Note that the Tausug vowels are lower and somewhat more front than the corresponding Bavarian vowels; in acoustic terms, the Tausug vowels have formant values which are higher, in general, than those of Bavarian. This accords with the notion that, barring asymmetries of the pharynx-to-mouth ratio, as discussed by Fant (1966), shorter vocal tracts yield higher formants, for it is generally true that Filipinos are shorter, and hence have shorter vocal tracts, than Alpine Austrians. Yet while the difference in stature between the two populations undoubtedly contributes to the difference in vowel quality, it cannot account for all of it.

The Tausug vowels are not uniformly shifted toward the higher formant ranges, with respect to the Bavarian vowels. These two vowel systems cannot be

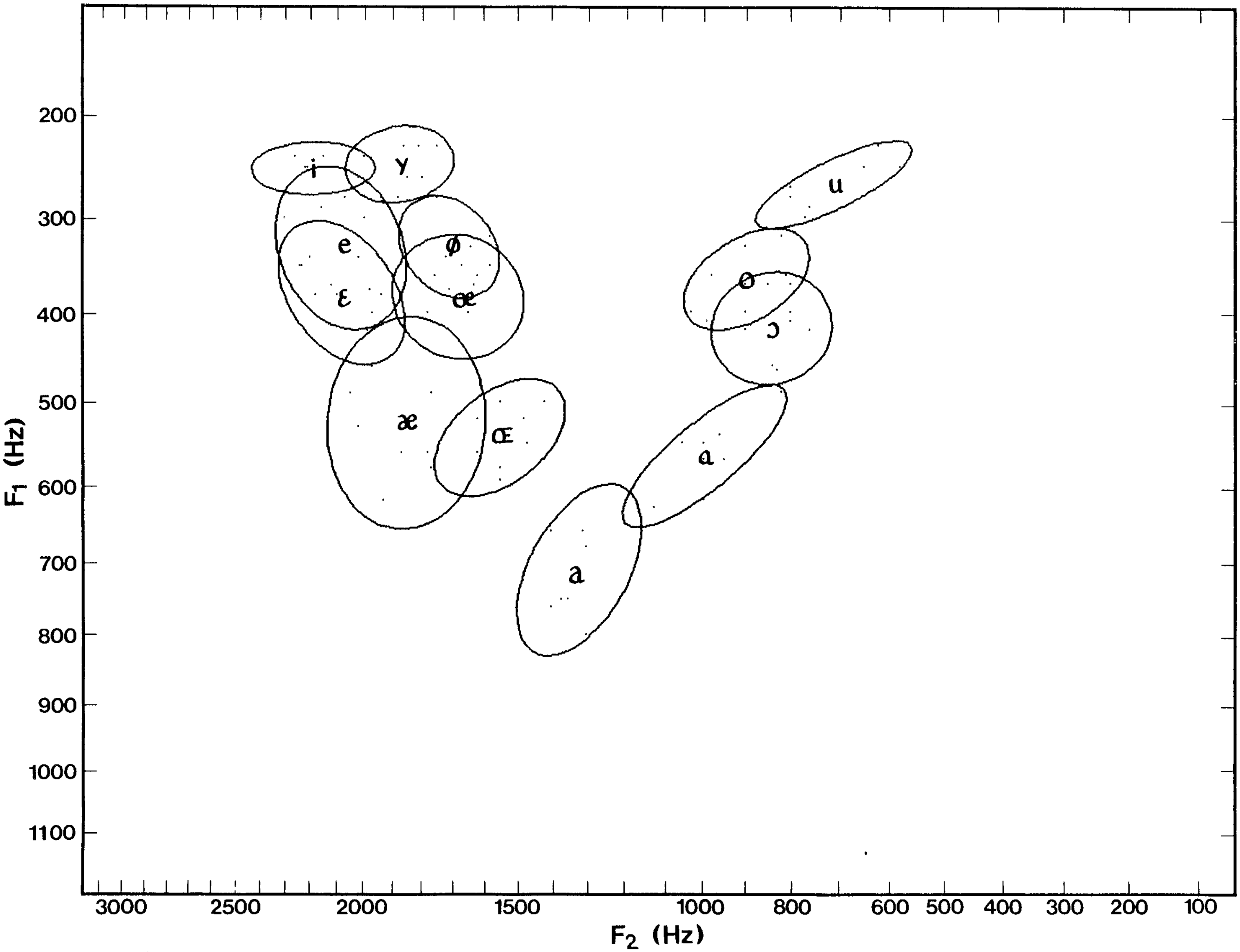

Fig. 2.3: Bavarian

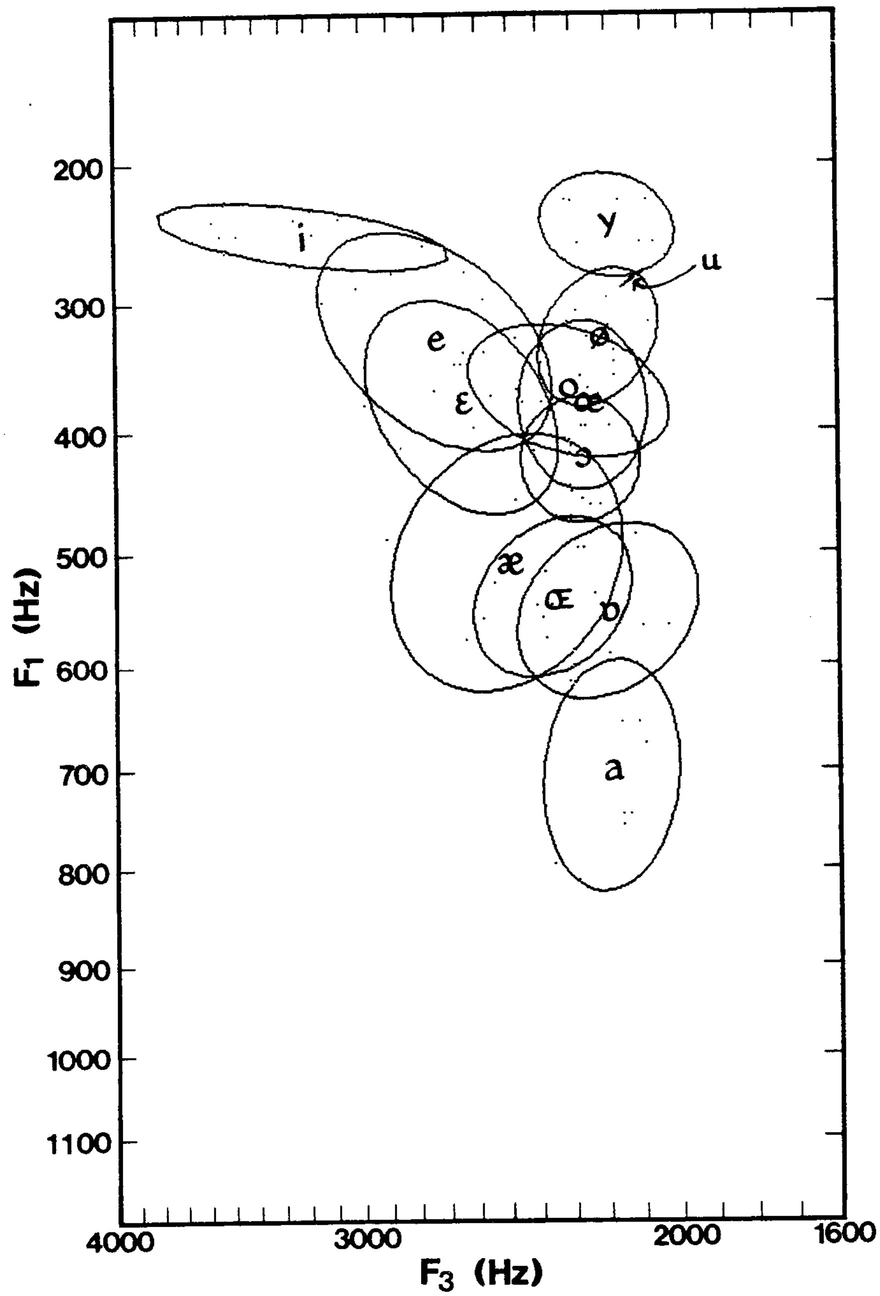

Fig. 2.3a: Bavarian

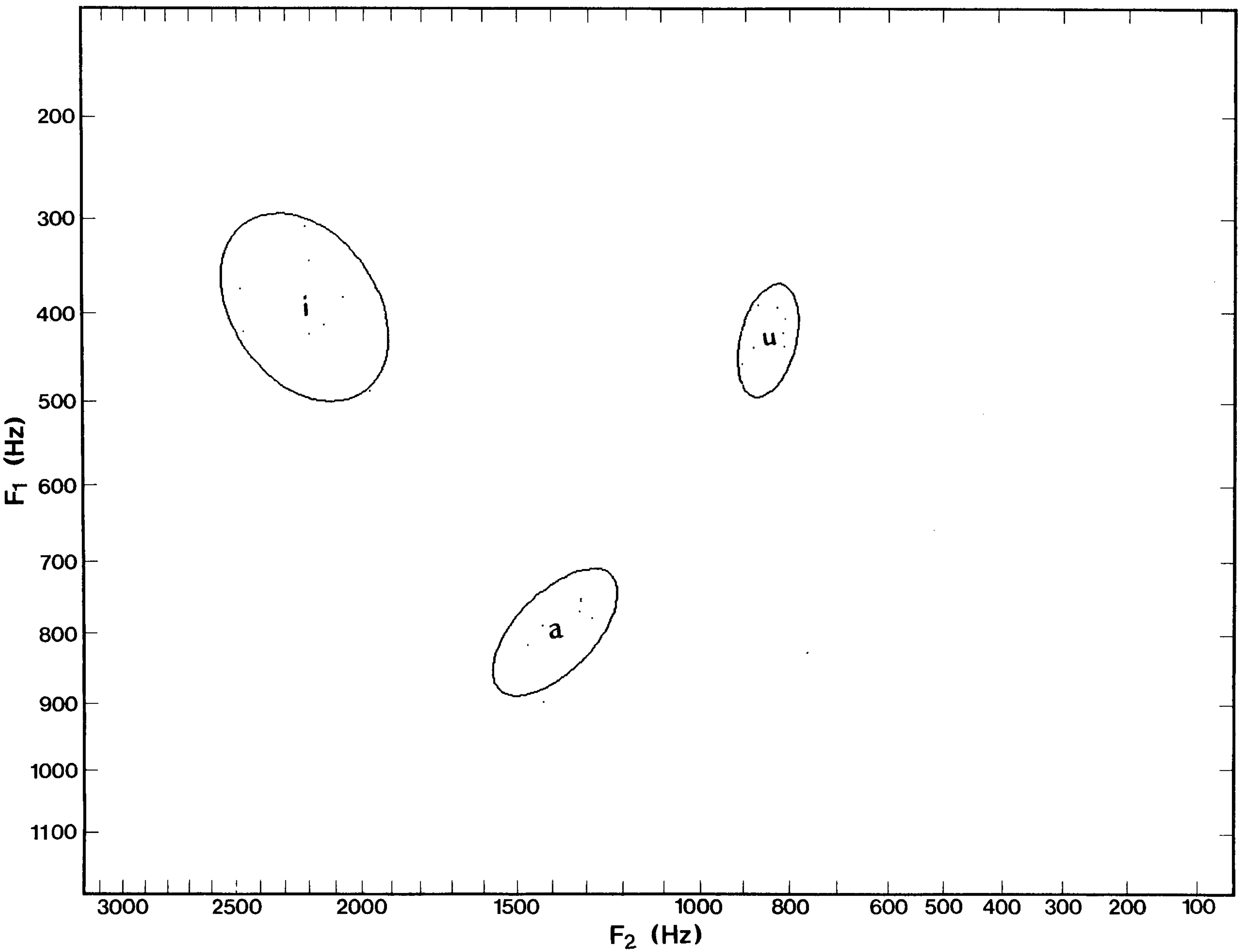

Fig. 2.4: Tausug

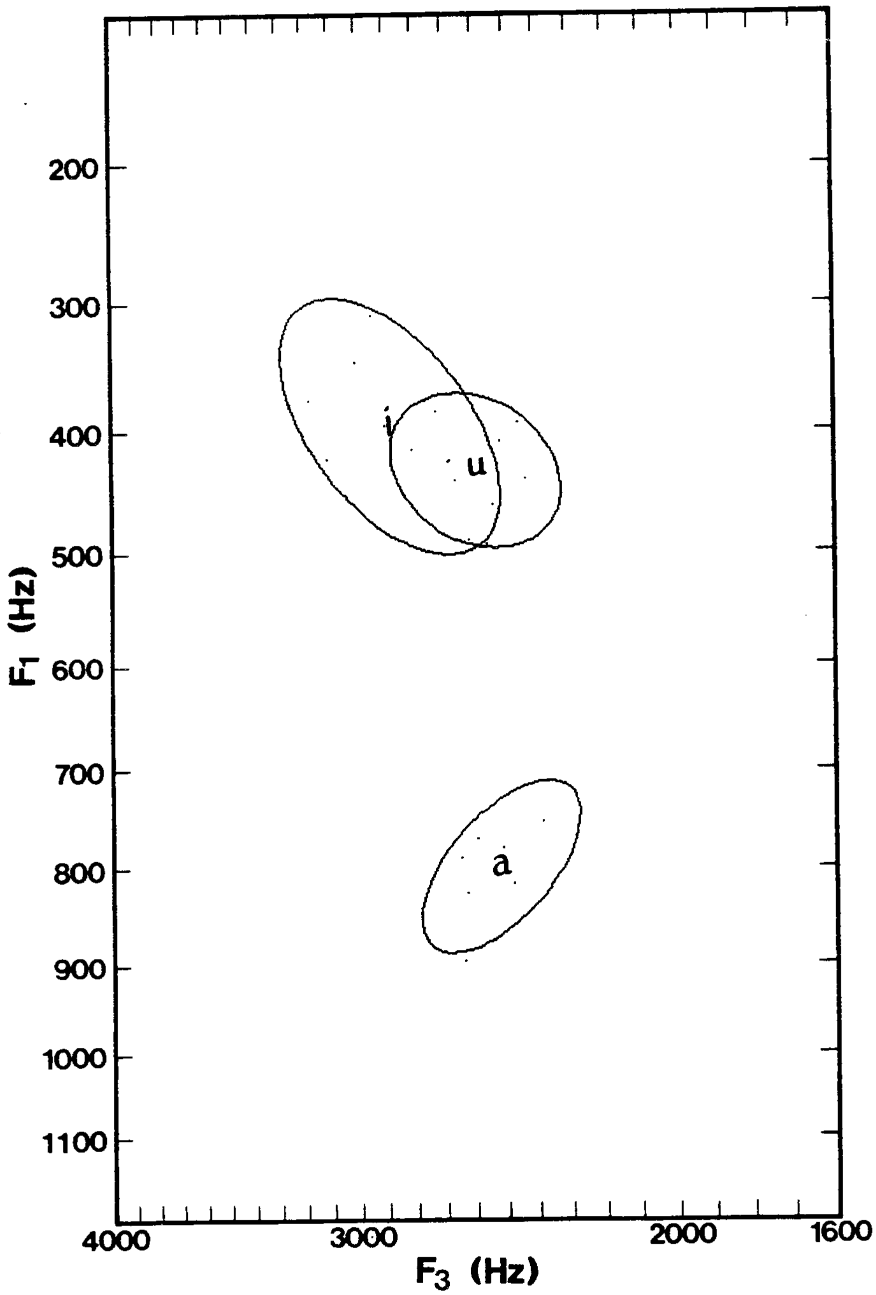

Fig. 2.4a: Tausug

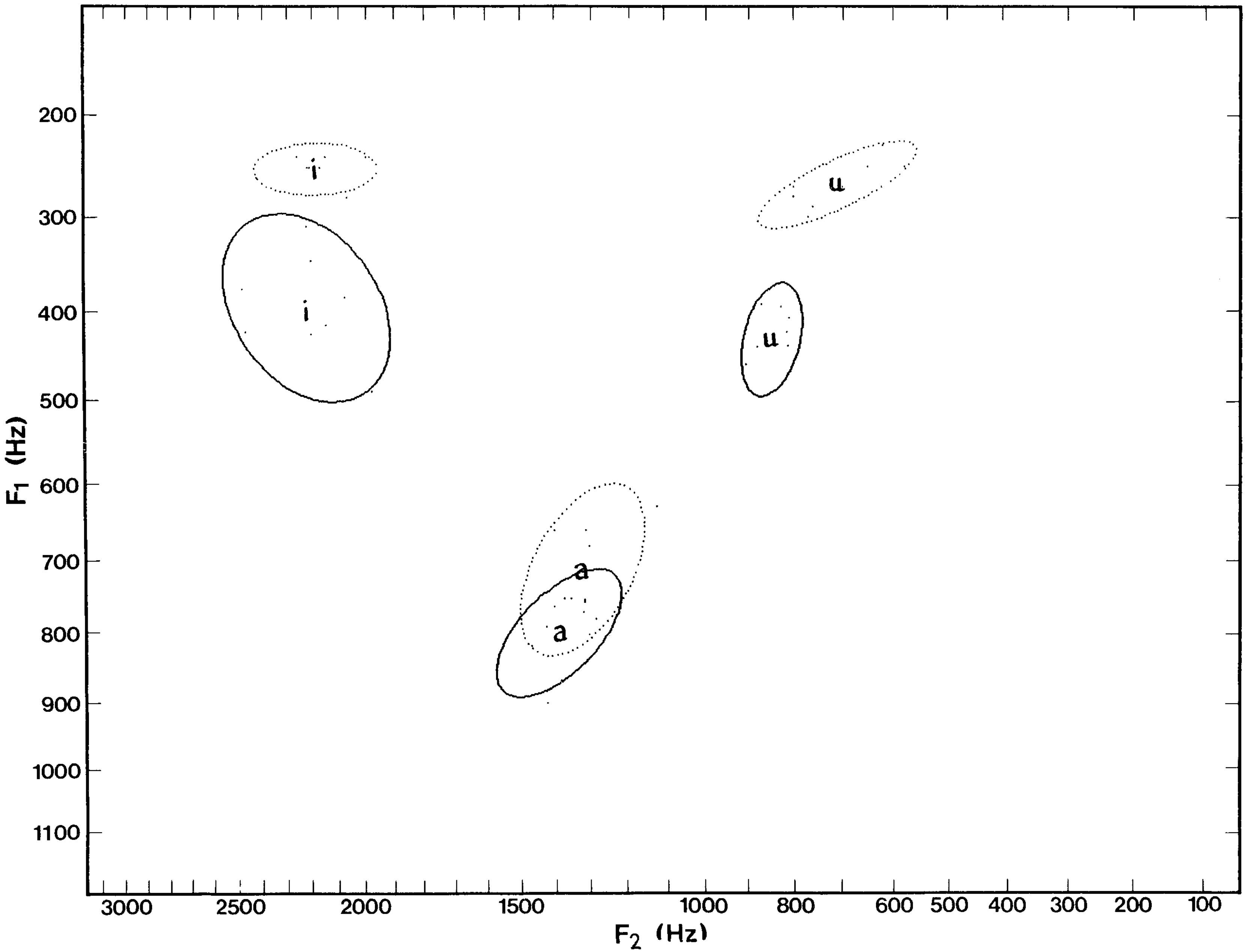

Fig. 2.5: Shared vowels of Tausug (solid) and Bavarian (dotted)

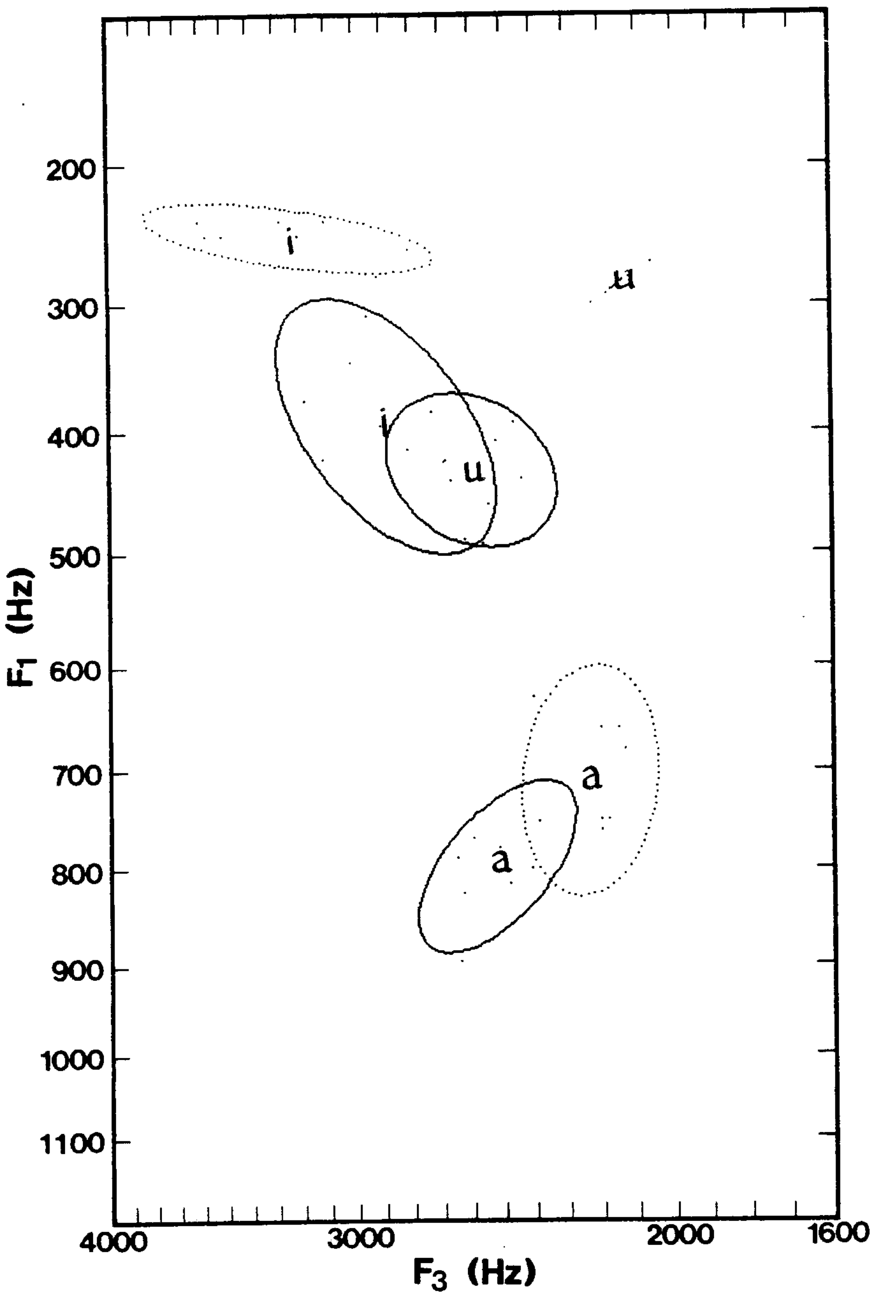

Fig. 2.6: Shared vowels of Bavarian (dotted) and Tausug (solid)

superimposed by any linear shifting or spreading of the formant values, as in most normalization procedures (e.g. Nearey 1977, Harshman 1970) designed to remove speaker-related differences in the data. Rather, the [a] vowels of the two languages occupy more nearly adjacent points along the F1 dimension than do either the [i] or the [u] vowels; similarly, the [i] vowels, and to a lesser extent the [a]s, occupy more nearly adjacent points along the F2 dimension than do the [u]s. How much of these overall differences is actually due to anatomical differences between the populations cannot be precisely determined without a fairly detailed set of vocal tract measurements -- or the extremely unlikely discovery of a group of bilingual Bavarian-Tausug speakers able to pronounce both sets of vowels with native accent. However, it can be assumed that a good deal of the difference is indeed linguistic.

The Tausug vowel space is a rather compact one, with relatively low [i] and [u] as compared to Bavarian (or, for that matter, to most other Germanic languages). It is not at all surprising that a three-vowel language should exploit less of the available phonetic space than a 13-vowel language. This fact is in keeping with the notion of adequate dispersion -- though not, one would suppose, with the quantal notion of an acoustically stable set of anchor points to be found in most languages. In Bavarian, which contrasts five levels of height, the highest and lowest vowels are more widely separated along the F1 dimension than they are in Tausug, which only contrasts two height levels.

There is less of a difference between the two languages along the F2 dimension. This is not surprising, as this dimension relates to the phonological parameter of backness, with only two contrastive values in either language. The Bavarian system does, however, make contrastive use of an additional phonological parameter, rounding, which in Tausug is merely redundant with backness. Both languages have front unrounded vowels and back rounded vowels, but the front unrounded vowels of Bavarian are matched by a set of vowels which are also [-back], but [+round]. According to a dispersion theory (though again, not to quantal theory), the front unrounded [i] of Bavarian would be relatively advanced in the vowel space with respect to the position of an unmatched [i], such as that of Tausug. This seems to be reflected in the F3 data (see fig. 2.6). The F3 values of Bavarian [a] and [u], each unmatched for rounding, are lower than their Tausug counterparts -- most likely due to a difference in head size between the two populations -- but the F3 of Bavarian [i] is distinctly higher. Here again is evidence of economy: when fewer contrasts need be made, the language exploits less of the phonetic space. One is drawn to the conclusion that the phonetic vowel quality of these vowels is not invariant, but rather, is influenced by language-particular factors such as the overall number of vowels and the range of phonological contrasts.

Vowel systems with the same structure

Having now examined the phonetic properties of a pair of very different vowel systems, let us proceed to a pair of languages which have very similar vowel systems. Lindau and Wood (1977) first addressed this problem, using data from several African languages. Their findings do not bear out the prediction that languages with the same number of vowels would tend to be realized with the same acoustic spaces, a basic premise of dispersion theory. Lindau and Wood conclude that phonological considerations such as vowel harmony and even the historical development of the vowel system must be taken into account as well. However, their data are limited in number, ranging from one to a maximum of four speakers of each language, and as such might reflect the idiosyncratic properties of the individual speakers to too great a degree. Moreover, in their comparison of Yoruba and two Edo languages, which involved the largest number of speakers, the data were not strictly comparable; the Edo vowels had been pronounced in words, preceded by a dental consonant, and the Yoruba vowels had been pronounced in isolation. This difference is likely to have had a bearing on the fact that the Yoruba vowel system occupies a considerably larger portion of the phonetic space in their data than do either of the Edo languages. (See Fant 1974 for a cogent discussion of contextual effects on vowels.)

In light of these drawbacks, the Lindau and Wood study has been repeated here with a larger number of speakers, all of whom pronounced their vowels in isolation. The languages in this study were Italian and Yoruba, each of which has a 7-vowel system that is transcribed by linguists as in Fig. 2.7:

i   u
e   o
ɛ   ɔ
a

Fig. 2.7 Schematic vowel system of Italian and Yoruba

Unlike Yoruba and the Edo languages, which are all members of the Kwa family of languages, spoken in a contiguous area of Nigeria, Italian and Yoruba are areally and genetically diverse languages.

The Italian data (Ferrero 1972) were drawn from 25 male speakers from Florence, each of whom was asked to pronounce the vowels in isolation after having pronounced a series of lexical items containing all of these vowels. The series of isolated vowels was analyzed spectrographically.

The Yoruba data combined the four speakers reported by Lindau and Wood and six additional speakers. Lindau and Wood's speakers were asked to pronounce the letters of the alphabet corresponding to the seven vowels of Yoruba; the six additional speakers were first asked to pronounce a training set of lexical items containing the seven vowels and then to pronounce these same vowels in isolation. The first three formant frequencies of both sets of isolated vowels were extracted using an LPC spectral analysis program within the UCLA WAVES analysis system, supplemented by spectrograms when the results were at all ambiguous.

To compare data measured in these different manners is not unjustified. Ladefoged *et al.* (1978) have argued that LPC spectral analysis and wide-band spectrograms give very similar results in the vast majority of cases.

The F1 and F2 values of the Italian data are shown in Fig. 2.8, and the Yoruba data in Fig. 2.9. As in the Bavarian and Tausug figures in the preceding section, ellipses have been drawn around each cluster of like vowels, with the phonetic symbol marked at the center of each ellipse.

The most striking feature of the Yoruba system is the close proximity of the high and high-mid vowels, particularly [i] and [e], which was also noted by

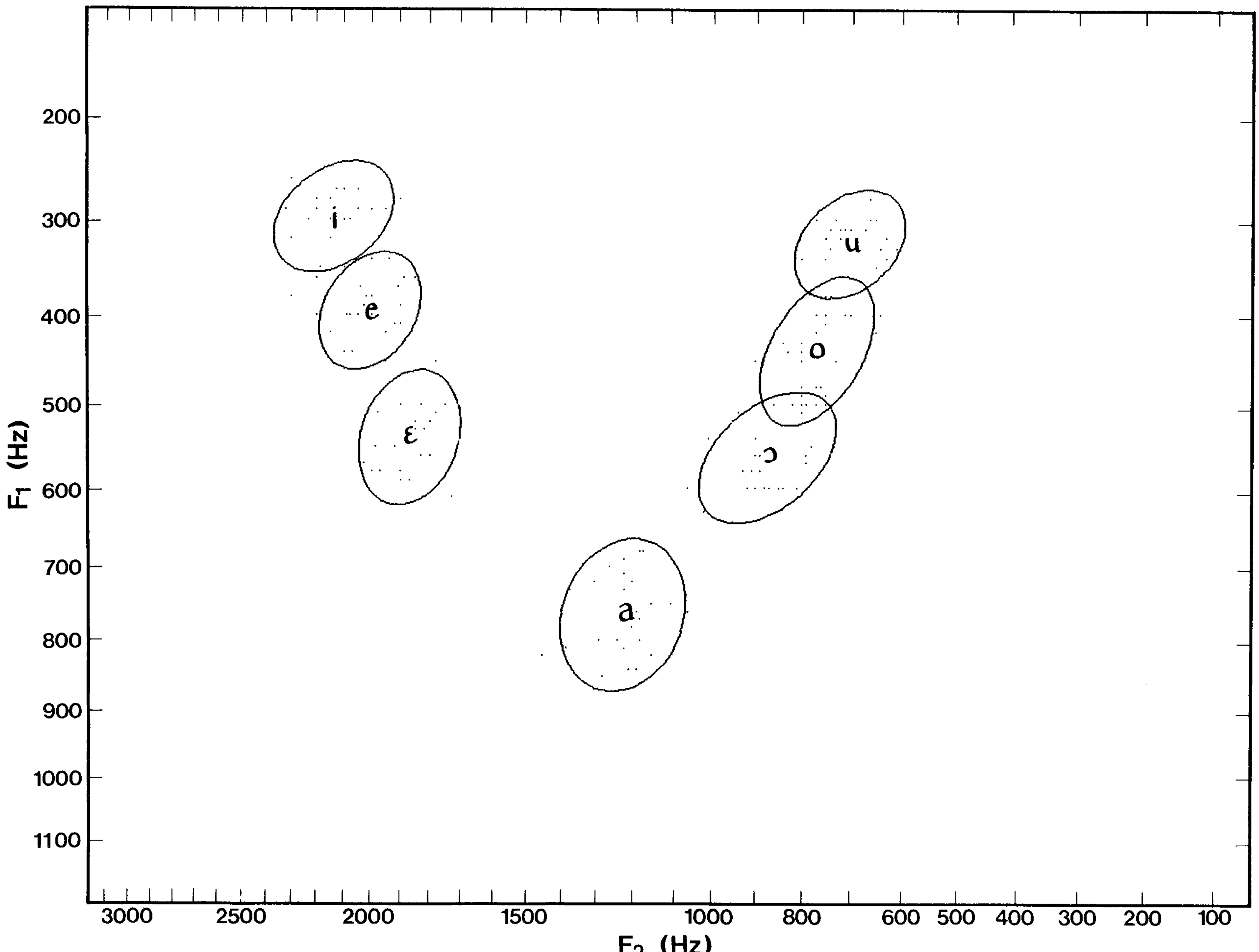

Fig. 2.8: Italian

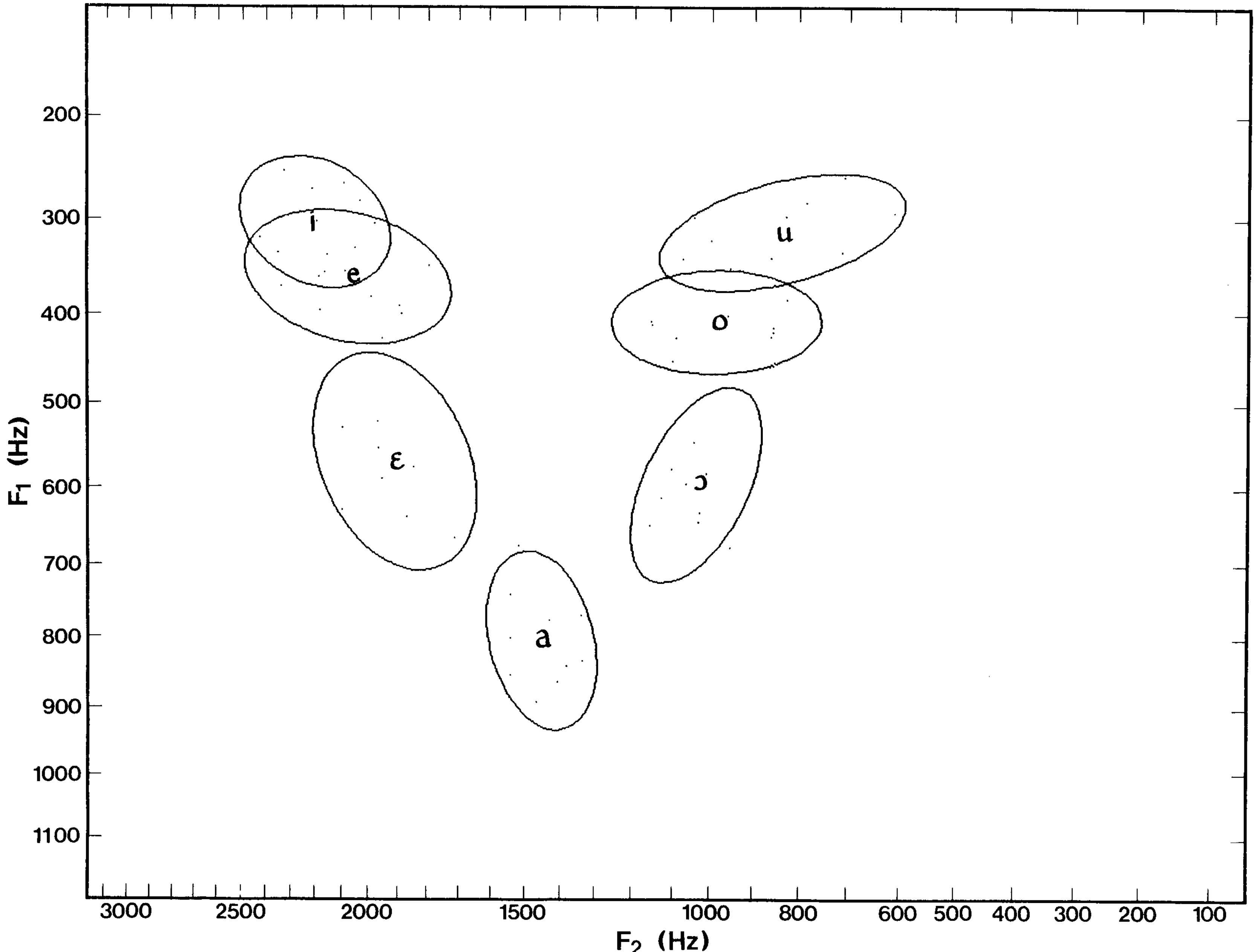

Fig. 2.9: Yoruba

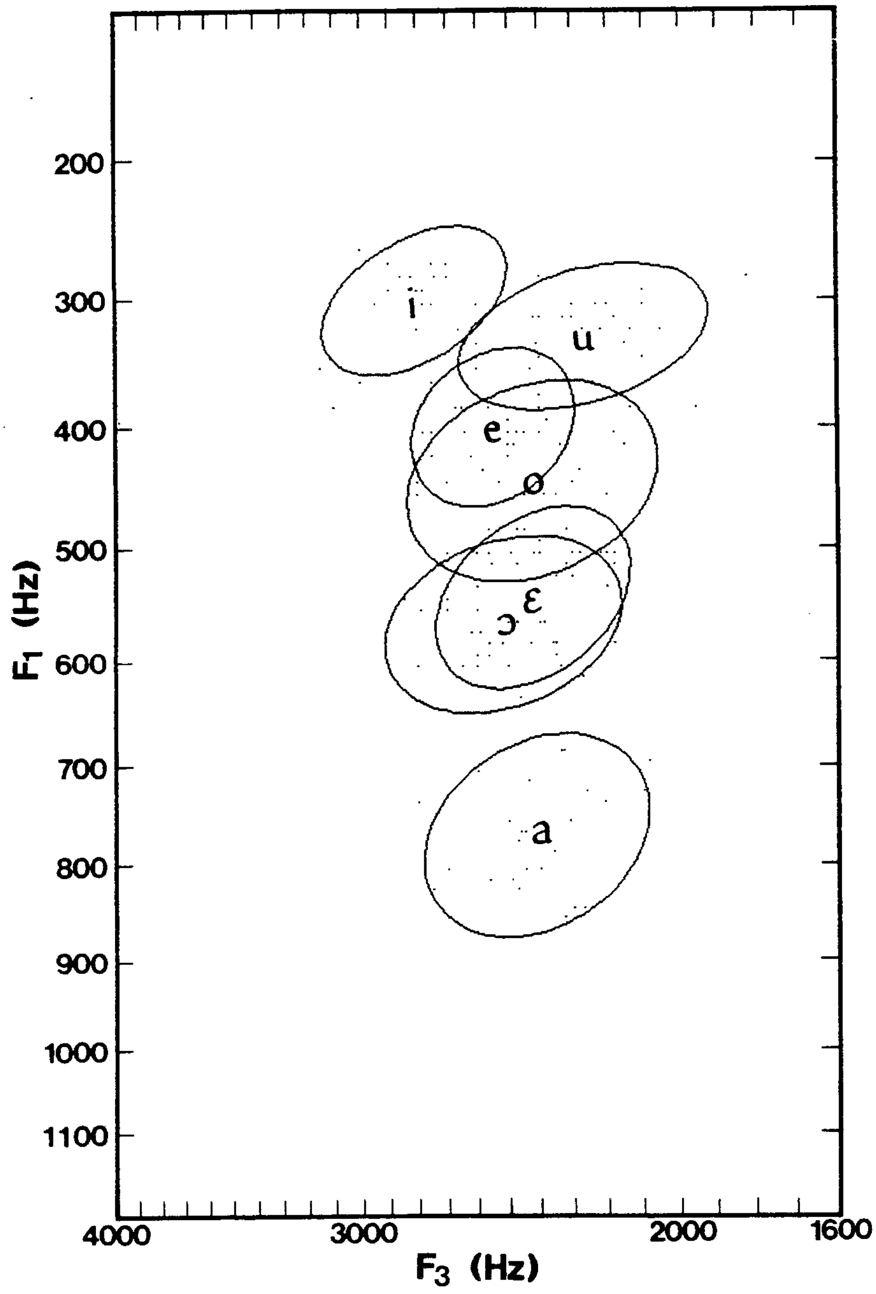

Fig. 2.10; Italian

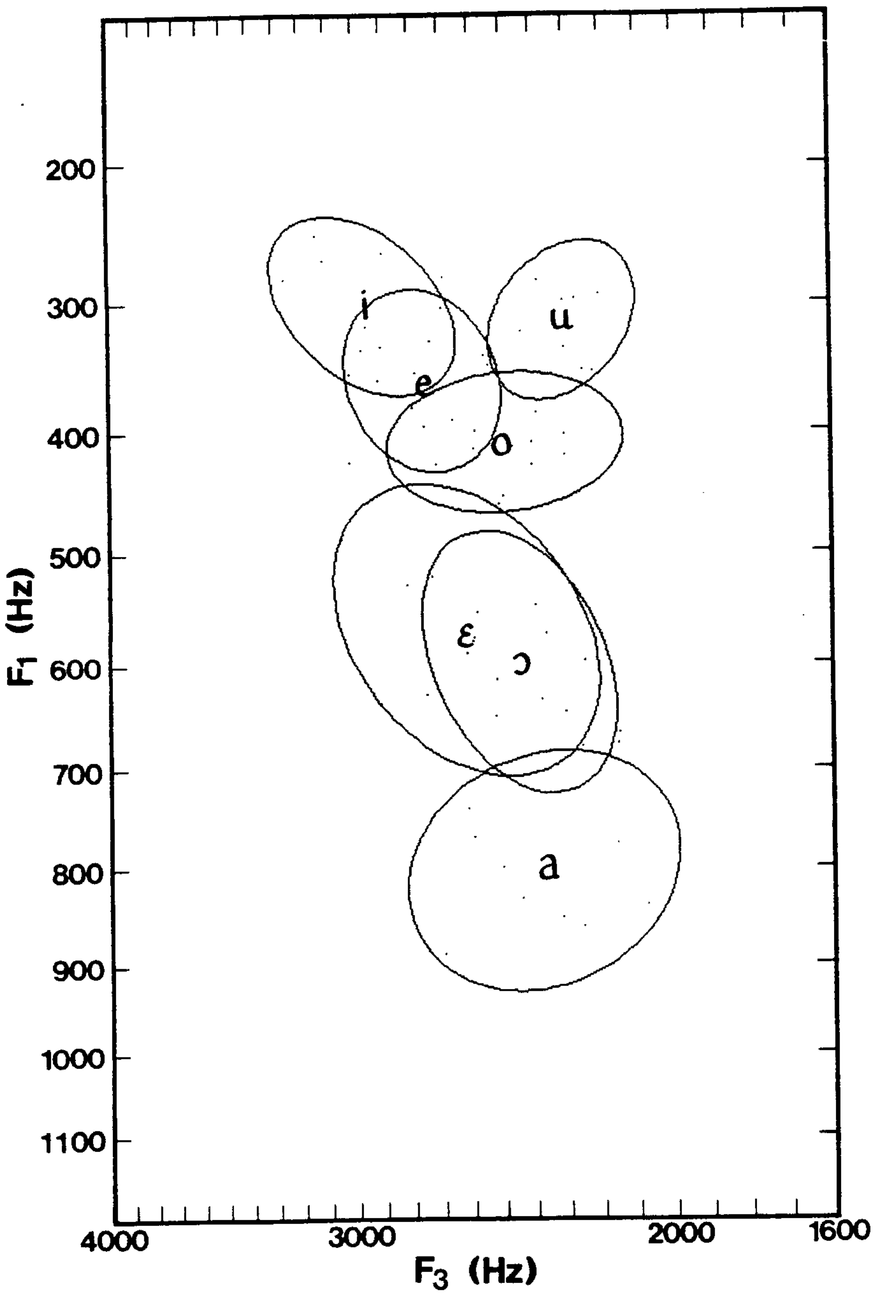

Fig. 2.11: Yoruba

Lindau and Wood. That the asymmetry in the Yoruba system should involve primarily the high and high-mid vowels, rather than the high-mid and low-mid vowels is surprising, in light of the fact that Yoruba has a partial vowel harmony system, whereby the high-mid vowels [e] and [o] almost never co-occur with the low-mid vowels [ɛ] and [ɔ] within words. This partial vowel harmony is the remnant of an earlier nine-vowel stage, attested in several contemporary Central Yoruba dialects (Adetugbo 1967). It is not clear why Yoruba should maintain a wide separation between the mid vowels, which even in the proto-language pertained to different vowel harmony sets. It is equally puzzling that Yoruba should nearly merge the two highest sets of vowels, which regularly distinguish words. The facts are only slightly elucidated by the F3 data (Fig. 2.11). The Yoruba high and high-mid vowels are somewhat more widely separated along the F3 dimension than they are along the F2 dimension, but the large variance in F3 tends to obscure this separation.

The Italian and Yoruba vowel systems depicted in Figs. 2.8 - 2.11 are superimposed in Figs. 2.12 and 2.13. The Yoruba vowel ellipses are marked with dashed lines and the Italian with solid lines. The two systems appear to be centered at very similar points along the F1 (vowel height) continuum. An analysis of variance confirms this observation: there is no significant "language effect", that is, no difference in the overall mean F1 values of Italian and Yoruba. There is, however, a difference in the way the F1 values of the vowels are arranged around their respective means. This is evidenced by a significant interaction between the variables of language and vowel, which we may term a "pattern effect". The overall pattern effect may, in turn, be broken down with a Duncan post-hoc analysis in order to determine where in these systems the greatest differences in vowel height lie.

	Language effect	Pattern effect	Significant differences ($p < .05$)	Non-significant differences
F1	No	Yes	e o ɔ a	i u ɛ

Table 2.4a Results of Analysis of Variance: Italian - Yoruba

As it happens there is a significant difference between the [a] vowels of each language, and also between the [e], [o], and [ɔ] vowels; there is no significant difference between the [i], the [u], or the [ɛ] vowels of each language. This finding is not inconsistent with Lindau and Wood's explanation for the configuration of the Yoruba vowel system. They suggest

> "a historical pull-chain process that raised /e/ and /o/ in connection with [the] raising of /ɩ/ and /ʊ/ to merge with /i/ and /u/." (Lindau and Wood 1977:47)

Whether the process was indeed an historical pull from *[ɩ ʊ] or a push from [ɛ ɔ], the greatest effect would have been on the present-day vowels [e] and [o]

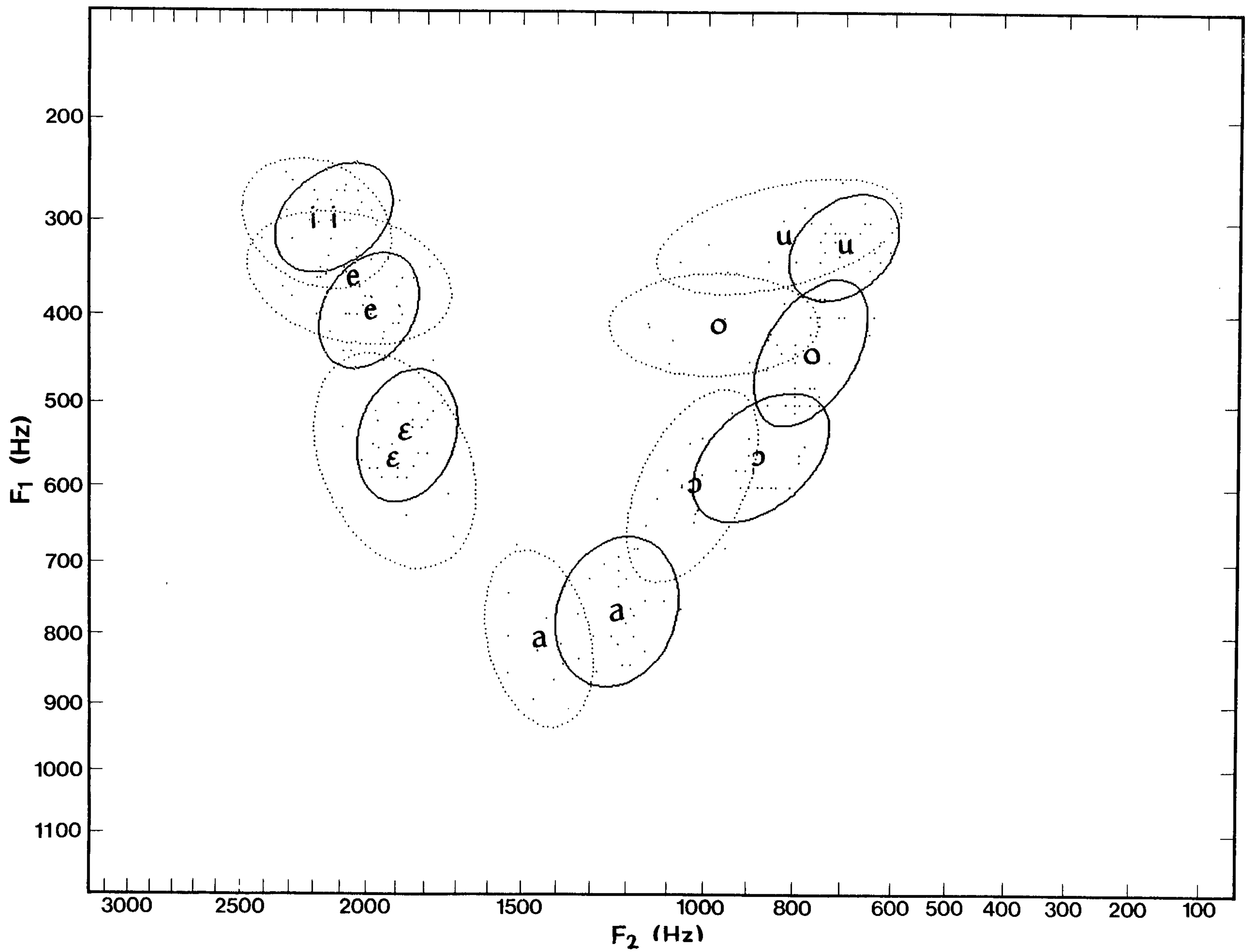

Fig. 2.12: Shared vowels of Yoruba (dotted) and Italian (solid)

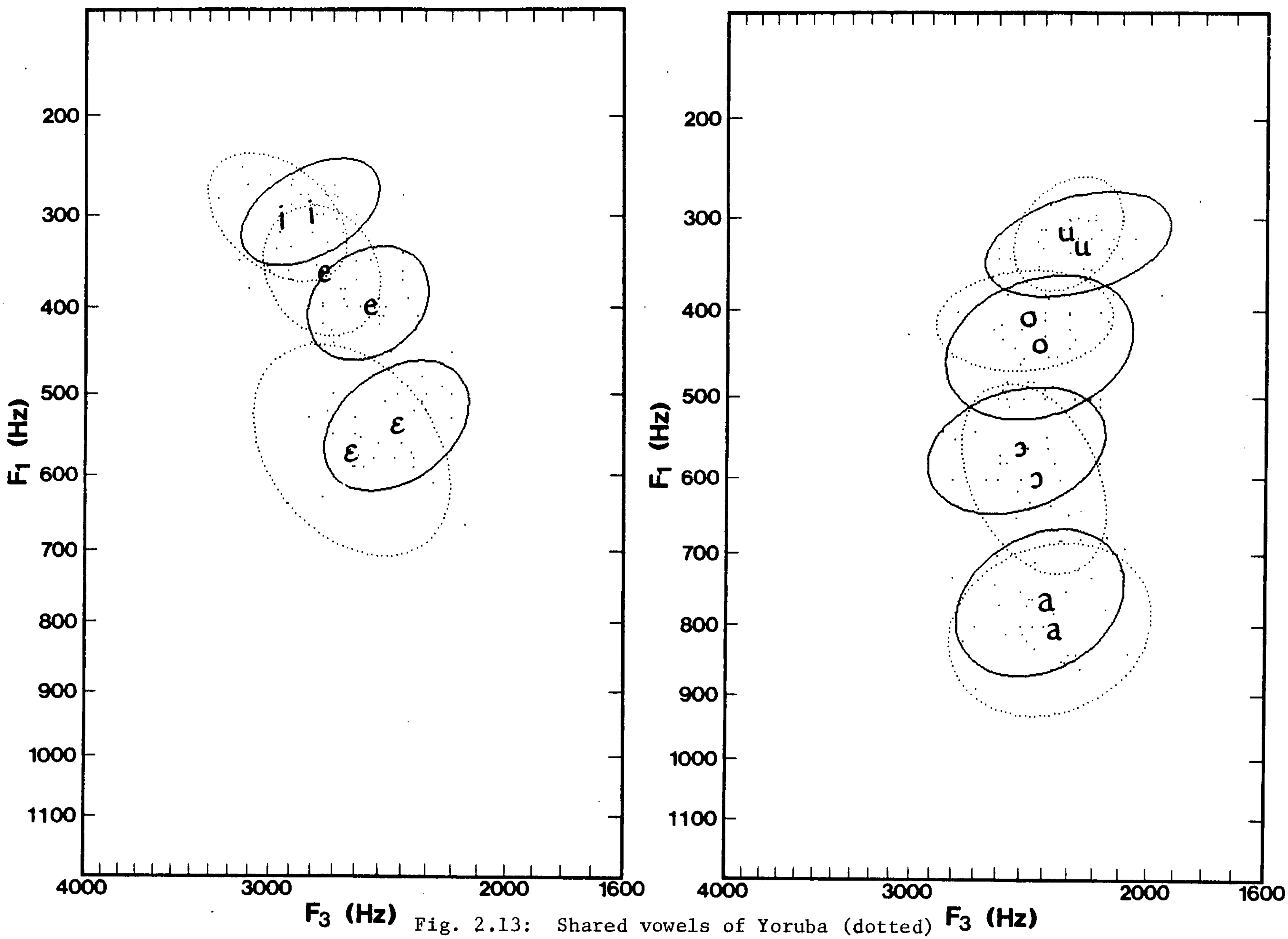

Fig. 2.13: Shared vowels of Yoruba (dotted) and Italian (solid)

and, arguably, the least effect would have been on [i] and [u] , lying outside the "chain". That two of the non-high vowels, [ɔ a], are significantly lower in Yoruba than in Italian is less readily explained, apart from noting that the Italian system, to which Yoruba is compared, is less than perfectly symmetrical on the height dimension. A subsidiary pull-chain seems also to have had an effect among the front vowels, for the vowel [e] , which has risen higher in the phonetic space than has [o], appears to exert a pull on [ɛ], which is, similarly, higher than [ɔ]. Unlike the other low and low-mid vowels of Yoruba, it is not significantly different from its Italian counterpart.

It has been suggested (B. Elugbe, pers. comm.) that the coalescence of the high front vowels occurred at an historically earlier time than that of the high back vowels.

The Italian system was also a nine-vowel system at an earlier stage in its historical development (Mendeloff 1969). The original Latin system of five long and five short vowels gave way to the Vulgar Latin system of ten distinct vowel qualities; this relatively soon became a nine-vowel system identical to that suggested for proto-Yoruba (though of course without vowel harmony). In evolving toward Italian, the Vulgar Latin vowels [ɩ ɷ] merged with the high-mid [e o]. It is possible that this merger is indirectly responsible for the gap in modern-day Italian between the low and low-mid vowels.

One might be tempted to interpret the gaps in both the Yoruba system and the Italian system as evidence in favor of a dispersion theory, rather than against it. The push-chain or pull-chain processes often invoked in diachronic studies may in fact be regarded as a language's attempt to restore some measure of even dispersion to its vowel system following the merger or loss of some vowels. By this reasoning, Italian and Yoruba, having lost the vowels [ɩ ɷ] through mergers with adjacent vowels, "repaired" their respective systems through a series of subsidiary vowel shifts in the direction of the gap.

Still, even if one were to accept this argument, it is difficult to accept the time frame; a millenium ought to be time enough for a system like that of Italian to regain its equilibrium. Moreover, it is surprising that the [e] of Yoruba is higher than the Italian [e], product of a merger with [ɩ].

Turning now to the domains of F2 and F3, we can see quite clearly from Figs. 2.12 and 2.13 that the Italian system is somewhat shifted back in the formant space with respect to the Yoruba system. Most noticeably in F2, but also in F3, the vowels of Italian have lower formant values than do the corresponding vowels of Yoruba.

An analysis of the variance of the two vowel systems confirms this observation. There is a significant difference in the overall mean values of the two languages' vowels, both in the F2 and in the F3 domain. That this is not merely the result of anatomical differences, such as greater vocal tract length, between Italians and Yorubas is shown by the lack of a significant difference between Italian and Yoruba in F1, and also by the lack of significant differences in F2 for the front vowels. We should not, however, rule out adjustments at the end of the vocal tract, such as lip rounding, as a possible explanation.

There is a significant language-by-vowel interaction in both F2 and F3. A Duncan post-hoc analysis reveals that in each instance, the group of front vowels differs from the group of non-front vowels in their contribution to the overall pattern difference between the languages. This results in the complementary pattern shown in Table 2.4b.

	Language effect	Pattern effect	Significant differences ($p < .05$)	Non-significant differences
F2	Yes	Yes	i e ɛ	u o ɔ a
F3	Yes	Yes	u o ɔ a	i e ɛ

Table 2.4b Results of Analysis of Variance: Italian-Yoruba

While most of the overall difference between Italian and Yoruba F2 is contributed by the non-front vowels [u o ɔ a], most of the F3 difference is contributed by the front vowels [i e ɛ]. Lindblom and Sundberg (1971:1176) note very similar patterns among the acoustic consequences of lip movement:

> "We conclude that 'rounding' lowers all formant frequencies under all conditions. This lowering is particularly pronounced for the F3 of vocal-tract shapes with palatal constrictions and for F2 associated with (palato-)velar and velopharyngeal constrictions."

In other words, rounding has the greatest effect on the F3 of front vowels and on the F2 of non-front vowels.

While there have been no cross-linguistic studies of lip activity in Italian and Yoruba comparable to that of Linker (1982), the evidence presented here suggests a consistent difference between the two languages in the degree of mouth opening, such that Yoruba speakers have effectively a greater opening than Italian speakers do.

This difference may be regarded as a difference in the articulatory setting, or "base of articulation" (Wallis 1653, and more recently Honikman 1964, Drachman 1973). Chomsky and Halle specifically disregard such base of articulation effects in their discussion of phonetic quality; in their view, base of articulation is a "socially determined aspect of speech" comparable to the normal rate of utterance of a speech community (1968:295). If we accept this latter view, the significant F2 and F3 language differences between Italian and Yoruba need not be taken as evidence against a theory of vowel dispersion, nor should the significant F2 and F3 pattern differences be viewed as more than the acoustic residue of the articulatory gesture of rounding.

However, it is not as easy to dismiss the difference previously noted in the domain of F1. No gesture, or combination of gestures, can be called upon to account for the differing patterns of vowel height in the two systems, which should, in light of their phonological similarity, be phonetically similar as well.

The failure of dispersion theory to account for the height difference between Italian and Yoruba also casts doubt on the adequacy of quantal theory, which assumes that the non-quantal vowels are evenly distributed between the quantal vowels. Still, quantal [i] and [u] display the predicted invariance. The sole low vowel, [a], does vary, but as we have seen, this is not among Stevens' quantal vowels.

Chapter 3: Acoustic Quality of Germanic Vowels I: Survey of individual languages

In what sense can two vowel sounds be considered "the same" or "different"? A system such as the IPA may be viewed as imposing a grid, of sorts, on the vowel systems of natural languages.

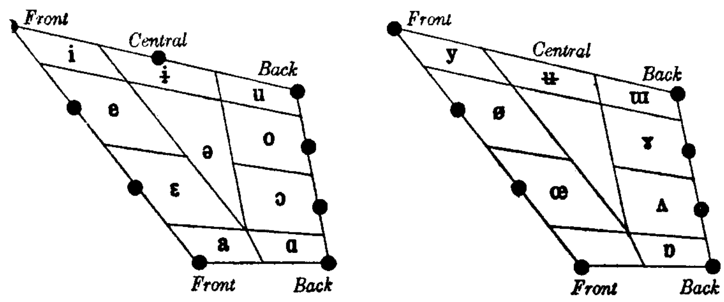

Fig. 3.1 IPA vowels
(From The Principles of the International Phonetic Association, 1949)

This grid is sufficiently fine to distinguish all contrasts within a given language. Still, the phonetic literature provides ample evidence of vowels of different languages which, though transcribed with the same IPA symbol, are recognized as having consistently different phonetic realizations, such as:

"Dutch [ɩ] is slightly more open than English [ɩ]" (Koolhoven 1968:7).

Norwegian [ø] "resembles German [ø], but is also less rounded" (Haugen 1935:12).

Swedish [i] is "closer than the vowel in English 'seen'" (McClean 1969:5).

"[ɛ] is somewhat more open in Dutch than in German" (ten Cate et al 1976:25).

Danish [ø] is "a little more close than Swedish [ø]" (Nielsen and Hjorth 1971:14).

This section will examine some pairs of vowels which are said to be "the same" or "different" across languages. However, as the impressionistic judgments of vowel quality made by even the most highly skilled phoneticians are not always consistent with the acoustic facts, or even with the judgments of other skilled phoneticians (Ladefoged 1957), the survey will rely on acoustic data directly. The use of measurable acoustic data further permits us to address the question of how fine a phonetic grid need be superimposed on the vowel systems of natural languages in order to capture all the significant differences between languages as well as within languages. It may also show whether it makes sense to speak of a grid at all, or whether all distinctions in vowel quality might be better described in terms of continuous phonetic parameters.

The acoustic data presented in this chapter, as in previous chapters, is not normalized in any way. It has been shown (Disner 1978, 1980) that most of the normalization procedures suggested in the phonetic literature are inadequate for cross-linguistic studies of vowel quality because of differences in the means of the respective systems, and differences in the distribution of individual vowels around these means. The use of raw data ensures that no procedural artifacts will alter the linguistic relationships between the languages. In the following chapter a method of verifying the trends in the raw data will be presented.

In the previous chapter we observed some differences between similarly transcribed vowels in several areally and genetically diverse languages. This chapter and the following chapters will examine a number of closely-related languages, all members of the Germanic family, and will search more systematically for vocalic differences between them. If there are found to be reliable and consistent differences even between the corresponding vowels of related languages such as these, it is more than likely that such differences exist among other, unrelated languages as well.

Languages

Formant frequency data from eight Germanic languages, including five reported previously (Disner 1978, 1980), were selected from published accounts. Each of these data sets was drawn from a minimum of five, and a maximum of 50 male speakers.

The American English data are those of Peterson and Barney (1952). Words containing the 10 monophthongs of English were pronounced by 33 male speakers, and measured with a sound spectrograph. The vowels in the words "hayed" and "hoed" are not included in this list, as they are usually diphthongized to [eᶦ] and [oᵒ]. Speakers of British English should note that the vowel in the word "hod" is transcribed as [ɑ] rather than as [ɒ]. The former is the standard American pronunciation of the lowest non-front vowel of English, although some American dialects have a more central vowel, verging on [a].

The German data, reported in Jørgensen (1969), are the eight long vowels of the language, as pronounced by six speakers. The formant frequencies were analyzed by means of a sound spectrograph. For the vowels [u] and [o], in which F3 is of very low amplitude (Fant 1956), no F3 values are provided. With regard to the somewhat controversial phonemic status of German [ɛ:], all of these subjects distinguish [ɛ:] from [e:] in their everyday speech. This characteristic, while not pervasive in the German-speaking world, does occur regularly in an area centered on the city of Köln. For these six speakers, at least, [ɛ:] should be considered a native, rather than an acquired, vowel phoneme.

The Norwegian data, nine long vowels pronounced by ten speakers, are from Gamnes (1965). The F2 and F3 values of the vowels [u] and [ɔ] are missing from these data, again, it may be presumed, because their amplitudes are so low. There is some ambiguity in the classification of the non-front low vowel of Norwegian. Vanvik (1966, 1972) is not consistent in his transcription of this vowel; even within the same article he sometimes describes it as [ɑ], sometimes as [a]. Its auditory similarity to the low back vowel of Swedish, with which it shares a common origin, leads others, such as Haugen (1976), to transcribe it as [ɑ]. Gamnes steers a middle course by adding a diacritic, listing this vowel as [ɑ̟].

The Danish data are the ten long vowels of the language, pronounced by eight speakers and analyzed spectrographically (Fischer-Jørgensen 1972). Seven of the speakers pronounced the list of Danish words in Table 3.1, below, but the eighth speaker pronounced a slightly different set of words, substituting "kube, hobe, habe" for "hule, Ole, åle" in order to minimize the effect of the formant transitions.

The Dutch data (Pols, Tromp and Plomp 1973) include both long and short vowels, in recognition of the considerable differences in quality which accompany the length difference in this language. (See Moulton 1962 for a detailed description, both synchronic and diachronic, of the Dutch vowel system.) Fifty speakers pronounced the twelve vowels of Dutch, and the formant values were extracted by means of a wave analyzer.

The Frisian data (T. de Graaf, pers. comm.) are the nine long vowels of the language, pronounced in words of the form w-t by five speakers. An LPC procedure was used to analyze the vowel data; only the first two formants have been reported, however. According to the transcriptions provided by de Graaf and by Cohen et al. (1971) the 19 vowels of Frisian are grouped into nine pairs of long and short vowels of like phonetic quality, plus an unstressed schwa. The only quality differences found within the pairs are in [e:]-[ɩ] and [ø:]-[œ]. It was therefore decided to use only the set of long vowels in the present study.

The Bavarian data (Traunmüller 1982), described more fully in the preceding chapter, are 13 long vowels pronounced by eight speakers. Wide-band spectrograms were used to obtain the formant frequencies. Some of the F3 values are not reported, chiefly among the back vowels, where the third formant is weakest. There is no established orthography for this dialect.

The Swedish data are the 9 long vowels of the language, pronounced in the context [h-l] by six speakers. The data for three of the speakers were gathered and analyzed spectrographically in Stockholm (Stålhammar, Karlsson and Fant 1973). The data for the remaining three native speakers of Swedish were gathered and analyzed at UCLA with a computerized LPC procedure and spectrograms as needed for clarification.

The largest data set available for Swedish (24 male speakers) is that of Fant, Henningsson, and Stålhammar (1969), but unlike the other data sets we have considered, it consists of isolated vowels only. This data set was included in two earlier studies of cross-linguistic vowel quality (Disner 1978, 1980). It has been shown by Stålhammar, Karlsson and Fant (1973) that the addition of consonantal context results in an overall shift toward more "neutral", less peripheral vowel quality, but they make clear that this effect is strongest in the short vowels (which were not included in the earlier Disner studies).

In order to determine how great the contextual effect actually is, the isolated-vowel data were compred with the word-context data by means of a series of t-tests. Three separate t-tests, one for each of the formants, were performed for each of the nine vowels of Swedish. Significant differences between the two conditions were most evident among the high vowels and the front rounded vowels, whereas the vowels [ɑ o e ɛ] were largely unaffected by context. It is, of course, possible that the differences noted here are due, not to any difference in consonantal context, but rather to the greater inherent variability of a particular phoneme or phonemes. To test for this, the larger dataset (vowels in isolation) was split into two equal parts, and another series of t-tests was performed on the split halves. The results revealed considerably fewer differences within condition than had been found across conditions. Thus, it was decided not to use the vowels which had been pronounced in isolation as the basis of cross-language comparisons in this chapter; the smaller dataset of vowels pronounced in context was used instead.

Experimental paradigms

The vowels in these different studies were pronounced in similar word contexts, chosen to minimize transitional effects as may be seen in Table 3.1

<u>Danish</u>			
	ile [i]	hyle [y]	hule [u]
	hele [e]	øde [ø]	Ole [o]
	hæle [ɛ]	høne [œ]	åle [ɔ]
	hale [æ]		
<u>Dutch</u>			
	hiet [i]	huut [y]	hoet [u]
	hit [ɩ]		
	heet [e]	heut [ø]	hoot [o]
	het [ɛ]	hut [œ]	hot [ɔ]
		hat [a]	hat [ɑ]
<u>American English</u>			
	heed [i]		who'd [u]
	hid [ɩ]		hood [ω]
	head [ɛ]		hawed [ɔ]
	had [æ]	Hud [ʌ]	hod [ɑ]
<u>German</u>			
	hiessen [i]	hüten [y]	hupen [u]
	Esel [e]	hölen [ø]	hoben [o]
	äsen [ɛ]		
		aβen [a]	

Norwegian	did [i] ded [e] dæd [æ]	dyd [y] død [ø]	dud [ʉ]	dod [u] dad [o] dad [ɑ]
Swedish	hil [i] hel [e] häl [ɛ]	hyl [y] höl [ø]	hul [ʉ]	hol [u] hål [o] hal [ɑ]
Frisian	wiit [i] weet [e] wêt [ɛ]	wút [y] weut [ø]	wat [a]	wût [u] woot [o] wât [ɔ]
(Eastern Central) Bavarian	[si] [se] [sɛ] [sæ]	[sy] [sø] [sœ] [sɶ]	[sa]	[su] [so] [sɔ] [sɒ]

Table 3.1

The majority of these words begin with [h], which is simply the voiceless variant of the following vowel. Most end with an alveolar or a dental consonant, the formant loci of which, in general, exert less of an influence on the preceding vowel than do either velar or bilabial consonants. A notable exception to this rule is found in the German words "hupen" and "hoben", and the Danish words "kube, hobe, habe" as pronounced by one of the speakers. These words were chosen by the authors of the studies cited because the formants are typically low in back rounded vowels, and here a bilabial context minimizes the transitional effects more effectively than an alveolar or dental context. However, the differences between a [h-d] environment and an entirely bilabial [b-b] environment are not very great for back vowels, as has been shown in the case of English by Stevens, House and Paul (1966). Moreover, in citation form the duration of the test words is typically longer than average, and transitional effects can be satisfactorily separated from a steady-state portion in the center of the vowel.

The Frisian words are preceded by /w/, which phonetically is the bilabial approximant [ʋ] (Cohen et al. 1971). This would be expected to lower the formant frequencies of the front vowels somewhat, though the effect is mitigated by the following [t], and by the citation form of the utterance.

The inclusion of lateral [l] among the consonantal environments of Swedish and Danish may surprise English-speaking linguists who are accustomed to a velarized ("dark") [ɫ] in syllable-final position, with very prominent back-vowel transitional effects on the preceding vowel. This is, however, not true of the

Scandinavian languages. Unlike English, their (dental) lateral does not become velarized when final.

The recognized diphthongs of these languages, including English [e^ɪ] and [o^ə], are not included in the present comparison. Still, there are a number of vowels in Table 3.1 (notably, the high vowels of Swedish and the high-mid vowels of Dutch) which are characterized by a degree of diphthongization. Diphthong trajectories may in fact serve to distinguish vowels whose steady-state portions are otherwise very similar. It should be emphasized that, by disregarding any diphthongization and focusing on the steady-state portion of the vowel, we are minimizing, rather than exaggerating, any potential differences between these languages.

Most of the words listed in Table 3.1 are actual lexical items; however, some of the Dutch, Frisian, Norwegian and Swedish "words" are nonsense syllables. The sources do not report any hesitancy on the part of the speakers in pronouncing them, however.

Figures 3.2-3.27 are plots of the formant frequency data in the eight Germanic languages. As described in the preceding chapter, the values along each axis are calibrated in Hertz, but plotted in mels in order to better represent the perceived distances in the phonetic space. The mel-scale intervals along the F1 axis have been expanded with respect to those along either the F2 or the F3 axis, in consideration of the greater perceptual importance of the first formant. An ellipse has been drawn around the data points of each vowel category, with axes oriented along the principal components; the radius of each ellipse is of two standard deviations, encompassing most of the data points. The IPA symbol for each vowel is marked at the center-point of the corresponding ellipse.

Analysis of Variance

In a previous study (Disner 1978) the results of a series of ANOVA tests on cross-language data were reported, including portions of some of the data sets used in the present investigation. Those data, consisting of F1 and F2 only, were first converted from Hertz to mels in order to standardize the formant values along a perceptually-based scale, and then subjected to analysis of variance.

It was decided that there was no point in conducting statistical tests to show that many of the vowels in one language were different from those in another. For example, it is obvious that German [i] is different from English [u]. Instead, the cross-language comparisons concentrated on examining vowels that might be expected to be the same, or very similar, in different languages. In general these are the vowels that are transcribed with the same phonetic symbol in different languages. These vowels will be referred to as the "shared" vowels of a pair of languages. The use of this term does not imply, _a priori_, that shared vowels are or are not the same in two different languages.

For each set of shared vowels of a pair of languages, four different statistics were calculated. The first, termed a "language effect", represents the difference between the overall means of all the speakers' vowels in the two languages; this would show whether one language had vowels that were, in general, higher or lower, or more front or back than the corresponding vowels of the other language. The second statistic, termed a "speaker effect", represents the differences between each of the individual speakers, averaged across all vowels, and as such is not of linguistic interest. The third, a "vowel effect", represents the difference between the individual vowels, grouped across language. This, too, is of scant linguistic interest, since it is to be expected that, for example, the vowel [u] differs from the vowel [i]. The fourth statistic, technically the interaction effect of language and vowel, and here termed a "pattern effect", indicates whether the vowels of two languages are arranged in a similar fashion around their respective means.

In the course of the present investigation the ANOVA procedure was performed on the first three formants of all eight Germanic languages in the sample. Pairs of languages were selected for comparison on the basis of their areal or genetic relatedness, or because of certain properties of the vowel systems, as discussed below. The significant ($p<.05$) language and pattern effects in these data are listed in Table 3.2.

A set of Duncan post-hoc analyses were performed on the data, in order to ascertain which individual vowels differ significantly from the corresponding vowels of other languages, and which do not. These results, too, are listed in Table 3.2.

Results

English-German [i u ɛ]

The two most widely-spoken Germanic languages, both members of the West Germanic branch, have relatively few vowels in common among those for which data are available. English lacks a set of front rounded vowels, has diphthongs [eᶦ] and [oᶷ] rather than monophthongs [e] and [o], and has no central low vowel; German has few low vowels at all, and no rhotacized vowels. With only three shared vowels [i u ɛ], an analysis of variance cannot be taken as representative of the systems in question; however, it can tell a fair amount about the individual vowels. The vowel [u] is said to be less rounded in English than in German (ten Cate et al. 1976), or less back (Moulton 1962), both of which would involve an increase in F2 (leaving open the question of which articulatory mechanism is involved). The ANOVA results support this view, showing the F2 of English [u] to be significantly higher than that of German [u]. (There are no F3 data available for the German back vowels.) In addition the vowel [ɛ] is significantly higher in German than in English. German and English [i] are not significantly different in any of the formants.

German-Dutch [i y u e ø o ɛ a]

The German and Dutch languages occupy geographically contiguous areas of northwest Europe, and are regarded by many as dialects of the same language. At

Table 3.2

Results of the Analysis of Variance

		Language effect?	Pattern effect?	Significant differences ($p < .05$)	Non-significant differences
English-German					
F1		Yes	No	[u ε]	[i]
F2		No	Yes	[u]	[ε i]
F3		No	No		[ε i]
German-Dutch					
F1		Yes	Yes	[i y u ϵ ø o ε]	[a]
F2		No	Yes	[u ϵ o ε]	[i y ø a]
F3		No	No	[ø a]	[i y ϵ ε]
English-Dutch					
F1		Yes	Yes	[i u ε ɔ ɑ]	[ɩ]
F2		Yes	Yes	[i u ε ɔ]	[ɩ ɑ]
F3		Yes	Yes	[i u ɔ ɑ]	[ɩ ε]
German-Bavarian					
F1		Yes	Yes	[ε a]	[i y u ϵ ø o]
F2		No	Yes	[y ø o ε]	[i u ϵ a]
F3		Yes	Yes	[i ø]	[y ϵ ε a]
Norwegian-Swedish					
F1		Yes	Yes	[ϵ]	[i y u ʉ ø ɑ]
F2		Yes	Yes	[i y ɑ]	[ʉ ϵ ø]
F3		Yes	Yes	[i]	[y ʉ ϵ ø ɑ]

Table 3.2 (continued)

	Language effect?	Pattern effect?	Significant differences	Non-significant differences
English-Danish				
F1	Yes	Yes	[i u ɛ ɔ æ]	
F2	No	Yes	[u ɛ ɔ]	[i æ]
F3	No	Yes	[i ɛ]	[u ɔ æ]
Frisian-Dutch				
F1	Yes	Yes	[o ɛ a]	[i y u єø ɔ]
F2	Yes	No		[i y u єø o ɛ ɔ a]
Frisian-English				
F1	No	No		[i u ɛ ɔ]
F2	No	Yes	[u]	[i ɛ ɔ]
Danish-Swedish				
F1	Yes	Yes	[i y u єø o ɛ]	
F2	Yes	Yes	[i ɛ]	[y u єø o]
F3	No	Yes	[i y u єɛ]	[ø o]
Danish-German				
F1	Yes	Yes	[ø o ɛ]	[i y u є]
F2	Yes	Yes	[y ø o ɛ]	[i u є]
F3	Yes	No	[i y єɛ]	[ø]
German-Swedish				
F1	Yes	Yes	[i y u ø ɛ]	[єo]
F2	No	Yes	[i y]	[u єøo ɛ]
F3	Yes	Yes	[y]	[i єø ɛ]

Table 3.2 (continued)

	Language effect?	Pattern effect?	Significant differences	Non-significant differences
<u>English-Swedish</u>				
F1	No	Yes	[ɑ]	[i u ɛ]
F2	Yes	Yes	[i u ɑ]	[ɛ]
F3	No	No		[i u ɛ ɑ]
<u>Norwegian-German</u>				
F1	Yes	No	[i y u ɛ ø]	
F2	Yes	Yes	[y]	[i ɛ ø]
F3	Yes	Yes	[i y ø]	[ɛ]
<u>Norwegian-English</u>				
F1	No	Yes	[i u ɔ æ ɑ]	
F2	Yes	Yes	[æ]	[i ɑ]
F3	Yes	Yes	[i ɑ]	[æ]

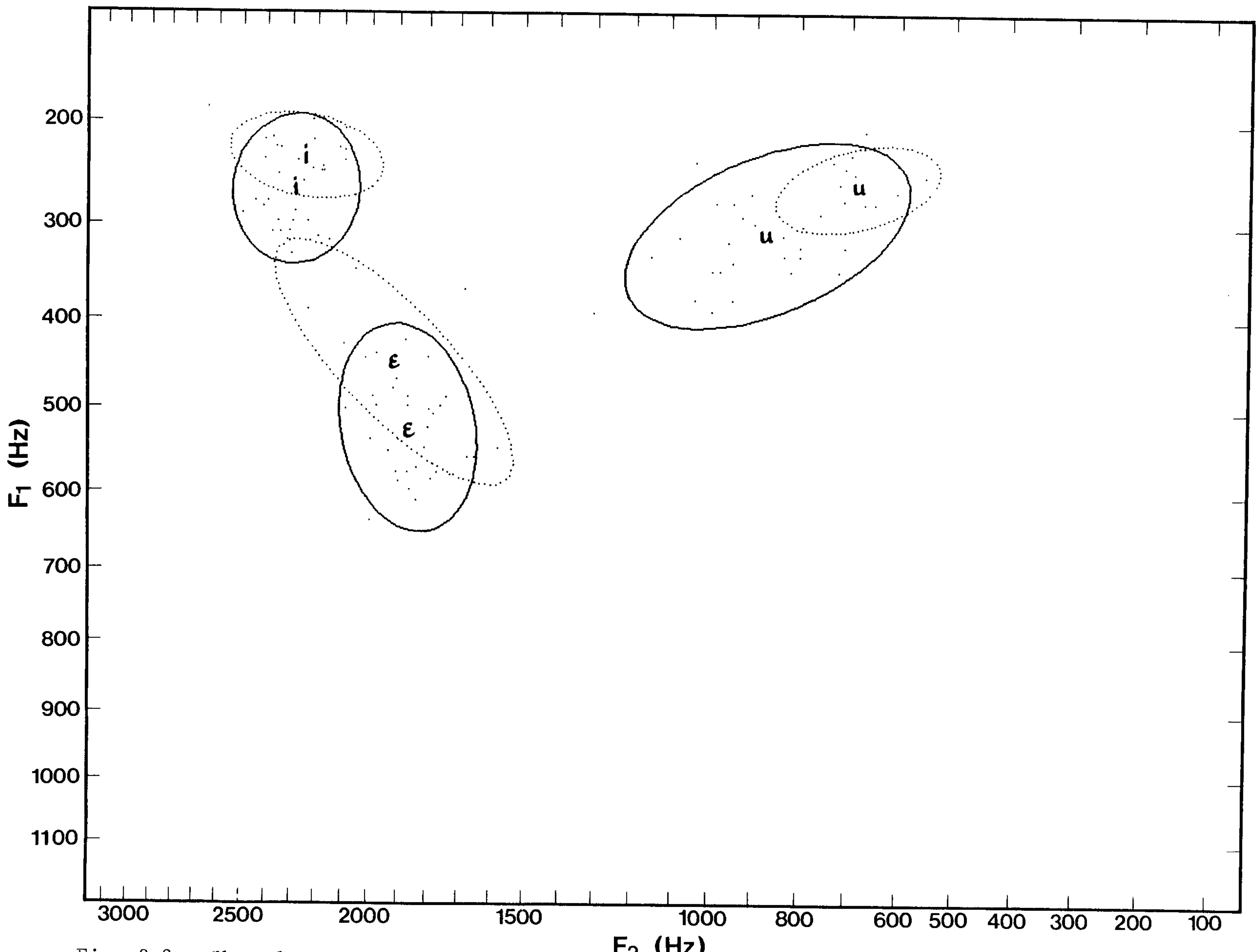

Fig. 3.2: Shared vowels of English(solid) and German (dotted)

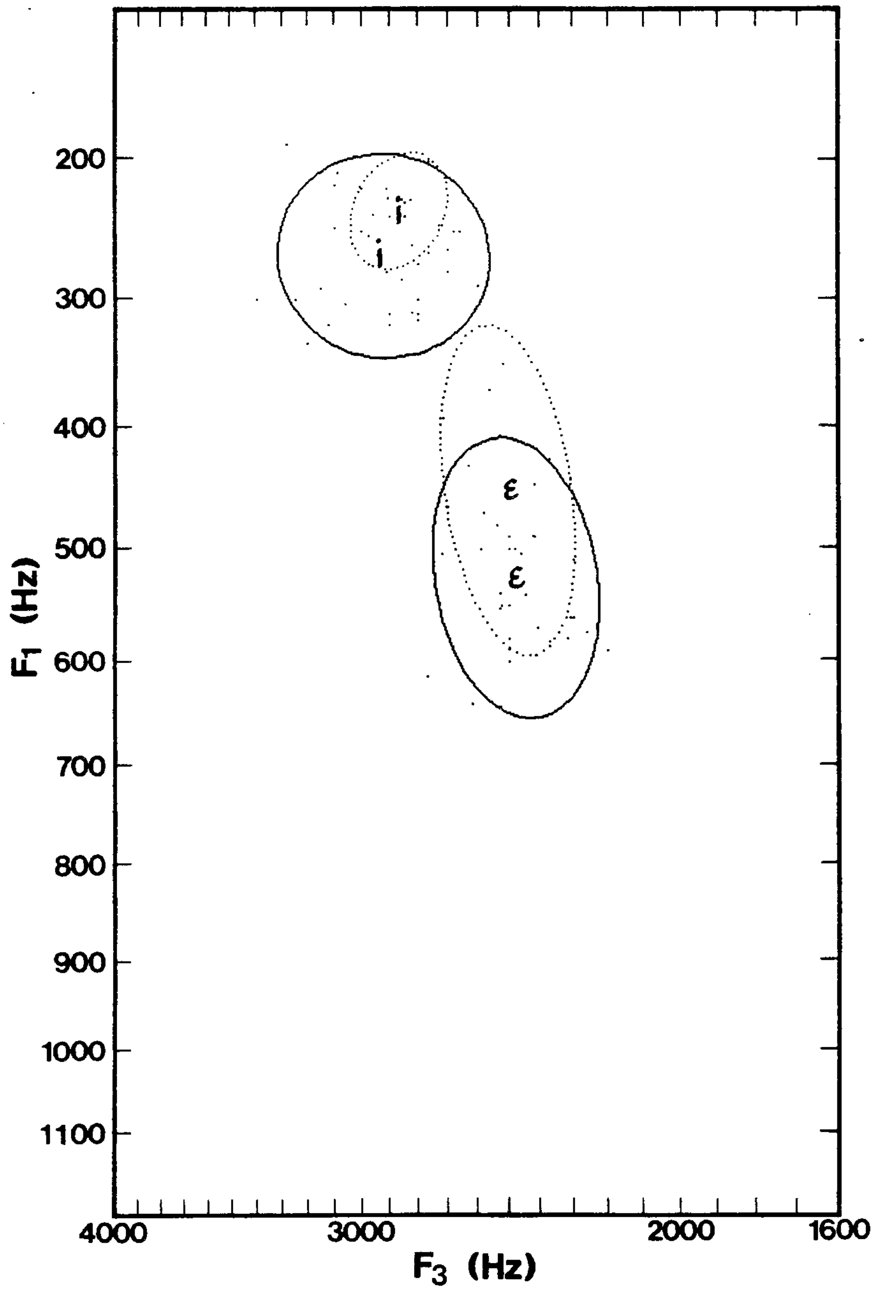

Fig. 3.3: Shared vowels of English (solid) and German (dotted)

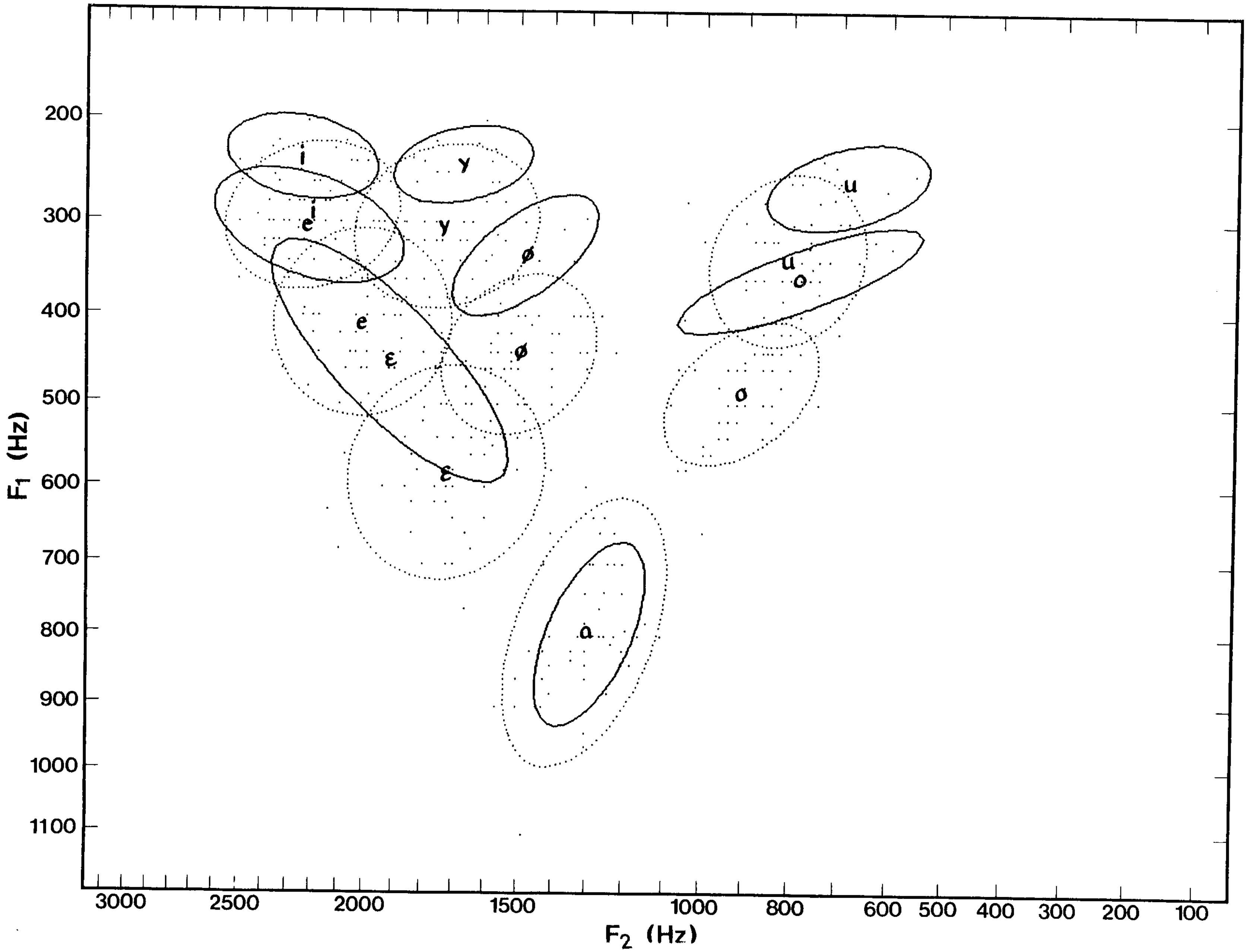

Fig. 3.4. Shared vowels of German (solid) and Dutch (dotted)

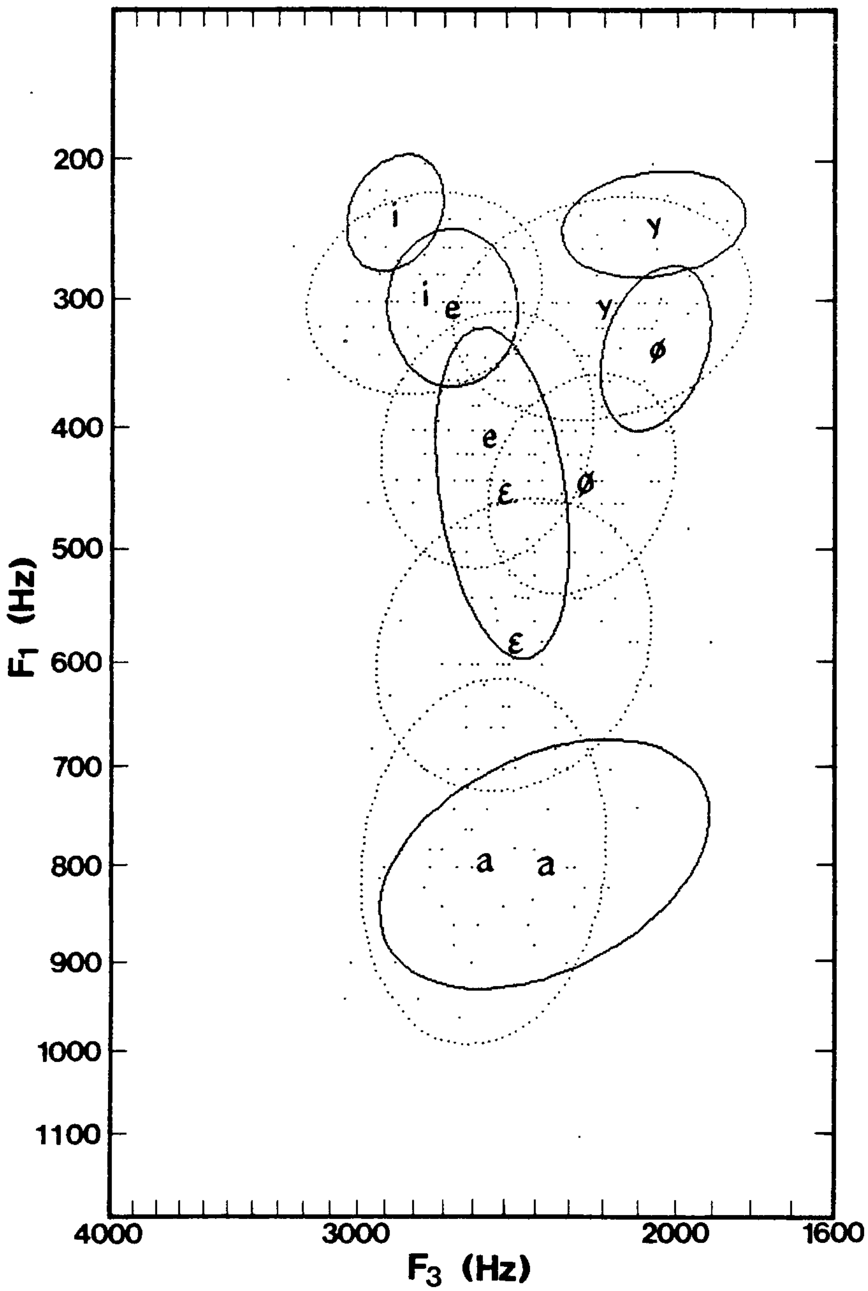

Fig. 3.5: Shared vowels of German (solid) and Dutch (dotted)

their borders the two are mutually intelligible, although neither the ABN Dutch nor the Standard Northern German of this sample approaches such an extreme. Dutch and German have considerably more vowels in common than do English and German; there are Dutch vowels corresponding to all eight of the long vowels of German. The quality differences among these vowels belie the areal and genetic relatedness of the two languages.

In the domain of F1 there is a significant language effect, showing German vowels to be on the average higher than their Dutch counterparts. The Duncan analysis reveals that, while the non-low vowels of German are significantly higher than those of Dutch, the low vowel [a] is not significantly different. It is, therefore, not sufficient to say that the German tongue position is uniformly higher than that of Dutch; any descriptively adequate account of these two languages must make note of the similarity of the low [a] vowels.

There are other particulars as well, which are not apparent from the ANOVA statistics alone. For example, among the significant height differences between the two languages, those of greatest magnitude are in the mid-vowel range. This fact receives implicit corroboration from ten Cate _et al._ (1976:25) who observe that the vowel [ɛ] is "somewhat more open in Dutch than in German". They report a tendency on the part of Dutch students to pronounce the German mid vowels [e ø o] as [i y u], which, in light of the ANOVA results, might be an overcompensation for the quality difference between the two languages. The proportionately smaller differences among the high vowels receive no mention at all.

In the domain of F2 there is no significant language effect, but there is a pattern effect which divides the vowels into natural classes based on the feature of rounding. All of the rounded vowels, [u o y ø], have higher F2 values in Dutch than in German, while the unrounded vowels have lower F2 values. The central vowel [a] is almost identical in the two languages. These trends lend support to the notion that the greater peripherality of German is linked to lip rounding, although it should be emphasized that the differences among the front rounded vowels, which are critical to this argument, are not statistically significant.

In the domain of F3 there are no significant language or pattern differences, and only [ø] and [a] differ significantly across languages. However, this analysis does not include the back vowels [u o], due to the unavailability of the F3 data for German, and it should therefore not be taken as representative of the system as a whole.

English-Dutch [i u ɩ ɛ ɔ ɑ]

English and Dutch share only about half the vowels in their respective inventories. The point vowels [i] [u] and [ɑ], though not Dutch [a] or English [æ], are among the vowels common to both languages. There are significant language and pattern effects for each of the formants.

The F1 results suggest that English utilizes more of the vowel space than does Dutch, its high vowels being significantly higher and its low vowel [ɑ] significantly lower than the corresponding vowels of Dutch. Yet this pattern is not carried on by all the remaining (non-point) vowels. Low-mid [ɔ] does indeed follow the pattern of the low vowel [ɑ], but low-mid [ɛ] does not; Dutch [ɛ] is

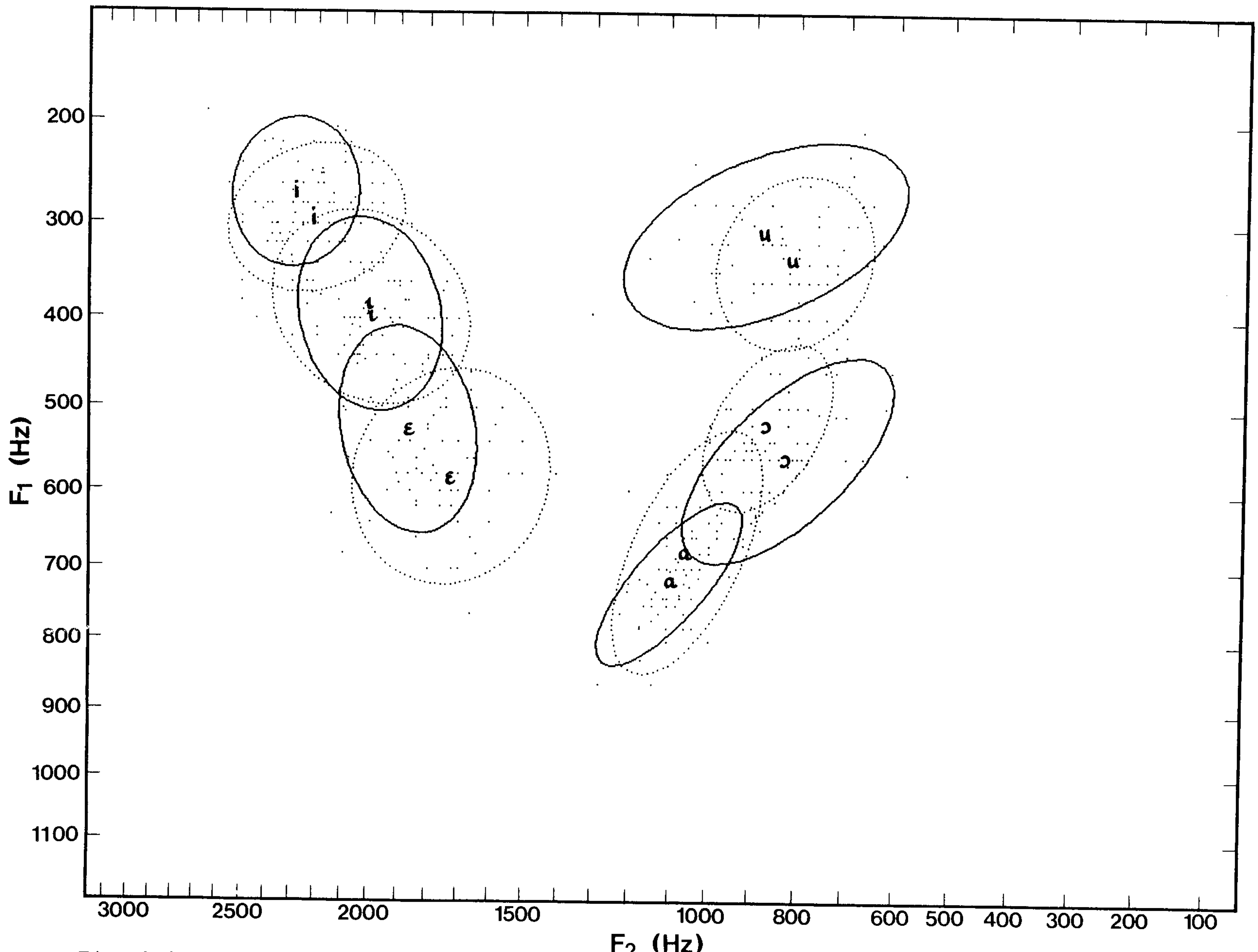

Fig. 3.6: Shared vowels of English (solid) and Dutch (dotted)

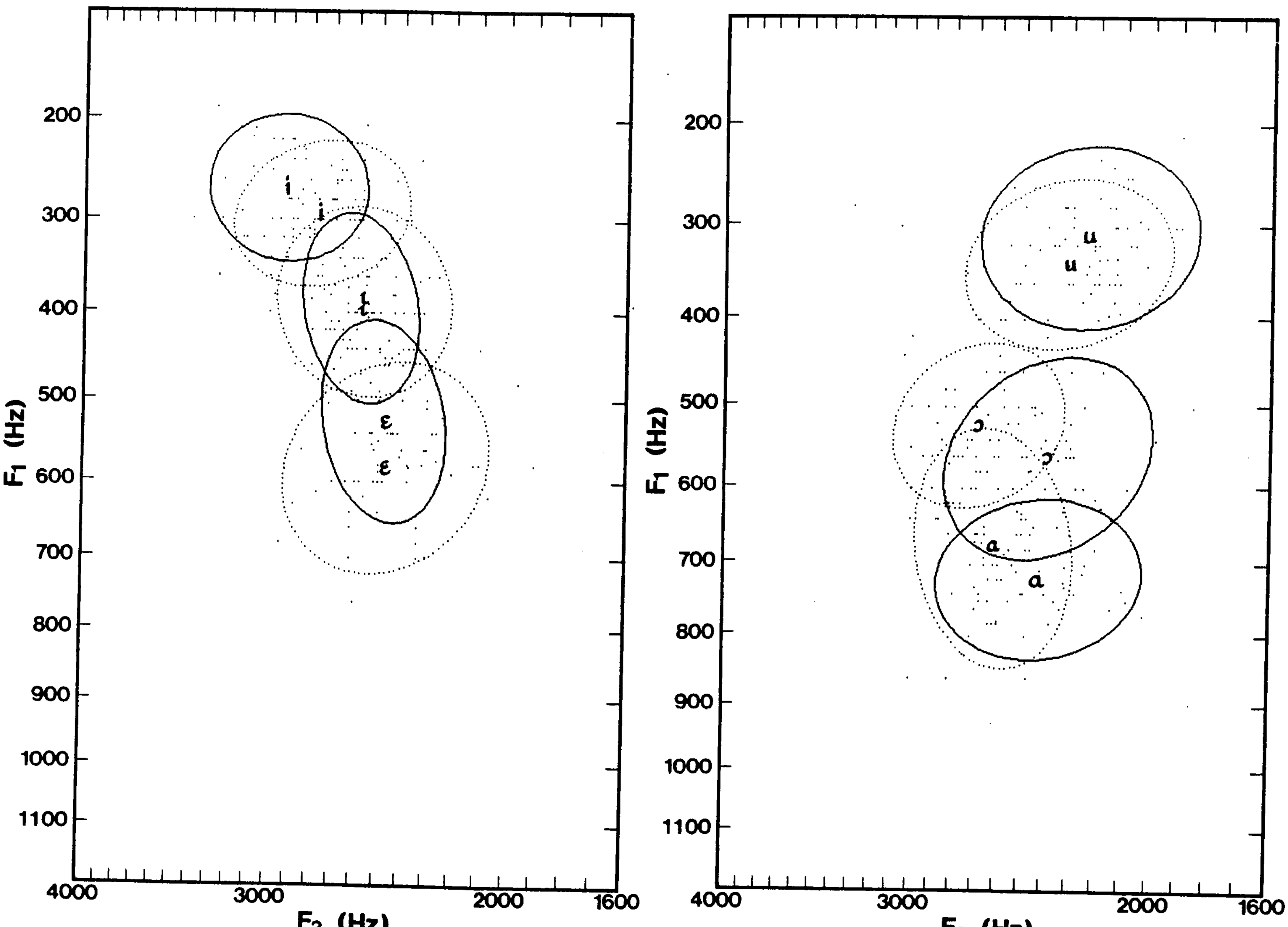

Fig. 3.7: Shared vowels of English (solid) and Dutch (dotted)

"more open than English [ɛ]" (Koolhoven 1968:8), following the pattern of the high vowels. Furthermore, the lower-high vowel [ɩ], which might be expected to display cross-linguistic differences similar to those found in the high vowels [i] and [u], is in fact nearly identical in these two languages. Any attempt to account for the differences between Dutch and English solely in terms of an expanded range of F2 in English inevitably falls short of descriptive adequacy.

The F2 effects cannot be associated with any single feature, or feature complex (e.g. peripherality). There are significant differences in the vowels [i u ɔ ɛ], but not in [ɑ] or [ɩ]; the vowels [i u ɛ] have higher F2 in English, and [ɔ] has higher F2 in Dutch. Because of these rather unnatural groupings, the differences must be treated individually in a phonetic description of these languages.

The F3 results reinforce some of the significant differences in F2, and are phonetically more interpretable than the F2 results. The three back vowels have consistently higher F3 values in Dutch than in English. In contrast, the F3 values of the front vowels are nearly identical in the two languages, or, in the case of [i], even higher in English than in Dutch. However, not much can be made of this separation into the natural classes front/back or rounded/unrounded, for F3 is not as strongly indicative of these phonetic parameters as is F2. In the absence of similar patterns in the F2 data, the F3 results are of diminished importance.

<u>German-Bavarian</u> [i y u e ø o ɛ a]

From a genetic standpoint one would perhaps least expect to encounter significant phonetic differences between the vowels of Standard German (here spoken by six speakers from northern Germany) and those of Eastern Central Bavarian (here spoken by twelve Austrians). Yet, considering the rich system of phonemic contrasts developed in Bavarian, such differences are not out of the question. In fact, there are significant language differences in both F1 and F3, and significant pattern differences in all three formants.

Closer inspection of the data reveals that most of the corresponding vowels are nearly identical in F1. What height differences there are seem to be localized in the two lowest vowels, [ɛ] and [a], which are both lower in Standard German. (Indeed, if the ANOVA procedure is repeated for the non-low vowels [i e y ø u o] only, the F1 pattern difference vanishes.) The difference in means between the German [ɛ] and the Bavarian [ɛ] is unusually large, but it should be noted that [ɛ] is the most variable of the German long vowels, whereas Bavarian [ɛ] has much less variance, perhaps because the Bavarian system includes a fourth long front vowel, [æ], lower than [ɛ].

The F2 patterns in Fig. 2.8 indicate a tendency for the vowels of Bavarian to be more advanced in the phonetic space than those of German. The F2 values of Bavarian [y ø o ɛ] are significantly higher; those of [u a] only very slightly higher. The two vowels which display the opposite tendency, [i] and [e], are precisely those in which F3, rather than F2, is generally considered to be the primary determinant of phonetic frontness; in fact Bavarian [i] and [e] are more fronted in the F1 x F3 space (Fig. 2.9) than are German [i] and [e]. Thus, the tendency for Bavarian vowels to be more fronted is reinforced by the patterns in

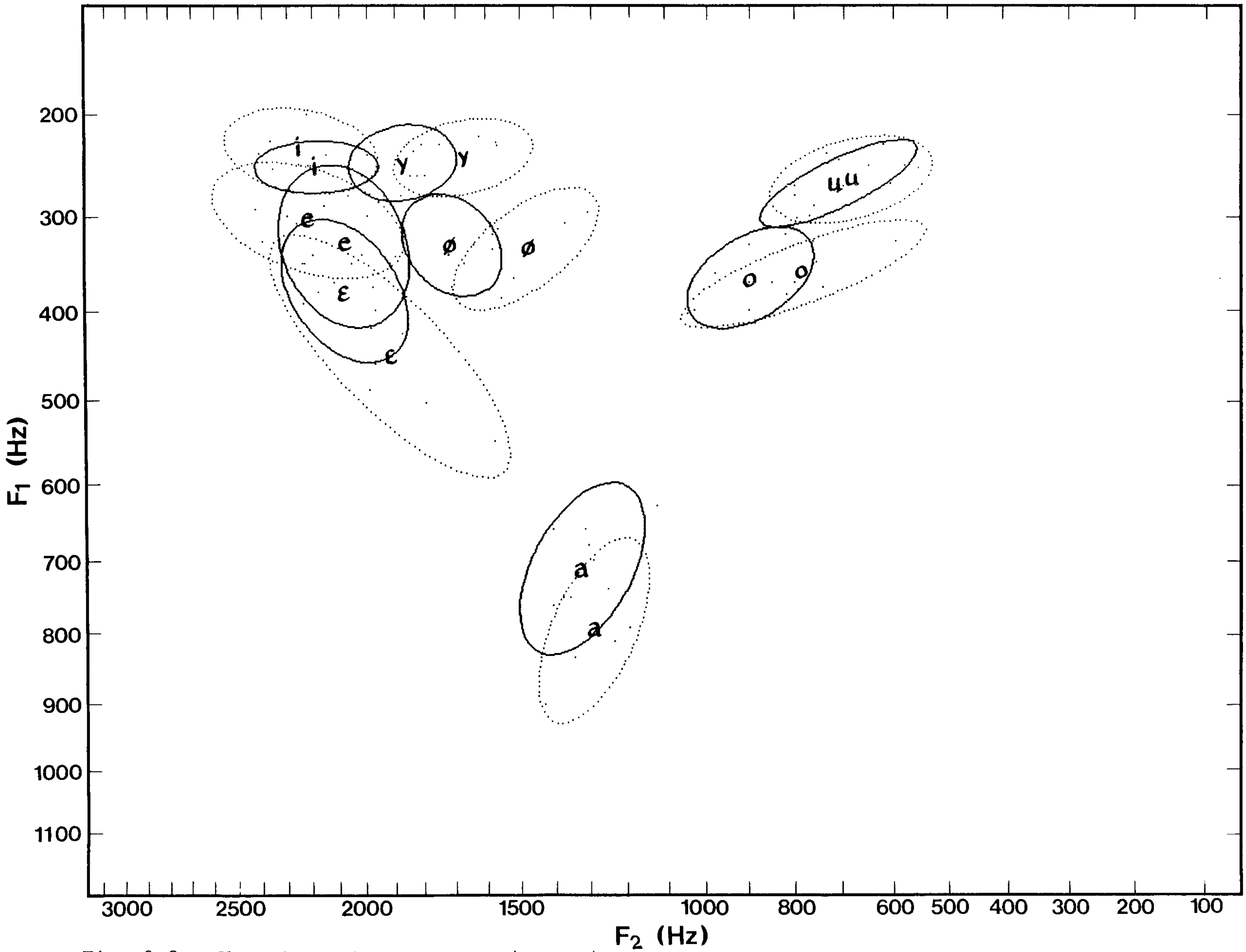

Fig. 3.8: Shared vowels of German (dotted) and Bavarian (solid)

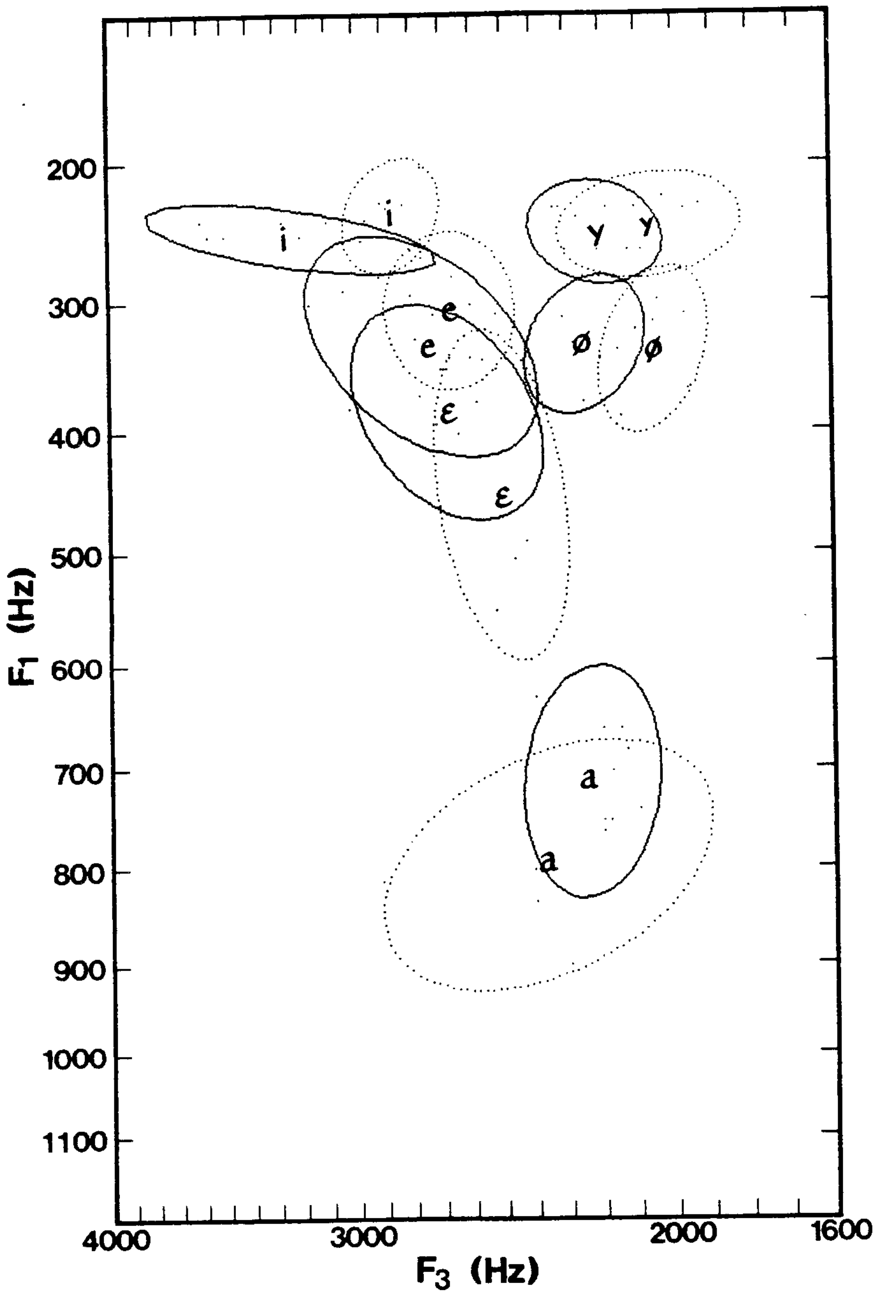

Fig. 3.9: Shared vowels of German (dotted) and Bavarian (solid)

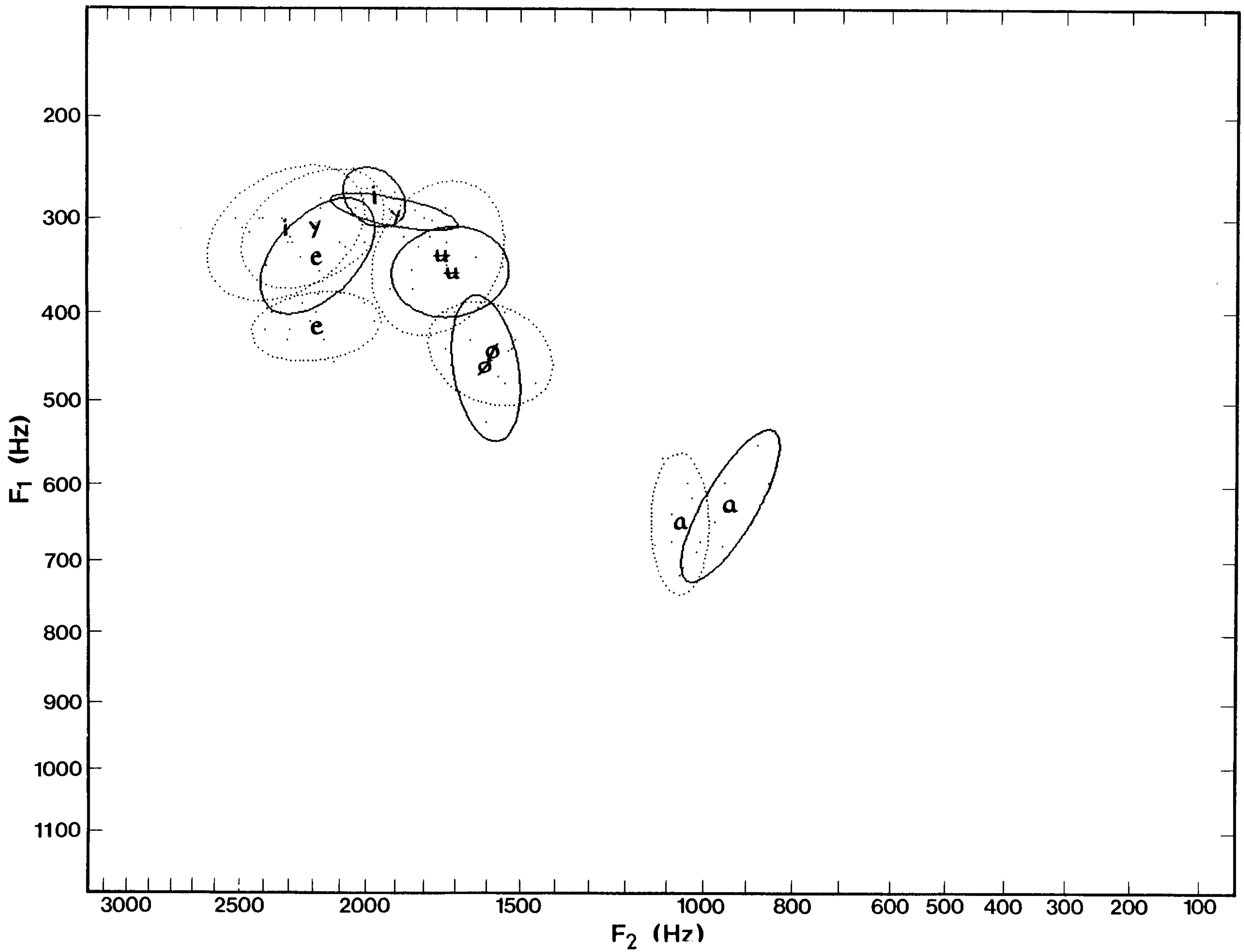

Fig. 3.10: Shared vowels of Swedish (solid) and Norwegian (dotted)

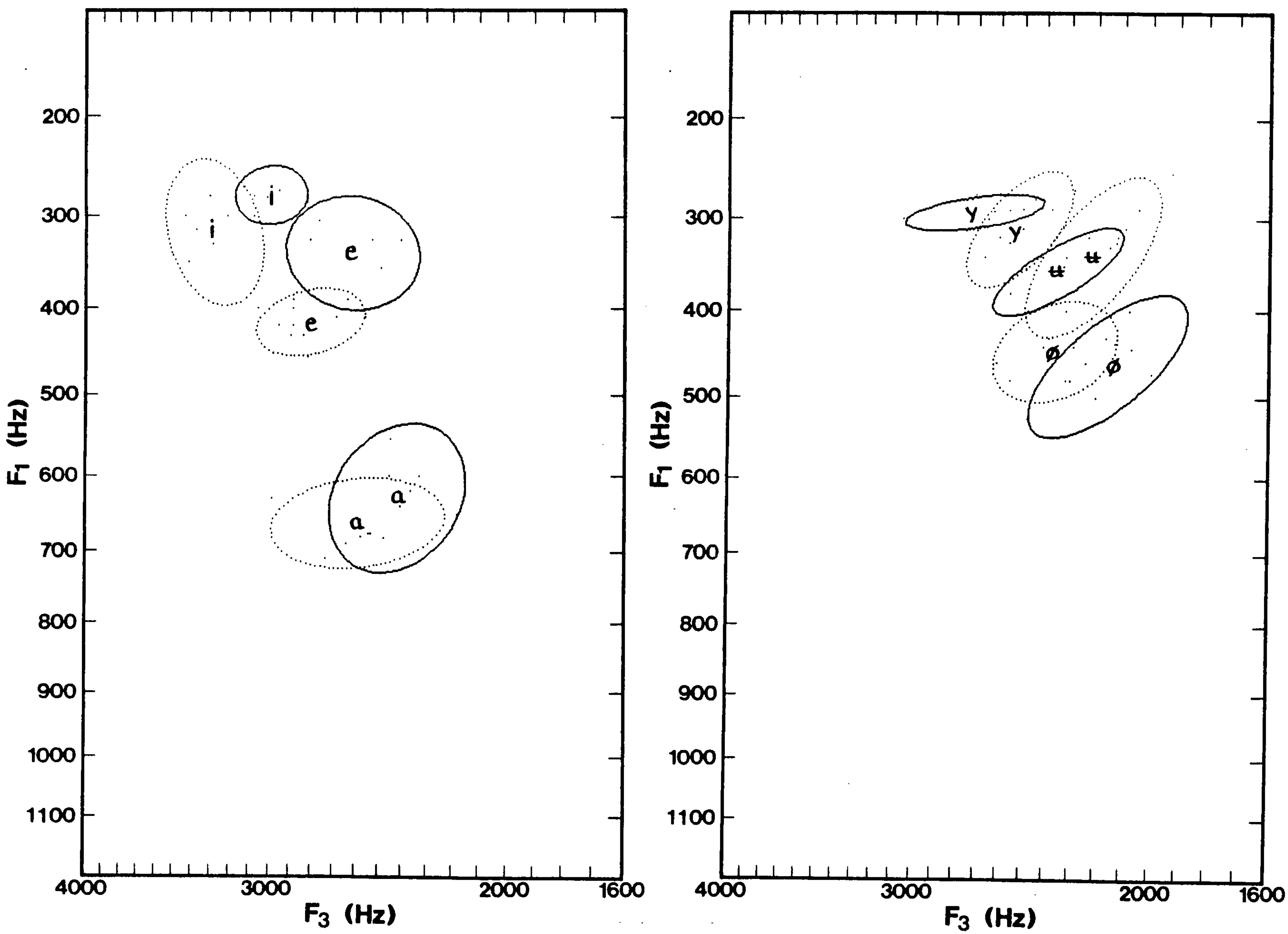

Fig. 3.11: Shared vowels of Swedish (solid) and Norwegian (dotted)

F3. However, the non-significance of the F2 and F3 differences in [e], [a], or [u] counteracts this tendency to a degree.

Swedish-Norwegian [i y u ʉ e ø ɑ]

As in the previous example, it would seem unlikely for there to be reliable and significant phonetic differences between two languages as closely related as Norwegian and Swedish. It is generally assumed that "Norwegian pronunciation is, on the whole, very similar to that of Swedish" (Walshe 1965:107). Yet significant language and pattern effects are present in all three formants of these data.

Most of the vowels of Swedish tend to be higher than their Norwegian counterparts, although in only one of these seven vowels, [e], is the difference a significant one. Swedish also displays a weak tendency toward having lower F2 and F3 values than Norwegian; the relatively few vowels which are significantly different between these languages all point in this direction, as do most of the others.

The vowel [ʉ] is one of the two (non-significant) exceptions to each of the above generalizations. It should be pointed out that this vowel is in fact not strictly comparable across languages. Irrespective of notation, the Swedish [ʉ] is phonetically a front vowel, though it alternates with the short central vowel [ɵ] (Fant 1971). (Fant also notes that [ʉ] may be articulated with a tongue position as low as that of the Swedish high-mid vowel [ø], although this is not apparent in these data.) In comparison, the Norwegian [ʉ] is a high central vowel. The use of identical phonetic symbols in transcribing these vowels is more a reflection of their common historical origin (both arose from the fronting of [u] in the course of the Scandinavian chain shift of the back vowels) than of phonetic reality (Bergman 1968). Yet even when the [ʉ] vowels are excluded from the Norwegian and Swedish data sets, the analysis of variance shows significant language and pattern differences in all three formants.

It should be pointed out that no high or mid back vowels were included in the F2 and F3 analyses, due to the unavailability of these formant values in the Norwegian data. With the present analysis shaped almost exclusively by the front vowels, it cannot be said for certain whether the Norwegian system is uniformly more advanced in the phonetic space, or whether it occupies a wider range of F2 and F3 values. Even if there were evidence in favor of the latter, it would be difficult to ascribe this language difference to either the feature of fronting or of rounding, in light of the ambiguity in the front rounded vowels.

English-Danish [i u ɛ ɔ æ]

The vowels of Danish are said to be 'spoken higher in the mouth' than the vowels of English. The ANOVA procedure lends support to this view. There is a significant F1 language effect in the five shared vowels of English and Danish; each Danish vowel is in fact significantly higher than the corresponding vowel of English. One is tempted to suggest that there is a higher 'base of articulation' in Danish as a means of capturing this generalization. The significant F1 pattern effect, reflecting a proportionally smaller difference in height among the highest and lowest vowels, [i] [u] and [æ], may be attributable to articulatory

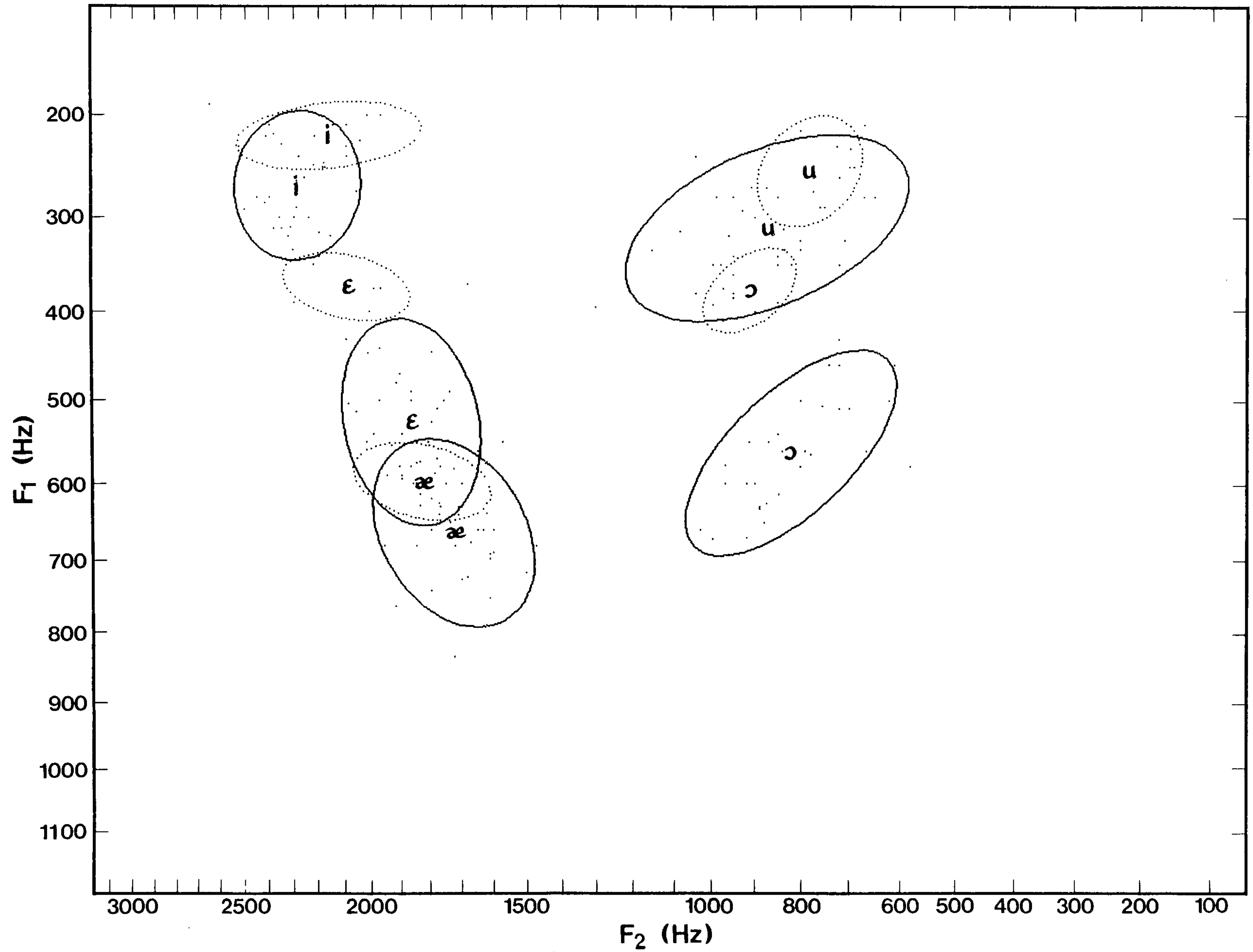

Fig. 3.12: Shared vowels of English (solid) and Danish (dotted)

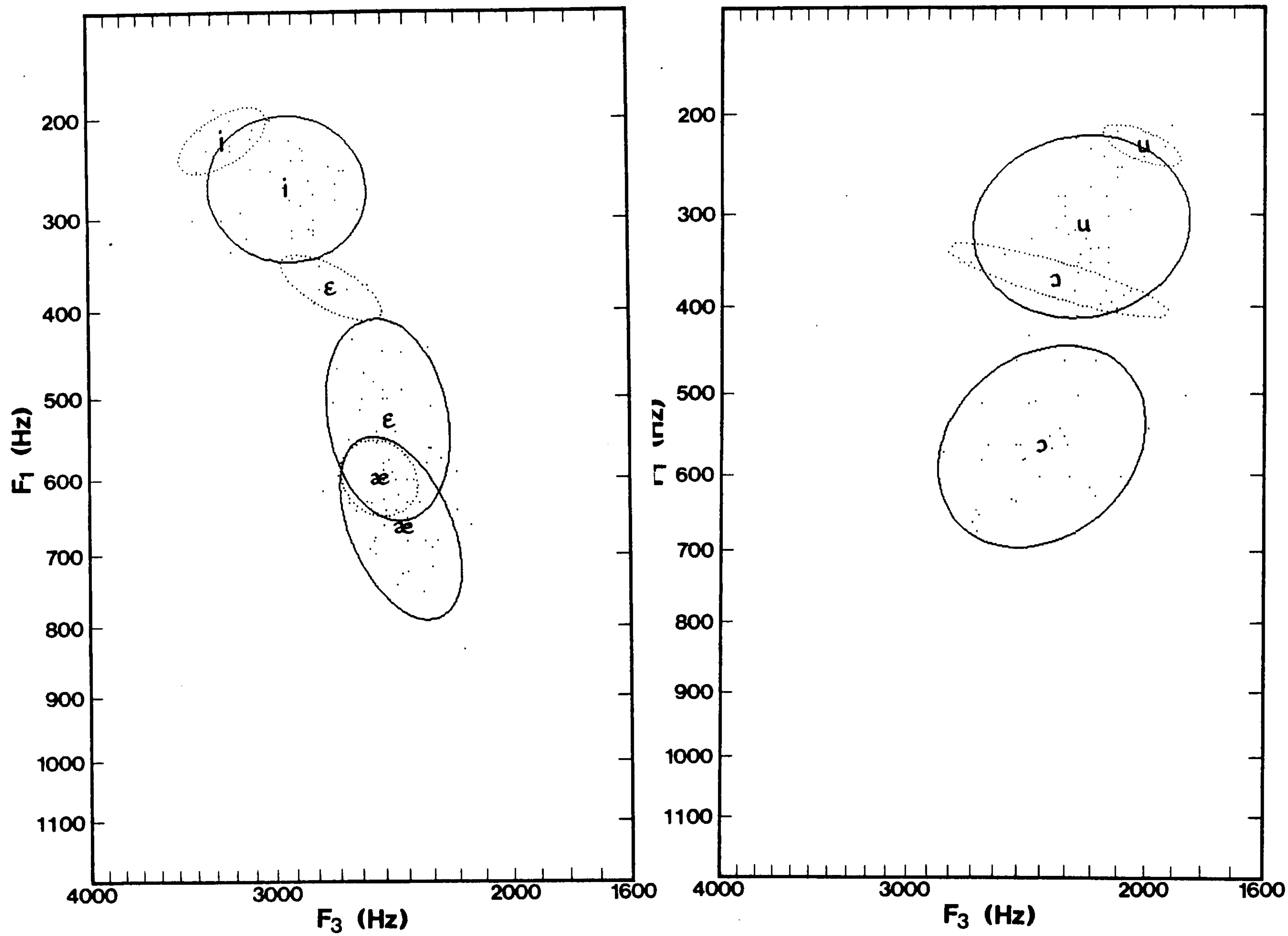

Fig. 3.13: Shared vowels of English (solid) and Danish (dotted)

limitations, rather than any difference in linguistic quality; there is simply less room for vowels to vary near the boundaries of the phonetic space (Disner 1978). This point will be discussed further in the final chapter.

The front vowels of Danish are uniformly fronter than their English counterparts, so long as one defines this parameter along the stronger of the higher formants, which in the case of high front vowels is generally F3. There is no such uniformity among the two back vowels. [u] appears to be more advanced or less rounded in English, consistent with the [ɯ̟] articulation prevalent among American speakers, while [ɔ] is very similar across the two languages. Once again it should be pointed out that the F3 ranges in the Danish back vowels are based on a very limited number of tokens.

Frisian-Dutch [i y u e ø o ɛ ɔ a] and
Frisian-English [i u ɛ ɔ]

Modern West Frisian is spoken in the Netherlands province of Friesland and on the islands of Schiermonnikoog and Terschelling. In spite of its areal proximity to Dutch, the Frisian language is genetically more closely related to English. Both are said to have descended from an original Anglo-Frisian language, and they developed along parallel lines long after their separation (Sipma 1913).

The question of whether Frisian vowel quality is better predicted by its areal relationship with Dutch or its genetic relationship with English receives only implicit -- and, for that matter, conflicting -- answers in the literature. Sipma, writing in English, compares the Frisian vowels to their English counterparts (e.g. "[o] in open syllables is as the English [o] in 'rope'" 1913:6). Cohen et al (1971:120) state that the Frisian vowels are articulatorily similar to the vowels of Standard Dutch, and, since acoustic data for the vowels of Frisian is "not generally available", they refer the reader to their acoustic data of Standard Dutch. An intermediate stand is taken by Fokkema (1967:19-22), who compares some Frisian vowels to their English counterparts and others to their Dutch counterparts. Writing in Dutch, Fokkema notes that:

"The long [i] sounds like the English [i] in 'cheese'."

"[e] sounds like the Dutch [e] in 'heel'."

"Long [ɛ] sounds about like the sound in English 'bed'."

"[ɔ] is approximately like English [ɔ] in 'crawl'."

"[o] is somewhat duller in quality than Dutch [o]."

"[u] sounds like English [u] in 'room'."

"The long [y] sounds approximately like the Dutch [y] in 'duur'."

"The long [ø] is similar to the Dutch [ø]."

"[a] is spoken somewhat farther front in the mouth than Dutch [a]."

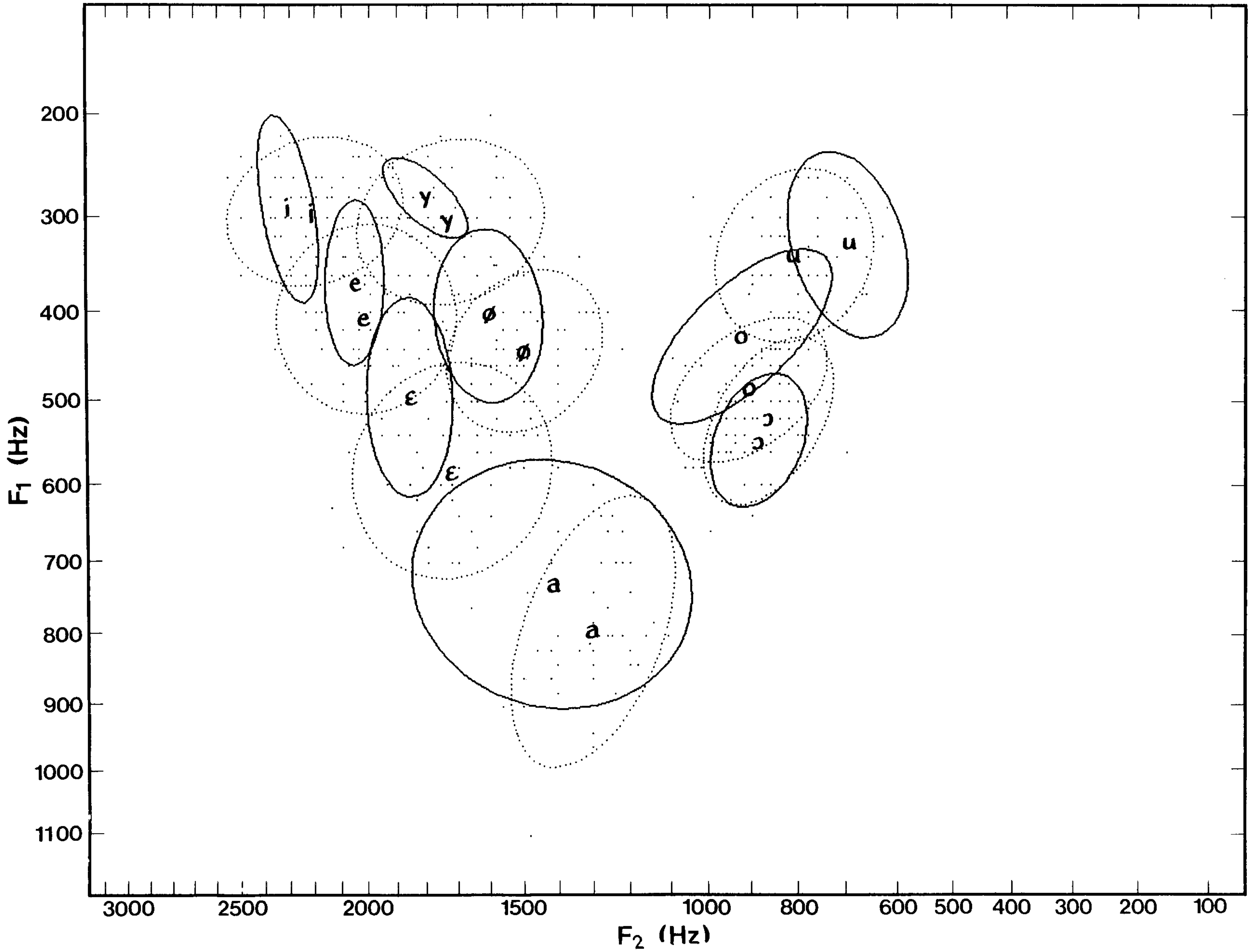

Fig. 3.14: Shared vowels of Frisian (solid) and Dutch (dotted)

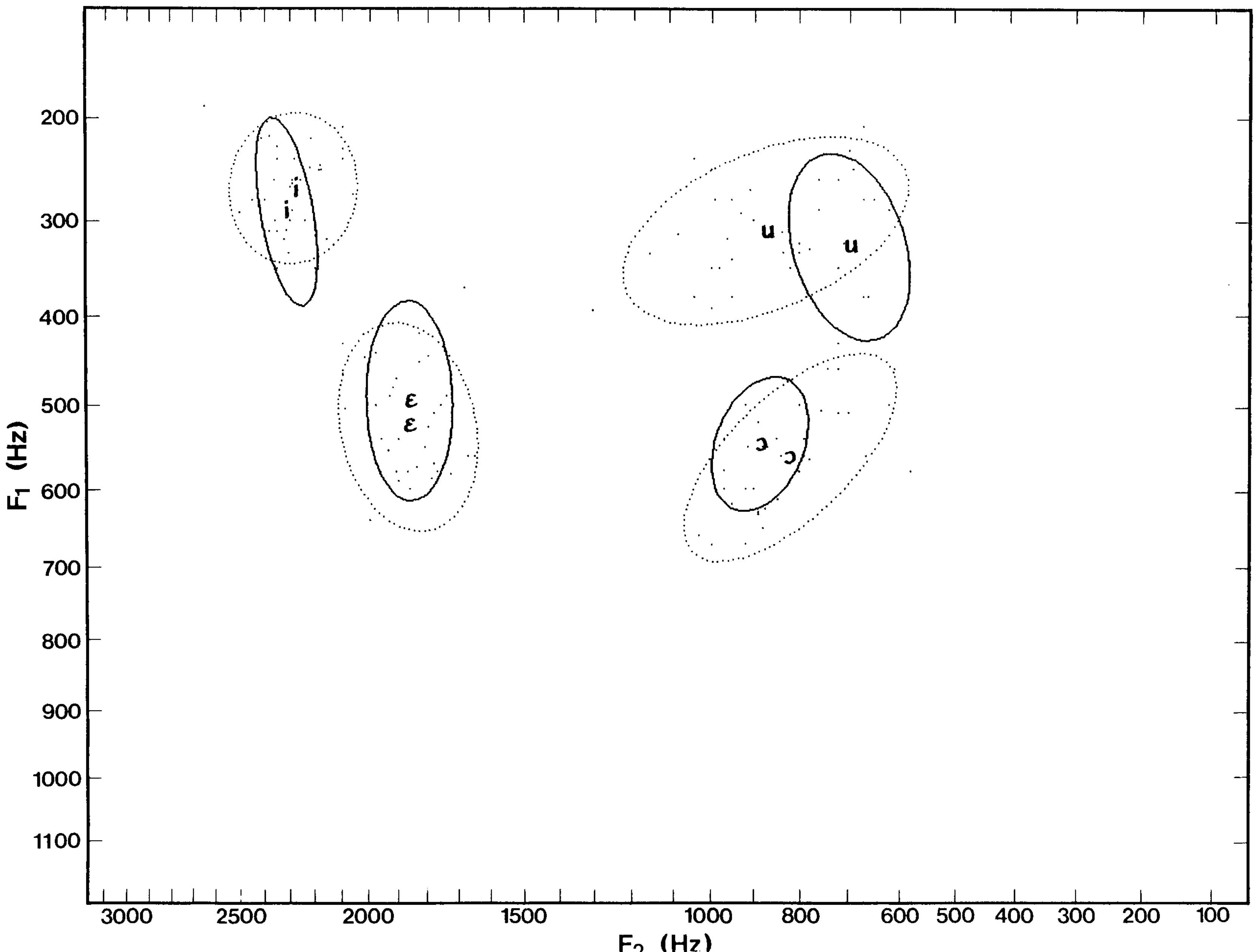

Fig. 3.15: Shared vowels of Frisian (solid) and English (dotted)

It should be noted that there are no English counterparts to [a] or to the front rounded vowels of Frisian, and hence no opportunity arises to compare these vowels with English.

Analysis of the variance in these two-formant data reveals significant F1 and F2 language differences between the nine Frisian vowels and their Dutch counterparts. The vowels of Dutch tend to have lower values of both F1 and F2 than do the vowels of Frisian, though in very few individual cases are these differences significant. This may well be a linguistic phenomenon, but it is also the pattern that arises when a group of speakers with larger vocal tracts is compared to a group of speakers with smaller vocal tracts. It is unfortunate that the speakers of Frisian in this sample (who, like all Frisians, are bilingual) did not also provide a sample of Dutch; this would have made it possible to determine whether linguistic or anatomical factors are responsible for these patterns in the data.

The analysis of variance reveals no significant language differences between the four vowels common to English and Frisian.

There is a significant F1 pattern effect in the Dutch-Frisian analysis, stemming largely from the vowels [ɛ a o], which are significantly lower in Dutch. There is no such pattern effect in F2. In the English-Frisian analysis there is a significant F2 pattern effect, largely determined by the significantly lower F2 of Frisian [u] FN, but no F1 pattern effect.

Yet on the whole, neither Dutch nor English differs greatly from Frisian. From a phonetic standpoint the Frisian vowel system is more or less intermediate between the more disparate vowel systems of Dutch and English, which is not surprising in light of its historical development.

<u>Danish-Swedish</u> [i y u e ø o ɛ] and
<u>Danish-German</u> [i y u e ø o ɛ]

Danish is another language which shares areal characteristics with one language and genetic characteristics with another. Its geographic proximity to German and its genetic relationship to Swedish each would be expected to have an influence on its phonetic development. Yet far from incorporating the phonetic characteristics of both Swedish and German, the Danish vowel system quite clearly stands apart from either one.

There is a significant F1 language effect in both of these analyses. Figures 3.16 and 3.18 reveal that the Danish system is higher, overall, than either German or Swedish. More specifically, each Danish vowel is higher than its Swedish and its German counterparts. The differences are significant for all seven of the corresponding vowels of Swedish and Danish, but only for the three lowest vowels common to German and Danish, [o ø ɛ].

There are significant F1 pattern effects in both analyses as well. Here, as in the English-Danish example above, the phonetic boundary appears to exert an

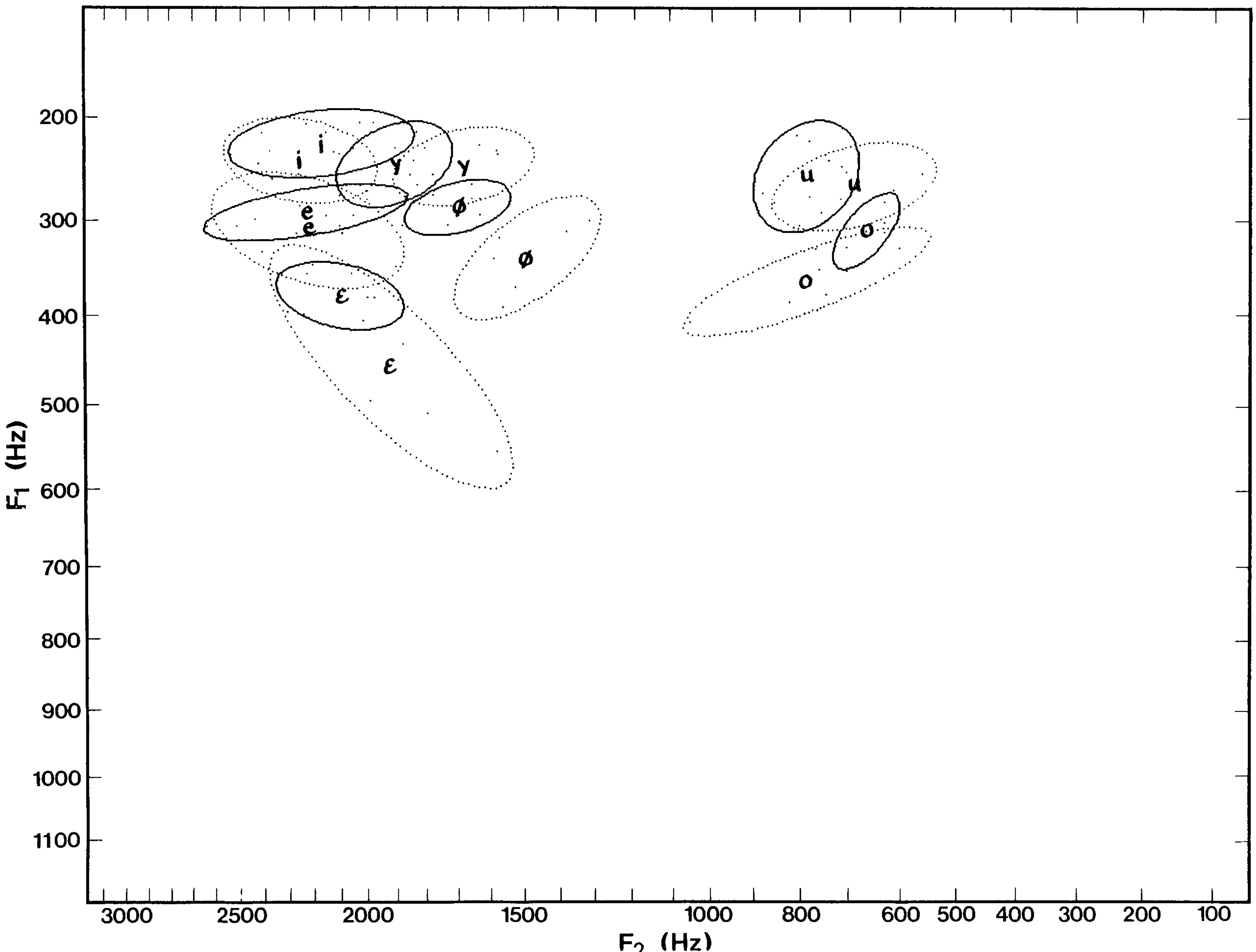

Fig. 3.16: Shared vowels of Danish (solid) and German (dotted)

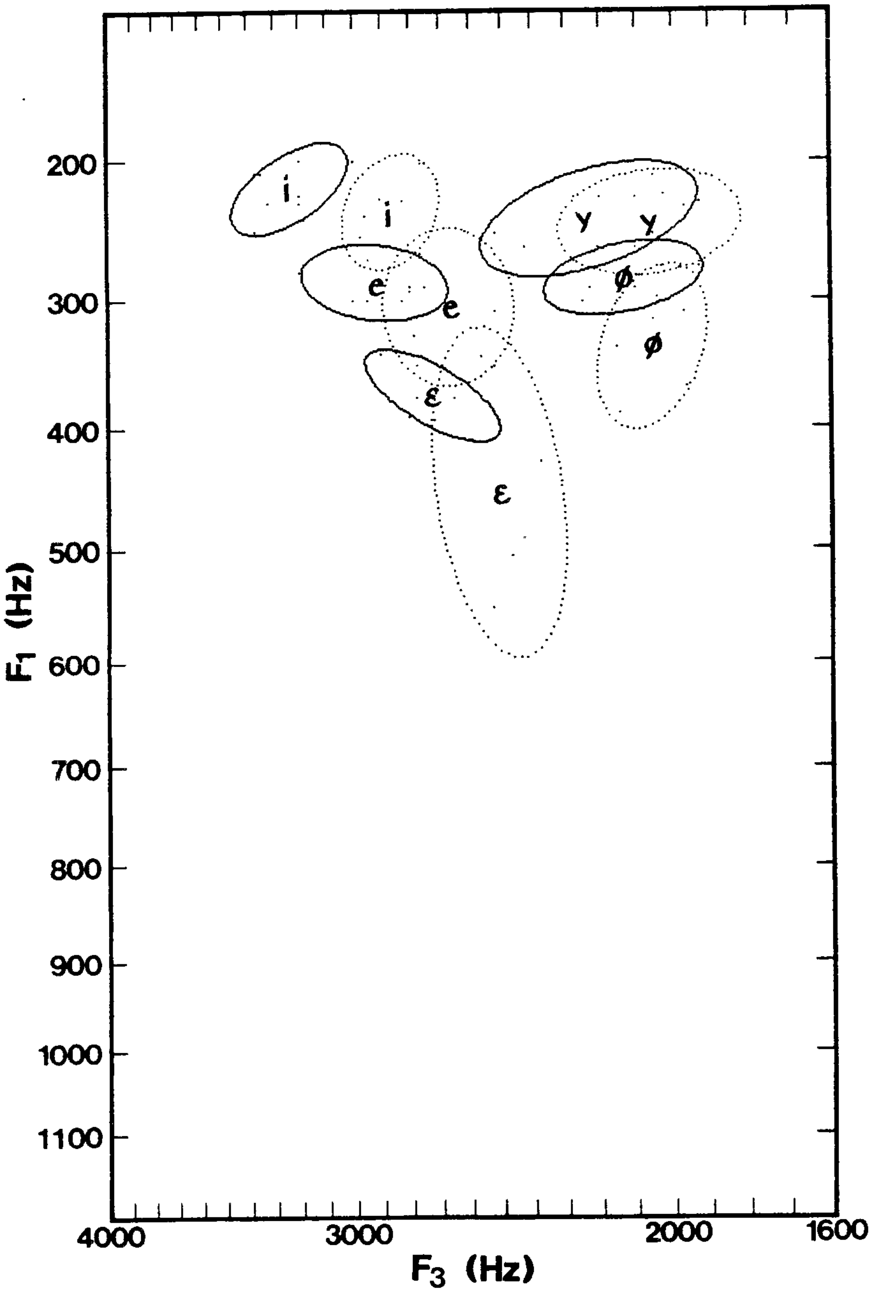

Fig. 3.17: Shared vowels of Danish (solid) and German (dotted)

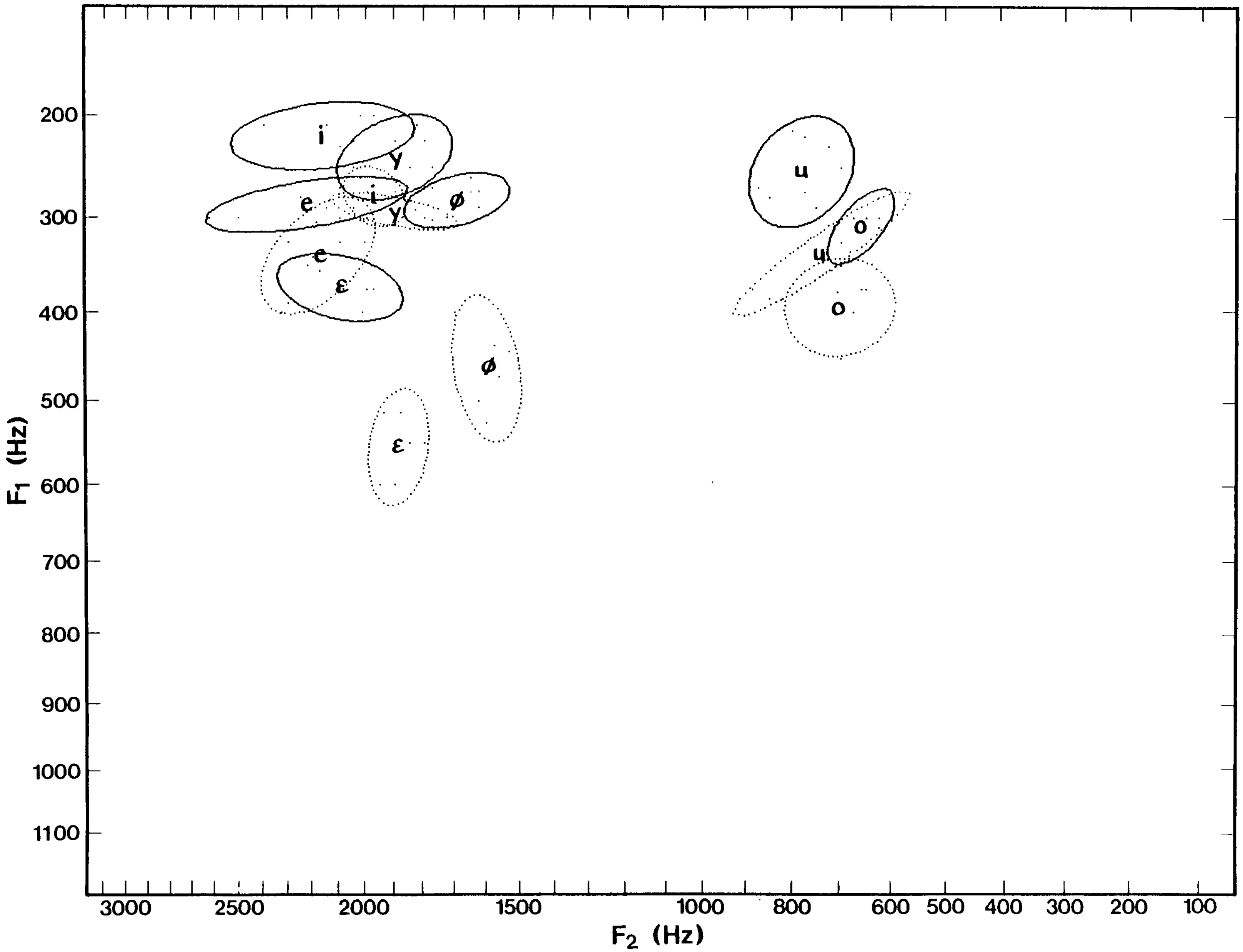

Fig. 3.18: Shared vowels of Danish (solid) and Swedish (dotted)

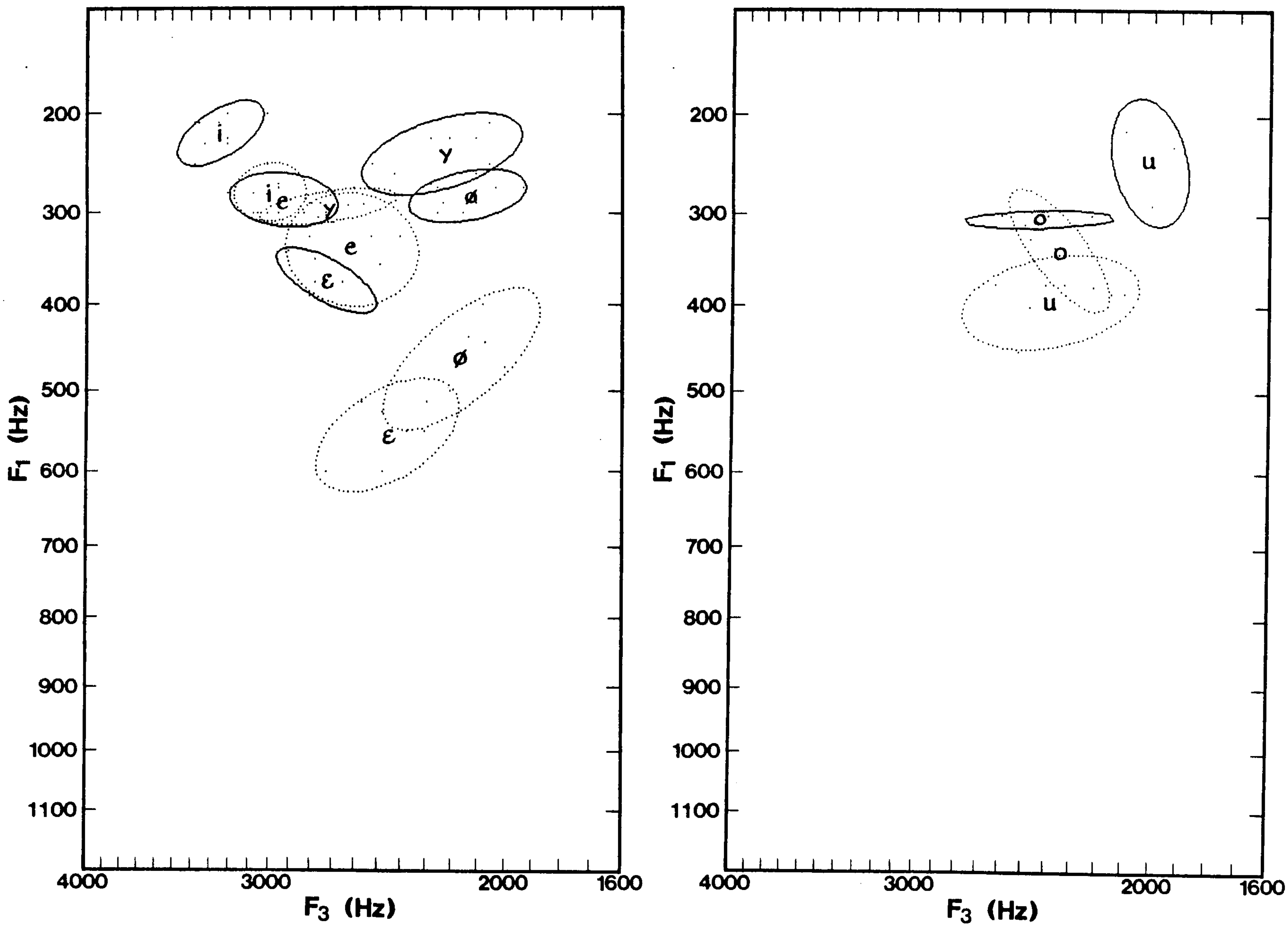

Fig. 3.19: Shared vowels of Danish (solid) and Swedish (dotted)

influence on what might otherwise be a quite uniform height difference between the languages. This is particularly noticeable among the high vowels in the German-Danish comparison; no more than 20 Hz. separates the mean of each Danish high vowel from the mean of its German counterpart. The high vowels of both German and Danish are among the highest, phonetically, in all the languages surveyed. Further evidence of this compression near the phonetic boundary is found among the high-mid vowels. In German the vowel [e] is phonetically higher than either [o] or [ø]; as a result, the German-Danish difference in [e] is not significant, just as the differences in the high vowels are non-significant. In contrast, the high-mid vowels [o ø], which are phonetically lower, follow the pattern of the low-mid vowel [ɛ] in displaying significant cross-linguistic differences.

The results of the F2 and F3 analyses are not as clear-cut as those of F1, due in part to differences in the relative salience of F2 and F3 in different vowels, and in part to specific cross-linguistic differences.

There is a strong tendency among the front vowels for Danish to be more advanced in the phonetic space than either German or Swedish; this is particularly true of the high front vowel [i], which in Danish has an exceptionally high F3. The F2 of this vowel is not proportionately as high. But if the vowel [i] is excluded from the F2 analysis of variance in Danish and German, a significant F2 language effect emerges. This procedure is not unjustified, in light of the fact that F2 is a weaker and phonetically less representative formant than F3 in the vowel [i], as well as in [e]. On the whole, Danish vowels can be said to be uniformly more front than German vowels.

There is a considerably greater spread in F3 between the front rounded and front unrounded vowels in Danish than in either Swedish or German, which suggests more vigorous rounding of the former and greater spreading of the latter two. This is particularly apparent in Figs. 3.17 and 3.19; the front unrounded vowels of Danish have higher F3 values than their Swedish counterparts and the front rounded vowels of Danish have lower F3 values. The net result is that in the Swedish-Danish analysis (with the back vowels virtually excluded) there is no significant difference between the mean F3 values of these two languages. There is, however, a significant pattern difference, which must have a place in any descriptively adequate comparison.

The back vowels [u o] are less consistent than the front vowels; Danish [u] is more advanced, and its [o] less advanced, than the corresponding vowels of German or Swedish. As F3 was measurable in only a small number of tokens of the Danish back vowels, and in none of the German back vowels at all, these results should not be taken as fully representative of the vowels in question.

<u>German-Swedish</u> [i y u e ø o ɛ]

As implied in the preceding section, all of the vowels of German are significantly higher than the corresponding vowels of Swedish. There is, however, no significant difference between the mean F2 of the two vowel systems. Much of the difference in the upper formants is attributable to differences in a single vowel, the front rounded [y], which in German is articulated with the tongue lower and more retracted (Hjorth 1905) and with a smaller lip-opening (Lindau

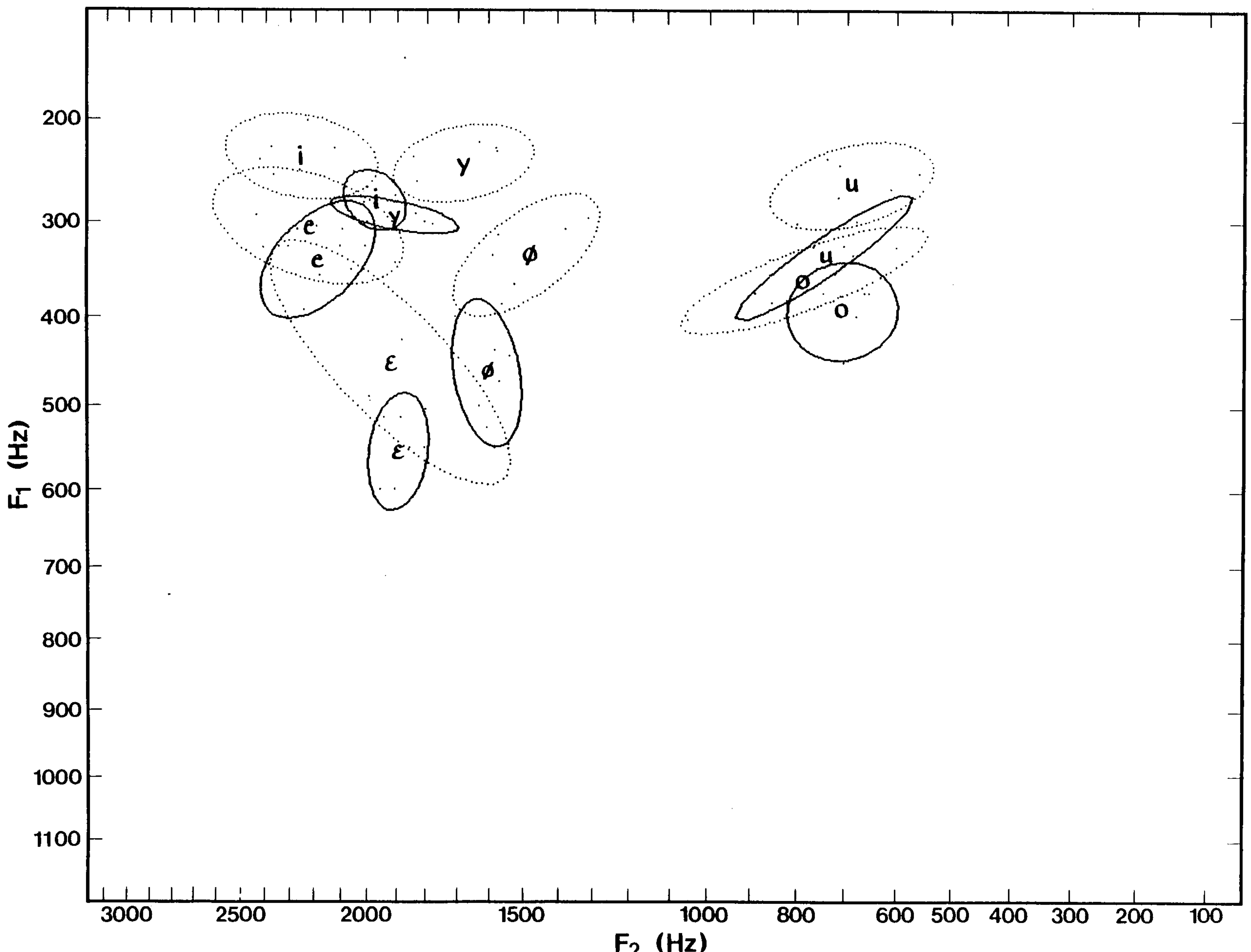

Fig. 3.20: Shared vowels of German (dotted) and Swedish (solid)

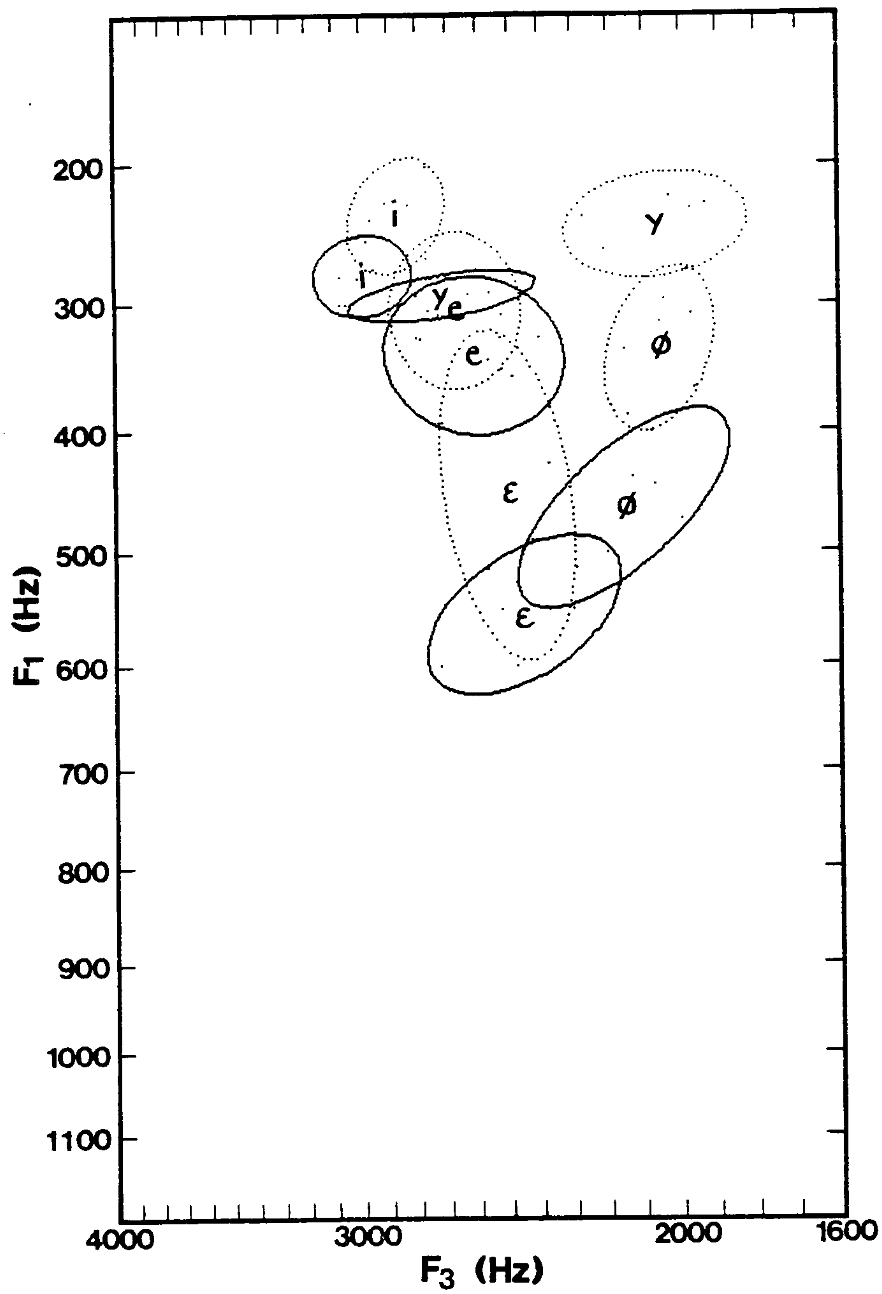

Fig. 3.21: Shared vowels of German (dotted) and Swedish (solid)

1978) than in Swedish. Such articulatory differences tend to lower F2 and F3, respectively. This can be seen in Figs. 3.20 and 3.21. Haugen (1976:257) describes the [y] of Swedish as "intermediate between German [i] and [y]", and he associates this quality difference with the historical fronting of Swedish [u] to [ʉ], which introduced another high front rounded vowel to the system.

English-Swedish [i u ɛ ɑ]

As in the English-German comparison, a relatively small number of vowels are common to English and Swedish, especially in view of the rather large vowel inventory of each language. English lacks a set of front rounded vowels, and its high-mid vowels are diphthongized and therefore not represented in these data; Swedish lacks the rich inventory of low and low-mid vowels, as well as the rhotacized vowels, of English.

There is no significant F1 language difference between the English and Swedish data; of the four vowels compared, only [ɑ] is significantly different across the languages. The difference in [ɑ] may in fact be the result of dialect heterogeneity within the English data. As we have seen, some American dialects have a rather central vowel in the word "hod", rather than the standard [ɑ]. Some of the speakers in the Peterson-Barney sample might indeed have produced this more fronted variant of [ɑ], although the data points for English [ɑ] in Fig. 3.22 do not give the appearance of bimodality. (There are, however, two points lying outside the ellipse boundary which have exceptionally high F1 and F2 for English [ɑ]. These may be different phonetic vowels, or they may simply be the vowels produced by speakers with particularly small resonating cavities or short vocal tracts. One cannot rule out either possibility with the data at hand.)

It is easy to hear that the high vowels of Swedish are even more diphthongized than the corresponding vowels of English. This is an additional dimension of contrast which, however, cannot be captured with these steady-state data.

Three of these four Swedish vowels are significantly more retracted in the vowel space than are the corresponding English vowels; this yields a significant F2 language effect. There is also a significant F2 pattern effect, most likely due to the failure of the fourth vowel, [ɛ], to follow suit. There are no significant cross-language differences in F3, either system-wide or vowel-specific. This is noteworthy in the case of [i], for which F3 is a better indicator of backness than F2. Fant (1965) has observed that the Swedish [i] is articulated at a point 5 mm. farther front than that of English [i], in the prepalatal region; the former is often referred to as tenser or sharper in quality than the latter. The absence of this expected quality difference in [i] is surprising (but see the discussion of the English-Swedish data in chapter 4).

Norwegian-German [i y u e ø]

Five vowels are common to the German and Norwegian vowel systems, but F2 and F3 data are available for only four, the front vowels [i y e ø]. Only these four vowels are plotted in figures 3.24 and 3.25, but the analysis of variance of the F1 data includes the vowel [u] as well.

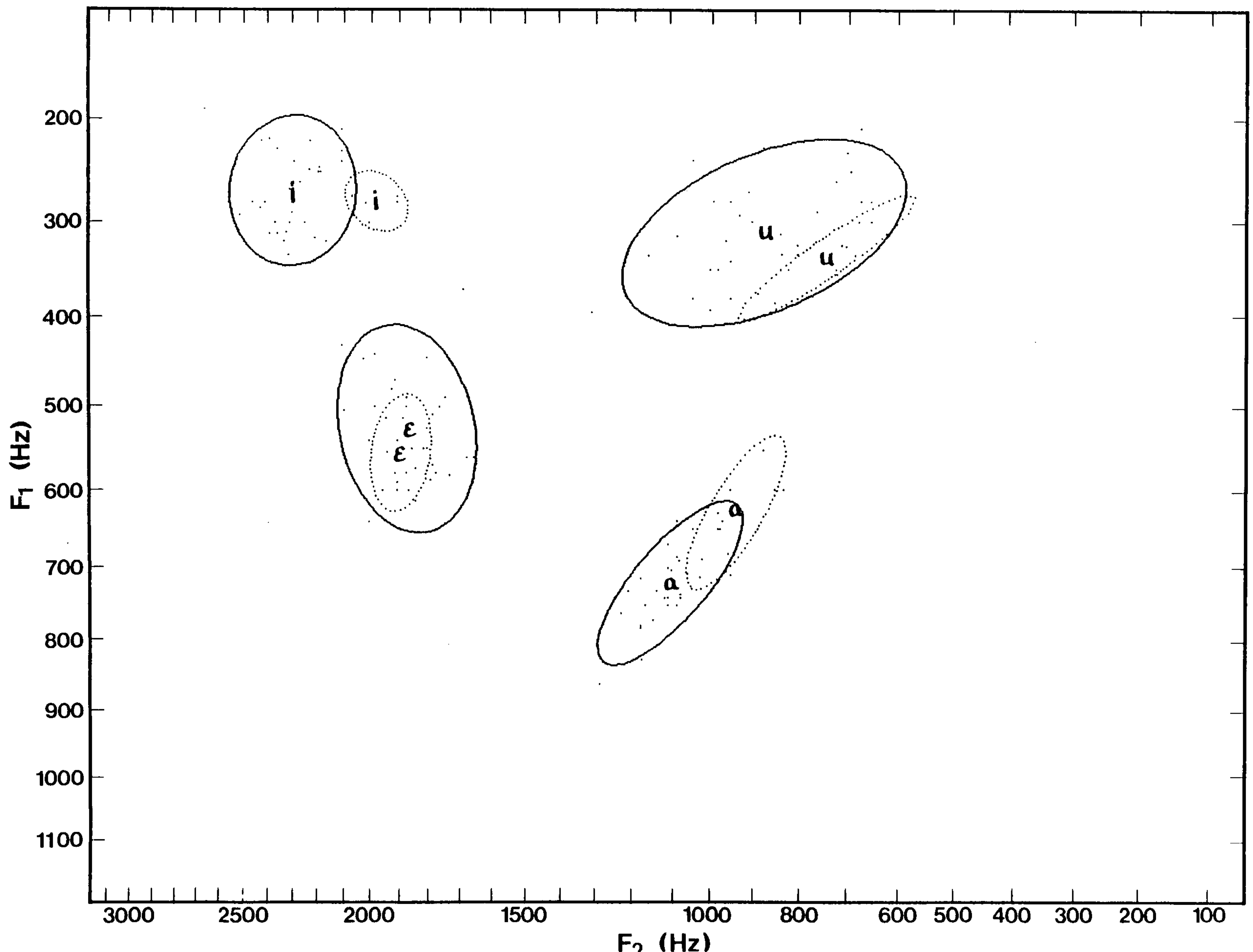

Fig. 3.22: Shared vowels of English (solid) and Swedish (dotted)

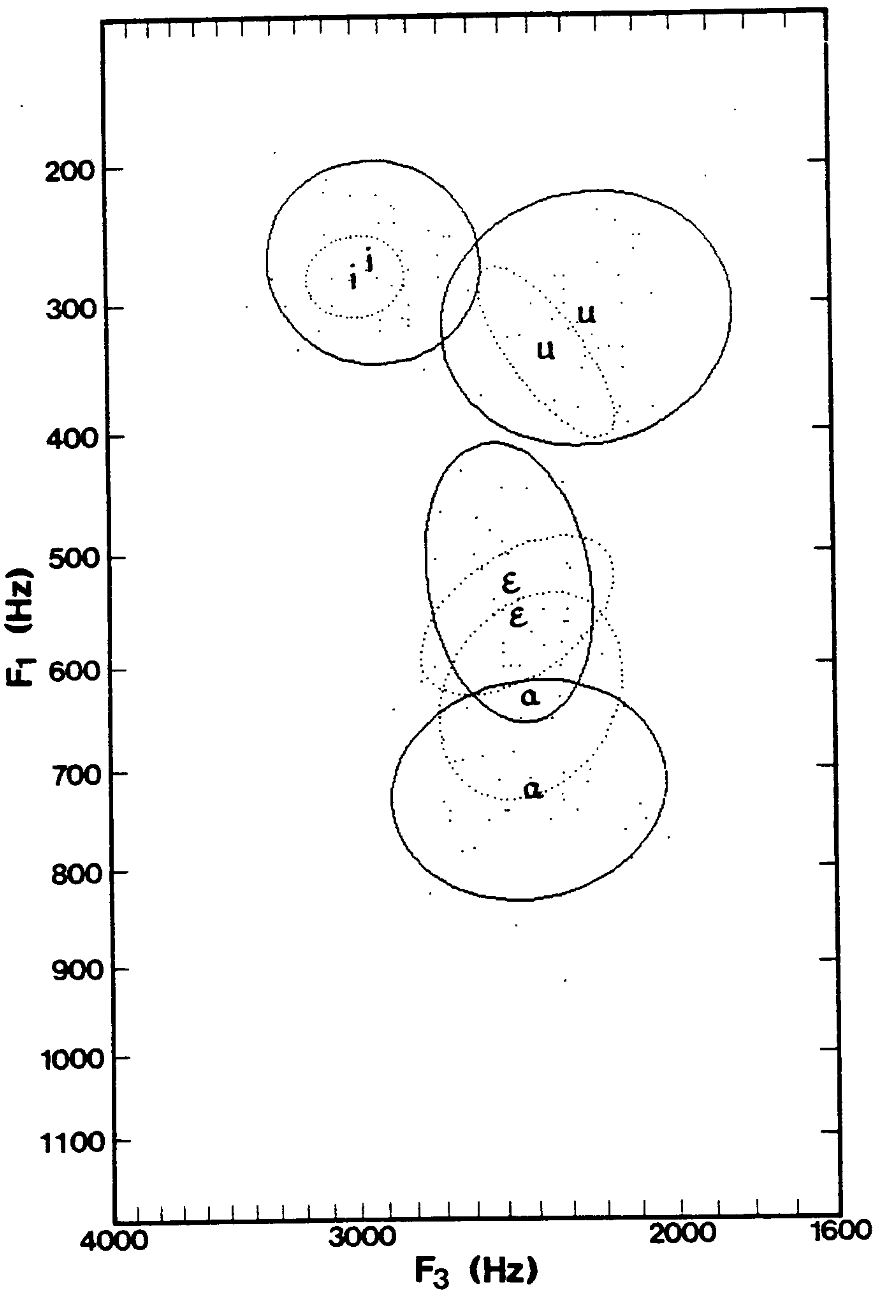

Fig. 3.23: Shared vowels of English (solid) and Swedish (dotted)

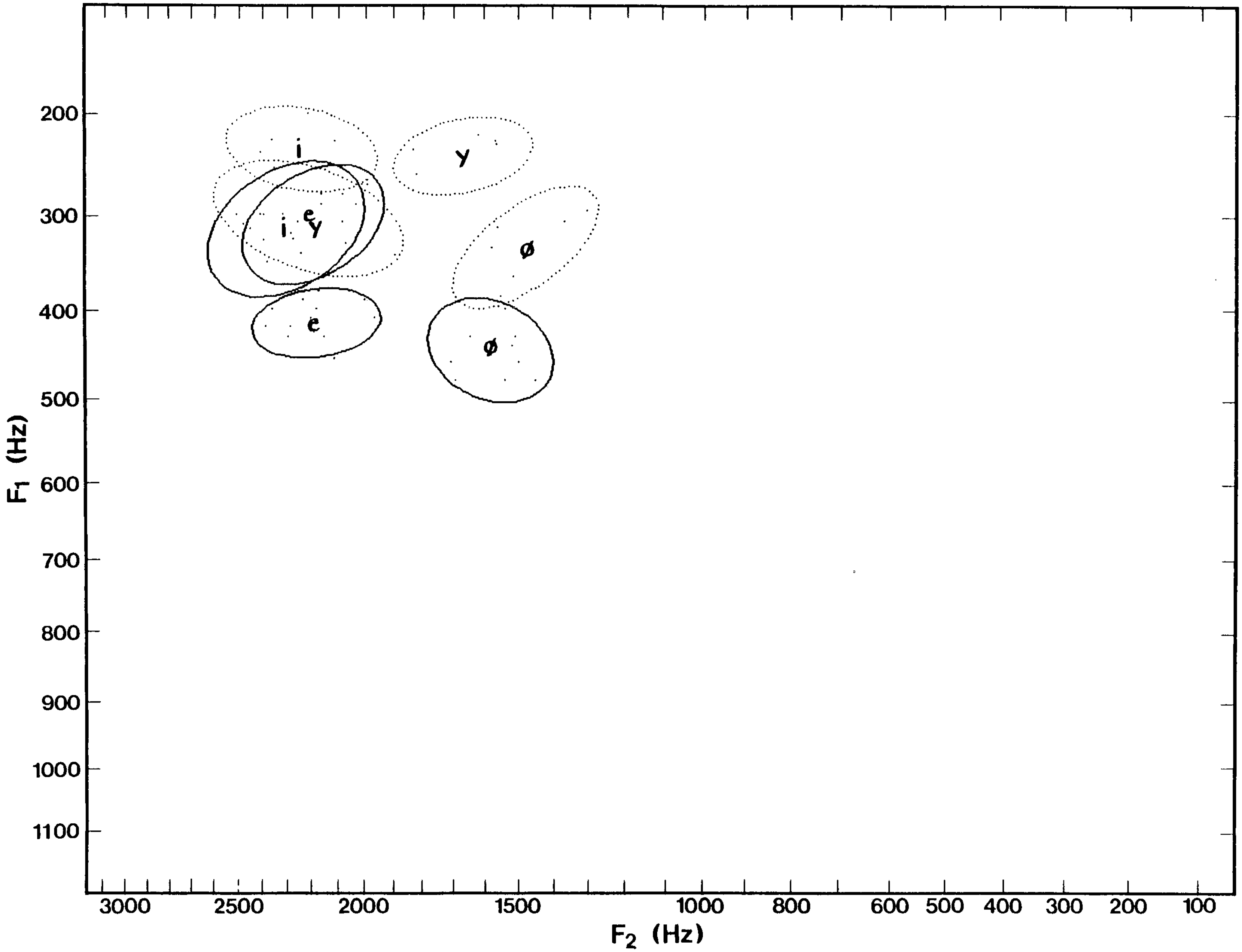

Fig. 3.24: Shared vowels of Norwegian (solid) and German (dotted)

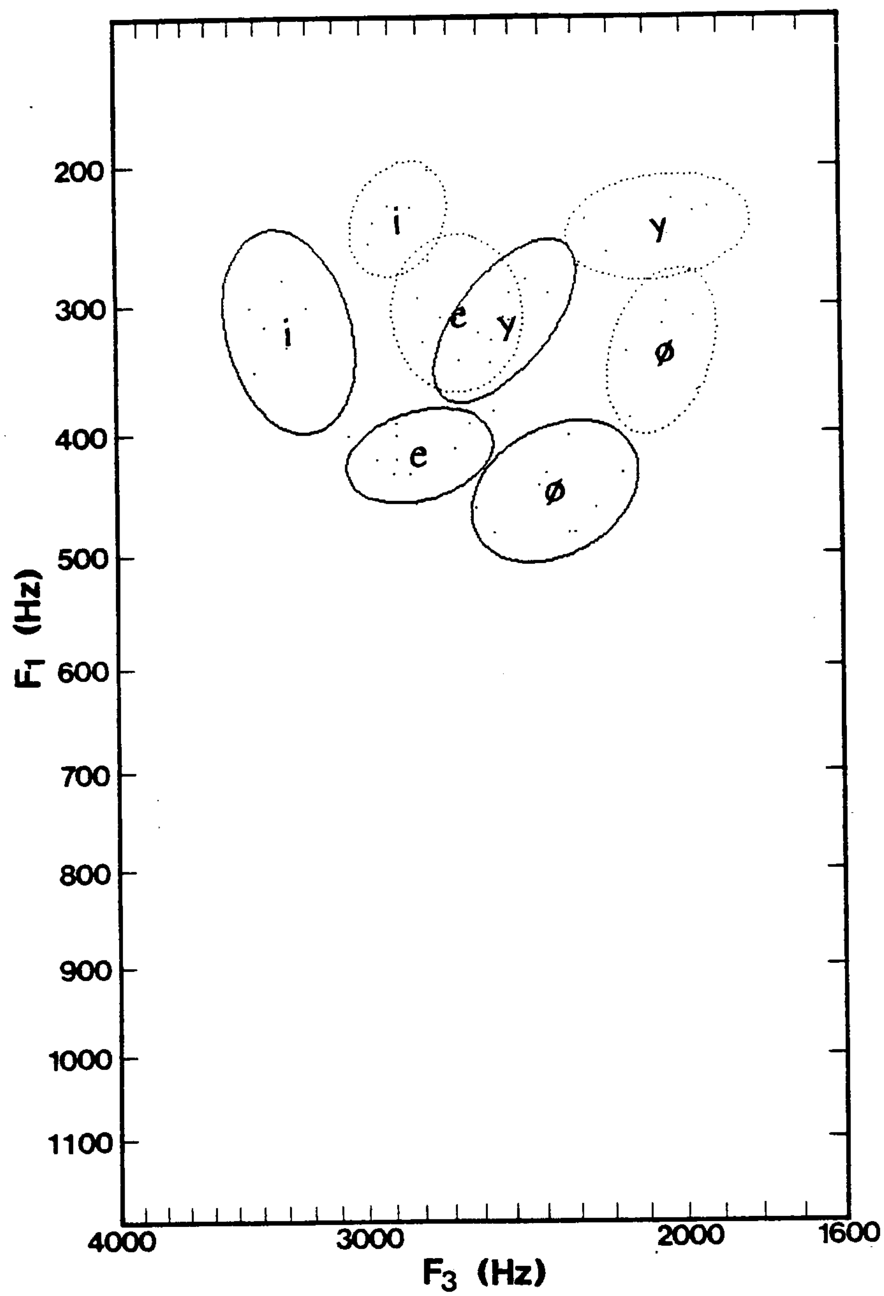

Fig. 3.25: Shared vowels of Norwegian (solid) and German (dotted)

The most striking differences between Norwegian and German are in the domain of F1. Each of the five German vowels is significantly higher than its Norwegian counterpart. This yields a significant language effect in the shared vowels of the two systems. The lack of a significant pattern effect indicates further that the height difference is a uniform one, with all five of the German vowels shifted upward by a comparable amount from the five Norwegian vowels.

Three of the four vowels for which F2 data are available display no significant differences along the F2 parameter. However, the Norwegian mean F2 is significantly higher than the German, evidently due to the very large difference in the remaining vowel, [y]. The Norwegian [y] is characterized by a significantly higher F2 than is the German [y]; the F2 of Norwegian [y] is so high, in fact, that it occupies a portion of the phonetic space nearly identical to that of Norwegian [i] (see Fig. 3.24). This ambiguity is resolved in the domain of F3, as may be seen in Fig. 3.25; the Norwegian [i] and [y] are quite widely separated along the F3 dimension, which, as Lindblom and Sundberg (1971) point out, is more indicative of rounding differences in front vowels than is F2. German [i] and [y] are also widely separated along the F3 dimension, although this pair of vowels is considerably less advanced than is the Norwegian [i y] pair. The two lower vowels, [e] and [ø], are similarly less advanced in German than in Norwegian, though the difference is not significant in the case of [e]. Nevertheless, the overall F3 of Norwegian is significantly higher than the overall F3 of German.

The fact that all of these language differences run in the same direction, with each German formant significantly lower than that of its Norwegian counterpart, raises the possibility of an anatomical, rather than a linguistic explanation for the patterns observed in these data. Without bilingual data, or data from population samples known to have comparable vocal tract dimensions, it cannot be said for certain that Norwegian speakers aim at a different set of phonetic targets than do German speakers; the difference may be merely one of vocal tract dimensions between the two groups of speakers represented in these data. However, the data to be presented in chapter 4 suggest that this possibility should be discounted.

Norwegian-English [i u ɔ æ ɑ]

Five monophthongal vowels are common to Norwegian and English, but F2 and F3 data are available for only three, [i æ ɑ]. Each of the five vowels displays significant F1 differences, but these differences are not uniform in direction. The non-high back vowels [ɑ ɔ] are higher in Norwegian, and the remaining vowels, [i u æ], are higher in English. The net result is that there is no significant F1 language difference between the Norwegian and English ($p < .75$). As might be expected under such circumstances, there is a significant pattern difference, reflecting the varying contributions of the five vowels to the overall mean of each language.

There is a significant difference in the F2 domain, due to the fact that English has relatively higher F2 values in this limited set of vowels. Yet only the difference in [æ] is significant, and the difference in [i] is very slight indeed. In contrast, it is Norwegian which has higher values along the F3 parameter. The differences in the vowels [i] and [ɑ] are significant, as is the

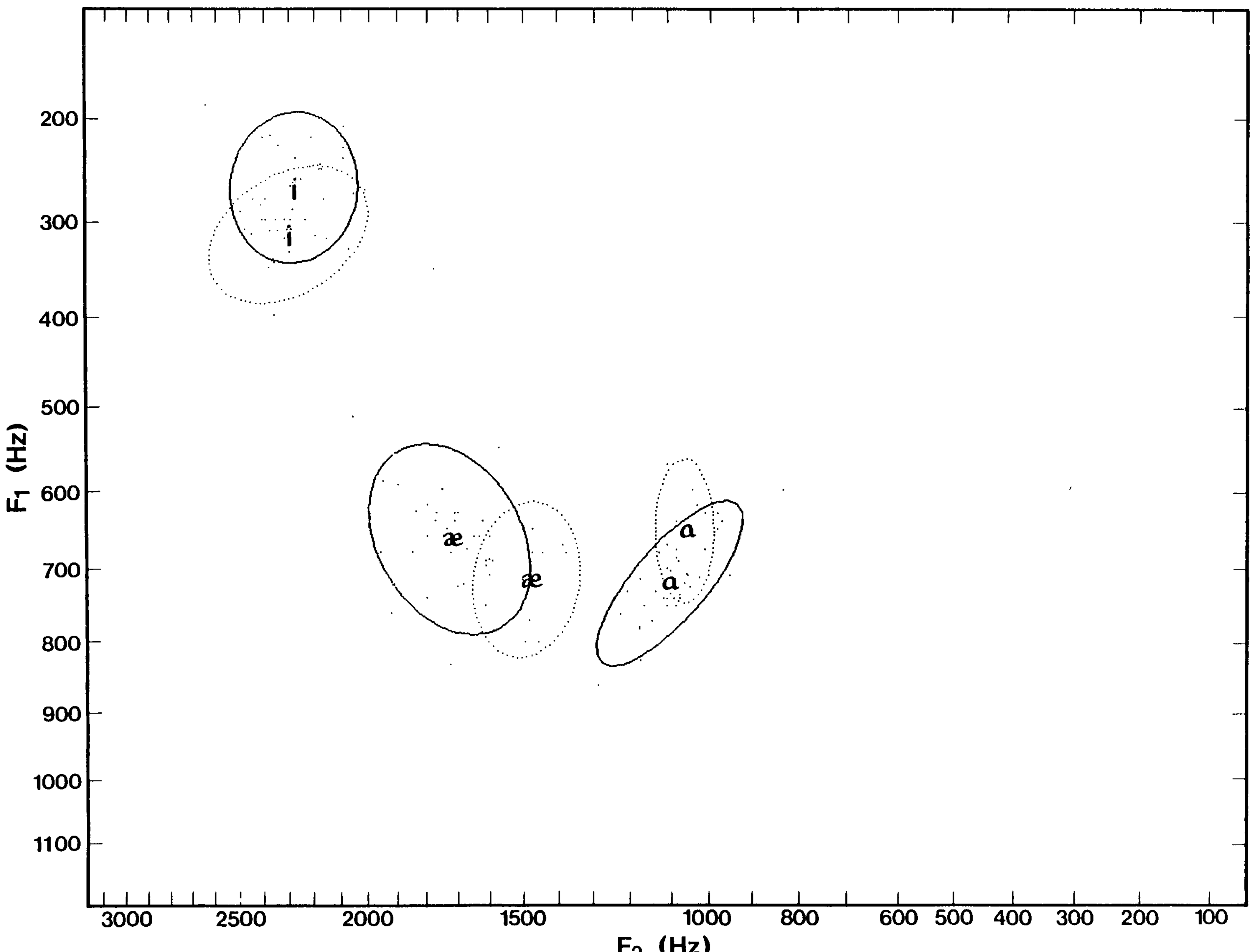

Fig. 3.26: Shared vowels of Norwegian (dotted) and English (solid)

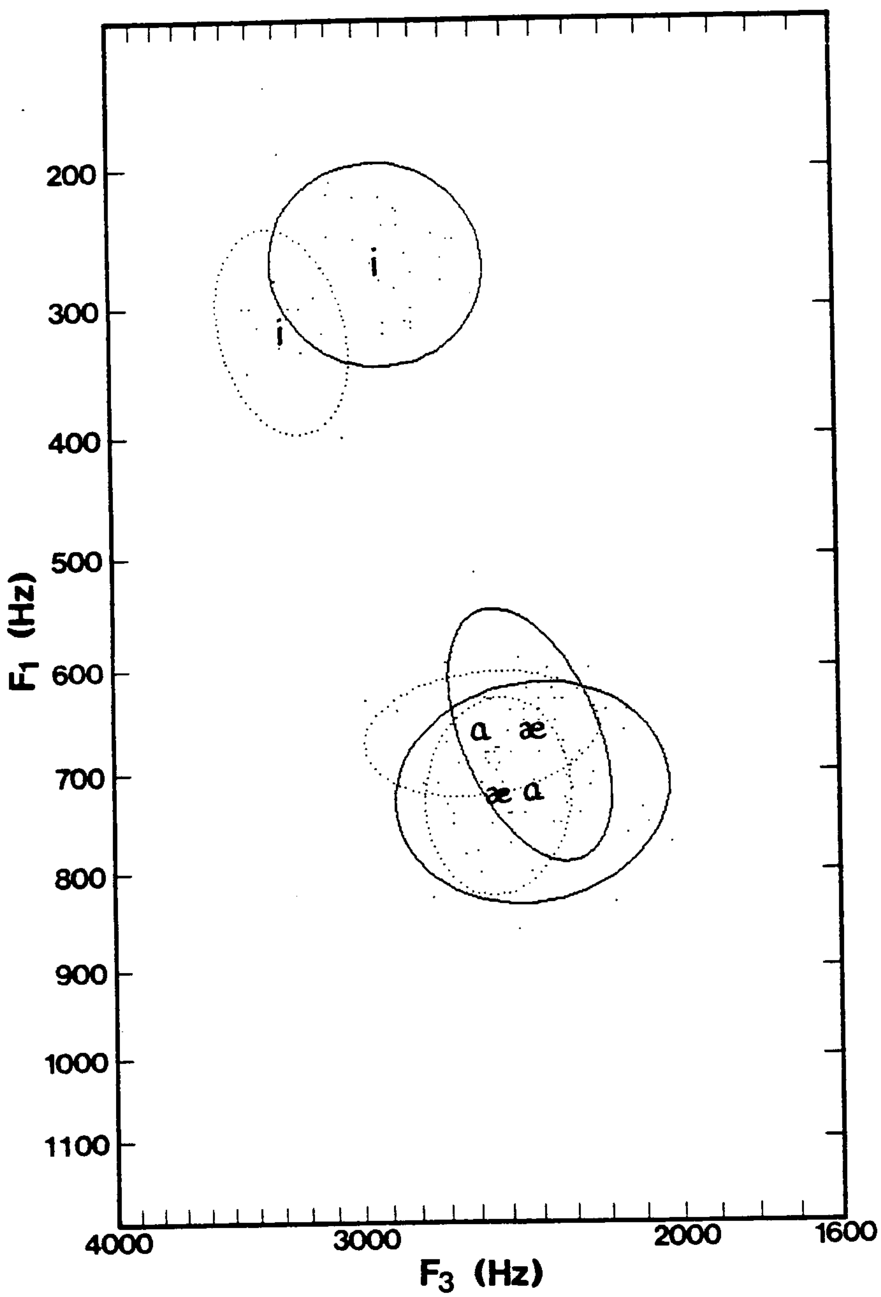

Fig. 3.27: Shared vowels of Norwegian (dotted) and English (solid)

difference between the overall language means. The vowels displaying significant differences in F2 and F3 are complementary.

Summary

We have observed a number of cases in which the vowels of two languages differ in reliable and significant ways. In some instances these differences appear to be part of a general trend -- the vowels of one language being uniformly higher or backer or more rounded than those of another. In many other instances, however, the differences appear to be idiosyncratic. These differences cannot be subsumed under any more global differences in height or backness or the like. But as they mark consistent differences between languages -- part of the "mode of meaning" of Dutch or Danish or American English (Firth 1951) -- they must be accorded a place in any descriptively adequate grammar.

Chapter 4: Acoustic Quality of Germanic Vowels II: Bilingual survey

It is conceivable that some of the results of chapter 3 might be due, not to any linguistic difference between the languages in question, but rather to anatomical differences between the speakers. Some of the broad differences that have been observed in chapters 2 and 3 may as readily be ascribed to differences in the mean vocal tract length or cavity size of different populations as to linguistic notions such as base of articulation.

Figure 4.1a, for example, compares the average formants of a group of 25 male speakers of R.P. English (Wells 1963) with the formants of one male speaker of British English (Received Pronunciation) who is taller and has "larger resonating cavities...than the average male speaker" (Ladefoged 1975:189). The vocal tract dimensions of the individual speaker, PL, were ascertained both by x-ray tracings and by an impression made of his entire vocal tract, down to the arytenoid cartilages, using dental impression material (Ladefoged, Anthony and Riley 1971). His vocal tract is 18 cm. long, which is also greater than average. In this figure the first formant values are plotted along the ordinate and the difference between the first and second formants (in some respects a better indicator of the psychoacoustic notion of "backness" than F2 alone) along the abcissa.

The vowel system of speaker PL (dashed line) is characterized by lower F1 and generally lower F2-F1 than the average vowel system of the more representative group of speakers (dotted line). As it happens, the inter-speaker difference in the F1 values (indicating a difference in vowel height) of British English parallels the cross-language difference that has been noted between Danish and English. This may be seen by comparing fig. 4.1a with fig. 4.1b, which is a plot of five similarly-transcribed vowels of English and Danish, the former pronounced by the 25 British speakers described above and the latter by the 7 Danish speakers described in ch. 3. (Data are not available for the somewhat diphthongized [e] and [o] of English). Figure 4.1b shows quite clearly that the F1 values of Danish are lower than those of British English, just as we have seen them to be lower than the F1 values of American English in chapter 3. While this may possibly be described in terms of base of articulation, or of certain articulatory gestures characteristic of one language or another, a purely anatomical explanation cannot be ruled out. That is to say, if Danes turn out to have larger resonating cavities or longer vocal tracts, on average, than Britons do, their F1 values would be expected to be somewhat lower. (Furthermore, it might not be coincidental that speaker PL is of Danish descent.) On the other hand, the inter-speaker difference in the F2-F1 values (indicating vowel backness) of British English, while also quite striking, has no obvious parallel in the cross-language study. The Danish high vowels [i] and [u] have lower F2-F1 values than the English, but the Danish non-high [ɛ æ ɔ] have higher F2-F1 values. These facts have no simple explanation in anatomical terms, as did the facts about F1. To the extent that these differences are reliable and

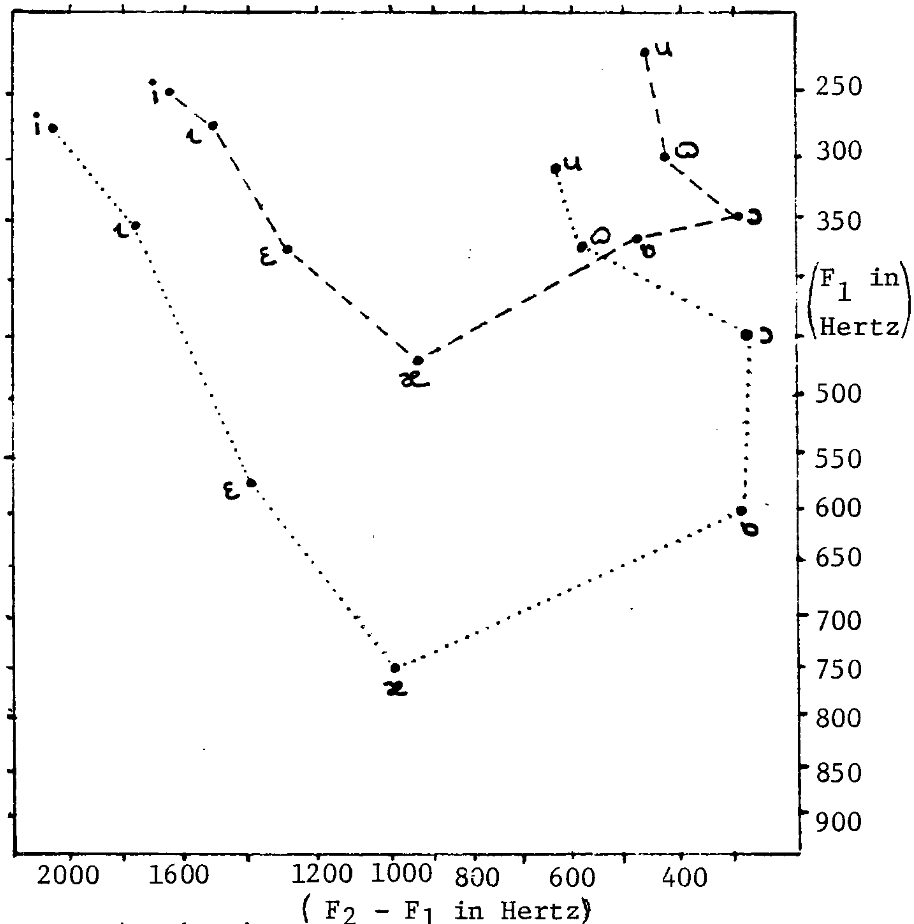

Fig. 4.1a:

Vowels of one speaker of R.P. English (dashed line) (Ladefoged 1975), compared with the mean of 25 R.P. speakers (dotted line) (Wells 1963).

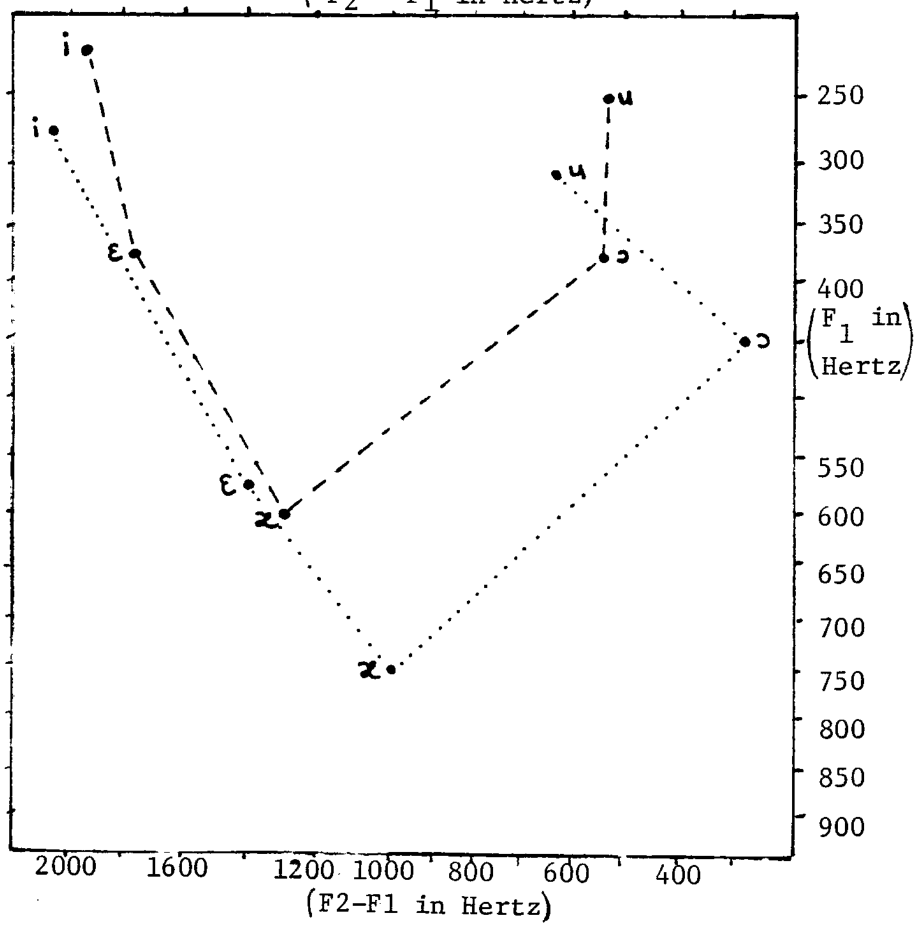

Fig. 4.1b:

Shared vowels of English (dotted line) and Danish (dashed line). Mean of 25 spkrs. of R.P. English (Wells 1963) and 8 speakers of Danish (Fischer-Jørgensen 1972).

significant, they suggest that at least some of the differences we have observed are linguistic ones. But the question of how much of any cross-language difference is anatomical and how much is linguistic still remains. Precise allometric measurements of the vocal apparatus are not available for populations such as these, and it is obviously impractical to have to measure the vocal tract of each speaker. Moreover, it is possible that what was once an anatomically-based trait might have become "phonologized" at some point, much as the lengthening of vowels before voiced obstruents has been phonologized in English (Wang and Fillmore 1961; Anderson 1981).

Fortunately, it is possible to circumvent this problem by utilizing bilingual speakers. Bilinguals obviously use the same vocal apparatus to produce the sounds of different languages; they thus provide a means of isolating just the linguistic differences which hold between languages. Shifting vowel patterns in a bilingual speaker cannot be ascribed to differences in head size, vocal tract length, lip mobility, or the like; they must be considered primarily linguistic in nature.

Even if only a few bilingual speakers are found, the language differences that they exhibit are likely to be of value in confirming or refuting findings which are based on larger samples of (monolingual) speakers. In addition, if enough bilinguals can be found to make up a sizable sample, statistical tests such as those described in chapter 3 can be used to seek out trends in the paired data.

Subjects

Speakers with a high degree of proficiency in at least two Germanic languages were sought to produce the speech for analysis. Polyglots -- that is, persons capable of conversing in several languages but without native command -- are not sufficiently skilled for this task; a mastery of the language is called for.

Table 4.1 shows the linguistic comparisons that can be made on the basis of the data at hand.

Many of the speakers were raised in bilingual households: some with parents from different language backgrounds (e.g. speakers 12 and 31), some raised in a foreign country but continuing to speak their native language at home (e.g. speakers 27, 14 and 32), some whose families had employed foreign help for many years (e.g. speaker 13). Many have had numerous years of foreign-language instruction in primary and secondary schools, as well as in college, and credit their skill to the quality and extent of this instruction. Interestingly, despite the fact that for the majority of individuals the ability to acquire native accent disappears at a fairly young age (Lenneberg 1967; Seliger, Krashen and Ladefoged 1975; Scovel 1977), one of the most accomplished bilinguals in the entire sample was speaker 29, who only learned English in his late teens, as an exchange student in the U.S.

	Danish	Dutch	English	German	Norwegian	Swedish
Danish			13 14 26	13 26		
Dutch			6 20 33 34 36	6 20 33 36		33
English				2 3 10 12 13 16 19 20 23 25 26 27 29 33 36	2 3 16 24	1 3 4 5 7 9 10 12 16 24 25 31 32 33
German					2 3 16	3 10 12 16 25 33
Norwegian						3 16 24
Swedish						

Table 4.1 Bilingual speakers
(Cells contain speaker identification numbers)

Most of the speakers spoke the standard language of the two or more countries they represented. There were, however, some examples of variations in accent which bear mention. Most notable was the split between American English and British English. In light of this, most of the English speakers were regarded as being representatives of either American or British English, depending on whether they appeared to be aiming at American English or British English vowel targets; these groups were then treated as separate languages. Four of the English speakers were somewhat ambiguous in their accentual preference, leaning toward American English in some words and toward British English in others. Alone among the 28 speakers of English, speaker 31 spoke with an accent that did not seem to aim at either Standard British or Standard American English. His accent suggested that of the Lancashire region, although modified by schooling and by a rather lengthy residence abroad. Speaker 5 spoke the Scanian dialect of southern Sweden. While such dialect differences can be overlooked when rating overall proficiency as a bilingual, they cannot be overlooked in the final analysis, as they might entail significant differences in the vowel system. Thus, the speakers with markedly regional accents should be considered separately from the rest.

All of the subjects claimed to be proficient in at least two languages. Several claimed proficiency in three or more languages, although in some cases (e.g. the German of speaker 6, the Dutch and Swedish of speaker 33) the speaker acknowledged a lesser degree of proficiency in one language than in the others. These were included, in hopes of obtaining a few more (marginally) acceptable examples of a 3- or 4-way language contrast, which would make for more interesting comparisons.

Method

Words

The test words, listed in Table 4.2, are, for the most part, the same as those used in the previous analyses; they are described in more detail in chapter 3. The first group of subjects to be recorded was asked to pronounce each test word in a sentence-frame. The frames are all translations of the phrase "(Now) say --- again". This commonly-employed sentence frame has the additional advantage of providing a vocalic environment on either side of the test word in each of the six Germanic languages of this study. (In German, of course, an initial vowel is always preceded by the glottal stop [ʔ]; this does not, however, introduce any formant transitions.)

Danish

ile [i]	hyle [y]	hule [u]
hele [e]	øde [ø]	Ole [o]
hæle [ɛ]	høne [œ]	åle [ɔ]
hale [æ]		

Dutch

hiet [i]	huut [y]	hoet [u]
hit [ɪ]		
heet [e]	heut [ø]	hoot [o]

	het [ɛ]	hut [œ]		hot [ɔ]
		haat [a]		hat [ɑ]
<u>American English</u>				
	heed [i]			who'd [u]
	hid [ɩ]			hood [ʊ]
	hayed [e$^{\iota}$]			hoed [o$^{\omega}$]
	head [ɛ]			hawed [ɔ]
	had [æ]	Hud [ʌ]		hod [ɑ]
<u>German</u>				
	hiessen [i]	hüten [y]		hupen [u]
	Esel [e]	hölen [ø]		hoben [o]
	äsen [ɛ]	aβen [a]		
<u>Norwegian</u>				
	il [i]	lys [y]	ut [ʉ]	pilot [u]
	hel [e]	lös [ø]		lat [o]
	hæl [æ]			lat [ɑ]
<u>Swedish</u>				
	hil [i]	hyl [y]	hul [ʉ]	hol [u]
	hel [e]	höl [ø]		hål [o]
	häl [ɛ]			hal [ɑ]

Table 4.2

For all the languages except English, this approach yielded excellent preliminary results; the words were spoken naturally and list intonation was avoided. However, in some of the English speech this particular frame had a deleterious effect on the intelligibility of the test words when they were considered in isolation (i.e., when they had been edited out from the frame). And, as described below, this process was necessary to evaluate the fluency of the speakers.

The problem lay in the fact that the test vowel and its immediate right-hand environment (including the unstressed initial vowel of 'again'):

$$h\ V\ d\ \#\ \begin{bmatrix} V \\ -\text{stress} \end{bmatrix} \ldots$$

is very close to the structural description of the so-called "flapping" rule of English (actually, a tapping rule, since it yields [ɾ]):

$$t,d \longrightarrow [\text{ɾ}] \quad / \quad V \;\_\_\; \begin{bmatrix} V \\ -\text{stress} \end{bmatrix}$$

Under fast-speech conditions, rules tend to become more general and boundaries such as the one in the flapping rule, above, are often disregarded. Indeed, some speakers did reach a speed at which this occurred. The most rapid English speakers (not all of whom were native-born) had [ɾ] instead of [d] at the end of all the test words. When edited out of their sentence-frames these words sounded quite odd. The last third of the speakers thus were asked to pronounce the test words in isolation, taking care to avoid list intonation. Speakers from the latter group are indicated with an asterisk in Table 4.4, below.

Measurements

High-quality recording equipment was used to record the speakers as they pronounced the test words. All of a given speaker's languages were recorded together on one of three machines: an Ampex professional tape deck at UCLA, a portable Sony 800, also from the UCLA lab, and a Studer B-62 at Lund University, all of which had good response characteristics within the range required for vowel discrimination.

The recorded speech was digitized at a sample rate of 10,000 Hz and then edited, using the WAVES system on the UCLA Phonetics Lab LSI-11 computer (Wittenstein & Rice 1981). The test words, illustrating the range of vowels in each language, were removed from the surrounding frame and then were re-recorded onto an audio tape for later use.

Evaluation

Because it is important to be sure that the language samples from the speakers do in fact represent proficient pronunciation, the following evaluation procedures were carried out.

The test words were submitted for preliminary review to a native speaker of each language (except Norwegian, which was reviewed by a skilled but non-native speaker). A number of words were determined to be uncharacteristic of the language, for any of a number of reasons. In some cases the segmental information (other than the test vowel) was affected; for example, the common tendency in Germanic languages to devoice final obstruents occasionally yielded "heat, hit, hate" in place of English "heed, hid, hayed". In other cases, the suprasegmental information was affected; some of the words had inappropriate vowel length, others had rather questionable intonation patterns (particularly when the speech showed the influence of a pitch-accent language such as Swedish). These shortcomings were deemed irrelevant to the phonetic quality of test vowels.

In a few instances, however, the preliminary review showed that a speaker definitely mispronounced the relevant vowel. Such words were eliminated from all further consideration. Any speaker who mispronounced more than one vowel was eliminated altogether.

One should not accept any of these data as representative of a language without first determining the speaker's proficiency in that language, for, unfortunately, the term "bilingual" is usually applied fairly loosely. Yet such a measure is not readily available. Both educators and laymen tend to equate bilingualism with a functional mastery of a second language. For example, K.

Hakuta of Yale University holds that the question "Would you hire this [second-language learner] as an employee in a retail store?" yields a rather accurate measure of the learner's bilingual proficiency; the responses to this question were quite highly correlated with the learners' scores on a number of more formal language-acquisition tests (Hakuta, pers. comm.). However, such a functional criterion is certainly not an adequate basis on which to judge the very fine phonetic adjustments made by a speaker in producing a variety of vowel sounds. Furthermore, it is probably not appropriate to generalize the strategies of an entire population: some speakers may place more emphasis on perfecting their syntax, others on semantics, and so on.

In view of the inadequacies of the standard criteria for bilingualism, a new technique was devised to determine, for each language, whether the speaker's pronunciation of the vowels was valid or not. This technique involves playing no more than a dozen words recorded by each speaker to a panel of native-speaker judges for evaluation.

The task involved listening to a recorded list of words from Table 4.2 and then rating each speaker's proficiency against that of an educated native speaker (assuming comparable conditions), on a six-point scale designed by the U.S. Government's Foreign Service Institute (Lowe 1976). (see Appendix) The FSI scale of language proficiency ranges from zero, signifying "entirely foreign", to five, signifying "entirely native", as in Fig. 4.2. In the present evaluation, though not in the original FSI test, the use of plus (+) and minus (-) was encouraged, for greater precision.

(4.2) Foreign ___ ___ ___ ___ ___ ___ Native

Foreign	___ 0	___ 1	___ 2	___ 3	___ 4	___ 5	Native

One of the features of the FSI scale is that it is adaptable to any of the major linguistic domains. In fact, FSI language examiners are expected to rate syntactic, semantic, and phonological skills separately along this same six-point scale. Of course, the present evaluation only concerned the speaker's accent.

The FSI does provide a separate set of guidelines for each domain, making it somewhat easier to choose between the equidistant, arbitrary points on the scale. In the present evaluation, the guidelines in Table 4.3 were made available (to the judges):

0 = pronunciation frequently unintelligible
1 = very heavy accent; difficult to understand
2 = marked "foreign accent"; requires concentrated listening
3 = occasional mispronunciations which do not interfere with understanding
4 = no conspicuous mispronunciations, but would not be taken for a native speaker
5 = native pronunciation, with no trace of "foreign accent"

Table 4.3 Guidelines for FSI Language Proficiency Test

Judges

70 judges were asked to listen to the recordings of their native language (or the language in which they were most proficient) for purposes of evaluation. 15 individuals judged the Swedish words, 7 the Danish, 7 the Norwegian, 13 the German, 9 the Dutch, 12 the American English, and 7 the British English.

The English-language judges were afterwards broken down into the categories American and British, just as the speakers had been. Many of these judges had been reluctant to rate regional accents with which they themselves were relatively unfamiliar. Thus, in the final tally, the British judged the British speech and the Americans judged the American; the four speakers whose accents were somewhat ambiguous were judged by all.

The majority of the judges were UCLA graduate students and professors of language or linguistics. Eight of the Scandinavian judges were employees of SAS, and four of the Dutch judges worked in the consulate of the Netherlands. Most had occasion to use their native language on a regular basis, either in the course of their work or at home with their families; the six who lived alone and whose work did not involve their native language were all recent arrivals in the United States (maximum two years′ residence).

Only four of the judges were familiar with the FSI scale beforehand, and only two had actually used the scale to evaluate language skills.

The listeners were presented with a list of individual words, rather than the entire sentences in which these words had, for the most part, been uttered. Words containing any questionable suprasegmental or segmental information, apart from the relevant vowel, were left out of the evaluation process, since it was suspected that their deviation from the norm might induce listeners to downgrade the quality of the vowel in question (which is a separate consideration). As noted above, words in which the relevant vowel was mispronounced were eliminated from the start.

It was decided to provide the listeners with only the minimum amount of speech necessary to judge the quality of the eight to twelve vowels in question. The addition of other consonants and vowels from the sentence frame, or from a brief passage containing all of the target words, as suggested by Scovel (1978), would only interfere with this judgment. Errors in pronouncing other segments might lower the rating of correctly-pronounced vowels, or, of even greater concern, a competent reading of the rest of the sentence might induce a judge to overlook slight errors in pronouncing the target vowels. Both of these circumstances are to be avoided.

There were, however, two isolated cases in which the entire sentence was presented to the listeners. English speakers 33 and 5 read the test sentences with such rapidity that the relevant vowels were considerably shorter than average, and the following [d] became a tap [ɾ], as discussed above; this severely degraded the quality of the test words. To correct for this effect, the words were again presented to the listeners, this time in their full sentential contexts (in spite of the disadvantages of doing so).

One might argue that the additional contextual material ought to be heard by the judges for purposes of evaluation, on the theory that any information in the speech signal can serve to define the speaker' proficiency. However, evidence from acquisition studies lends support to the hypothesis that language is not acquired uniformly (nor, presumably, is it maintained uniformly). For example, on the basis of an oral interview task involving 106 foreign students of different language backgrounds, Oller and Hinofotis (1980:13) suggest that "language skill is separable into components related [...] to linguistically defined categories (e.g. phonology, syntax, and lexicon)". There seems to be a consensus that "it is clearly possible for a learner to master the syntax of a language, but not its phonology" (Tarone 1978). (Scovel (1978) refers to this as the "Joseph Conrad effect", but it may be updated to the "Henry Kissinger effect" for those accustomed to hearing the former Secretary of State deliver addresses in heavily accented, but syntactically and semantically flawless English.)

Moreover, the evidence from syntax, at least, suggests that the differential rate of acquisition operates within a particular domain as well. A recent study of German as a second language by Meisel, Clahsen and Pienemann (1981) reveals well-defined differences in the pattern of acquisition of relative clauses, WH-questions, and adverbials.

Irrespective of the way they are acquired, errors in certain phonetic areas seem to be more readily considered as "foreign accent" than errors in others. Recent work by Gårding (1981), for example, underscores the importance of prosody. She observes that prosodic errors are "responsible for a great deal of what is generally described as `foreign accent'." In an interesting series of experiments, she gradually altered the tempo, rhythm, and intonation of a heavily accented French, Swedish, or Greek phrase read by a foreign speaker until it was judged acceptable ("almost too good" in one instance) to native speakers. M. Lindau (pers. comm.) notes that, initially, the quality of the vowels in the Swedish phrase read by a Greek speaker was quite unacceptable; however, the improvement rendered by the adjustments in prosody completely overwhelmed these vocalic deficiencies.

A very conservative approach to the judgment of foreign accent was thus adopted: only the words containing the vowels in question were presented to the listeners. This is by no means an impossible task for the listeners. It has been noted that "recognition of phonological non-nativeness is usually immediate and based on a small speech corpus" (Scovel 1977). To further aid the listeners, a list of the spoken words was provided.

In order to correct the impression that speakers who read longer word lists were perhaps more skilled, all the speakers' word lists were brought down to the same number within each language. First, words which had been mispronounced in any way were deleted; then a complement of up to two words per speaker was randomly selected for deletion as well.

The most conservative approach of all -- presenting the listeners with only the vowels, edited out of the words -- was rejected because many of the judges lacked the phonetic training which is probably necessary to perform the task in this manner. Kahn (1978:29) has noted that, in the course of his own vowel-quality experiments, "[n]aive subjects, and to a certain degree even trained phoneticians, find it more difficult to pair isolated sounds with phonetic transcriptions than actual words with standard spellings, and are thus more likely to make extraneous errors of production and transcription if use is not made of actual words of English."

Two monolingual speakers of (British) English, speakers 15 and 35, were added to the bilingual corpus as controls. The scores achieved by each speaker were averaged; the means are listed in Table 4.4a, with languages listed in descending order of proficiency for each speaker.

Very few of the bilingual speakers achieved perfect scores of 5.0 in any of their languages. Of the 69 individual language scores, only eight were a perfect 5.0. One of the perfect scores went to the Assistant Director of the UCLA Phonetics Lab, whose identity was correctly guessed by almost all of the English-speaking judges. To define as "true bilinguals" only the persons who scored 5.0 in both languages is probably too high a standard, in light of the fact that only seven speakers achieved this score for even one language, without the benefit of some sort of speaker recognition on the part of the listeners. Moreover, a truly monolingual speaker of English, speaker 15, scored only 4.49 (perhaps because he spoke rapidly, flapping his final [d]s). There are surely speakers with native proficiency who have been given less than perfect scores by one or more of the judges. The crucial question is: how low a score can a native speaker be expected to receive?

Table 4.4a. Mean scores on FSI Language Proficiency Examination
Bilingual speakers and controls

Speaker:	Scores:			
1.	English 2.87			
2.	Norwegian 4.71	German 3.98	English 3.01	
3.	Swedish 4.4	English 3.43	German 3.27	Norwegian 3.27
4.	Swedish 4.87	English 3.63		
5.	Swedish 5.0	English 3.76		
6.	Dutch 4.44	English 4.02	German 2.87	
7.	Swedish 4.49	English 4.07		
9.	English 4.19	Swedish 3.74		
10.	English 4.22	German 3.68	Swedish 3.64	
12.*	Swedish 4.68	English 4.37	German 3.03	
13.*	Danish 4.79	English 4.37	German 3.54	
14.*	English 4.49	Danish 4.14		
15.	English 4.49			
16.	Swedish 5.0	German 4.57	English 4.51	Norwegian 4.22
19.*	German 4.66	English 4.59		
20.*	Dutch 4.67	English 4.61	German 4.03	
23.	English 4.68	German 4.3		
24.	Swedish 5.0	English 4.69	Norwegian 4.49	
25.	Swedish 4.73	English 4.7	German 4.45	

26.*	German 4.91	English 4.74	Danish 4.36	
27.*	English 4.76	German 4.64		
29.*	German 5.0	English 4.82		
31.	Swedish 5.0	English 4.86		
32.	English 4.87	Swedish 4.42		
33.	German 4.91	English 4.54	Swedish 3.13	Dutch 2.42
34.	English 5.0	Dutch 4.48		
35.*	English 5.0			
36.	English 5.0	German 4.91	Dutch 4.87	

Asterisks (*) indicate speakers who pronounced words in isolation, rather than in sentence frames.

Control evaluation

These considerations prompted a second evaluation, conducted several days after the first. The second group of subjects to be evaluated were monolingual speakers of American English, recorded in the UCLA Phonetics Lab by D. Kahn (1978). Seven of the eight monolinguals were born, raised, and educated in Los Angeles; the eighth, added later, was a New Yorker. Four non-native speakers of English from the previous test (34, 13, 12 and 4) representing different levels of proficiency (previous mean scores: 5.0, 4.37, 4.37, and 3.63) and a native speaker of British English (previous mean score: 4.96) were added as controls.

All and only the American judges were asked, once again, to listen to the tape and to rate each speaker according to the FSI guidelines. The American speakers in the second study did well, but not perfectly, as can be seen in Table 4.4b. The New Yorker scored lowest, which is rather surprising in light of the fact that a majority of the judges were natives of the Eastern United States.

Figure 4.3 is a graph of the means in both Table 4.4a. and Table 4.4b, along with their standard deviations. The solid-line bars mark the bilingual speakers and the broken-line bars mark the monolingual Americans. These scores form a fairly smooth progression from speaker 6 to speakers 25-27. The scores of the first five speakers are sharply lower. A t-test was used to compare the scores achieved by speaker 6, the lowest-scoring (bilingual) speaker in the "main series" and those achieved by speaker 8, the lowest-scoring monolingual American; the scores are not significantly different. Thus, the mean score achieved by speaker 6 -- by coincidence, almost exactly at the 4.0 level which is defined as "no conspicuous mispronunciations" in the test -- may be regarded as the minimum score at which a speaker's vowels may be considered representative of the language in question. The English of speakers 1 through 5, rated below this level, will not be considered in the balance of this study.

It is, moreover, quite apparent that the scores of the bilingual speakers are interleaved with those of the monolingual Americans, rather than forming separate populations. Apart from subjects 1-5, the native speakers of English and the bilingual group received comparable scores from the American judges.

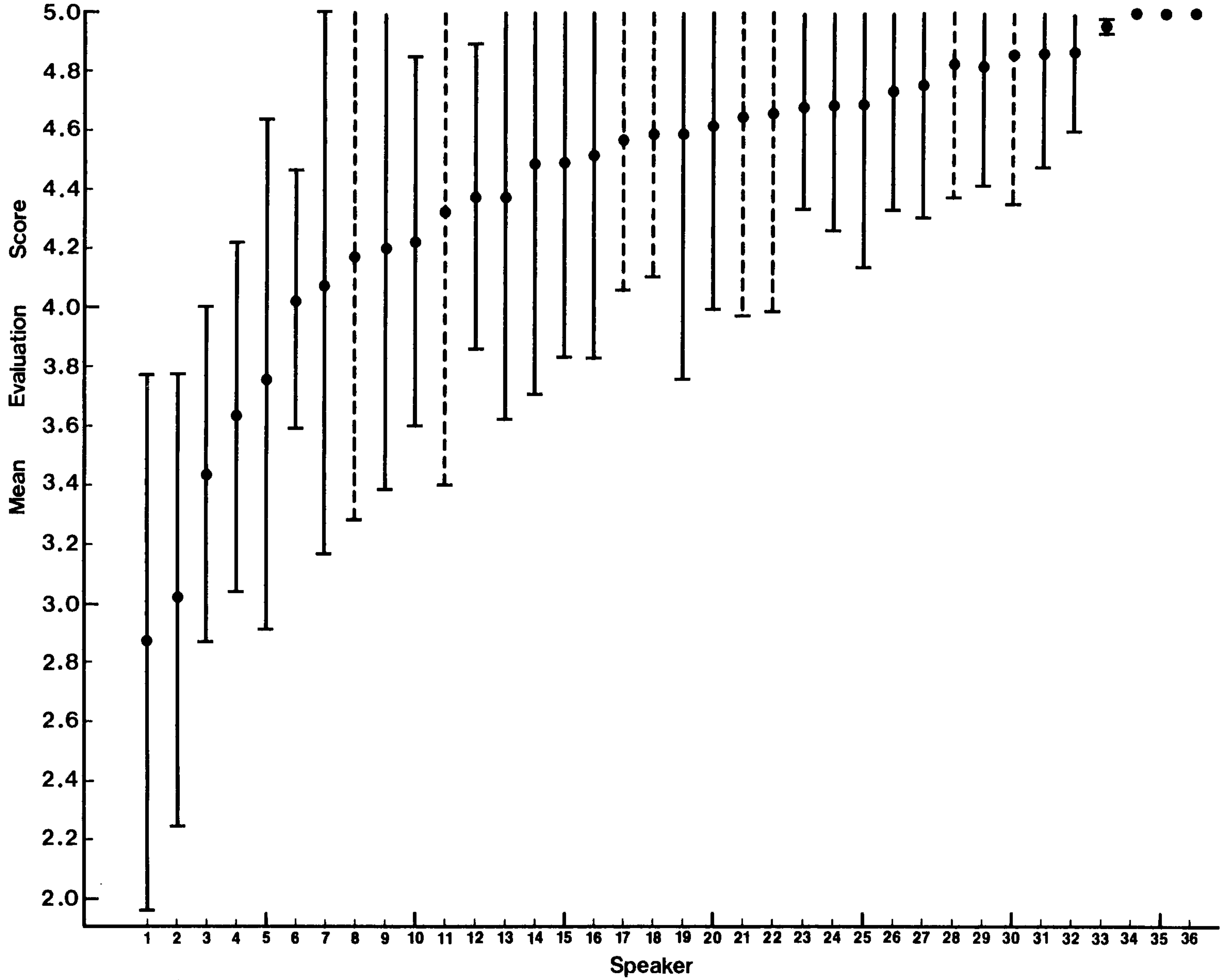

Fig. 4.3: Means and standard deviations of FSI test scores.

Table 4.4b. Mean scores on FSI Language Proficiency Examination: Monolingual speakers of English

Speaker:	Score for English:
8.	4.17
11.	4.32
17.	4.57
18.	4.59
21.	4.65
22.	4.66
28.	4.83
30.	4.86

Results of evaluation procedure

In light of these English-language results, it seems reasonable to establish the 4.0 level as a minimal level of bilingual proficiency for testing purposes in the other five languages as well. The speakers who attained this minimum level of proficiency in at least two languages are listed in Table 4.4c. The sole exception is speaker 2, whose score of 3.98 in German nonetheless seemed sufficiently close to the 4.0 cutoff to warrant his inclusion in the sample.

Table 4.4c. Mean scores on FSI Language Proficiency Examination Bilingual speakers selected for cross-language examination

Speaker:	Scores:			
2.	Norwegian 4.71	German 3.98		
6.	Dutch 4.44	English 4.02		
7.	Swedish 4.49	English 4.07		
12.	Swedish 4.68	English 4.37		
13.	Danish 4.79	English 4.37		
14.	English 4.49	Danish 4.14		
16.	Swedish 5.0	German 4.57	English 4.51	Norwegian 4.22
19.	German 4.66	English 4.59		
20.	Dutch 4.67	English 4.61	German 4.03	
23.	English 4.68	German 4.3		
24.	Swedish 5.0	English 4.69	Norwegian 4.49	
25.	Swedish 4.73	English 4.7	German 4.45	
26.	German 4.91	English 4.74	Danish 4.36	
27.	English 4.76	German 4.64		
29.	German 5.0	English 4.82		
31.	Swedish 5.0	English 4.86		
32.	English 4.87	Swedish 4.42		
33.	German 4.91	English 4.54		
34.	English 5.0	Dutch 4.48		
36.	English 5.0	German 4.91	Dutch 4.87	

The WAVES analysis system was used to edit the relevant vowel of each test word out of its consonantal context; an LPC spectral analysis program within this system was then used to extract the formant frequencies and formant bandwidths of these vowels. The procedure for the formant analysis involved determining the fourteen LPC coefficients for a 25.6 msec. Hamming window of the waveform, and solving for the roots of the LPC equation. Bandwidths were of use in distinguishing very broad-band "false formants" (and very narrow-band harmonics) from the true formant resonances. Any peak with a bandwidth of less than 50 Hz. or more than 600 Hz. was eliminated from consideration. In those cases which presented any ambiguity, wide-band spectrograms were made for clarification on a Kay Sona-Graph.

The formant values were selected from the steady-state portion of each vowel. In those cases in which the formants reached a steady state at slightly different points in time, the steady-state of F1 was given preference over those of the higher formants. Occasionally, in certain vowels, there was little or no steady-state portion to be found; in these cases the formants were selected from the very beginning of the vowel. This approach also ensured that the [e] or [o] portion of the English diphthongs [e^{i}] and [o$^{\upsilon}$] would be chosen over their offglides, thus maximizing the comparability of these sounds with the [e] and [o] monophthongs of other languages. Since most of the test vowels were preceded by [h], which is simply an unvoiced variant of the test vowel itself, transitional effects at the beginning of each vowel were negligible.

The use of identical analysis procedures for all of the languages in this study is a distinct advantage over the use of different procedures in the studies discussed in chapter 3. There is no cause to suspect that the phonetic differences found are due to different strategies for selecting the formants (e.g. peaks in amplitude, narrow bandwidths, frequencies near the 'expected' targets).

Figures 4.4–4.23 show many of the formant values derived in this manner. A complete listing of the bilingual speakers' formant values is provided in Appendix 3. Each of the figures is a two-dimensional formant plot of selected vowels of a pair of languages, as pronounced by up to ten speakers. The vowels selected for representation in these figures are those which have been defined as comparable, as discussed in the preceding chapter. For each speaker, an arrow has been drawn from a given vowel point in the one language to the similarly-transcribed vowel in the other. There is no inherent significance to the choice of origin and terminus for these comparisons. The purpose of the arrow-points is merely to clarify the correspondences between the two languages depicted in each figure.

Results

English-German [i e ɛ u o]

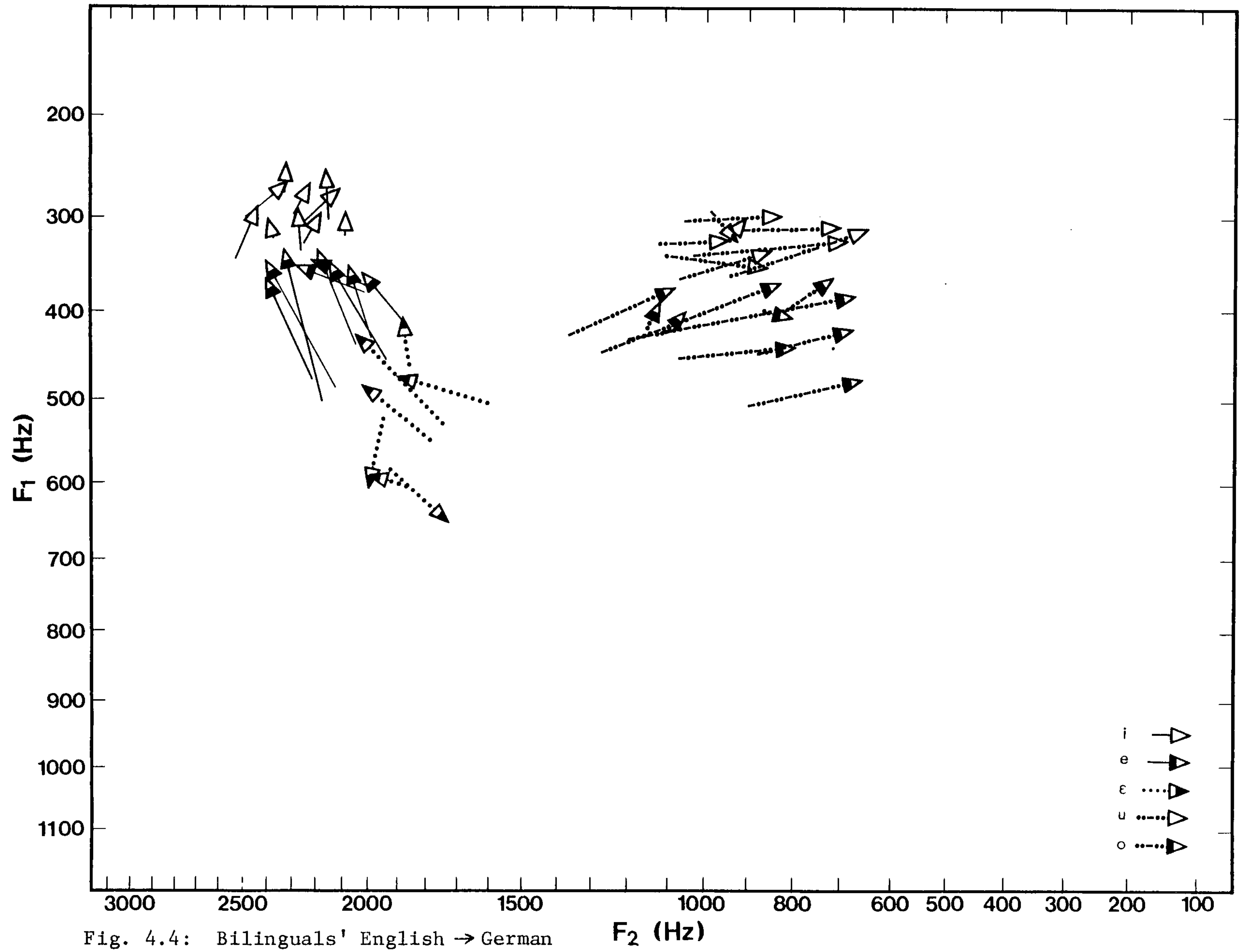

Fig. 4.4: Bilinguals' English → German

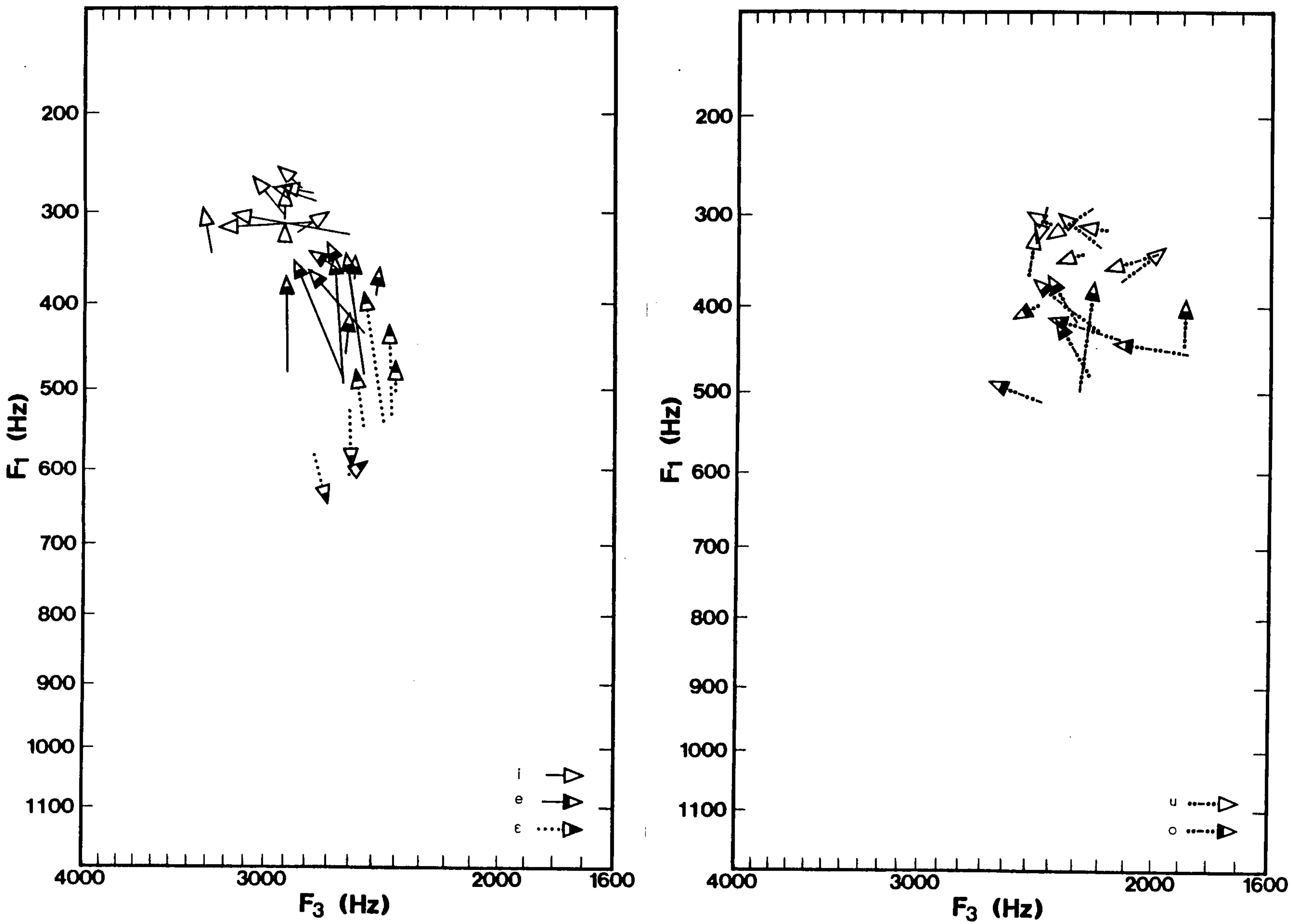

Fig. 4.5: Bilinguals' English → German

Among the ten bilingual speakers of English and German are six whose English favors the British pronunciation and four whose English favors the American. The patterns displayed by these speakers were found to be very similar, suggesting that the differences between these two varieties of English are not very significant in comparison with the inter-language differences between English and German. Thus, the vowels of these two groups have been plotted together in Figs. 4.4 and 4.5.

Unlike the monolingual data described in the previous chapter, these data include the vowels [e] and [o], which are usually described as diphthongs $[e^{\iota}]$ and $[o^{\omega}]$ in English, and for which Peterson and Barney provide no formant data. Actually, these vowels were less diphthongal than one might have imagined. Formant values were measured in the steady-state portion of these vowels, or at the beginning of the diphthong trajectory if there was no steady state.

In general, the data seem to bear out Moulton's observation that "all German vowels are tenser than their English counterparts" (1962:58), if tenseness is interpreted as peripherality (Stockwell 1973), and more specifically, peripherality in an acoustic formant space. There are general differences in both F1 and F2. For F2 there is a striking cross-linguistic difference in the back rounded vowels [u] and [o], due, perhaps, to the greater lip rounding employed in German for these vowels. (In their prescriptive phonetic handbook for learners of German, ten Cate *et al.* (1976:19) make the rather droll observation that a tendency to under-round the vowels of German is common among "the Dutch, the English, and ventriloquists.") Regional characteristics seem to have a bearing on this difference: the longest arrows for [u] in Fig. 4.4 correspond to the American English speakers. This reflects an American tendency to unround this vowel, hence increasing the phonetic difference between the English and German varieties of [u]. In general, the cross-linguistic difference in the back vowels takes the form of a shift along the F2 dimension, although there is a small but consistent shift toward lower F1 values in German, as well.

Fig. 4.5, which plots F1 against F3, presents a rather different picture of the back vowels. For most speakers the back vowels of German have marginally higher F3 values than do the back vowels of English. Yet this pattern is not inconsistent with greater lip rounding, for although rounding has the general effect of lowering all of the formants, its effect on F3 is less pronounced in the back vowels (Lindblom and Sundberg 1971); it is also not inconsistent with a more retracted tongue position, for F3 is less sensitive than F2 to changes in backness (*ibid.*). In any case, the F3 of back vowels is typically very low in amplitude, and therefore not always a reliable indicator of vowel quality.

Among the front vowels the English-German language difference emerges as a shift primarily in F1. This shift is less pronounced in the high vowel [i] than in the mid front vowels, perhaps because this vowel is at or near the articulatory limit, and a proportional shift is impossible to achieve. (It is, nevertheless, more pronounced here than in the German and English data sets shown in fig. 3.2.) Still, the trend is clear: a shift from English to German front vowels involves a considerable rise toward lower F1 values, and a lesser shift in F2.

One should bear in mind that English vowels tend to be more diphthongized than their German counterparts. This dimension of contrast is quite salient, but as it cannot be examined with the data at hand, it will not be considered here.

The heterogeneity of the vowel [ɛ] seems to relate to a difference between the British and American varieties of English. The three speakers for whom English [ɛ] is not lower than German [ɛ] are all speakers of American English. The height of their English vowels is a dialect-particular fact and, needless to say, cannot be explained in universal terms.

The F3 data parallel the F2 data in the mid vowels [e] and [ɛ], but there is a marked difference in [i]. Where there had been a tendency toward slightly lower F2 values in the German [i], the F3 values are considerably higher. Yet this too is fully consistent with greater peripherality, or at least greater fronting of the vowel [i], according to Fant's (1960) set of nomograms. In these diagrams, which chart the articulatory-acoustic relations in a system of resonators approximating the human vocal tract, a high front unrounded vowel such as [i] is characterized by a relatively high F2 and F3. As the major constriction in the vocal tract is moved even farther forward, F3 goes up while F2 remains steady or may even go down in frequency. The acoustic consequences of such a fronting gesture parallel those seen in Figs. 4.4 and 4.5, where the arrows mark a shift from English [i] to German [i].

In sum, the shift from English to German is a shift toward greater peripherality, or at least toward a greater range of frequencies in the higher formants, with a greater contribution on the part of F1 in the front vowels and of F2 in the back vowels. The difference between front and back vowels can be explained rather conveniently in terms of more vigorous lip rounding in German rounded vowels. Note, however, that German does not have a more rounded lip position for vowels in general, since the front vowels involved in this comparison have a higher F2 in German. The relative difference in F1 is also difficult to account for in terms of uniform adjustments of the articulatory setting. While the front vowels might appear to reflect a higher position of the tongue in German than in English, the back vowels show almost no difference. Localized differences of this sort cannot be attributed to an overall difference in the articulatory setting.

<u>Dutch-German</u> [i y u e ǿ o ɛ a]

The shift from Dutch to German exhibited by the two bilingual speakers of these languages (Fig. 4.6) is similar, but not identical, to the difference between the German and Dutch data sets described in the preceding chapter. Here too, the German vowels are, on the whole, higher than their Dutch counterparts, although this trend is reversed in several of the high vowels from one or the other speaker.

With the exception of the vowel [a], and of one speaker's [ɛ], there is much less of a height difference between the bilinguals' Dutch and German vowels than there is between the mean values of the monolingual speakers' Dutch and German vowels, shown in Fig. 3.4. (The difference in [ɛ] may in fact be atypical, as ten Cate <u>et al.</u> (1976:25) point out that the Dutch vowel [ɛ] is pronounced "very open, almost [a]" in the eastern portion of the Netherlands.) One possible explanation for this discrepancy is a difference in cavity size between the two monolingual groups, similar to that depicted in fig. 4.1a. Still, one should not read too much into the data in Figs. 4.6 and 4.7, in view of the limited number of speakers involved.

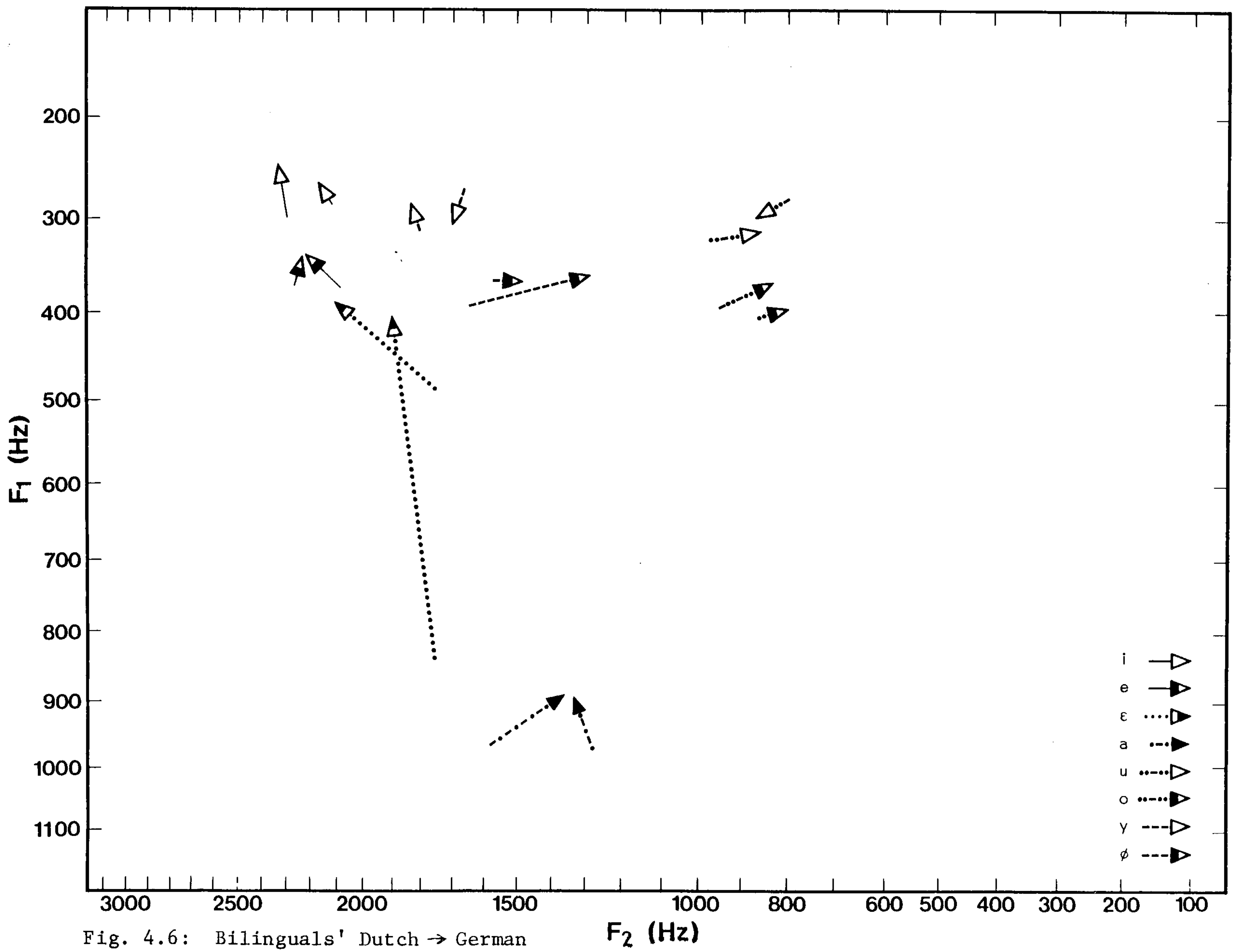

Fig. 4.6: Bilinguals' Dutch → German

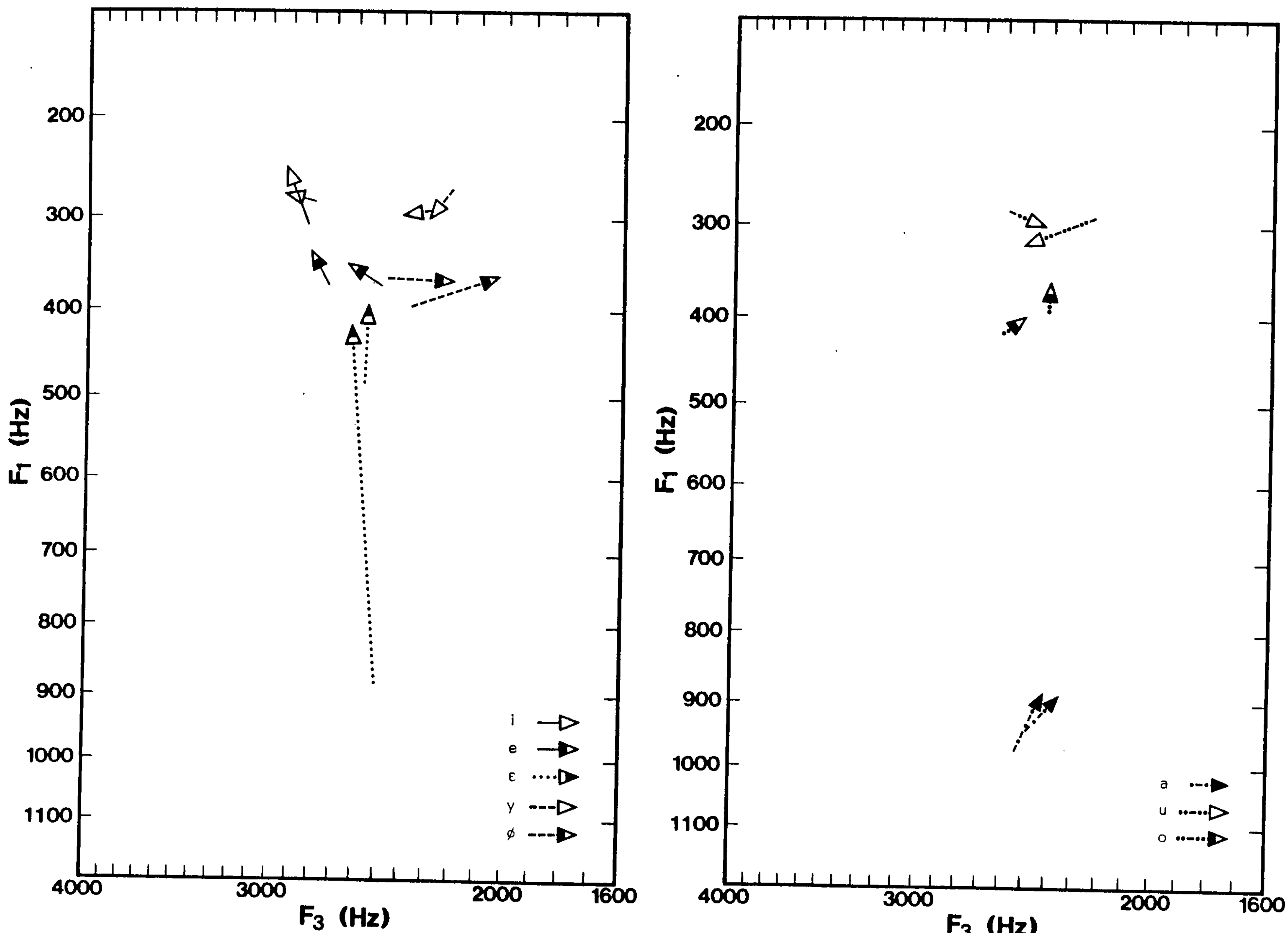

Fig. 4.7: Bilinguals' Dutch → German

It should also be kept in mind that Dutch vowels, like English vowels, are typically more diphthongized than their German counterparts. This very salient cross-linguistic difference fails to emerge from steady-state data such as these.

Dutch-English [i u ɩ e o ɛ ɔ ɑ]

The Dutch-English differences illustrated in fig. 4.8 are in rather close agreement with the differences discussed in chapter 3. The mid vowels [e] and [o], which had not been considered previously, fit the description provided by Koolhoven (1968:5):

"Dutch [e] is closer than English [e]."

"Dutch [o] is more rounded than English [o]."

The most striking difference between the two languages is in the vowel [ɛ]. The exceedingly large language difference displayed by one speaker may well be the result of a regional, rather than standard, pronunciation of Dutch [ɛ]. Still, it is clear from the literature (Renier 1960, Koolhoven 1968) that Standard Dutch [ɛ] is a lower vowel than English [ɛ], and this is apparent in the bilingual, as well as the monolingual, data.

English [i] is higher and more fronted than Dutch [i], just as in the monolingual data, in spite of the fact that the latter is paired with a front rounded [y]. The F2 difference between English [e] and Dutch [e] (the latter, like Dutch [i], having a front rounded counterpart) is not a consistent one; for two of the speakers the F2 of [e] is higher in English, and for the other two it is lower. All four bilingual speakers concur in having lower F1 values in English [e] than in Dutch [e].

Of the four English-Dutch bilinguals, only the two whose speech reflects American, rather than British pronunciation have a low vowel [ɑ] which is comparable to Dutch [ɑ]; these two are plotted in Fig. 4.8. (The British pronunciation of the vowel in the word "hod" is closer to [ɒ] than to [ɑ], and is therefore not comparable.) The two "American" bilinguals agree with the monolingual speakers (ch. 3) in having a lower English [ɑ] than Dutch [ɑ].

Swedish-Norwegian [i y u ʉ e ø a]

The two speakers whose vowels are plotted in Figs 4.10-4.11 do not consider themselves to be as proficient in Norwegian as they are in Swedish, in English, or (in the case of one speaker) in German. These therefore may not be fully representative of the differences between the Norwegian and Swedish languages. Nevertheless, the most significant trends in the monolingual data are confirmed here: the more fronted Norwegian [i] [y] and [ɑ], and the lower Norwegian [e]. In addition, the vowel [u], which was not represented in the monolingual data, displays a consistent shift toward higher and slightly more fronted (or less rounded) vowel quality in Norwegian than in Swedish. All of these differences merit a place in the phonetic description.

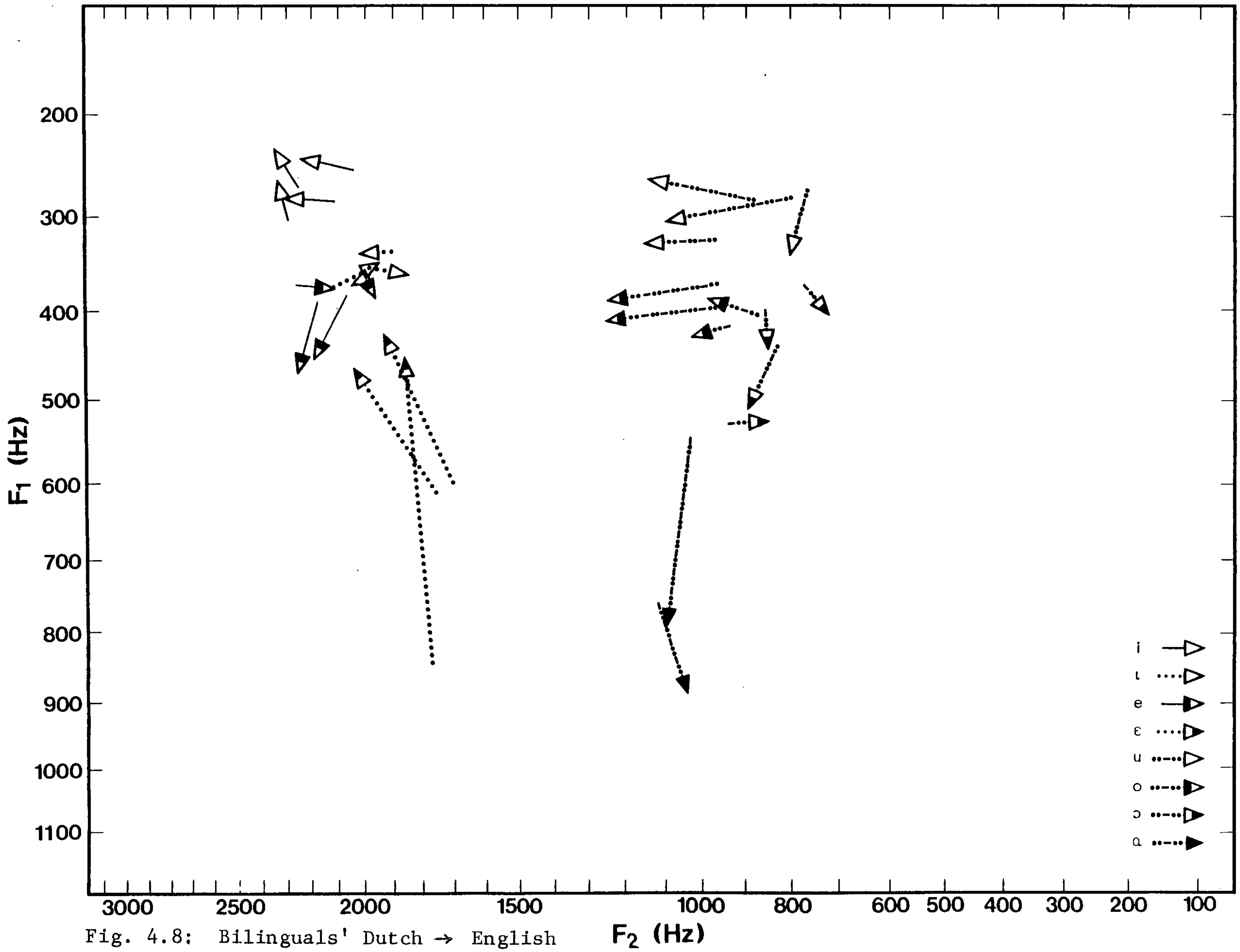

Fig. 4.8: Bilinguals' Dutch → English

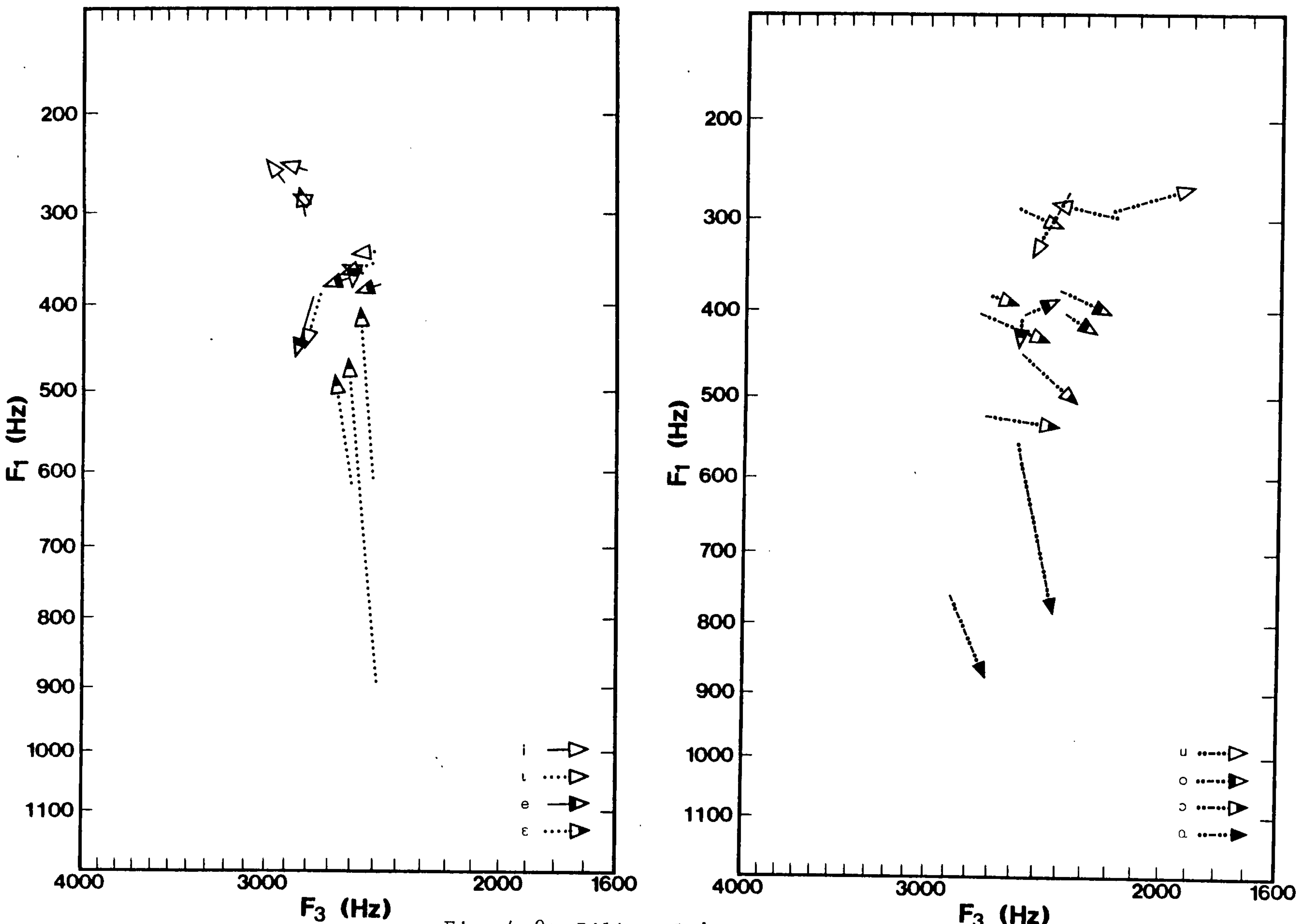

Fig. 4.9: Bilinguals' Dutch → English

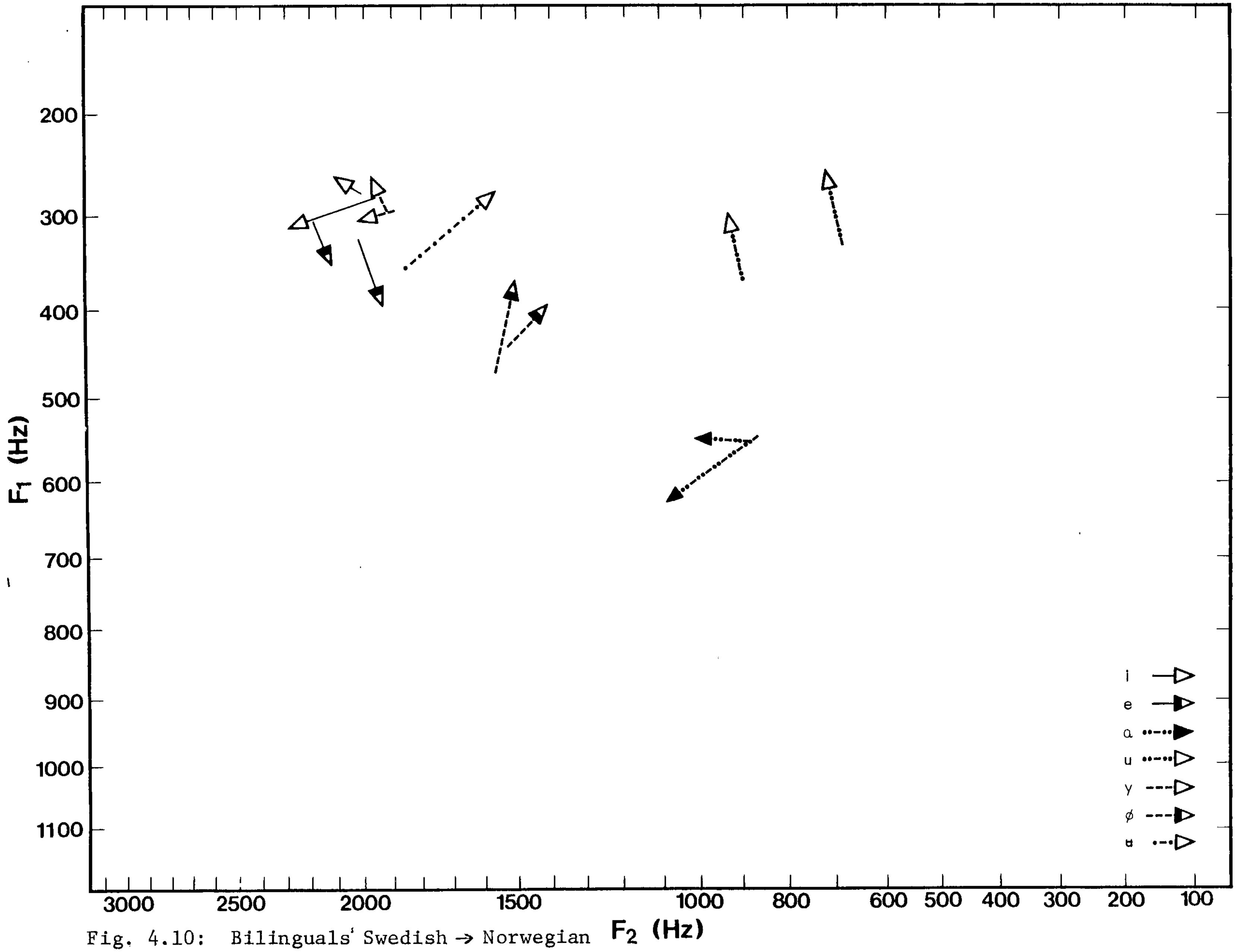

Fig. 4.10: Bilinguals' Swedish → Norwegian

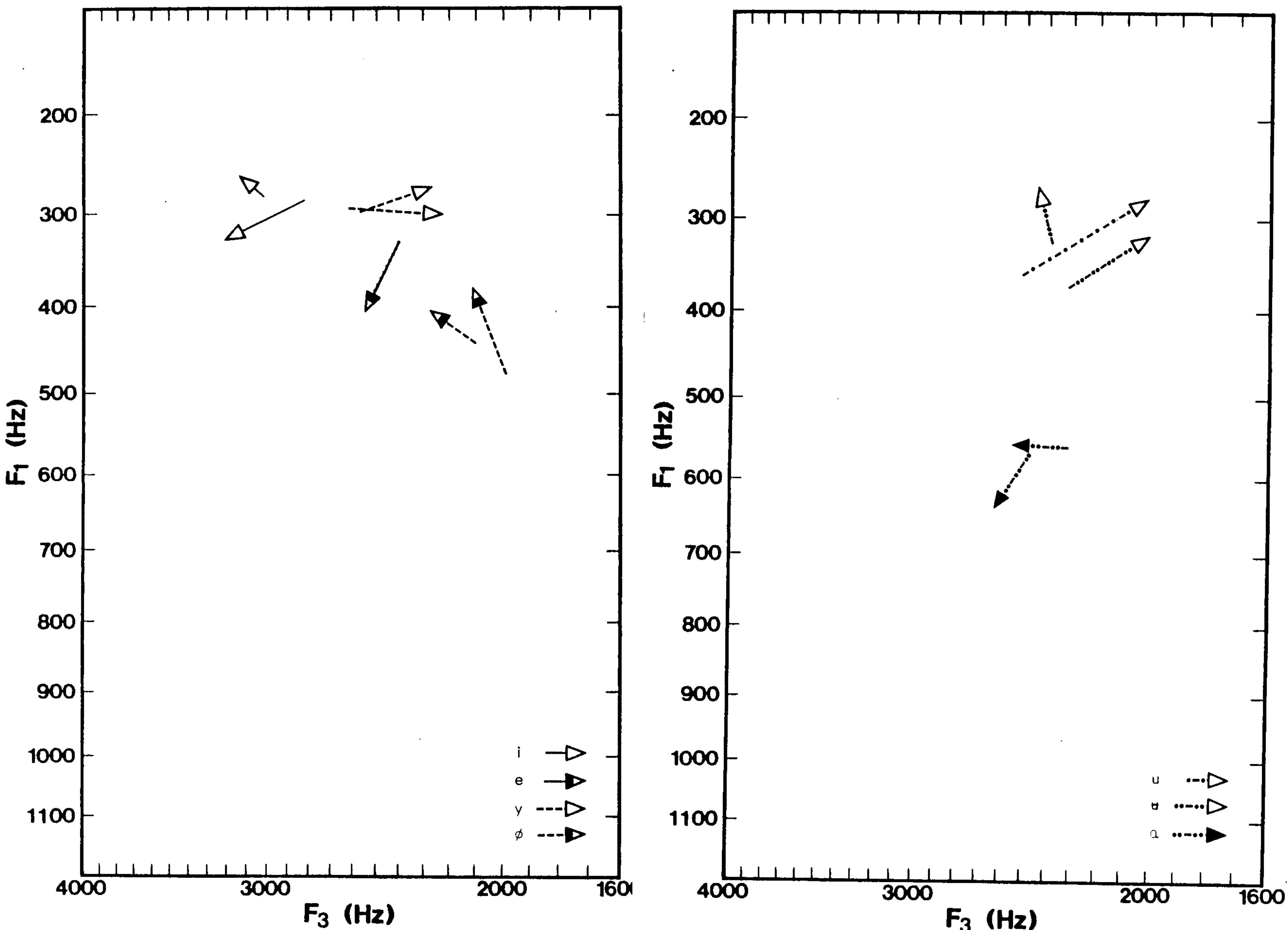

Fig. 4.11: Bilinguals' Swedish → Norwegian

It is unlikely that the cross-language differences noted in chapter 3 are due primarily to anatomical differences between the populations. In the bilingual data there are consistent differences between the vowels of Norwegian and Swedish as spoken by the same individual. These differences are, moreover, of roughly the same magnitude as those noted among the groups of monolingual speakers.

The single token of [ʉ] in this data set confirms that the Swedish [ʉ] is a good deal more fronted than the [ʉ] of Norwegian. This is in keeping with the historical development of this vowel, as described by Bergman (1968). Each language's [ʉ] had been a central vowel in the eighteenth century, but the Swedish vowel progressed steadily frontward in the vowel space, while the Norwegian vowel remained closer to the earlier form.

English-Danish [i u e o ɛ̧ ɔ æ]

The bilingual data show more clearly than do the monolingual data in Fig. 3.12-3.13 that a shift from English to Danish entails a strong upward shift in the phonetic space, and also a movement toward the periphery of this space. The most extreme differences are found in the vowels [æ] [ɔ] and [ɛ]; those in [e] and [o] are somewhat smaller, and those in [i] and [u] the smallest of all. The proportionally smaller cross-linguistic differences in the high vowels, which had also been noted in the monolingual data, thus appear to be merely the last in a series of progressively smaller height differences. The difference in [i] is fractionally less than that of [u], in keeping with its greater mean phonetic height. This phenomenon is in accordance with the low-level boundary limitations discussed in chapter 3.

Danish-German [i y u e ø o ɛ]

The Danish-German differences shown in Figs. 4.14-4.15 are based on a single bilingual speaker. There is a small but consistent height difference between the two languages, much the same as that shown in Figs. 3.16-3.17. There is almost no difference in the F2 of corresponding vowels, except for the greater backness of [o] in Danish. The differences in F3 are also small. Except for the vowels [y] and [e], in which the F3 values are nearly identical across languages, Danish has higher F3 values in the front vowels and lower F3 values in the back vowels. These differences are indicative of greater peripherality in Danish vowels than in German.

Swedish-German [i y u e ø o ɛ]

The striking difference in F1 between the (monolingual) German and Swedish data sets shown in Figs. 3.20-3.21 is largely absent from the bilingual data in Figs. 4.16-4.17. There is a weak tendency for the vowels of German to be higher than those of Swedish, but the majority of vowels produced by these two speakers are equally high in both languages. What height differences there are are largely confined to the mid front vowels. Recall, however, that the high vowels of Swedish are characterized by a good deal of diphthongization, which is lacking in the high vowels of German. This is, of course, a separate parameter that cannot be measured with the data at hand.

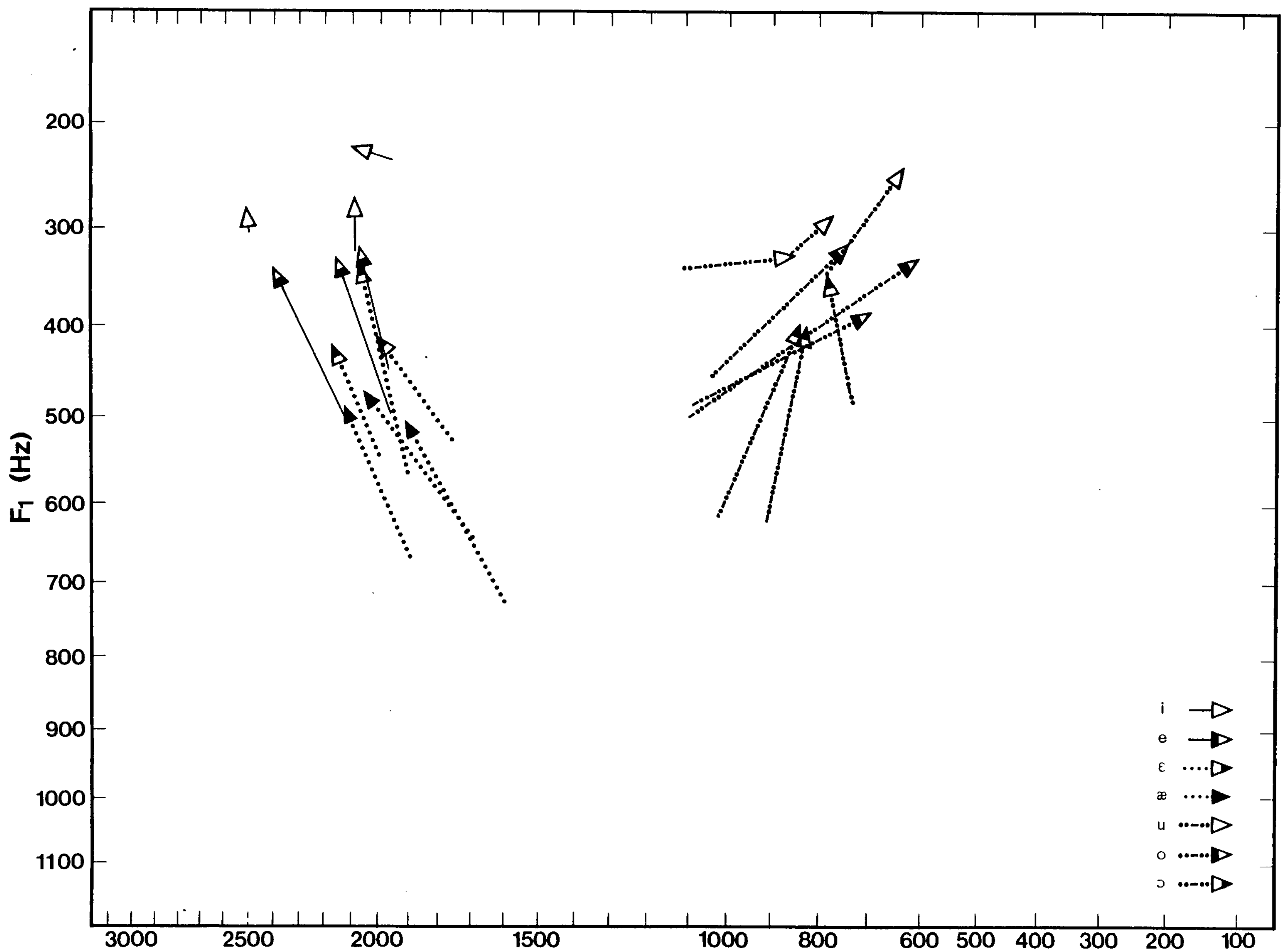

Fig. 4.12: Bilinguals' English → Danish

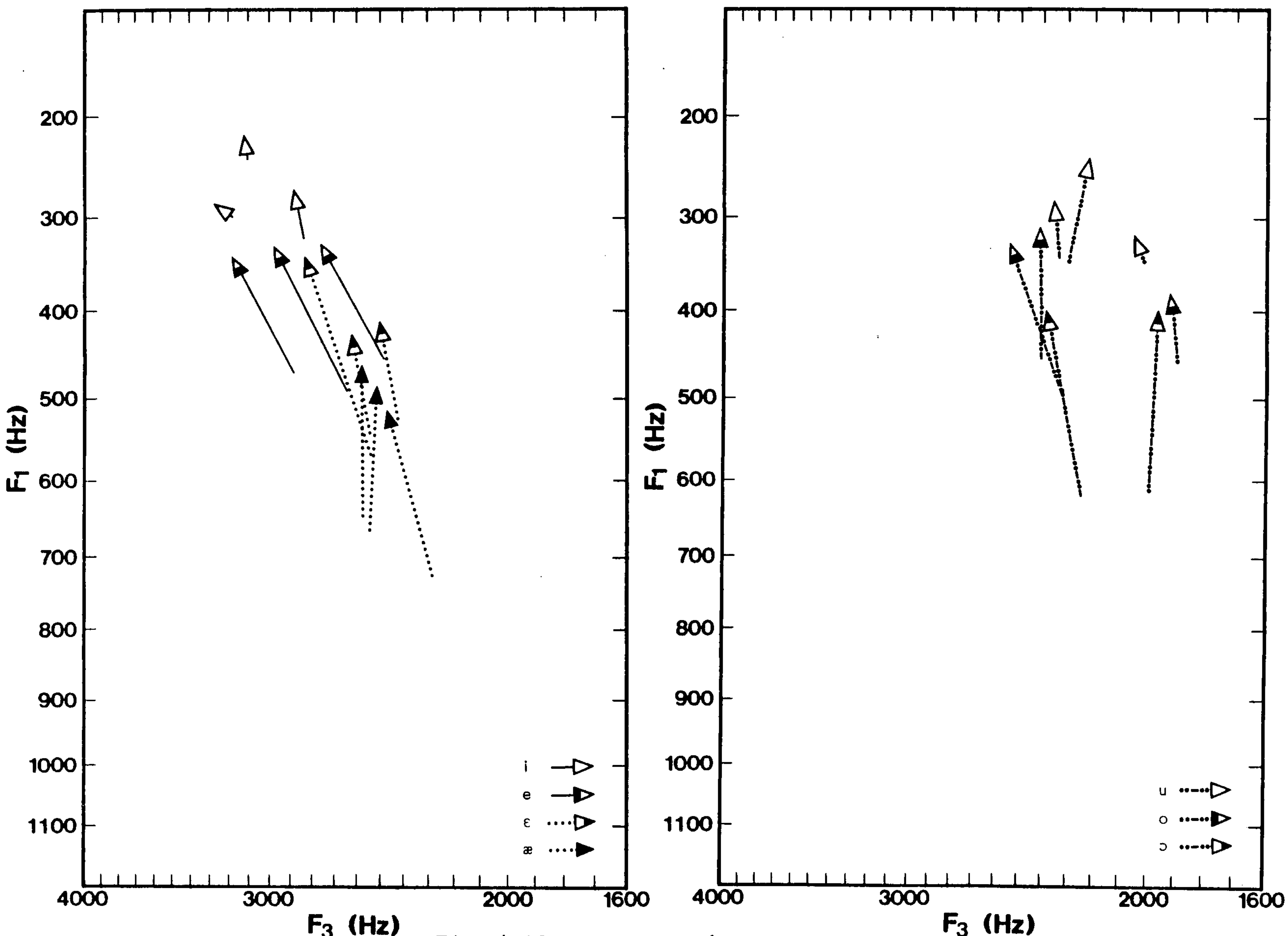

Fig. 4.13: Bilinguals' English → Danish

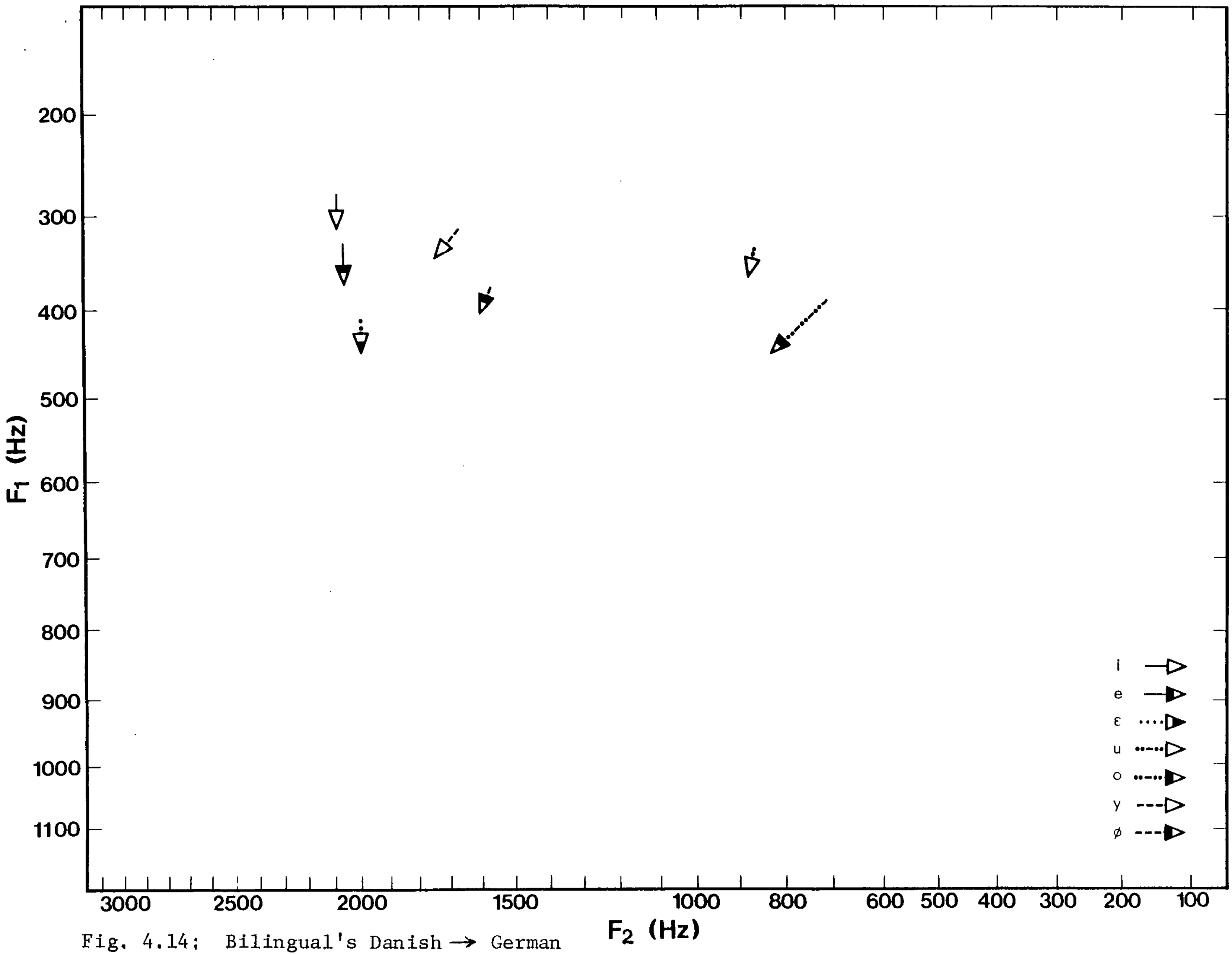

Fig. 4.14; Bilingual's Danish → German

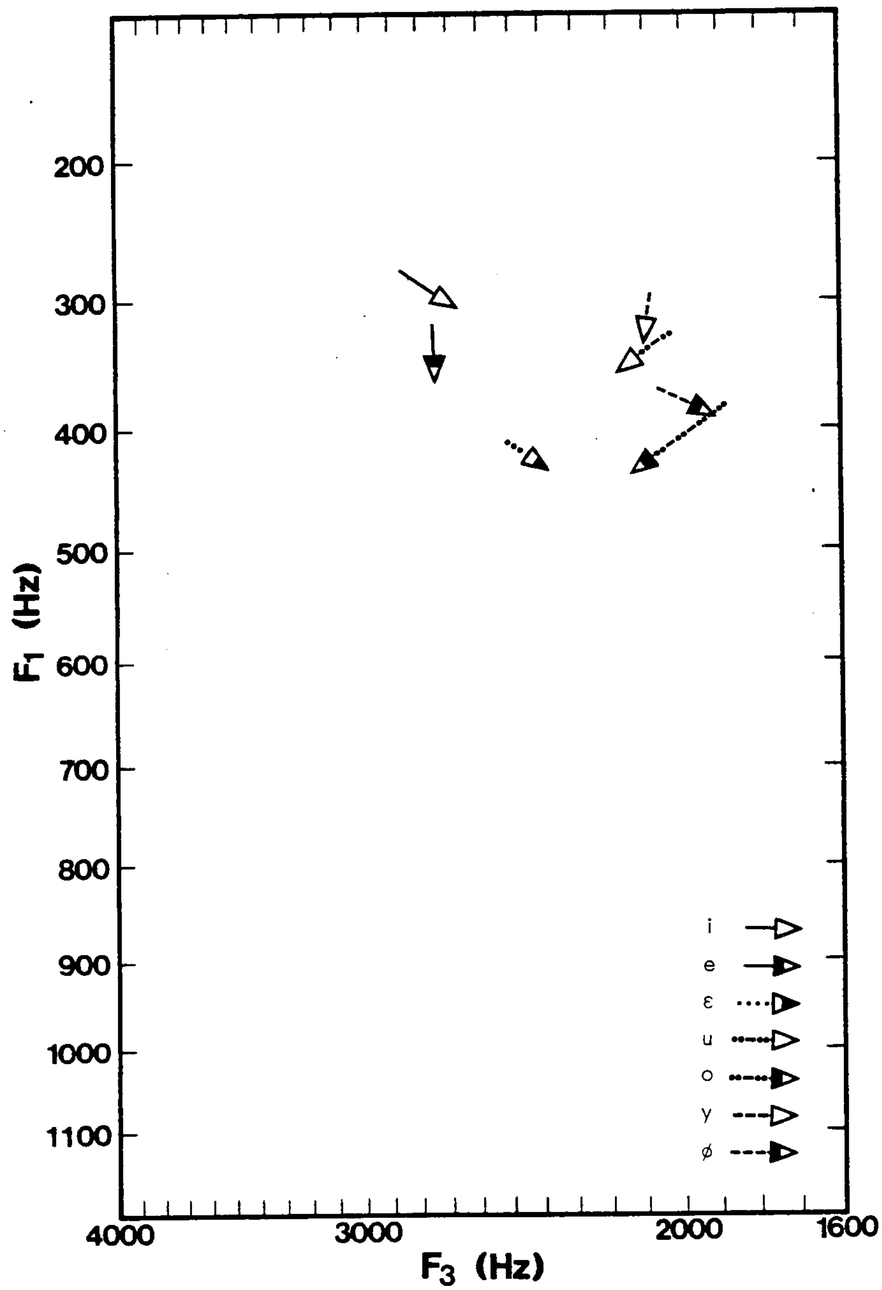

Fig. 4.15: Bilingual's Danish → German

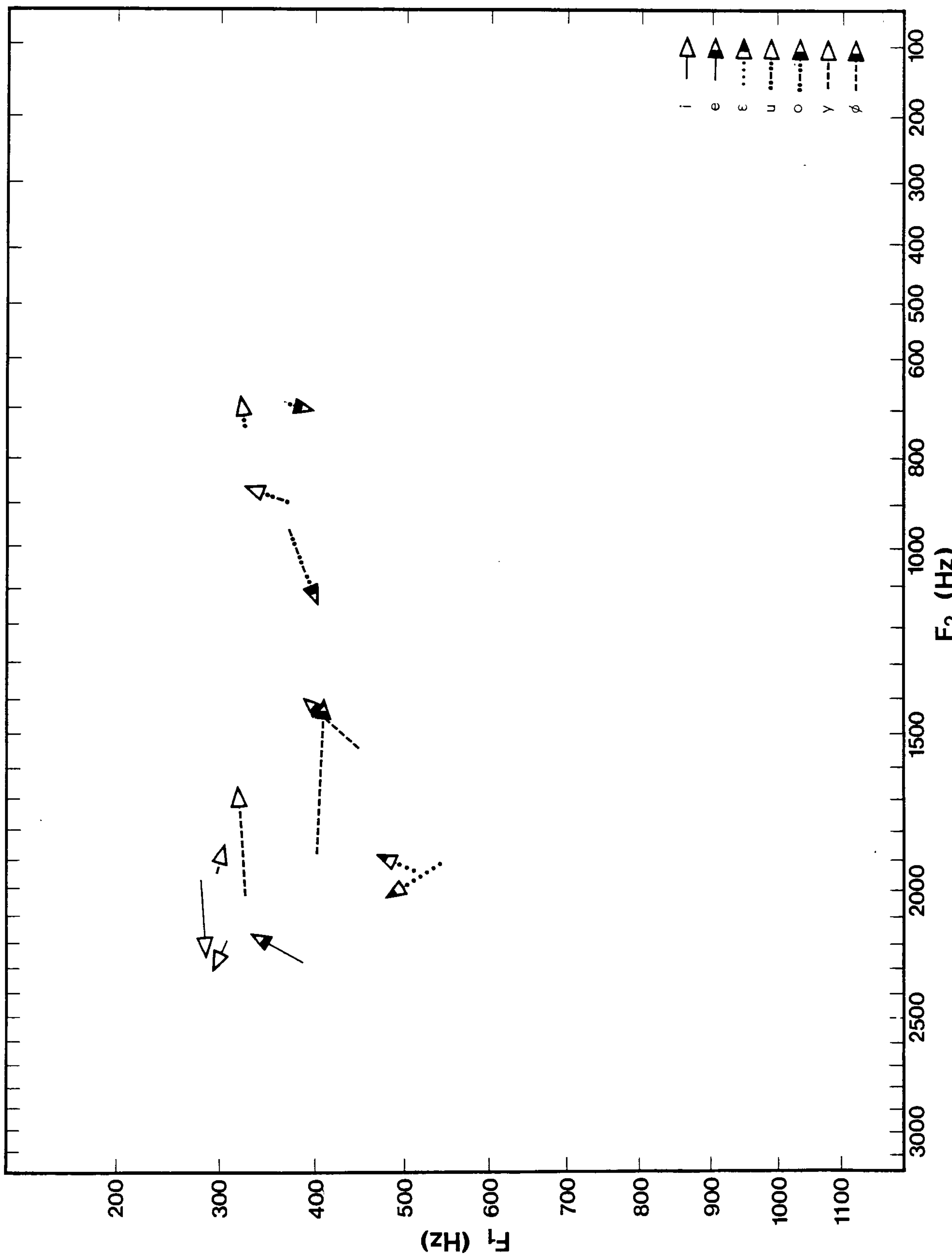

Fig. 4.16: Bilinguals' Swedish → German

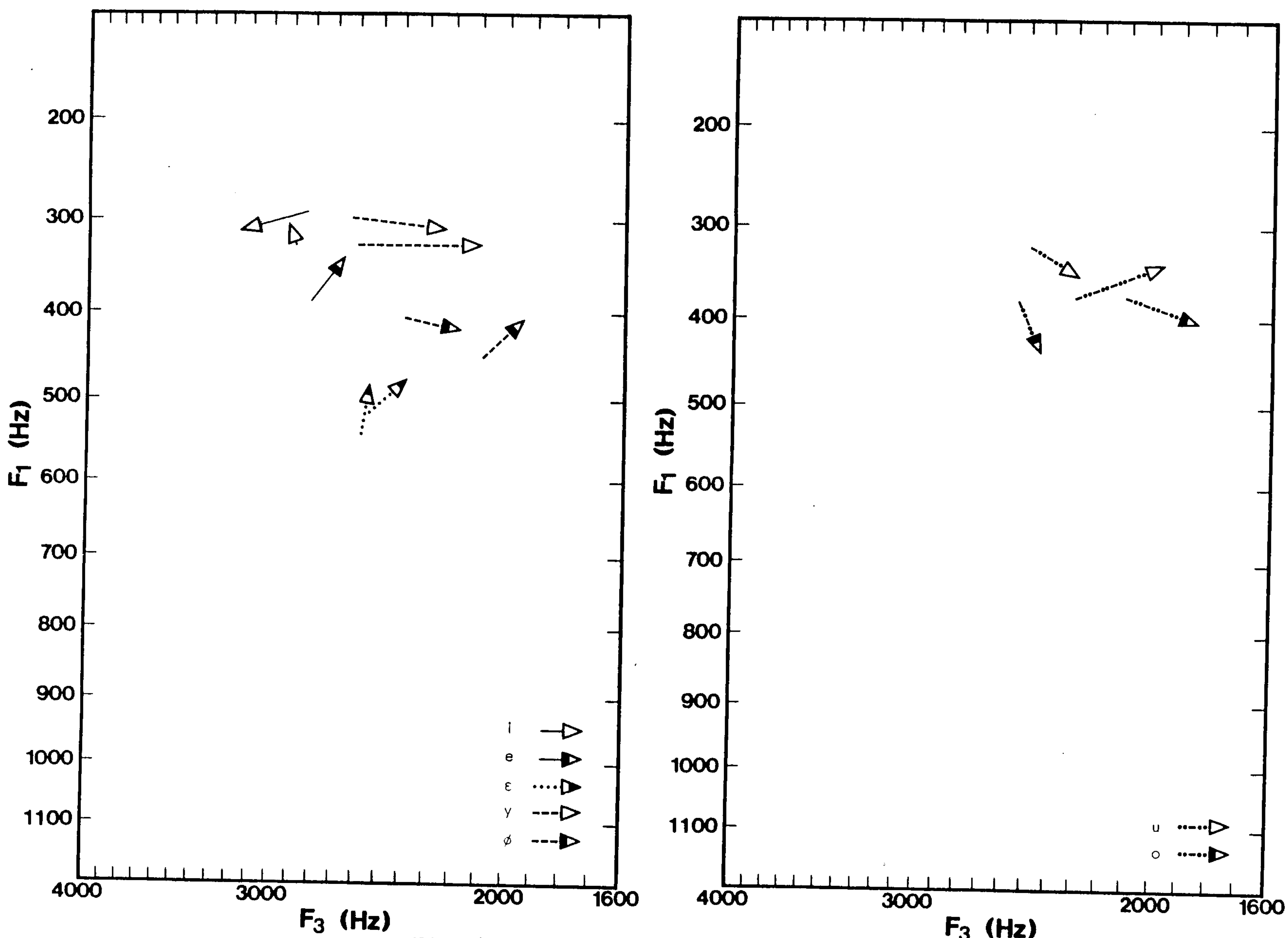

Fig. 4.17: Bilinguals' Swedish → German

The F2 differences in fig. 4.16 agree more closely with those in the monolingual data. Here as well, the front vowels of Swedish are seen to occupy a much narrower portion of the phonetic space than the front vowels of German; the Swedish front unrounded vowels tend to have lower F2 values, and its front rounded vowels higher F2 values, than the corresponding vowels of German. Front unrounded [e] does not conform to this generalization, as it has higher F2 and F3 values in Swedish than in German; this observation is, however, based on the vowels of only one speaker.

Among the back vowels, [u] appears to be more peripheral in German than in Swedish, with lower F2 and F3 values in the former language. However, just as in the monolingual data, there is something of an opposite tendency in the vowel [o], with one speaker's Swedish vowel more peripheral than his German vowel. (The other speaker, intentionally or otherwise, produced identical [o] vowels in both languages.)

With a single exception, the F3 values of the German vowels are lower than those of Swedish.

<u>English-Swedish</u> [i u e o ɛ]

The set of Swedish and English vowel phonemes discussed in this section is rather different from the set discussed in chapter 3. The vowels [e] and [o] are included here, the English data having been obtained by taking formant measurements at the initial portion of the vowels [eɩ] and [əʊ]. The vowel [ɑ] is missing, however, for the six bilingual speakers of Swedish and English all tended toward the British pronunciation of the latter, and most produced a vowel closer to [ɒ] than to [ɑ] in the word "hod". (The word "hard", which in British English is pronounced with an unrounded [ɒ], was not elicited; it was feared that rhotacization, an American characteristic, might have subtly affected the pronunciation of this vowel.)

The six bilingual speakers are in fairly close agreement, particularly in the domains of F1 and F2 shown in fig. 4.18. The F1 and F2 results suggest a considerably greater F2 range in Swedish than in English, with the Swedish front vowels fronter and back vowels backer than the comparable vowels of English. The vowel [i] is an apparent exception to this generalization, as most of the speakers produced this vowel with a lower F2 in Swedish than in English. However, the F3 of Swedish [i] tends to be higher than that of English [i], and as F3 is more indicative of the phonetic quality of a high front vowel than is F2, the generalization holds.

The only vowel to display a marked difference in height across these two languages is [e], which in Swedish is a good deal higher than it is in English. Of the remaining vowels, [i] and [o] are slightly higher in Swedish, [u] is slightly higher in English, and [ɛ] varies from speaker to speaker. Evidently, the differences in F1 do not fall into natural classes, and must be accounted for individually in any linguistic description.

In the monolingual data the vowel [ɛ] was found not to differ significantly between these two languages; if anything, the English vowel was slightly more fronted than the Swedish. However, in the bilingual data, reflecting the British

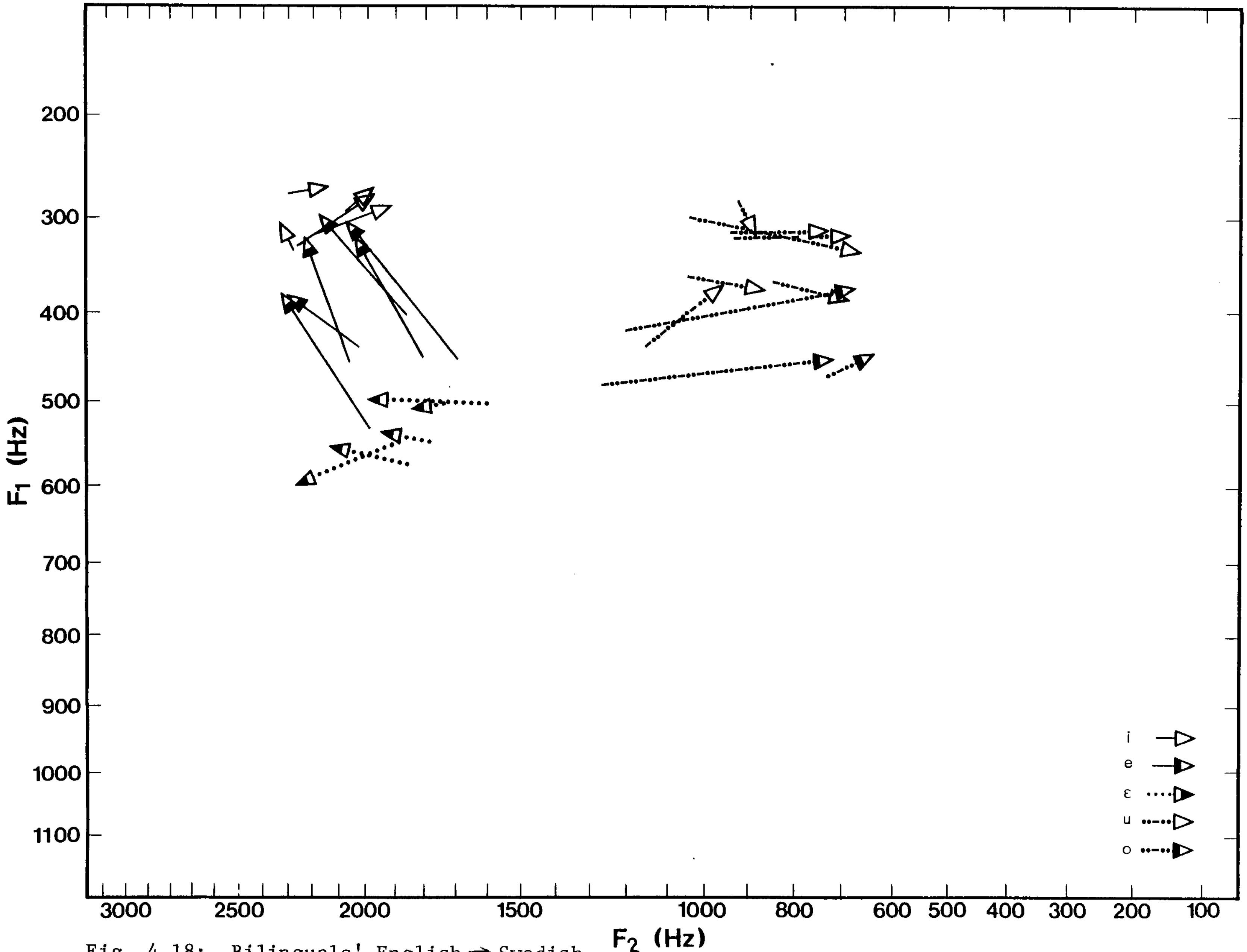

Fig. 4.18: Bilinguals' English → Swedish

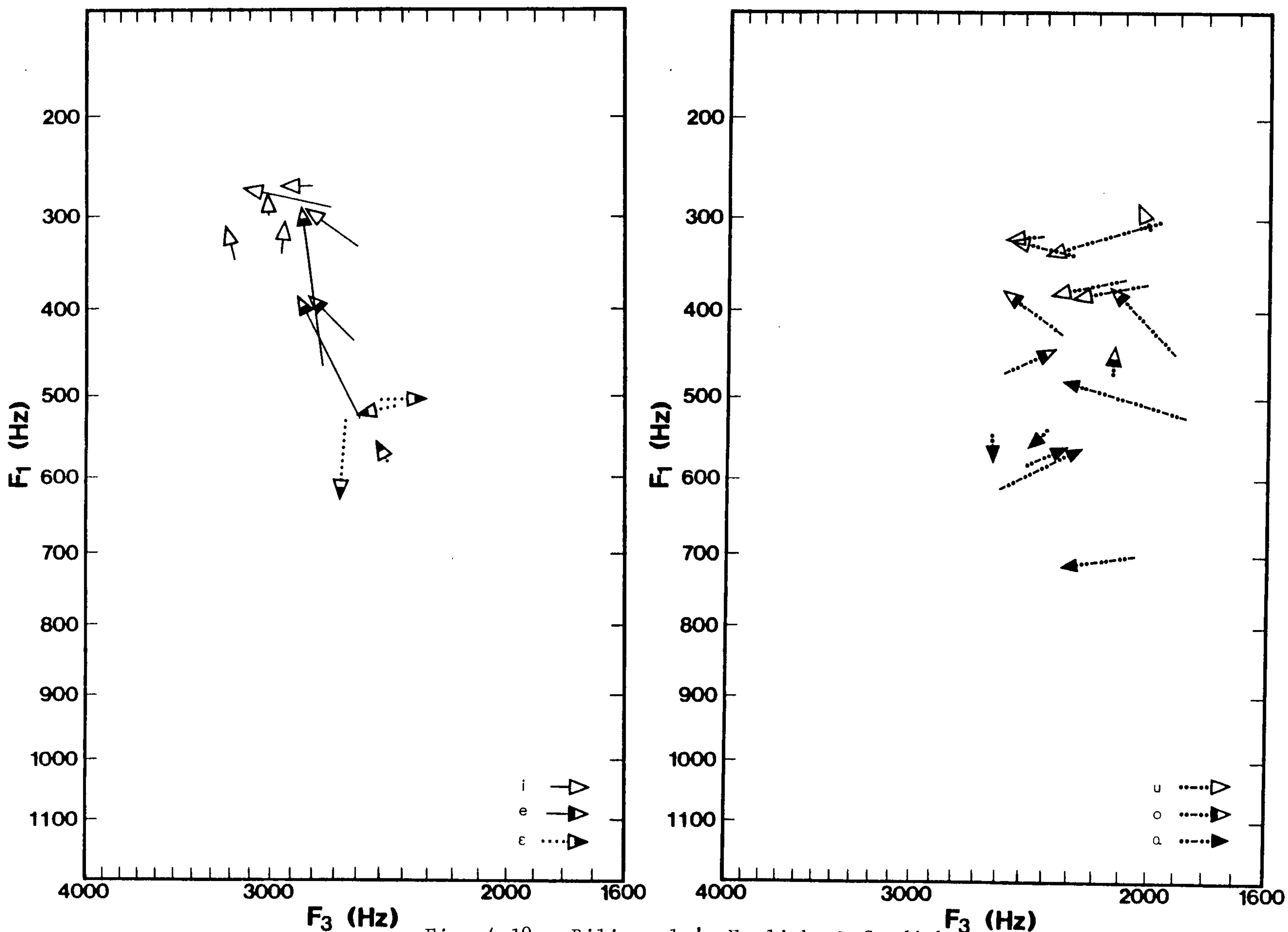

Fig. 4.19 Bilinguals' English → Swedish

rather than the American pronunciation, the difference is apparently significant, and it points in the opposite direction. Here the Swedish vowel is more fronted than the English.

The overall pattern established in the English-Swedish comparison is remarkably similar to that established in the English-German comparison (Fig. 4.4, above). In both cases the F2 range of English is narrower, the major F1 differences are confined to the front vowels, and to the vowel [e] in particular, and the pronunciation of the vowel [ɛ] is not as consistent across speakers as that of other vowels. One cannot dismiss this similarity by citing duplication of speakers; trilingual speakers of English, Swedish and German were in the minority in both the English-German and the English-Swedish comparisons. More likely, the similar patterns are due to the distinctive characteristics of the English vowels, present in both comparisons, and a degree of similarity between Swedish and German vowels.

Norwegian-German [i y u e ø]

The two Norwegian-German bilinguals produce patterns of shift which are smaller than the differences in the monolingual data. (Compare Fig. 4.20 to Fig. 3.24.) However, just as in the monolingual data, there appears to be a trend in the bilingual data toward lower values of F2 and F3 in German than in Norwegian, although the F1 results are mixed. This effectively rules out the hypothesis, raised in the previous chapter, that anatomical differences between the Norwegian and German groups might be responsible for the observed differences. To the extent that one can generalize from two speakers, it appears that in German one aims at a set of acoustic targets which are clearly more retracted, if no higher in the phonetic space than the targets of Norwegian.

The F2 difference is a small but consistent one; all of the arrows in fig. 4.20 point to the right, indicating lower F2 values in German. The F3 difference is somewhat greater in magnitude, again indicating lower formant values in German. In contrast, the F1 difference is not at all uniform across vowels; [i] and [y] are higher in German, [e] and [u] are higher in Norwegian, and [ø] is almost identical in the two languages. These patterns do not fall into any natural classes, and they do not agree with the patterns established in the monolingual data, wherein the German vowels were uniformly higher (>75 Hz. difference) than the corresponding vowels of Norwegian. Still, the two bilingual speakers are in rather close agreement with each other, both in the direction and in the magnitude of the language shift they produce in the domains of F1, F2, and F3.

English-Norwegian [i u e ɔ æ]

Five vowels common to Norwegian and English are plotted in Figs. 4.22 and 4.23. As in the case of English and Swedish, the bilingual comparison involves a slightly different set of vowels than did the monolingual comparison. The vowel [e] is included here, with the Swedish data drawn from the initial portion of the diphthong [eɪ]. The vowel [ɑ] is excluded, as the two Norwegian-English bilinguals tend toward a British pronunciation of the low back vowel in the word "hod". This rounded vowel is not strictly comparable with the unrounded low back vowel of Norwegian.

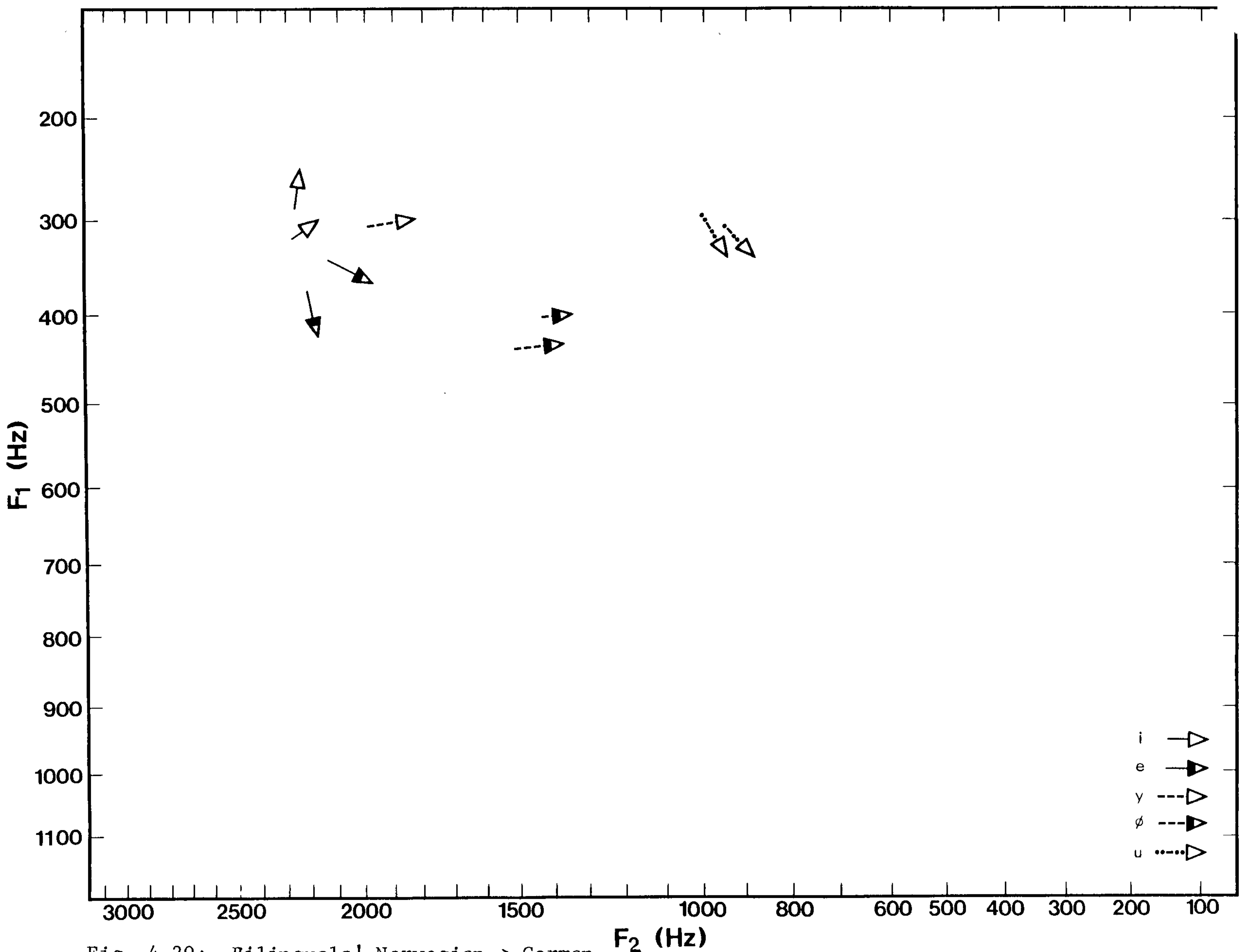

Fig. 4.20: Bilinguals' Norwegian → German

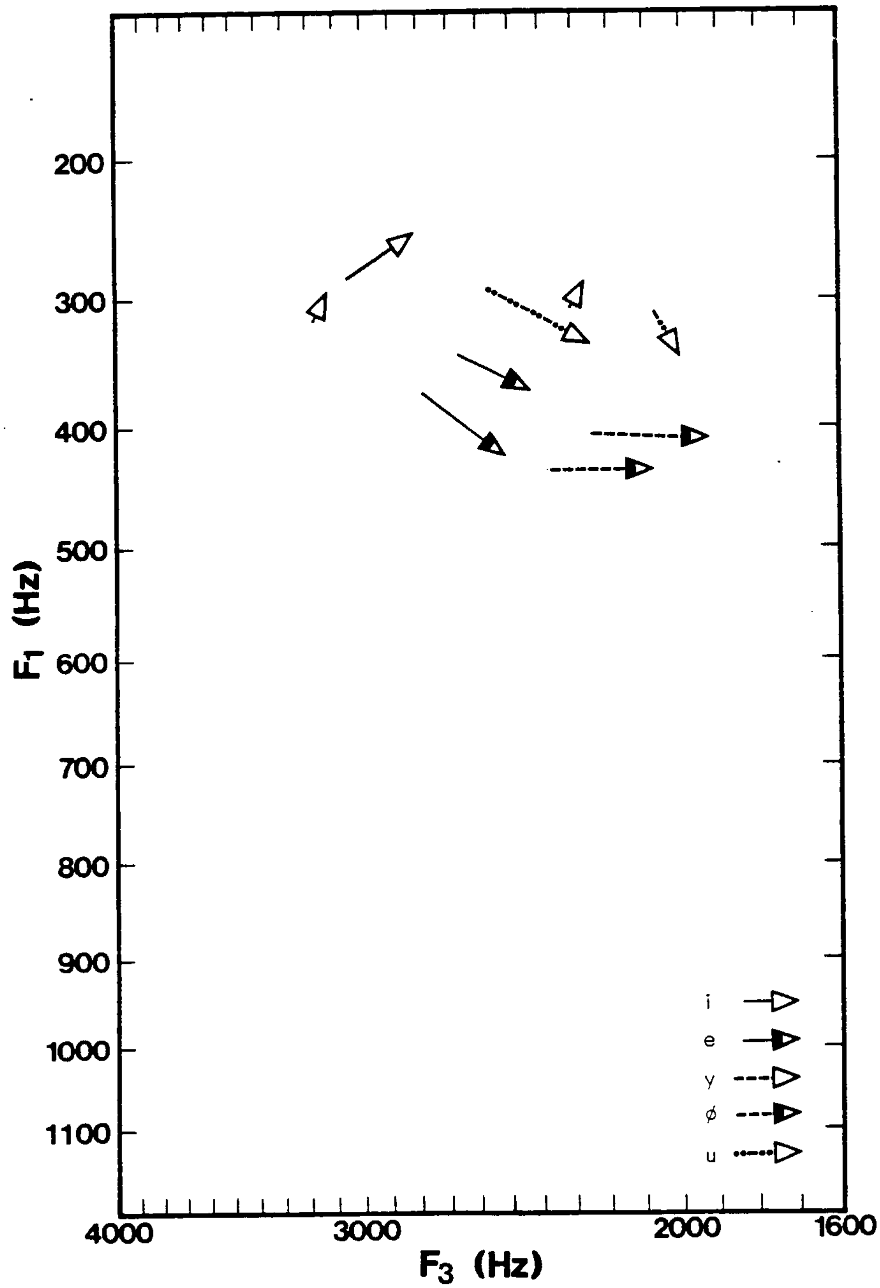

Fig. 4.21: Bilinguals' Norwegian → German

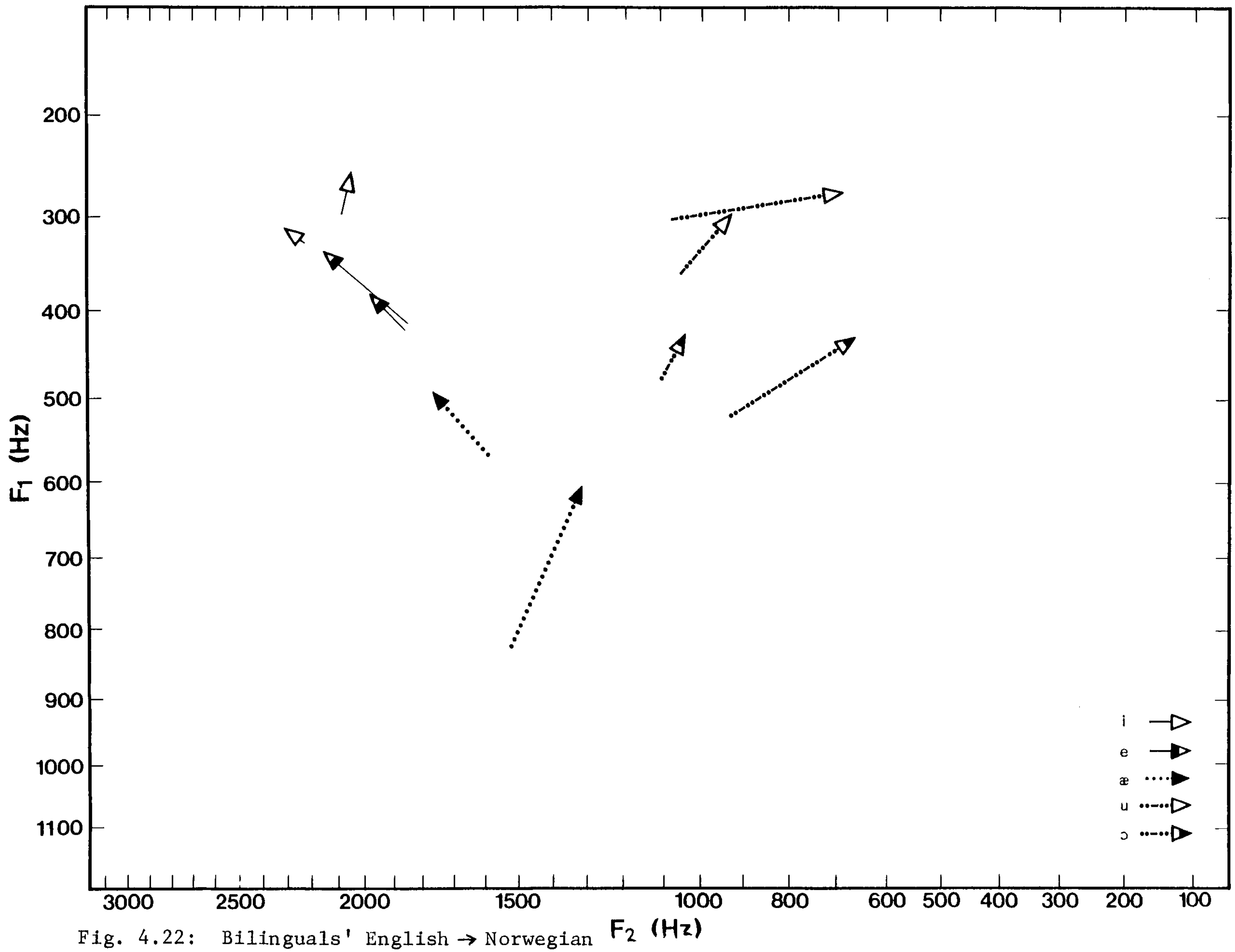

Fig. 4.22: Bilinguals' English → Norwegian

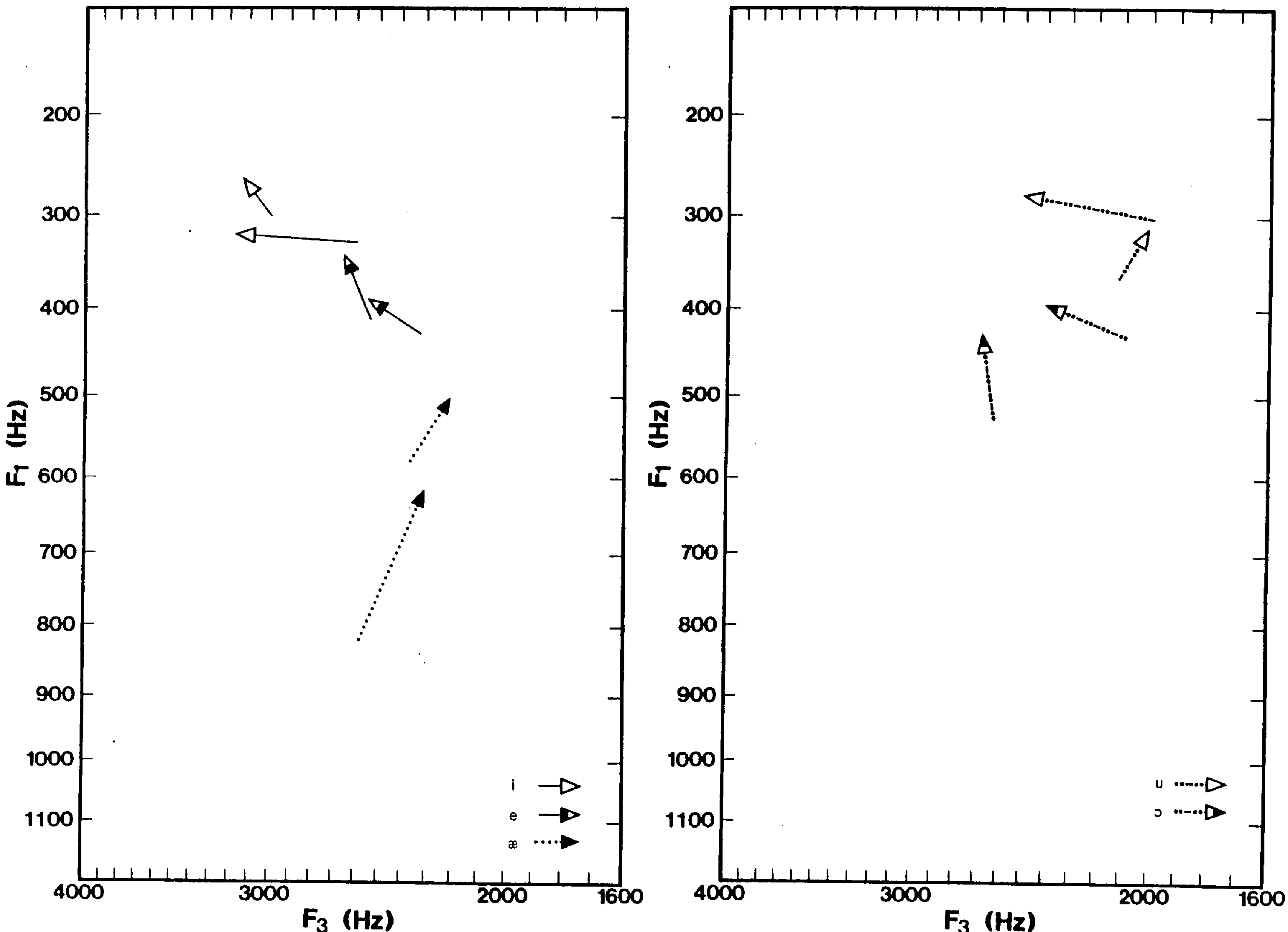

Fig. 4.23: Bilinguals' English → Norwegian

The two speakers display fairly similar patterns of shift from English to Norwegian. The trends in Fig. 4.22 suggest that Norwegian vowels are higher and somewhat more peripheral along the F2 axis than are English vowels. The clearer of the two is the height difference; every token in Fig. 4.22 indicates greater vowel height in Norwegian than in English. (It is worth noting that this is quite unlike the mixed results for F1 in the monolingual data of the preceding chapter.) The peripherality difference is less clear, as only three of the five vowels are consistently higher or consistently lower across speakers. The F3 data in Fig. 4.23 show more clearly than F2 that the vowel [i] is more peripheral in Norwegian than in English. However, the F3 values for the remaining vowels do not in general follow the patterns set by F2. The Norwegian vowels [æ] and [ɔ] are less peripheral than their English counterparts, and the vowel [u] differs from speaker to speaker. One should in any case be mindful of the very limited sample size before attaching great significance to these results.

Chapter 5: The Base of Articulation

Evidence from the preceding two chapters does not lend strong support to the view that vowel systems in natural languages are arranged in accordance with a principle of vowel dispersion. Not infrequently groups of vowels cluster together in a relatively small sector of the available phonetic space, while other regions remain relatively unpopulated. In Swedish, for example, the high front region of the phonetic space contains a disproportionate number of the vowels. In Danish, almost the entire vowel system is crowded into the upper region of the available phonetic space. Symmetrical systems are apparently the exception, rather than the rule.

Many counterexamples to the basic assumptions of dispersion theory have been noted in the preceding chapters. For example, the theory predicts that the vowels in one nine-vowel system ought to be phonetically similar to the vowels in another nine-vowel system. Yet not even such closely related vowel systems as those of Norwegian and Swedish are correctly predicted by the theory. In the first place, not all the vowels of these languages are even commonly transcribed in the same manner -- Norwegian is usually transcribed as having [æ] and [ɔ] where Swedish commonly has [ɛ] and [o] -- and even some of those vowels which are usually given the same phonetic transcription have been shown to display reliable and consistent differences from one language to the other. Reliance on dispersion theory alone would result in a less than adequate account of the facts of Norwegian and Swedish.

There is, however, an alternative interpretation of dispersion which is in better agreement with the facts discussed in chapters 3 and 4. Perhaps dispersion theory should not be expected to do more than predict the <u>separation</u> between vowels. It may be less important that the high front vowels of two identical systems have the same set of formant frequencies, than that they be equally distant from the corresponding high back vowel of each system. Let us, for example, consider the data from Dutch and English in figs. 3.6 and 3.7 (reproduced here as figs. 5.1 and 5.2). The front unrounded vowel [i] of Dutch is paired phonologically with a front rounded [y]. The "standard" dispersion theory would predict that the Dutch [i] would be more fronted than the [i] of a language such as English, which has but a single high front vowel, since a higher F2 and F3 for [i] maximizes its separation from [y]. The data in figs. 5.1 and 5.2 show that this particular prediction is not borne out, since English [i] is in fact more advanced in the phonetic space than is Dutch [i]. However, if we consider instead the separation between the vowels, we can see that the distance in the phonetic space between Dutch [i] and [u] is slightly greater than that between English [i] and [u]. This is in accordance with the predictions of dispersion theory.

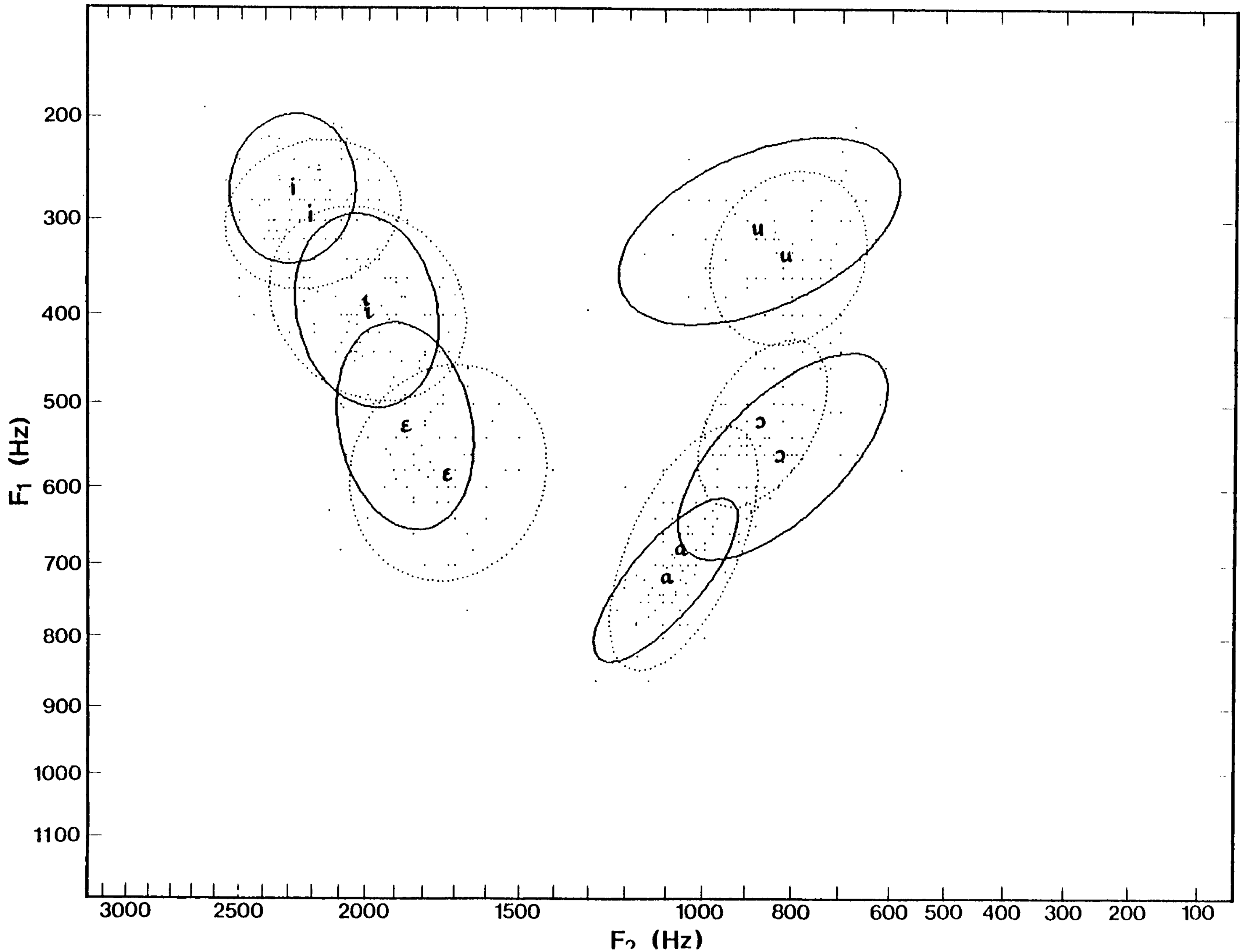

Fig. 5.1: Shared vowels of English (solid) and Dutch (dotted)

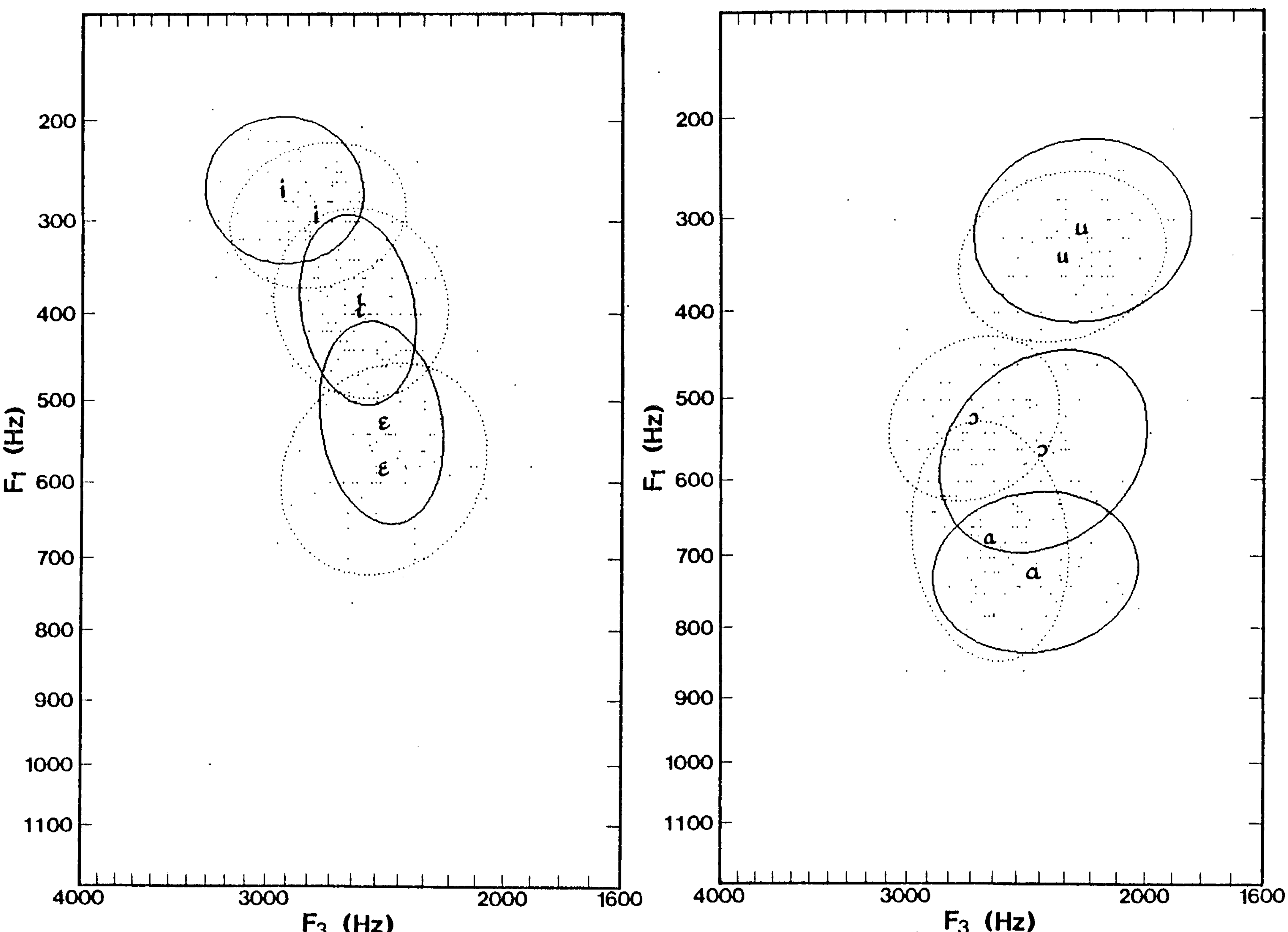

Fig. 5.2 : Shared vowels of English (solid) and Dutch (dotted)

Base of Articulation

It does not seem at all unreasonable to separate the question of vowel dispersion from more specific questions of vowel placement, such as whether one particular system is uniformly more fronted or lower than another system, or even whether the vowels of one particular system are rotated in a clockwise or counterclockwise direction with respect to the similarly-transcribed vowels of another system. The effects of one should not be regarded as lessening the validity of the other.

Questions of vowel placement have, in fact, been considered long before questions of vowels dispersion. In the seventeenth century John Wallis observed:

> "Notandum tamen est, apud varias gentes nonnihil diversitatis inter pronunciandum reperiri, quae non tam singularum literarum, quam totius potius loquelae communis est affectio. Angli nempe totam pronunciationem quasi promovent versus anteriorem oris partem, et faucibus apertioribus loquuntur; unde et soni fiunt distinctiores. Germani potius retrahunt versus posteriorem oris partem et gutturis imum; unde fortius et magis strenue pronunciant. Galli propius ad palatum omnia formant, et faucibus minus dilatatis; unde pronunciatio evadit minus distincta, et quasi admisto murmure confusa. Item; Itali, et praesertim Hispani, productiori tenore loquuntur; Galli magis properantur; Angli tenore medio. Galli (et Scoti eorum aemuli) periodorum et clausularum postremas syllabas elevant seu acuunt; Angli deprimunt seu gravant; quae non tam singularum vocum, quam totius sententiae tenoris est affectio. Aliaque hujusmodi etiam apud alias Gentes discrimina, cuilibet, prout se res offert, observanda, relinquo."
>
> [It is worth noting, however, that differences in pronunciation occur in various languages which are not attributable so much to the individual letters, as to the whole style of speech of the community. For instance, the English as it were push forward the whole of their pronunciation into the front part of the mouth, speaking with a wide mouth cavity, so that their sounds are more distinct. The Germans, on the other hand, retract their pronunciation to the back of the mouth and the bottom of the throat, so that they have a stronger and more forceful pronunciation. The French articulate all their sounds nearer the palate, and the mouth cavity is not so wide; so their pronunciation is less distinct, muffled as it were by an accompanying murmur. The Italians, and the Spaniards even more, speak with a slow tempo, the French speak faster, and the English are in between. The French, and the Scots equally, raise or sharpen the pitch of the last syllables of sentences and clauses, while the English lower or deepen it; this is a characteristic not of individual words but of the sentence taken as a continuous whole. I leave it to others to observe differences of this kind among other peoples, as the opportunity presents itself.]
>
> Wallis 1653 (Translation by Kemp (1972))

This notion of uniform differences between languages has persisted in the phonetic literature under various labels. Sweet (1892) referred to the "organic basis" of a language--certain general tendencies which control its organic movements and positions--and outlined the differences between French, German, and English in more specific articulatory terms than did Wallis. Honikman continued in Sweet's descriptive tradition, describing the basis as "the gross oral posture and mechanics, both external and internal, requisite as a framework for the comfortable, economic, and fluent merging and integrating of the isolated sounds into that harmonious, cognizable whole which constitutes the established pronunciation of a language (1964:73)." Others, such as Jespersen (1913), Trubetzkoy (1929), Malmberg (1963), Delattre (1965), and Drachman (1973), have gone beyond the enumeration of cross-language differences and have sought to integrate the notion of "base of articulation" (as it has come to be called in most modern sources) into phonological theory.

The notion of base of articulation is intuitively very appealing. It would seem to account in a very natural way for much of the variation between languages, as a global adaptation of the articulators to the phonological processes of a particular language. Indeed, this basic concept is a familiar one; those persons with a gift for mimicry can re-create the base of articulation of various languages with great success (what might be called a "Sid Caesar effect"), and most individuals can convey some semblance of a "French accent" or "Italian accent" with some adjustments of the articulators. However, the question of what adjustments (if any) characterize the base of articulation in different languages has not received adequate attention.

Let us now examine whether differences in the base of articulation of different languages could be associated with the sort of reliable phonetic differences across a set of vowels that we have observed in the previous chapters.

Germanic bases of articulation

Surprisingly few linguists have attempted to describe the base of articulation of any language in detail. Honikman (1964) and Erazmus (1980) have done so for English and some other European languages, notably French and Polish. Little has been said about the languages in our sample, apart from references to "the vigorous lip rounding" of German, as opposed to the "relatively unvigorous lip rounding" of English (Honikman 1964:75) and to the fact that "frequently in German, especially in men, pharyngeal contraction is usual" (p. 79). Let us see what evidence our data provide.

Honikman's claim about the considerably greater degree of lip-rounding in German than in English seems to be borne out, within the limitations of the data. The only [+round] vowels common to German and English are [u] and [o], and full data for the latter are unavailable in the monolingual study (chapter 3). Still, the evidence we have suggests that the F2 of German rounded vowels is significantly lower than that of English rounded vowels; this is consistent with more vigorous rounding in German.

There is little support in these data for the claim that German employs greater pharyngeal contraction than do English and French (in which the pharynx is "relaxed"). It may be surmised that Honikman refers here to pharyngeal constriction, rather than shortening of the pharyngeal length. In fact, Lindau (1975) suggests that the primary acoustic effect is the same for both narrowing and shortening the pharynx: the frequency of the first formant is raised. Yet the vowels of German tend to have lower F1 values than their English counterparts, both in the monolingual and bilingual comparisons.

A third global observation about German comes from Moulton (1962:58): "All German vowels are tenser than their English counterparts." In spite of its name, which suggests increased muscular tension in one or more of the articulators, the feature [Tense] is probably not an articulatory feature at all. It is more closely associated with the notion of peripherality in an acoustic (F1 x F2) space (Stockwell 1973). With this interpretation, the data in figures 3.2 and 4.4 bear out Moulton's observation in a convincing fashion.

Acoustic peripherality cannot be achieved by any single articulatory gesture. The front vowels cannot be advanced by some overall postural preference without concomitant advancement of the back vowels, nor the back vowels retracted without retraction of the front vowels. Peripherality can perhaps be achieved by the union of several concomitant gestures -- e.g. vigorous lip rounding, fronted tongue position, and narrowed pharynx. Still, it is evident that peripherality falls within the acoustic, rather than the articulatory, domain.

Beyond the few German-English correspondences discussed above, we cannot directly determine whether base of articulation accounts for any (or all) of the phonetic differences described in the previous chapters. However, we can at least look at these acoustic differences in an articulatory light, and attempt to reconstruct a set of gestures that might have given rise to them. To do so is, of course, not to confirm that these gestures are actually employed in the languages in question; this would require a considerable amount of articulatory data, not presently available. But this would at least give us an idea of which phonetic differences are open to interpretation as differences in base of articulation.

As a guideline, we might use the set of articulatory parameters defined by Ladefoged (1980). These are the parameters along which the articulators typically deviate from a "neutral" position of the vocal organs. The parameters of major relevance to our discussion are those involving the tongue and the lips. Ladefoged's Back raising and Front raising parameters represent the Height and Backness dimensions, while the features of Lip protrusion and Lip width represent the Rounding and Spreading of the lips.

Language comparisons

Let us review some of the cross-linguistic comparisons described in the preceding two chapters in an articulatory light. Some of the differences between individual vowels may suggest overall differences in the base of articulation. (It should, of course, be borne in mind that these differences are only inferred from the acoustic data. The corresponding articulatory measurements have not been made.)

English-German

As discussed above, the most salient of all differences between the vowel systems of English and German is not attributable to any single articulatory parameter. It is, rather, a difference in peripherality, the result of several concomitant gestures.

The German vowels appear to be more peripheral than the English. However, here peripherality does not take the form of a uniform expansion of the German vowel system within the phonetic space. Rather, it appears to be split into two separate phenomena: horizontal expansion and vertical expansion. This is best observed in figs. 4.4 and 4.5. The (non-low) front vowels of German display a strong vertical expansion and a slight horizontal expansion with respect to the front vowels of English. The back vowels of German display a strong horizontal expansion and almost no vertical expansion with respect to the back vowels of English.

The horizontal expansion of the German system may be attributable to the "vigorous rounding" commented on by Honikman (1964). It should be made clear that the difference we are speaking of is not a base of articulation difference in the conventional sense. It is unlikely that German speakers have a more rounded "neutral position" of the lips than English speakers do, for though rounding tends to lower F2 and F3, the front unrounded vowels of German have higher F2 and F3 values than their English counterparts. Rather, the difference appears to be directly related to the value of the phonetic feature [Round]. The German data suggest that this feature is mapped onto the parameters of lip position in a very different way from that of English: positive and negative values of the feature [Round] in German seem to span a wider range of lip positions than do the positive and negative values of this feature in English. The [-round] vowels are relatively more spread and the [+round] vowels relatively more rounded in German than in English. Differences of just this kind have been documented by Linker (1982) in a study of lip position in a number of areally diverse languages.

The vertical expansion of the German system is almost entirely restricted to the front vowel domain. Because of this context-sensitivity, it cannot be said that German has a uniformly higher neutral tongue position than English does. The German front vowels appear to be mapped onto larger values along the parameter representing the height of the tongue than are the English front vowels, but this is not true of the back vowels. The dependence of this mapping on the backness context must be reflected in any descriptively adequate grammar.

German-Dutch

In the monolingual data the vowels of German are, on average, higher than the vowels of Dutch, though the difference is not entirely uniform: the high vowels display smaller cross-linguistic differences than the mid vowels, and the low vowel [a] is nearly identical in these two languages. Much of this non-uniformity may be attributed to the geometry of the vocal tract. As argued in Disner (1978), there is simply less room for vowels to vary near the boundaries of the phonetic space. By this reasoning, however, the vowels [i] and [u], bounded by a fixed articulator, should vary less than [a]. The unexpected similarity of [a] in the two languages -- whether it be the result of a higher than expected position in Dutch or a lower than expected position in German -- is an exception to the generalization that applies to mid and high vowels.

The two bilingual speakers present a somewhat different picture. Here, the F1 differences are greatest in the [+low] vowels [ɛ a] and rather small elsewhere. Due to the limited number of German-Dutch bilingual speakers and their differences from each other, these data should be interpreted with some caution.

It was mentioned in chapter 3 that the greater horizontal peripherality of German may be due to a difference in lip rounding, rather than tongue position, in light of the tendency for all the [+round] vowels, [y ø u o], to pattern together. While the statistics are not entirely conclusive, the evidence suggests that the feature [Round] is mapped onto a wider range of lip positions in German than it is in Dutch, just as noted previously in the English-German comparison.

English-Dutch

The differences between these two languages do not seem to be attributable to any uniform articulatory difference.

German-Bavarian

The vowels of Eastern Central Bavarian are all more advanced in the phonetic space than are the corresponding vowels of German. This tendency may reflect a base of articulation difference. However, not all of the F2 and F3 differences are significant, and those that are significant do not fall into natural classes. These facts may therefore be properties of individual vowels which have to be specified separately, rather than by a choice of overall articulatory settings.

Swedish-Norwegian

There is a weak tendency in the monolingual data for the vowels of Swedish to be higher and more retracted than the vowels of Norwegian. Few of the differences are significant, however, and in some cases (F1 of ʉ, ø; F2 of ø) the trends are reversed.

In the bilingual data, however, the trends are rather different. The majority of the vowels tend to be higher in Norwegian; only the vowel [e] is distinctly lower. The Norwegian [e ʉ ø] are in fact more retracted than the Swedish. It should be borne in mind, however, that the bilingual data represent only two speakers.

English-Danish

The vowels of Danish are all higher than those of English, and very likely more peripheral as well. It is said, colloquially, that Danish is spoken 'higher in the mouth' than English is; in conventional terms, this might be described as a higher neutral position of the tongue in Danish.

The boundary effect described above for German-Dutch seems to hold in this example as well. The cross-linguistic differences are less pronounced at the boundaries of the phonetic space (vowels [i u æ]) than in the mid region. As predicted, the high vowels vary even less across languages than the low vowels, and the high-mid vowels less the low-mid. To the extent that these facts follow from the geometry of the vocal tract, they need not be specified as properties of the individual vowels in the grammar.

In the bilingual data (Figs. 4.12-4.13) there is a clear difference in peripherality between the two languages, rather more pronounced in the back-vowel domain than in the front. This suggests a difference in the degree of rounding employed by the two languages, as in the German-English example above. The trend is not as clear in the monolingual data (Figs. 3.12-3.13), possibly because of the limited number of tokens for Danish [u] and [ɔ].

Danish-Swedish and Danish-German

As in the Danish-English example, the vowels of Danish give indications of having larger values along the tongue height parameter than do the vowels of Swedish or German. All the vowels in the Danish-Swedish comparison are significantly different in height from one language to the other; in contrast, only about half the vowels in the Danish-German comparison are significantly different. In both cases the differences are diminished near the articulatory boundaries.

The very limited bilingual data (from a single speaker) suggest greater peripherality in Danish vowels than in German. (There were no Danish-Swedish bilinguals in the sample.)

The front rounded vowels of Danish are more widely separated along the F3 dimension than are the front rounded vowels of either German or Swedish. That is to say, there is more of a distance between [i] and [y], and between [e] and [ø], in Danish than in either German or Swedish. This might suggest a more rounded neutral position of the lips, were the front unrounded vowels of Danish not more advanced in the phonetic space than those of Swedish. But figures 3.16-3.19 give ample evidence of such advancement. What seems rather to be the case is that Danish draws a sharper distinction betwen positive and negative values of the feature [Round] than does German or Swedish.

German-Swedish

The German vowels in the monolingual sample tend to be higher than the corresponding vowels of Swedish. The bilingual data (from two speakers only) show much less of a height difference between these two languages; cross-linguistic differences among the high vowels are especially small, perhaps due to a boundary effect.

The distance between the front rounded and front unrounded vowels is greater in German than in Swedish, in both samples.

English-Swedish

Of the vowels common to these two languages, those of Swedish are more peripheral than those of English. The bilingual data indicate that the greatest differences in F1 are found in the front vowels [i e] and the greatest differences in F2 are found in the back vowels [u o]. The distribution of these is reminiscent of that of English-German, and English-Danish, above, and would seem to suggest that this pattern reflects an idiosyncracy of English, rather than of the languages it is compared to. (Compare fig. 4.18 with fig. 4.4, also 4.12.)

Norwegian-German

The German vowels tend to be more retracted in the F2 and F3 space than the Norwegian vowels. These differences are small but consistent across the monolingual speakers and the two bilingual speakers.

English-Norwegian

The two vowels common to the monolingual and bilingual data sets show very different correspondences between these two languages. Norwegian [i æ] are lower than the corresponding vowels of English in the monolingual sample, and higher than the corresponding vowels of English in the bilingual sample.

The cross-linguistic differences exhibited by the two bilingual speakers (figs. 4.22-23) are in rather close agreement with each other, apart from the F2 of [æ]. They suggest a uniformly higher and more horizontally expanded vowel system in Norwegian. This further attests to the low and centralized quality of English vowels with respect to the vowels of other Germanic languages.

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This is by no means an exhaustive list of the differences between these selected pairs of languages. These are only the ones which can be deduced by comparing the formant frequencies of a subset of each system -- the sometimes very limited number of vowels which are phonetically similar in both languages.

It is, of course, possible that other correspondences would come to light if all of the vowels having like values of a feature such as [Round], irrespective of other feature values, were considered together; that is a very different topic from this one. (It is not at all clear how this could be done, considering the obvious interactions between features.)

There are, however, a good many cross-linguistic differences that cannot be captured by even an exhaustive list of the possible base of articulation differences between the languages concerned. These are the unique differences between individual segments which, though reliably and consistently produced by speakers, are not associated with any global adjustment of the articulators. For example, the [y] of German differs from the [y] of Swedish by having the tongue lower and more retracted (Hjorth 1905) and by having a smaller lip-opening (Lindau 1978). As we have seen, the vowels of German are otherwise a good deal higher than those of Swedish. Furthermore, though the vowels of German do tend to be more retracted in the formant space than those of Swedish, consistent with tongue retraction and lip rounding, this effect is disproportionately large in [y] (particularly for a front vowel). Similarly, the vowel [ɛ] in Standard Dutch, and particularly in certain regional dialects, is even lower than would be expected in comparison to the vowel [ɛ] of German or English.

These and other exceptional differences might be integrated into the grammar as extremely context-sensitive base of articulation rules. There are also context-free rules, such as those governing the uniform height difference between English and Danish, which would have to find a place in the grammar. All such rules might be incorporated in a set of phonetic implementation rules such as those suggested by Kim (1967). The format of the context-free rules might be:

If Danish, subtract n Hertz from F1
If English, add m Hertz to F1

These would be followed by context-sensitive rules such as those governing the height difference among the front vowels of English and German:

If German, and if [-back], subtract x Hertz from F1
If English, and if [-back], add y Hertz to F1

Then there would be extremely restricted rules such as those governing the height difference between the vowel transcribed as [ɛ] of Dutch and that of other languages:

```
If Dutch, and if [-back], add z Hertz to F1
                 [-high]
                 [+mid ]
                  ....
```

The optimal form of such mapping rules remains to be determined, but there should be litle doubt that rules of this form are needed in the grammar. Without them, it would be impossible to describe the sounds of a language beyond a very general specification. Such a specification would surely not meet the standard of descriptive adequacy, which is the least we can expect of a grammar.

Appendix 1: Data from Chapter 2

BAVA	I	1	240	2150	3100
BAVA	I	2	240	2000	3600
BAVA	I	3	250	2170	3200
BAVA	I	4	280	2070	2910
BAVA	I	5	250	2220	3570
BAVA	I	6	240	2260	3270
BAVA	I	7	260	2420	2800
BAVA	I	8	250	2210	3500
BAVA	Y	1	260	1850	2120
BAVA	Y	2	230	1860	2320
BAVA	Y	3	260	1800	2080
BAVA	Y	4	280	1880	2250
BAVA	Y	5	230	1750	2100
BAVA	Y	6	230	2030	2340
BAVA	Y	7	260	2020	2300
BAVA	Y	8	230	1810	2180
BAVA	U	1	250	650	2107
BAVA	U	2	230	620	2107
BAVA	U	3	250	580	2107
BAVA	U	4	290	760	2160
BAVA	U	5	270	700	2050
BAVA	U	6	300	770	2220
BAVA	U	7	280	800	2107
BAVA	U	8	270	800	2107
BAVA	E	1	290	2160	3040
BAVA	E	2	280	1940	2660
BAVA	E	3	300	2000	2600
BAVA	E	4	375	1980	2580
BAVA	E	5	370	2120	2770
BAVA	E	6	300	2300	3170
BAVA	E	7	340	2200	2670
BAVA	E	8	400	1970	2640
BAVA	Ø	1	330	1640	2280
BAVA	Ø	2	280	1750	2200
BAVA	Ø	3	320	1580	2100
BAVA	Ø	4	375	1710	2250
BAVA	Ø	5	340	1720	2200
BAVA	Ø	6	310	1880	2310
BAVA	Ø	7	350	1670	2420
BAVA	Ø	8	340	1720	2200
BAVA	O	1	370	800	2284
BAVA	O	2	370	900	2284
BAVA	O	3	320	820	2284
BAVA	O	4	400	1030	2300
BAVA	O	5	360	980	2100
BAVA	O	6	330	900	2500
BAVA	O	7	370	850	2500
BAVA	O	8	400	900	2290
BAVA	EH	1	380	2180	3020
BAVA	EH	2	350	1920	2700
BAVA	EH	3	340	2020	2600
BAVA	EH	4	460	1970	2510
BAVA	EH	5	350	2230	2684
BAVA	EH	6	380	2100	2684
BAVA	EH	7	350	2240	2680
BAVA	EH	8	420	1990	2570
BAVA	OE	1	360	1620	2300
BAVA	OE	2	370	1630	2280
BAVA	OE	3	350	1580	2200
BAVA	OE	4	465	1620	2250
BAVA	OE	5	360	1760	2200
BAVA	OE	6	380	1940	2480
BAVA	OE	7	380	1650	2420
BAVA	OE	8	400	1650	2220
BAVA	AO	1	420	760	2291
BAVA	AO	2	410	990	2150
BAVA	AO	3	460	840	2300
BAVA	AO	4	465	830	2280
BAVA	AO	5	400	800	2300
BAVA	AO	6	360	810	2291
BAVA	AO	7	420	900	2450
BAVA	AO	8	410	800	2350
BAVA	AE	1	490	2050	2950
BAVA	AE	2	560	1620	2620
BAVA	AE	3	400	1780	2300
BAVA	AE	4	560	1780	2430
BAVA	AE	5	560	1870	2430
BAVA	AE	6	620	1930	2546
BAVA	AE	7	530	2020	2580
BAVA	AE	8	490	1770	2500
BAVA	Œ	1	550	1470	2400
BAVA	Œ	2	520	1480	2420
BAVA	Œ	3	500	1420	2300
BAVA	Œ	4	595	1550	2230
BAVA	Œ	5	580	1550	2420
BAVA	Œ	6	580	1770	2680
BAVA	Œ	7	520	1620	2420
BAVA	Œ	8	500	1550	2320
BAVA	ɒ	1	550	1000	2239
BAVA	ɒ	2	570	1000	2130
BAVA	ɒ	3	490	820	2150
BAVA	ɒ	4	570	950	2060
BAVA	ɒ	5	620	1000	2350
BAVA	ɒ	6	640	1200	2239
BAVA	ɒ	7	550	1050	2450
BAVA	ɒ	8	540	960	2270
BAVA	A	1	750	1370	2200
BAVA	A	2	630	1120	2400
BAVA	A	3	750	1350	2180
BAVA	A	4	660	1310	2150
BAVA	A	5	800	1300	2410
BAVA	A	6	680	1300	2130
BAVA	A	7	660	1400	2200
BAVA	A	8	760	1400	2200

TAUS	Speaker	1	A1	819	1525	2381
TAUS	Speaker	2	A1	788	1424	2648
TAUS	Speaker	3	A1	762	1189	2372
TAUS	Speaker	4	A1	752	1312	2386
TAUS	Speaker	1	A2	796	1485	2448
TAUS	Speaker	2	A2	888	1467	2638
TAUS	Speaker	3	A2	768	1317	2595
TAUS	Speaker	4	A2	755	1314	2278
TAUS	Speaker	1	I1	384	2080	2726
TAUS	Speaker	2	I1	375	2484	3181
TAUS	Speaker	3	I1	489	1978	2615
TAUS	Speaker	4	I1	309	2223	2950
TAUS	Speaker	1	I2	424	2205	2684
TAUS	Speaker	2	I2	422	2470	3114
TAUS	Speaker	3	I2	415	2150	2805
TAUS	Speaker	4	I2	345	2205	3005
TAUS	Speaker	1	U1	395	829	2902
TAUS	Speaker	2	U1	407	811	2512
TAUS	Speaker	3	U1	423	816	2680
TAUS	Speaker	4	U1	439	880	2661
TAUS	Speaker	1	U2	438	812	2432
TAUS	Speaker	2	U2	392	871	2459
TAUS	Speaker	3	U2	493	854	2555
TAUS	Speaker	4	U2	460	907	2538

YORU	1	A	838	1373	2068
YORU	2	A	775	1422	2155
YORU	3	A	861	1400	2253
YORU	4	A	852	1538	2314
YORU	5	A	768	1333	2592
YORU	6	A	675	1514	2149
YORU	7	A	740	1535	2610
YORU	8	A	830	1330	2440
YORU	9	A	800	1535	2500
YORU	10	A	890	1460	2690
YORU	1	E	382	1997	2793
YORU	2	E	391	1896	2655
YORU	3	E	354	2092	2783
YORU	4	E	349	1797	2537
YORU	5	E	396	2184	2748
YORU	6	E	282	2036	2685
YORU	7	E	320	2420	2955
YORU	8	E	400	1890	2580
YORU	9	E	370	2335	2900
YORU	10	E	360	2190	2910
YORU	1	EH	638	1869	2903
YORU	2	EH	577	1847	2587
YORU	3	EH	522	1973	2727
YORU	4	EH	572	1648	2360
YORU	5	EH	553	1968	2576
YORU	6	EH	427	1956	2710
YORU	7	EH	590	1955	2610
YORU	8	EH	665	1710	2145
YORU	9	EH	630	2100	2745
YORU	10	EH	530	2100	2810

YORU	1	I	337	2159	2972
YORU	2	I	356	2169	3015
YORU	3	I	305	1984	2689
YORU	4	I	303	2197	2957
YORU	5	I	253	2326	3142
YORU	6	I	265	2096	2895
YORU	7	I	285	2500	3260
YORU	8	I	330	2055	2730
YORU	9	I	335	2350	2900
YORU	10	I	270	2215	3110
YORU	1	O	408	1147	2404
YORU	2	O	402	959	2303
YORU	3	O	453	1093	2490
YORU	4	O	427	1085	2402
YORU	5	O	412	1145	2460
YORU	6	O	341	1068	2534
YORU	7	O	425	860	3010
YORU	8	O	420	855	2300
YORU	9	O	415	855	2585
YORU	10	O	385	825	2390
YORU	1	AO	634	1026	2373
YORU	2	AO	580	1095	2589
YORU	3	AO	547	1040	2391
YORU	4	AO	597	1058	2243
YORU	5	AO	679	954	2253
YORU	6	AO	460	864	2504
YORU	7	AO	585	1010	2750
YORU	8	AO	645	1030	2300
YORU	9	AO	650	1150	2520
YORU	10	AO	615	1120	2515
YORU	1	U	298	828	2272
YORU	2	U	353	931	2220
YORU	3	U	323	998	2436
YORU	4	U	352	953	2247
YORU	5	U	259	705	2171
YORU	6	U	299	1040	2308
YORU	7	U	295	610	1580
YORU	8	U	335	710	1640
YORU	9	U	340	860	2550
YORU	10	U	285	785	2385

ITAL	1I	300.	2150.	2600.	3280.
ITAL	1E	370.	1910.	2400.	3120.
ITAL	1EH	500.	1830.	2200.	3100.
ITAL	1A	760.	1060.	2450.	3210.
ITAL	1AO	600.	810.	2650.	3450.
ITAL	1O	480.	770.	2450.	2900.
ITAL	1U	330.	640.	2410.	2740.
ITAL	2I	300.	2080.	2780.	3230.
ITAL	2E	380.	2020.	2650.	3110.
ITAL	2 EH	530.	1850.	2200.	3280.
ITAL	2A	700.	1260.	2600.	3700.
ITAL	2AO	500.	770.	2600.	3500.
ITAL	2O	400.	700.	2450.	2900.
ITAL	2U	300.	650.	2100.	3000.
ITAL	3I	280.	2200.	2740.	3480.
ITAL	3E	400.	2090.	2470.	3310.
ITAL	3 EH	590.	1870.	2350.	3080.
ITAL	3A	840.	1210.	2300.	3000.
ITAL	3AO	600.	900.	2340.	3690.
ITAL	3O	500.	800.	2180.	3600.
ITAL	3U	330.	740.	2150.	3300.
ITAL	4I	300.	2100.	2750.	3350.
ITAL	4E	400.	2000.	2500.	3200.
ITAL	4 EH	500.	1900.	2300.	3230.
ITAL	4A	730.	1220.	2210.	2820.
ITAL	4AO	600.	840.	2500.	3750.
ITAL	4O	400.	770.	2400.	3330.
ITAL	4U	320.	720.	2220.	2800.
ITAL	5I	280.	2150.	2860.	3680.
ITAL	5E	390.	2030.	2380.	3200.
ITAL	5 EH	480.	1950.	2320.	3000.
ITAL	5A	840.	1190.	2270.	2940.
ITAL	5AO	570.	790.	2590.	3400.
ITAL	5O	480.	800.	2560.	3250.
ITAL	5U	300.	730.	2300.	2920.
ITAL	6I	320.	2150.	2800.	3450.
ITAL	6E	350.	2100.	2600.	3500.
ITAL	6 EH	500.	1900.	2700.	3400.
ITAL	6A	800.	1290.	2700.	3400.
ITAL	6AO	540.	900.	2700.	3750.
ITAL	6O	380.	750.	2560.	2940.
ITAL	6U	310.	740.	2420.	3810.
ITAL	7I	280.	1900.	2400.	2900.
ITAL	7E	360.	1850.	2400.	3200.
ITAL	7EH	450.	1780.	2200.	3550.
ITAL	7A	680.	1170.	2340.	3150.
ITAL	7AO	500.	820.	2490.	3200.
ITAL	7O	360.	700.	2240.	2870.
ITAL	7U	380.	740.	2130.	3150.
ITAL	8I	290.	2050.	2800.	3450.
ITAL	8E	410.	1920.	2480.	3270.
ITAL	8EH	560.	1830.	2500.	3800.
ITAL	8A	810.	1380.	2490.	3250.
ITAL	8AO	560.	900.	2470.	3650.
ITAL	8O	500.	860.	2400.	3470.
ITAL	8U	400.	750.	2300.	3310.
ITAL	9I	290.	1950.	2800.	3400.
ITAL	9E	360.	1890.	2750.	3450.
ITAL	9 EH	590.	1870.	2560.	3860.
ITAL	9A	730.	1370.	2800.	3300.
ITAL	9AO	600.	870.	2800.	3850.
ITAL	9O	450.	730.	2800.	3900.
ITAL	9U	330.	610.	2600.	3300.
ITAL	10I	280.	2150.	2700.	3550.
ITAL	10E	340.	1940.	2400.	3270.
ITAL	10 EH	520.	1700.	2300.	3450.
ITAL	10A	760.	1190.	2460.	3500.
ITAL	10AO	630.	1020.	2460.	3100.
ITAL	10O	440.	830.	2300.	3030.
ITAL	10U	310.	710.	2300.	3000.
ITAL	11I	260.	2300.	3000.	3600.
ITAL	11E	370.	2040.	2600.	3600.
ITAL	11EH	580.	1900.	2520.	3150.
ITAL	11A	800.	1240.	2450.	3100.
ITAL	11AO	560.	790.	2500.	3300.
ITAL	11O	420.	650.	2500.	3150.
ITAL	11U	290.	600.	2100.	2720.
ITAL	12I	290.	2000.	2780.	3700.
ITAL	12E	390.	1900.	2500.	3150.
ITAL	12EH	500.	1750.	2420.	3150.
ITAL	12A	710.	1220.	2440.	2900.
ITAL	12AO	560.	890.	2390.	3800.
ITAL	12O	430.	800.	2280.	3700.
ITAL	12U	300.	770.	2200.	3430.
ITAL	13I	270.	2050.	2900.	3250.
ITAL	13E	400.	2050.	2640.	3320.
ITAL	13EH	530.	1820.	2600.	3360.
ITAL	13A	750.	1100.	2310.	2830.
ITAL	13AO	500.	790.	2280.	3130.
ITAL	13O	400.	640.	2180.	3130.
ITAL	13U	280.	660.	1820.	2620.
ITAL	14I	300.	2150.	2600.	3450.
ITAL	14E	340.	2000.	2400.	3330.
ITAL	14EH	510.	1780.	2320.	3400.
ITAL	14A	720.	1200.	2100.	3300.
ITAL	14AO	510.	940.	2180.	3130.
ITAL	14O	380.	760.	1950.	3000.
ITAL	14U	320.	630.	2050.	2950.
ITAL	15I	270.	2100.	2750.	3300.
ITAL	15E	410.	1900.	2340.	3260.
ITAL	15EH	520.	1850.	2300.	3200.
ITAL	15A	690.	1220.	2080.	2710.
ITAL	15AO	580.	890.	2360.	3350.
ITAL	15O	490.	800.	2400.	3100.
ITAL	15U	340.	630.	2100.	2780.
ITAL	16I	300.	2230.	2950.	3400.

ITAL 16E	400.	2080.	2500.	3400.
ITAL 16	510.	1980.	2470.	3300.
ITAL 16A	820.	1150.	2470.	2880.
ITAL 16AO	600.	880.	2650.	3470.
ITAL 16O	490.	750.	2580.	3390.
ITAL 16U	350.	650.	2430.	3100.
ITAL 17I	320.	2300.	2660.	3450.
ITAL 17E	460.	2100.	2550.	3780.
ITAL 17EH	580.	2000.	2350.	3150.
ITAL 17A	720.	1300.	2260.	3400.
ITAL 17AO	580.	930.	2180.	3600.
ITAL 17O	480.	760.	2470.	3500.
ITAL 17U	310.	700.	2400.	3000.
ITAL 18I	280.	2150.	2820.	3230.
ITAL 18E	420.	1950.	2500.	3150.
ITAL 18 EH	560.	1800.	2400.	3100.
ITAL 18A	680.	1180.	2330.	3750.
ITAL 18AO	580.	910.	2560.	3130.
ITAL 18O	450.	900.	2390.	3150.
ITAL 18U	320.	750.	2270.	3030.
ITAL 19I	290.	1950.	2780.	3360.
ITAL 19E	410.	1900.	2500.	3100.
ITAL 19EH	520.	1800.	2350.	3500.
ITAL 19A	750.	1150.	2500.	3800.
ITAL 19AO	500.	800.	2220.	3300.
ITAL 19O	410.	750.	2150.	3100.
ITAL 19U	310.	670.	2180.	2950.
ITAL 20I	290.	2320.	2900.	3260.
ITAL 20E	420.	2150.	2750.	3250.
ITAL 20EH	570.	2030.	2620.	3230.
ITAL 20A	820.	1450.	2750.	3780.
ITAL 20AO	540.	1010.	2850.	3330.
ITAL 20O	430.	840.	2580.	3380.
ITAL 20U	340.	800.	2600.	3330.
ITAL 21I	350.	2190.	3150.	3650.
ITAL 21E	440.	2070.	2700.	3400.
ITAL 21EH	550.	1990.	2700.	3400.
ITAL 21A	780.	1200.	2360.	2800.
ITAL 21AO	550.	780.	2790.	3430.
ITAL 21O	400.	710.	2780.	3170.
ITAL 21U	380.	760.	2400.	3150.
ITAL 22I	290.	2200.	2900.	3480.
ITAL 22E	380.	2000.	2670.	3580.
ITAL 22EH	550.	1920.	2600.	3300.
ITAL 22A	770.	1180.	2470.	3600.
ITAL 22AO	510.	800.	2550.	3400.
ITAL 22O	450.	800.	2350.	3200.
ITAL 22U	320.	750.	2130.	3120.
ITAL 23I	380.	2300.	3100.	3530.
ITAL 23E	400.	2200.	2750.	3500.
ITAL 23EH	590.	1900.	2600.	3400.
ITAL 23A	850.	1280.	2330.	3000.
ITAL 23AO	600.	1060.	2800.	3470.
ITAL 23O	420.	770.	2620.	3400.
ITAL 23U	340.	750.	2600.	3330.
ITAL 24I	360.	2200.	3000.	3380.
ITAL 24E	440.	2100.	2800.	3400.
ITAL 24 EH	580.	1970.	2430.	3180.
ITAL 24A	810.	1220.	2560.	3300.
ITAL 24AO	600.	920.	2500.	3200.
ITAL 24O	440.	800.	2530.	3190.
ITAL 24U	300.	660.	2230.	2850.
ITAL 25I	270.	2130.	2700.	3500.
ITAL 25E	450.	1950.	2450.	3150.
ITAL 25 EH	610.	1730.	2270.	2800.
ITAL 25A	800.	1180.	2400.	3160.
ITAL 25AO	600.	850.	2600.	3560.
ITAL 25O	500.	750.	2560.	3390.
ITAL 25U	310.	720.	2330.	3000.

Appendix 2: Data from Chapter 3

ENG	1	I	240.	2280.	2850.
ENG	1	IH	390.	2030.	2640.
ENG	1	EH	490.	1870.	2420.
ENG	1	AE	630.	1700.	2550.
ENG	1	UH	590.	1250.	2620.
ENG	1	AA	740.	1070.	2490.
ENG	1	AO	600.	970.	2280.
ENG	1	OO	440.	1120.	2210.
ENG	1	U	240.	1040.	2150.
ENG	1	ER	370.	1520.	1670.
ENG	2	I	220.	2220.	2910.
ENG	2	IH	410.	1890.	2680.
ENG	2	EH	500.	1760.	2590.
ENG	2	AE	690.	1610.	2560.
ENG	2	UH	650.	1080.	2420.
ENG	2	AA	650.	1040.	2450.
ENG	2	AO	580.	580.	2470.
ENG	2	OO	450.	940.	1910.
ENG	2	U	280.	650.	3300.
ENG	2	ER	510.	1210.	1570.
ENG	3	I	250.	2180.	2680.
ENG	3	IH	400.	1930.	2610.
ENG	3	EH	550.	1810.	2500.
ENG	3	AE	630.	1710.	2400.
ENG	3	UH	612.	1160.	2350.
ENG	3	AA	640.	1080.	2140.
ENG	3	AO	550.	870.	2300.
ENG	3	OO	460.	1150.	2290.
ENG	3	U	340.	950.	2240.
ENG	3	ER	500.	1370.	1780.
ENG	4	I	300.	2240.	3400.
ENG	4	IH	440.	2050.	2360.
ENG	4	EH	570.	1780.	2410.
ENG	4	AE	750.	1610.	2340.
ENG	4	UH	660.	1200.	2330.
ENG	4	AA	750.	1100.	2550.
ENG	4	AO	540.	850.	2320.
ENG	4	OO	460.	960.	2210.
ENG	4	U	380.	950.	2050.
ENG	4	ER	590.	1400.	1840.
ENG	5	I	310.	2310.	2820.
ENG	5	IH	440.	2060.	2640.
ENG	5	EH	580.	1910.	2500.
ENG	5	AE	830.	1720.	2180.
ENG	5	UH	630.	1300.	1950.
ENG	5	AA	760.	1220.	2140.
ENG	5	AO	540.	970.	1980.
ENG	5	OO	470.	1040.	1990.
ENG	5	U	380.	950.	2140.
ENG	5	ER	560.	1510.	1800.
ENG	6	I	312.	2350.	2800.
ENG	6	IH	420.	2000.	2660.
ENG	6	EH	600.	1860.	2500.
ENG	6	AE	676.	1670.	2540.
ENG	6	UH	726.	1270.	2560.
ENG	6	AA	740.	1100.	2680.
ENG	6	AO	660.	1030.	2690.
ENG	6	OO	456.	1080.	2520.
ENG	6	U	313.	838.	2340.
ENG	6	ER	503.	1305.	1775.
ENG	7	I	320.	2320.	3120.
ENG	7	IH	410.	2040.	2715.
ENG	7	EH	614.	1840.	2770.
ENG	7	AE	740.	1800.	2450.
ENG	7	UH	640.	1250.	2400.
ENG	7	AA	650.	980.	2350.
ENG	7	AO	430.	720.	2450.
ENG	7	OO	460.	1120.	2150.
ENG	7	U	380.	1040.	2260.
ENG	7	ER	570.	1300.	1750.
ENG	8	I	218.	2380.	3100.
ENG	8	IH	206.	2130.	2570.
ENG	8	EH	430.	2100.	2630.
ENG	8	AE	514.	2060.	2600.
ENG	8	UH	640.	1300.	2300.
ENG	8	AA	714.	1170.	2420.
ENG	8	AO	578.	970.	2460.
ENG	8	OO	467.	1110.	2400.
ENG	8	U	270.	910.	2200.
ENG	8	ER	460.	1400.	1790.
ENG	9	I	316.	2200.	2800.
ENG	9	IH	450.	1820.	2475.
ENG	9	EH	582.	1725.	2375.
ENG	9	AE	600.	1750.	2375.
ENG	9	UH	641.	1120.	2225.
ENG	9	AA	708.	1054.	2420.
ENG	9	AO	614.	848.	2200.
ENG	9	OO	500.	1000.	2325.
ENG	9	U	334.	1150.	2200.
ENG	9	ER	518.	1305.	1570.
ENG	10	I	260.	2260.	2820.
ENG	10	IH	400.	2040.	2500.
ENG	10	EH	500.	1870.	2500.
ENG	10	AE	660.	1650.	2500.
ENG	10	UH	650.	1220.	2550.
ENG	10	AA	750.	1080.	2680.
ENG	10	AO	580.	800.	2650.
ENG	10	OO	461.	993.	2350.
ENG	10	U	280.	950.	2300.
ENG	10	ER	500.	1340.	1700.
ENG	11	I	248.	2225.	3100.
ENG	11	IH	405.	1925.	2550.
ENG	11	EH	588.	1790.	2500.
ENG	11	AE	725.	1700.	2425.
ENG	11	UH	627.	1038.	2360.
ENG	11	AA	725.	1046.	2325.

ENG	11	AO	560.	840.	2500.
ENG	11	OO	495.	1080.	2275.
ENG	11	U	290.	760.	2300.
ENG	11	ER	511.	1561.	1876.
ENG	12	I	220.	2410.	3000.
ENG	12	IH	450.	1880.	2450.
ENG	12	EH	560.	1650.	2300.
ENG	12	AE	680.	1720.	2330.
ENG	12	UH	560.	1430.	2250.
ENG	12	AA	740.	1240.	2280.
ENG	12	AO	600.	920.	2080.
ENG	12	OO	400.	1200.	2210.
ENG	12	U	300.	900.	2130.
ENG	12	ER	400.	1450.	1650.
ENG	13	I	290.	2290.	2600.
ENG	13	IH	390.	1950.	2550.
ENG	13	EH	490.	1740.	2500.
ENG	13	AE	660.	1630.	2500.
ENG	13	UH	600.	1220.	2530.
ENG	13	AA	670.	1100.	2700.
ENG	13	AO	510.	720.	2450.
ENG	13	OO	440.	1030.	2400.
ENG	13	U	350.	720.	2750.
ENG	13	ER	430.	1370.	1610.
ENG	14	I	228.	2350.	2860.
ENG	14	IH	407.	2070.	2500.
ENG	14	EH	445.	2020.	2420.
ENG	14	AE	721.	1680.	2400.
ENG	14	UH	552.	1122.	2500.
ENG	14	AA	686.	1078.	2570.
ENG	14	AO	560.	665.	2620.
ENG	14	OO	448.	980.	2370.
ENG	14	U	232.	696.	2200.
ENG	14	ER	432.	1300.	1400.
ENG	15	I	230.	2100.	2850.
ENG	15	IH	365.	1900.	2340.
ENG	15	EH	440.	1980.	2310.
ENG	15	AE	660.	1800.	2150.
ENG	15	UH	660.	1000.	2380.
ENG	15	AA	600.	830.	2250.
ENG	15	AO	500.	620.	2250.
ENG	15	OO	390.	730.	2180.
ENG	15	U	260.	720.	2100.
ENG	15	ER	450.	1230.	1600.
ENG	16	I	300.	2355.	3250.
ENG	16	IH	385.	2242.	2805.
ENG	16	EH	504.	2090.	2720.
ENG	16	AE	680.	1958.	2542.
ENG	16	UH	675.	1320.	2550.
ENG	16	AA	825.	1168.	2750.
ENG	16	AO	671.	1000.	2670.
ENG	16	OO	443.	1273.	2430.
ENG	16	U	395.	1300.	2160.
ENG	16	ER	532.	1500.	1890.
ENG	17	I	264.	2290.	2700.
ENG	17	IH	380.	1880.	2440.
ENG	17	EH	510.	1780.	2300.
ENG	17	AE	630.	1770.	2350.
ENG	17	UH	601.	1273.	2130.
ENG	17	AA	703.	1092.	2320.
ENG	17	AO	565.	780.	2350.
ENG	17	OO	420.	1100.	2140.
ENG	17	U	315.	1080.	2260.
ENG	17	ER	444.	1300.	1625.
ENG	18	I	210.	2100.	3090.
ENG	18	IH	280.	2000.	2710.
ENG	18	EH	470.	1910.	2580.
ENG	18	AE	640.	1620.	2200.
ENG	18	UH	610.	1100.	2230.
ENG	18	AA	700.	1100.	2240.
ENG	18	AO	460.	720.	2180.
ENG	18	OO	320.	770.	1860.
ENG	18	U	210.	670.	1900.
ENG	18	ER	390.	1320.	1550.
ENG	19	I	190.	2650.	3280.
ENG	19	IH	370.	1750.	2700.
ENG	19	EH	370.	1680.	2560.
ENG	19	AE	550.	1570.	2600.
ENG	19	UH	570.	1050.	2500.
ENG	19	AA	640.	970.	2870.
ENG	19	AO	570.	820.	2820.
ENG	19	OO	350.	1000.	2500.
ENG	19	U	250.	1000.	2100.
ENG	19	ER	360.	1300.	1920.
ENG	20	I	250.	2180.	2660.
ENG	20	IH	400.	1900.	2440.
ENG	20	EH	560.	1670.	2310.
ENG	20	AE	680.	1470.	2280.
ENG	20	UH	620.	1100.	2390.
ENG	20	AA	630.	980.	2330.
ENG	20	AO	560.	790.	2480.
ENG	20	OO	360.	860.	2200.
ENG	20	U	280.	670.	2140.
ENG	20	ER	480.	1410.	1760.
ENG	21	I	280.	2400.	2910.
ENG	21	IH	450.	2050.	2670.
ENG	21	EH	540.	1900.	2530.
ENG	21	AE	620.	1800.	2440.
ENG	21	UH	680.	1290.	2600.
ENG	21	AA	740.	1110.	2500.
ENG	21	AO	650.	880.	2660.
ENG	21	OO	430.	1130.	2440.
ENG	21	U	280.	990.	2330.
ENG	21	ER	420.	1350.	1600.
ENG	22	I	300.	2300.	2800.
ENG	22	IH	410.	2200.	2680.

ENG	22	EH	580.	1870.	2320.
ENG	22	AE	760.	1920.	2480.
ENG	22	UH	810.	1110.	2100.
ENG	22	AA	750.	1160.	2080.
ENG	22	AO	670.	920.	2240.
ENG	22	OO	550.	970.	2200.
ENG	22	U	300.	600.	2300.
ENG	22	ER	560.	1520.	2100.
ENG	23	I	240.	2100.	2900.
ENG	23	IH	380.	1870.	2450.
ENG	23	EH	580.	1770.	2500.
ENG	23	AE	715.	1500.	2300.
ENG	23	UH	620.	880.	2500.
ENG	23	AA	710.	950.	2520.
ENG	23	AO	460.	610.	2500.
ENG	23	OO	390.	900.	2100.
ENG	23	U	250.	690.	2080.
ENG	23	ER	540.	1280.	1720.
ENG	24	I	280.	2450.	2700.
ENG	24	IH	400.	2080.	2530.
ENG	24	EH	590.	1900.	2200.
ENG	24	AE	680.	1850.	2400.
ENG	24	UH	660.	1370.	2110.
ENG	24	AA	770.	1140.	2020.
ENG	24	AO	500.	800.	1850.
ENG	24	OO	380.	1060.	1950.
ENG	24	U	324.	800.	2220.
ENG	24	ER	560.	1350.	1780.
ENG	25	I	250.	2190.	3000.
ENG	25	IH	330.	1967.	2670.
ENG	25	EH	464.	2100.	2700.
ENG	25	AE	595.	1900.	2700.
ENG	25	UH	620.	1200.	2420.
ENG	25	AA	750.	1160.	2360.
ENG	25	AO	460.	740.	2300.
ENG	25	OO	400.	1020.	2200.
ENG	25	U	392.	1000.	2120.
ENG	25	ER	547.	1340.	1688.
ENG	26	I	246.	2185.	2730.
ENG	26	IH	420.	2300.	2800.
ENG	26	EH	480.	1920.	2540.
ENG	26	AE	628.	1837.	2570.
ENG	26	UH	628.	1254.	2470.
ENG	26	AA	690.	1072.	2660.
ENG	26	AO	510.	700.	2650.
ENG	26	OO	465.	990.	2440.
ENG	26	U	324.	708.	2440.
ENG	26	ER	488.	1468.	1712.
ENG	27	I	275.	2060.	2800.
ENG	27	IH	349.	2030.	2760.
ENG	27	EH	444.	1800.	2500.
ENG	27	AE	688.	1600.	2300.
ENG	27	UH	550.	1150.	2250.
ENG	27	AA	712.	1024.	2250.
ENG	27	AO	550.	913.	2360.
ENG	27	OO	360.	1028.	2160.
ENG	27	U	294.	930.	2050.
ENG	27	ER	440.	1250.	1625.
ENG	28	I	320.	2160.	2900.
ENG	28	IH	440.	1750.	2400.
ENG	28	EH	525.	1800.	2480.
ENG	28	AE	660.	1600.	2400.
ENG	28	UH	600.	1250.	2300.
ENG	28	AA	860.	1280.	2470.
ENG	28	AO	560.	810.	2290.
ENG	28	OO	455.	970.	2140.
ENG	28	U	350.	820.	2130.
ENG	28	ER	472.	1430.	1840.
ENG	29	I	333.	2305.	3200.
ENG	29	IH	375.	2188.	2750.
ENG	29	EH	500.	1980.	2480.
ENG	29	AE	640.	1710.	2450.
ENG	29	UH	583.	1110.	2360.
ENG	29	AA	777.	1170.	2600.
ENG	29	AO	630.	891.	2519.
ENG	29	OO	438.	975.	2300.
ENG	29	U	333.	800.	2130.
ENG	29	ER	480.	1320.	1870.
ENG	30	I	267.	2300.	2940.
ENG	30	IH	431.	2040.	2460.
ENG	30	EH	540.	2000.	2450.
ENG	30	AE	590.	1950.	2460.
ENG	30	UH	630.	1140.	2200.
ENG	30	AA	730.	1130.	2320.
ENG	30	AO	600.	900.	2400.
ENG	30	OO	450.	1000.	2180.
ENG	30	U	333.	835.	2170.
ENG	30	ER	488.	1300.	1600.
ENG	31	I	312.	2380.	2900.
ENG	31	IH	490.	2000.	2620.
ENG	31	EH	640.	2000.	2620.
ENG	31	AE	697.	1610.	2540.
ENG	31	UH	633.	1260.	2530.
ENG	31	AA	730.	1203.	2700.
ENG	31	AO	507.	755.	2420.
ENG	31	OO	456.	1040.	2300.
ENG	31	U	350.	1000.	2250.
ENG	31	ER	539.	1370.	1800.
ENG	32	I	292.	2500.	3150.
ENG	32	IH	372.	2220.	2640.
ENG	32	EH	574.	1840.	2260.
ENG	32	AE	650.	1738.	2400.
ENG	32	UH	600.	1370.	2180.
ENG	32	AA	735.	1070.	2100.
ENG	32	AO	625.	875.	2180.
ENG	32	OO	420.	1100.	2000.

ENG	32	U	350.	980.	2200.
ENG	32	ER	554.	1480.	1800.
ENG	33	I	286.	2415.	2860.
ENG	33	IH	400.	1980.	2500.
ENG	33	EH	553.	1935.	2530.
ENG	33	AE	640.	1773.	2490.
ENG	33	UH	672.	1272.	2640.
ENG	33	AA	780.	1170.	2640.
ENG	33	AO	633.	891.	2500.
ENG	33	OO	490.	1102.	2420.
ENG	33	U	320.	960.	2290.
ENG	33	ER	543.	1310.	1643.
NORW	1	OE	480.	1540.	2300.
NORW	1	Y	325.	2280.	2555.
NORW	1	I	315.	2455.	3370.
NORW	1	E	430.	2300.	2830.
NORW	1	AE	770.	1475.	2495.
NORW	1	AA	720.	1060.	0.
NORW	1	AO	470.	0.	0.
NORW	1	U	385.	0.	0.
NORW	1	Ʉ	375.	1840.	0.
NORW	2	OE	480.	1695.	2550.
NORW	2	Y	340.	2250.	2665.
NORW	2	I	350.	2385.	3410.
NORW	2	E	455.	2120.	2810.
NORW	2	AE	710.	1600.	2585.
NORW	2	AA	675.	1080.	2530.
NORW	2	AO	490.	0.	0.
NORW	2	U	365.	0.	0.
NORW	2	Ʉ	375.	1915.	2470.
NORW	3	OE	460.	1500.	2240.
NORW	3	Y	280.	2090.	2450.
NORW	3	I	280.	2170.	3300.
NORW	3	E	430.	2160.	2890.
NORW	3	AE	680.	1370.	2560.
NORW	3	AA	630.	1010.	2980.
NORW	3	AO	470.	0.	0.
NORW	3	U	320.	0.	0.
NORW	3	Ʉ	310.	1690.	2090.
NORW	4	OE	430.	1650.	2390.
NORW	4	Y	320.	2290.	2600.
NORW	4	I	300.	2410.	3430.
NORW	4	E	390.	2240.	2880.
NORW	4	AE	690.	1590.	2530.
NORW	4	AA	680.	1120.	2570.
NORW	4	AO	450.	0.	0.
NORW	4	U	360.	0.	0.
NORW	4	Ʉ	340.	1630.	2320.
NORW	5	OE	430.	1510.	2160.
NORW	5	Y	270.	2000.	2290.
NORW	5	I	270.	2020.	3130.
NORW	5	E	410.	1970.	2550.
NORW	5	AE	670.	1380.	2330.
NORW	5	AA	640.	1080.	2400.
NORW	5	AO	470.	0.	0.
NORW	5	U	440.	0.	0.
NORW	5	Ʉ	290.	1730.	2040.
NORW	6	OE	440.	1520.	2410.
NORW	6	Y	290.	2040.	2500.
NORW	6	I	330.	2080.	3280.
NORW	6	E	390.	2010.	2630.
NORW	6	AE	680.	1440.	2490.
NORW	6	AA	620.	1030.	2360.
NORW	6	AO	500.	0.	0.
NORW	6	U	330.	0.	0.
NORW	6	Ʉ	320.	1780.	2230.
NORW	7	OE	400.	1740.	2320.
NORW	7	Y	310.	2200.	2500.
NORW	7	I	300.	2400.	0.
NORW	7	E	420.	2290.	2950.
NORW	7	AE	800.	1490.	2430.
NORW	7	AA	675.	1010.	2540.
NORW	7	AO	460.	0.	0.
NORW	7	U	380.	0.	0.
NORW	7	Ʉ	330.	1820.	2150.
NORW	8	OE	400.	1540.	2320.
NORW	8	Y	380.	2180.	2550.
NORW	8	I	400.	2360.	3050.
NORW	8	E	400.	2190.	2880.
NORW	8	AE	650.	1470.	0.
NORW	8	AA	570.	1100.	0.
NORW	8	AO	460.	0.	0.
NORW	8	U	410.	0.	0.
NORW	8	Ʉ	440.	1730.	2290.
NORW	9	OE	460.	1710.	2610.
NORW	9	Y	300.	2510.	2650.
NORW	9	I	310.	2480.	0.
NORW	9	E	420.	2390.	2880.
NORW	9	AE	710.	1600.	2780.
NORW	9	AA	600.	1040.	0.
NORW	9	AO	460.	0.	0.
NORW	9	U	310.	0.	0.
NORW	9	Ʉ	320.	1870.	0.
NORW	10	OE	480.	1450.	2320.
NORW	10	Y	290.	2170.	2380.
NORW	10	I	300.	2320.	3210.
NORW	10	E	410.	2210.	2680.
NORW	10	AE	800.	1450.	2590.
NORW	10	AA	710.	1050.	2730.
NORW	10	AO	480.	0.	0.
NORW	10	U	340.	0.	0.
NORW	10	Ʉ	320.	1540.	2120.

DUTC	1 OE	420.	1540.	2380.
DUTC	1 Ø	430.	1580.	2260.
DUTC	1 Y	320.	1680.	2140.
DUTC	1 I	280.	2300.	2780.
DUTC	1 IH	350.	2000.	2520.
DUTC	1 E	420.	2000.	2620.
DUTC	1 EH	600.	1720.	2700.
DUTC	1 A	780.	1300.	2460.
DUTC	1 AA	720.	1060.	2420.
DUTC	1 AO	520.	1000.	2520.
DUTC	1 O	500.	940.	2420.
DUTC	1 U	320.	630.	2560.
DUTC	2 OE	540.	1370.	2320.
DUTC	2 Ø	460.	1500.	2300.
DUTC	2 Y	340.	1600.	2050.
DUTC	2 I	320.	2400.	3040.
DUTC	2 IH	430.	2030.	2660.
DUTC	2 E	420.	2200.	2650.
DUTC	2 EH	760.	1660.	2600.
DUTC	2 A	940.	1300.	2780.
DUTC	2 AA	800.	1000.	2480.
DUTC	2 AO	560.	800.	2800.
DUTC	2 O	500.	740.	2700.
DUTC	2 U	440.	780.	2600.
DUTC	3 OE	400.	1520.	2120.
DUTC	3 Ø	360.	1520.	2080.
DUTC	3 Y	280.	1600.	1900.
DUTC	3 I	270.	2040.	2860.
DUTC	3 IH	350.	2000.	2660.
DUTC	3 E	380.	1940.	2580.
DUTC	3 EH	560.	1840.	2520.
DUTC	3 A	860.	1500.	2580.
DUTC	3 AA	680.	1020.	2460.
DUTC	3 AO	500.	820.	2520.
DUTC	3 O	480.	820.	2280.
DUTC	3 U	280.	740.	2160.
DUTC	4 OE	480.	1320.	2200.
DUTC	4 Ø	440.	1320.	2060.
DUTC	4 Y	300.	1540.	2020.
DUTC	4 I	240.	2060.	2580.
DUTC	4 IH	440.	1920.	2380.
DUTC	4 E	460.	1920.	2460.
DUTC	4 EH	660.	1660.	2340.
DUTC	4 A	840.	1300.	2280.
DUTC	4 AA	680.	1000.	2480.
DUTC	4 AO	500.	800.	2520.
DUTC	4 O	500.	900.	2320.
DUTC	4 U	360.	820.	2220.
DUTC	5 OE	560.	1440.	2280.
DUTC	5 Ø	540.	1540.	2160.
DUTC	5 Y	360.	1860.	2200.
DUTC	5 I	300.	2300.	2900.
DUTC	5 IH	560.	1920.	2400.
DUTC	5 E	520.	1960.	2400.
DUTC	5 EH	700.	1720.	2300.
DUTC	5 A	820.	1420.	2180.
DUTC	5 AA	780.	1040.	2620.
DUTC	5 AO	600.	880.	3000.
DUTC	5 O	540.	960.	2460.
DUTC	5 U	440.	880.	2300.
DUTC	6 OE	440.	1700.	2660.
DUTC	6 Ø	460.	1750.	2300.
DUTC	6 Y	260.	2100.	2500.
DUTC	6 I	240.	2500.	3000.
DUTC	6 IH	340.	2340.	3000.
DUTC	6 E	300.	2320.	2860.
DUTC	6 EH	560.	2080.	2840.
DUTC	6 A	820.	1460.	2760.
DUTC	6 AA	700.	1080.	2660.
DUTC	6 AO	550.	900.	2740.
DUTC	6 O	450.	900.	2460.
DUTC	6 U	260.	700.	2550.
DUTC	7 OE	460.	1560.	2400.
DUTC	7 Ø	450.	1660.	2260.
DUTC	7 Y	280.	1780.	2160.
DUTC	7 I	260.	2340.	2640.
DUTC	7 IH	340.	2000.	2600.
DUTC	7 E	400.	2040.	2400.
DUTC	7 EH	620.	1760.	2560.
DUTC	7 A	800.	1320.	2540.
DUTC	7 AA	600.	1000.	2760.
DUTC	7 AO	560.	960.	2760.
DUTC	7 O	520.	920.	2600.
DUTC	7 U	280.	860.	2340.
DUTC	8 OE	400.	1560.	2280.
DUTC	8 Ø	500.	1480.	2300.
DUTC	8 Y	320.	1760.	2060.
DUTC	8 I	280.	2080.	2620.
DUTC	8 IH	340.	1960.	2480.
DUTC	8 E	400.	1940.	2540.
DUTC	8 EH	540.	1860.	2540.
DUTC	8 A	800.	1160.	2600.
DUTC	8 AA	700.	1080.	2540.
DUTC	8 AO	560.	920.	2320.
DUTC	8 O	560.	980.	2360.
DUTC	8 U	320.	880.	2200.
DUTC	9 OE	500.	1580.	2400.
DUTC	9 Ø	500.	1500.	2280.
DUTC	9 Y	300.	1760.	2160.
DUTC	9 I	300.	2380.	2960.
DUTC	9 IH	400.	2040.	2600.
DUTC	9 E	480.	2100.	2580.
DUTC	9 EH	640.	1700.	2620.
DUTC	9 A	860.	1300.	2660.
DUTC	9 AA	700.	1120.	2620.
DUTC	9 AO	560.	900.	2940.

DUTC	9	O	500.	940.	2500.
DUTC	9	U	300.	680.	2400.
DUTC	10	OE	460.	1480.	2260.
DUTC	10	Ø	460.	1580.	2360.
DUTC	10	Y	400.	1880.	2800.
DUTC	10	I	340.	2200.	2920.
DUTC	10	IH	460.	2100.	2800.
DUTC	10	E	460.	2080.	2800.
DUTC	10	EH	600.	1860.	2640.
DUTC	10	A	880.	1400.	2660.
DUTC	10	AA	660.	1040.	2660.
DUTC	10	AO	520.	860.	2880.
DUTC	10	O	460.	940.	2400.
DUTC	10	U	360.	900.	2220.
DUTC	11	OE	500.	1440.	2200.
DUTC	11	Ø	440.	1520.	2040.
DUTC	11	Y	300.	1740.	2040.
DUTC	11	I	300.	2100.	2600.
DUTC	11	IH	300.	1960.	2400.
DUTC	11	E	340.	2040.	2460.
DUTC	11	EH	600.	1760.	2380.
DUTC	11	A	820.	1340.	2200.
DUTC	11	AA	660.	1060.	2300.
DUTC	11	AO	560.	900.	2300.
DUTC	11	O	520.	840.	2040.
DUTC	11	U	320.	830.	2060.
DUTC	12	OE	380.	1600.	2540.
DUTC	12	Ø	480.	1600.	2620.
DUTC	12	Y	300.	1670.	2350.
DUTC	12	I	300.	2500.	2880.
DUTC	12	IH	360.	2220.	2780.
DUTC	12	E	480.	2220.	2640.
DUTC	12	EH	630.	2140.	2880.
DUTC	12	A	940.	1520.	3040.
DUTC	12	AA	860.	1280.	3000.
DUTC	12	AO	640.	900.	3000.
DUTC	12	O	580.	1040.	2960.
DUTC	12	U	400.	860.	2700.
DUTC	13	OE	460.	1600.	2460.
DUTC	13	Ø	460.	1580.	2400.
DUTC	13	Y	300.	1960.	2500.
DUTC	13	I	260.	2560.	3240.
DUTC	13	IH	380.	2500.	2980.
DUTC	13	E	460.	2320.	2960.
DUTC	13	EH	680.	2100.	2940.
DUTC	13	A	900.	1560.	2860.
DUTC	13	AA	860.	1140.	2820.
DUTC	13	AO	540.	800.	2740.
DUTC	13	O	440.	850.	2600.
DUTC	13	U	260.	780.	2460.
DUTC	14	OE	500.	1640.	2620.
DUTC	14	Ø	420.	1740.	2560.
DUTC	14	Y	360.	1900.	2420.
DUTC	14	I	360.	2500.	3000.
DUTC	14	IH	400.	2360.	2740.
DUTC	14	E	380.	1780.	2420.
DUTC	14	EH	600.	1940.	2700.
DUTC	14	A	900.	1500.	3020.
DUTC	14	AA	600.	1000.	2720.
DUTC	14	AO	500.	800.	2800.
DUTC	14	O	450.	900.	2700.
DUTC	14	U	340.	720.	2500.
DUTC	15	OE	480.	1420.	2220.
DUTC	15	Ø	460.	1660.	2200.
DUTC	15	Y	320.	1740.	2220.
DUTC	15	I	300.	2360.	2960.
DUTC	15	IH	440.	2120.	2500.
DUTC	15	E	400.	2240.	2560.
DUTC	15	EH	680.	1640.	2340.
DUTC	15	A	860.	1420.	2420.
DUTC	15	AA	660.	980.	2500.
DUTC	15	AO	560.	860.	2780.
DUTC	15	O	440.	840.	2480.
DUTC	15	U	360.	780.	2320.
DUTC	16	OE	360.	1600.	2400.
DUTC	16	Ø	440.	1560.	2260.
DUTC	16	Y	380.	1720.	2200.
DUTC	16	I	280.	2200.	2880.
DUTC	16	IH	340.	2080.	2680.
DUTC	16	E	360.	2140.	2620.
DUTC	16	EH	520.	1800.	2480.
DUTC	16	A	660.	1000.	2500.
DUTC	16	AA	780.	1060.	2380.
DUTC	16	AO	540.	920.	2640.
DUTC	16	O	500.	920.	2520.
DUTC	16	U	360.	760.	2300.
DUTC	17	OE	500.	1760.	2600.
DUTC	17	Ø	500.	1720.	2400.
DUTC	17	Y	360.	2100.	2420.
DUTC	17	I	360.	2300.	3260.
DUTC	17	IH	400.	2440.	3000.
DUTC	17	E	440.	2360.	2860.
DUTC	17	EH	660.	1840.	2620.
DUTC	17	A	1100.	1480.	2260.
DUTC	17	AA	660.	940.	2820.
DUTC	17	AO	540.	860.	2860.
DUTC	17	O	520.	940.	2560.
DUTC	17	U	400.	820.	2200.
DUTC	18	OE	460.	1380.	2200.
DUTC	18	Ø	440.	1400.	2200.
DUTC	18	Y	340.	1340.	2040.
DUTC	18	I	340.	2040.	2500.
DUTC	18	IH	400.	1800.	2400.
DUTC	18	E	420.	1760.	2420.
DUTC	18	EH	560.	1640.	2400.
DUTC	18	A	740.	1300.	2660.

DUTC	18	AA	740.	1040.	2800.
DUTC	18	AO	540.	920.	2520.
DUTC	18	O	460.	800.	2620.
DUTC	18	U	360.	860.	2520.
DUTC	19	OE	440.	1500.	2400.
DUTC	19	Ø	440.	1500.	2500.
DUTC	19	Y	300.	1540.	2100.
DUTC	19	I	260.	2000.	2680.
DUTC	19	IH	400.	2000.	2500.
DUTC	19	E	400.	1900.	2680.
DUTC	19	EH	600.	1700.	2640.
DUTC	19	A	780.	1140.	2740.
DUTC	19	AA	800.	1100.	2720.
DUTC	19	AO	500.	800.	3000.
DUTC	19	O	460.	1020.	2700.
DUTC	19	U	320.	840.	2360.
DUTC	20	OE	440.	1500.	2440.
DUTC	20	Ø	400.	1480.	2380.
DUTC	20	Y	300.	1760.	2220.
DUTC	20	I	280.	2380.	2720.
DUTC	20	IH	400.	2040.	2640.
DUTC	20	E	400.	2000.	2600.
DUTC	20	EH	440.	1800.	2620.
DUTC	20	A	800.	1220.	2380.
DUTC	20	AA	780.	1100.	2600.
DUTC	20	AO	460.	860.	2600.
DUTC	20	O	500.	1080.	2500.
DUTC	20	U	400.	960.	2400.
DUTC	21	OE	400.	1200.	2000.
DUTC	21	Ø	400.	1300.	2000.
DUTC	21	Y	260.	1920.	2900.
DUTC	21	I	300.	1940.	2620.
DUTC	21	IH	300.	1900.	2380.
DUTC	21	E	300.	1900.	2340.
DUTC	21	EH	540.	1500.	2280.
DUTC	21	A	800.	1100.	2300.
DUTC	21	AA	660.	920.	2520.
DUTC	21	AO	400.	740.	2580.
DUTC	21	O	420.	700.	2440.
DUTC	21	U	300.	700.	2100.
DUTC	22	OE	500.	1440.	2300.
DUTC	22	Ø	540.	1460.	2260.
DUTC	22	Y	300.	1980.	2900.
DUTC	22	I	300.	2300.	2800.
DUTC	22	IH	300.	2200.	2700.
DUTC	22	E	420.	2100.	2600.
DUTC	22	EH	540.	1900.	2600.
DUTC	22	A	760.	1260.	2620.
DUTC	22	AA	660.	1100.	2460.
DUTC	22	AO	550.	900.	3000.
DUTC	22	O	540.	860.	2600.
DUTC	22	U	400.	780.	2500.
DUTC	23	OE	500.	1500.	2300.

DUTC	23	Ø	400.	1500.	2160.
DUTC	23	Y	320.	1800.	2500.
DUTC	23	I	300.	2260.	3000.
DUTC	23	IH	460.	2100.	2880.
DUTC	23	E	460.	2020.	2800.
DUTC	23	EH	640.	1600.	2500.
DUTC	23	A	800.	1250.	2650.
DUTC	23	AA	760.	1120.	2700.
DUTC	23	AO	550.	940.	2420.
DUTC	23	O	520.	960.	2200.
DUTC	23	U	360.	900.	2140.
DUTC	24	OE	400.	1520.	2400.
DUTC	24	Ø	410.	1460.	2360.
DUTC	24	Y	300.	1870.	2300.
DUTC	24	I	270.	2140.	2580.
DUTC	24	IH	360.	1940.	2550.
DUTC	24	E	360.	2000.	2520.
DUTC	24	EH	600.	1600.	2580.
DUTC	24	A	840.	1400.	2500.
DUTC	24	AA	620.	1020.	2770.
DUTC	24	AO	500.	900.	2700.
DUTC	24	O	460.	900.	2520.
DUTC	24	U	360.	860.	2460.
DUTC	25	OE	460.	1500.	2300.
DUTC	25	Ø	400.	1440.	2160.
DUTC	25	Y	380.	1660.	2000.
DUTC	25	I	360.	2240.	2760.
DUTC	25	IH	340.	2040.	2580.
DUTC	25	E	460.	2000.	2520.
DUTC	25	EH	540.	1700.	2460.
DUTC	25	A	880.	1240.	2400.
DUTC	25	AA	600.	1000.	2600.
DUTC	25	AO	540.	1000.	2600.
DUTC	25	O	460.	920.	3300.
DUTC	25	U	360.	860.	2200.
DUTC	26	OE	400.	1620.	2440.
DUTC	26	Ø	400.	1600.	2400.
DUTC	26	Y	360.	1800.	2400.
DUTC	26	I	360.	2500.	2840.
DUTC	26	IH	400.	2060.	2540.
DUTC	26	E	360.	2080.	2680.
DUTC	26	EH	600.	1940.	2600.
DUTC	26	A	960.	1300.	2640.
DUTC	26	AA	740.	1140.	2400.
DUTC	26	AO	560.	980.	2900.
DUTC	26	O	460.	860.	2460.
DUTC	26	U	400.	800.	2500.

DUTC 27	OE	440.	1440.	2440.
DUTC 27	Ø	520.	1480.	2400.
DUTC 27	Y	250.	1720.	2220.
DUTC 27	I	260.	2180.	2560.
DUTC 27	IH	360.	1900.	2600.
DUTC 27	E	360.	2100.	2650.
DUTC 27	EH	600.	1600.	2500.
DUTC 27	A	780.	1300.	2400.
DUTC 27	AA	680.	1050.	2550.
DUTC 27	AO	560.	950.	2700.
DUTC 27	O	550.	1000.	2480.
DUTC 27	U	300.	900.	2300.
DUTC 28	OE	440.	1500.	2480.
DUTC 28	Ø	450.	1520.	2320.
DUTC 28	Y	240.	1800.	2140.
DUTC 28	I	220.	2340.	2960.
DUTC 28	IH	300.	2140.	2760.
DUTC 28	E	300.	2200.	2600.
DUTC 28	EH	500.	1660.	2620.
DUTC 28	A	780.	1300.	2840.
DUTC 28	AA	440.	700.	3040.
DUTC 28	AO	420.	700.	3000.
DUTC 28	O	440.	860.	2860.
DUTC 28	U	280.	740.	2500.
DUTC 29	OE	440.	1550.	2200.
DUTC 29	Ø	480.	1400.	2160.
DUTC 29	Y	280.	1540.	1960.
DUTC 29	I	300.	2040.	2640.
DUTC 29	IH	400.	1780.	2360.
DUTC 29	E	460.	1760.	2320.
DUTC 29	EH	480.	1660.	1960.
DUTC 29	A	640.	1250.	2480.
DUTC 29	AA	720.	1150.	2600.
DUTC 29	AO	480.	840.	2840.
DUTC 29	O	560.	1000.	2480.
DUTC 29	U	340.	660.	2320.
DUTC 30	OE	440.	1360.	2360.
DUTC 30	Ø	460.	1400.	2340.
DUTC 30	Y	300.	1540.	2300.
DUTC 30	I	340.	2300.	2620.
DUTC 30	IH	420.	2000.	2640.
DUTC 30	E	440.	2000.	2540.
DUTC 30	EH	620.	1840.	2560.
DUTC 30	A	600.	1300.	2600.
DUTC 30	AA	750.	1140.	2640.
DUTC 30	AO	520.	820.	2680.
DUTC 30	O	500.	860.	2440.
DUTC 30	U	360.	800.	2540.
DUTC 31	OE	380.	1540.	2400.
DUTC 31	Ø	460.	1540.	2380.
DUTC 31	Y	300.	1800.	2220.
DUTC 31	I	280.	2260.	2620.
DUTC 31	IH	320.	2100.	2460.
DUTC 31	E	460.	1900.	2260.
DUTC 31	EH	500.	1740.	2400.
DUTC 31	A	820.	1200.	2250.
DUTC 31	AA	760.	1060.	2340.
DUTC 31	AO	460.	840.	2580.
DUTC 31	O	440.	820.	2540.
DUTC 31	U	340.	740.	2240.
DUTC 32	OE	500.	1520.	2440.
DUTC 32	Ø	420.	1520.	2260.
DUTC 32	Y	380.	1700.	2100.
DUTC 32	I	400.	2000.	2560.
DUTC 32	IH	460.	1720.	2400.
DUTC 32	E	440.	1740.	2420.
DUTC 32	EH	580.	1540.	2460.
DUTC 32	A	640.	1280.	2340.
DUTC 32	AA	720.	1200.	2580.
DUTC 32	AO	580.	1020.	2700.
DUTC 32	O	460.	920.	2360.
DUTC 32	U	360.	900.	2200.
DUTC 33	OE	380.	1560.	2360.
DUTC 33	Ø	460.	1600.	2540.
DUTC 33	Y	320.	1860.	2200.
DUTC 33	I	300.	2260.	2880.
DUTC 33	IH	440.	2040.	2600.
DUTC 33	E	440.	2180.	2660.
DUTC 33	EH	620.	1720.	2060.
DUTC 33	A	900.	1440.	2600.
DUTC 33	AA	680.	1000.	2200.
DUTC 33	AO	600.	860.	2900.
DUTC 33	O	460.	860.	2600.
DUTC 33	U	400.	700.	2600.
DUTC 34	OE	460.	1200.	2360.
DUTC 34	Ø	440.	1300.	2220.
DUTC 34	Y	320.	1540.	2080.
DUTC 34	I	300.	2040.	2580.
DUTC 34	IH	400.	1800.	2360.
DUTC 34	E	380.	1860.	2450.
DUTC 34	EH	580.	1500.	2380.
DUTC 34	A	700.	1200.	2580.
DUTC 34	AA	720.	1080.	2640.
DUTC 34	AO	480.	820.	2580.
DUTC 34	O	500.	840.	2460.
DUTC 34	U	370.	900.	2230.
DUTC 35	OE	400.	1600.	2460.
DUTC 35	Ø	420.	1560.	2480.
DUTC 35	Y	250.	1760.	2320.
DUTC 35	I	300.	2160.	2700.
DUTC 35	IH	400.	2100.	2640.
DUTC 35	E	440.	1940.	2550.
DUTC 35	EH	580.	1820.	2460.
DUTC 35	A	820.	1300.	2760.
DUTC 35	AA	600.	1040.	2540.
DUTC 35	AO	460.	860.	2660.

DUTC 35	O	440.	1220.	2580.
DUTC 35	U	280.	1040.	2340.
DUTC 36	OE	380.	1360.	2200.
DUTC 36	Ø	460.	1300.	2140.
DUTC 36	Y	320.	1660.	2060.
DUTC 36	I	300.	1900.	2580.
DUTC 36	IH	400.	1740.	2340.
DUTC 36	E	400.	1780.	2320.
DUTC 36	EH	540.	1600.	2260.
DUTC 36	A	660.	1260.	2540.
DUTC 36	AA	640.	1000.	2880.
DUTC 36	AO	540.	860.	2720.
DUTC 36	O	500.	900.	2600.
DUTC 36	U	360.	740.	2160.
DUTC 37	OE	480.	1460.	2260.
DUTC 37	Ø	460.	1520.	2160.
DUTC 37	Y	320.	1800.	2200.
DUTC 37	I	320.	2120.	2600.
DUTC 37	IH	460.	1820.	2480.
DUTC 37	E	320.	1920.	2460.
DUTC 37	EH	600.	1600.	2480.
DUTC 37	A	700.	1240.	2460.
DUTC 37	AA	640.	1120.	2480.
DUTC 37	AO	500.	950.	2450.
DUTC 37	O	480.	960.	2140.
DUTC 37	U	300.	900.	2140.
DUTC 38	OE	400.	1460.	2160.
DUTC 38	Ø	440.	1400.	2220.
DUTC 38	Y	300.	1640.	2080.
DUTC 38	I	280.	2240.	2700.
DUTC 38	IH	360.	2060.	2440.
DUTC 38	E	440.	2040.	2600.
DUTC 38	EH	580.	1700.	1900.
DUTC 38	A	840.	1180.	2700.
DUTC 38	AA	660.	1060.	2700.
DUTC 38	AO	500.	840.	2920.
DUTC 38	O	500.	920.	2400.
DUTC 38	U	320.	760.	2080.
DUTC 39	OE	380.	1500.	2220.
DUTC 39	Ø	440.	1580.	2260.
DUTC 39	Y	200.	1600.	2060.
DUTC 39	I	260.	2200.	2700.
DUTC 39	IH	400.	1700.	2320.
DUTC 39	E	400.	2200.	2600.
DUTC 39	EH	540.	1750.	2420.
DUTC 39	A	700.	1420.	2680.
DUTC 39	AA	700.	1060.	2720.
DUTC 39	AO	520.	820.	2560.
DUTC 39	O	500.	940.	2500.
DUTC 39	U	320.	760.	2480.
DUTC 40	OE	440.	1400.	2320.
DUTC 40	Ø	360.	1500.	2180.
DUTC 40	Y	260.	1560.	2050.
DUTC 40	I	280.	2160.	2920.
DUTC 40	IH	360.	1920.	2560.
DUTC 40	E	360.	2020.	2500.
DUTC 40	EH	460.	1660.	2460.
DUTC 40	A	740.	1200.	2550.
DUTC 40	AA	640.	1120.	2500.
DUTC 40	AO	500.	840.	2580.
DUTC 40	O	420.	860.	2420.
DUTC 40	U	300.	680.	1920.
DUTC 41	OE	420.	1520.	2320.
DUTC 41	Ø	560.	1600.	2200.
DUTC 41	Y	320.	1760.	2100.
DUTC 41	I	300.	2260.	2800.
DUTC 41	IH	420.	2080.	2600.
DUTC 41	E	500.	2020.	2660.
DUTC 41	EH	700.	1800.	2620.
DUTC 41	A	840.	1200.	2500.
DUTC 41	AA	580.	1100.	2680.
DUTC 41	AO	540.	860.	2720.
DUTC 41	O	580.	1060.	2300.
DUTC 41	U	360.	880.	2320.
DUTC 42	OE	400.	1440.	2360.
DUTC 42	Ø	400.	1560.	2120.
DUTC 42	Y	340.	1680.	2240.
DUTC 42	I	320.	2360.	2820.
DUTC 42	IH	380.	2120.	2720.
DUTC 42	E	400.	2180.	2760.
DUTC 42	EH	700.	1700.	2340.
DUTC 42	A	800.	1400.	2900.
DUTC 42	AA	600.	1200.	2760.
DUTC 42	AO	500.	780.	2840.
DUTC 42	O	420.	820.	2480.
DUTC 42	U	420.	800.	2400.
DUTC 43	OE	400.	1340.	2060.
DUTC 43	Ø	400.	1340.	2100.
DUTC 43	Y	240.	1580.	1860.
DUTC 43	I	240.	2000.	2340.
DUTC 43	IH	440.	1720.	2100.
DUTC 43	E	360.	1640.	2080.
DUTC 43	EH	580.	1400.	2120.
DUTC 43	A	740.	1200.	2360.
DUTC 43	AA	620.	900.	2500.
DUTC 43	AO	500.	800.	2460.
DUTC 43	O	460.	860.	2200.
DUTC 43	U	300.	760.	2020.
DUTC 44	OE	420.	1420.	2400.
DUTC 44	Ø	420.	1400.	2300.
DUTC 44	Y	260.	1580.	2260.
DUTC 44	I	240.	2040.	2680.
DUTC 44	IH	280.	1960.	2560.
DUTC 44	E	380.	2000.	2600.
DUTC 44	EH	540.	1640.	2440.
DUTC 44	A	780.	1300.	2700.

DUTC	44	AA	620.	1000.	2820.
DUTC	44	AO	480.	840.	2800.
DUTC	44	O	480.	900.	2500.
DUTC	44	U	260.	800.	2400.
DUTC	45	OE	320.	1400.	2140.
DUTC	45	Ø	400.	1260.	2020.
DUTC	45	Y	300.	1480.	1940.
DUTC	45	I	260.	1960.	2440.
DUTC	45	IH	360.	1860.	2300.
DUTC	45	E	440.	1880.	2380.
DUTC	45	EH	500.	1560.	2300.
DUTC	45	A	800.	1220.	2280.
DUTC	45	AA	700.	1020.	2600.
DUTC	45	AO	540.	780.	2400.
DUTC	45	O	500.	920.	2120.
DUTC	45	U	300.	840.	3060.
DUTC	46	OE	460.	2320.	3360.
DUTC	46	Ø	400.	1600.	2280.
DUTC	46	Y	300.	1860.	2160.
DUTC	46	I	320.	2340.	3140.
DUTC	46	IH	420.	2200.	2740.
DUTC	46	E	420.	2200.	2760.
DUTC	46	EH	500.	2100.	2760.
DUTC	46	A	660.	1400.	2540.
DUTC	46	AA	700.	1040.	2720.
DUTC	46	AO	600.	920.	2700.
DUTC	46	O	520.	940.	2580.
DUTC	46	U	320.	860.	2380.
DUTC	47	OE	460.	1440.	2140.
DUTC	47	Ø	500.	1400.	2200.
DUTC	47	Y	320.	1800.	2100.
DUTC	47	I	320.	2240.	2940.
DUTC	47	IH	440.	1920.	2560.
DUTC	47	E	420.	2040.	2400.
DUTC	47	EH	600.	1600.	2520.
DUTC	47	A	700.	1220.	2760.
DUTC	47	AA	620.	1080.	2800.
DUTC	47	AO	560.	700.	2780.
DUTC	47	O	540.	940.	2640.
DUTC	47	U	360.	800.	2120.
DUTC	48	OE	440.	1440.	2560.
DUTC	48	Ø	420.	1380.	2100.
DUTC	48	Y	220.	1760.	2120.
DUTC	48	I	220.	2080.	2900.
DUTC	48	IH	420.	1720.	2720.
DUTC	48	E	440.	2060.	2780.
DUTC	48	EH	580.	1400.	2100.
DUTC	48	A	800.	1260.	2740.
DUTC	48	AA	540.	900.	2400.
DUTC	48	AO	520.	900.	2300.
DUTC	48	O	460.	840.	1840.
DUTC	48	U	300.	760.	1900.
DUTC	49	OE	380.	1460.	2400.
DUTC	49	Ø	340.	1440.	2260.
DUTC	49	Y	280.	1820.	2220.
DUTC	49	I	280.	2140.	2580.
DUTC	49	IH	420.	1960.	2700.
DUTC	49	E	340.	2100.	2500.
DUTC	49	EH	500.	1640.	2500.
DUTC	49	A	700.	1280.	2500.
DUTC	49	AA	620.	1100.	2840.
DUTC	49	AO	500.	960.	2720.
DUTC	49	O	460.	1060.	2380.
DUTC	49	U	320.	1000.	2220.
DUTC	50	OE	400.	1360.	2160.
DUTC	50	Ø	400.	1320.	2120.
DUTC	50	Y	280.	1600.	1900.
DUTC	50	I	300.	1860.	2440.
DUTC	50	IH	360.	1740.	2260.
DUTC	50	E	340.	1740.	2260.
DUTC	50	EH	520.	1580.	2240.
DUTC	50	A	660.	1220.	2500.
DUTC	50	AA	560.	1000.	2600.
DUTC	50	AO	380.	800.	2560.
DUTC	50	O	420.	760.	2440.
DUTC	50	U	340.	780.	2020.

SWED	1	i	286	1969	2815
SWED	2	i	281	2013	3009
SWED	3	i	280	1900	3075
SWED	4	i	300	2000	3075
SWED	5	i	250	2050	3000
SWED	6	i	275	1900	2950
SWED	1	e	305	2187	2762
SWED	2	e	325	2010	2400
SWED	3	e	355	2177	2486
SWED	4	e	400	2325	2675
SWED	5	e	325	2100	2525
SWED	6	e	325	2300	2800
SWED	1	eh	514	1941	2567
SWED	2	eh	550	1800	2300
SWED	3	eh	514	1881	2295
SWED	4	eh	600	1950	2725
SWED	5	eh	550	1850	2375
SWED	6	eh	600	1900	2475
SWED	1	y	292	1830	2625
SWED	2	y	291	1921	2556
SWED	3	y	303	1775	2725
SWED	4	y	300	2025	3050
SWED	5	y	275	2075	2600
SWED	6	y	300	1800	2725
SWED	1	ø	443	1530	2065
SWED	2	ø	472	1562	1992
SWED	3	ø	437	1574	2127
SWED	4	ø	525	1600	2475
SWED	5	ø	400	1700	2075
SWED	6	ø	500	1625	2200
SWED	1	u	374	889	2335
SWED	2	u	334	680	2376
SWED	3	u	385	850	2150
SWED	4	u	325	700	2475
SWED	5	u	300	650	2400
SWED	6	u	300	675	2400
SWED	1	o	385	820	2100
SWED	2	o	374	659	2409
SWED	3	o	378	705	2218
SWED	4	o	450	700	2525
SWED	5	o	375	650	2625
SWED	6	o	400	675	2475
SWED	1	aa	553	876	2445
SWED	2	aa	682	957	2470
SWED	3	aa	689	1017	2636
SWED	4	aa	600	950	2450
SWED	5	aa	600	850	2325
SWED	6	aa	650	975	2175
SWED	1	ʉ	354	1842	2487
SWED	3	ʉ	351	1547	2327
SWED	4	ʉ	400	1725	2475
SWED	5	ʉ	325	1725	2125
SWED	6	ʉ	350	1725	2350

FRIS	1	i	350	2200
FRIS	2	i	260	2290
FRIS	3	i	260	2360
FRIS	4	i	240	2350
FRIS	5	i	350	2350
FRIS	1	y	280	1850
FRIS	2	y	270	1780
FRIS	3	y	290	1710
FRIS	4	y	250	1920
FRIS	5	y	310	1780
FRIS	1	u	380	670
FRIS	2	u	380	660
FRIS	3	u	290	620
FRIS	4	u	260	760
FRIS	5	u	330	780
FRIS	1	e	450	2040
FRIS	2	e	320	1990
FRIS	3	e	370	2020
FRIS	4	e	360	2140
FRIS	5	e	340	2090
FRIS	1	ø	460	1620
FRIS	2	ø	350	1590
FRIS	3	ø	450	1490
FRIS	4	ø	410	1750
FRIS	5	ø	350	1580
FRIS	1	o	450	880
FRIS	2	o	360	780
FRIS	3	o	450	1090
FRIS	4	o	490	980
FRIS	5	o	380	910
FRIS	1	eh	420	1830
FRIS	2	eh	450	1830
FRIS	3	eh	580	1760
FRIS	4	eh	540	1960
FRIS	5	eh	490	1930
FRIS	1	oh	500	920
FRIS	2	oh	540	790
FRIS	3	oh	620	950
FRIS	4	oh	520	890
FRIS	5	oh	550	880
FRIS	1	a	600	1210
FRIS	2	a	680	1800
FRIS	3	a	740	1490
FRIS	4	a	820	1300
FRIS	5	a	810	1310

DANI	1OE	410.	1450.	2150.
DANI	1Ø	290.	1625.	2100.
DANI	1Y	250.	1775.	2520.
DANI	1I	230.	2100.	3200.
DANI	1E	290.	2150.	2800.
DANI	1EH	400.	2015.	2500.
DANI	1AE	600.	1700.	2520.
DANI	1AO	360.	950.	2250.
DANI	1O	300.	700.	0.
DANI	1U	280.	850.	0.
DANI	2OE	360.	1450.	2250.
DANI	2Ø	270.	1775.	2275.
DANI	2Y	225.	1900.	2200.
DANI	2I	210.	2150.	3250.
DANI	2E	280.	2250.	3200.
DANI	2EH	340.	2200.	2900.
DANI	2AE	550.	2025.	2650.
DANI	2AO	340.	850.	2550.
DANI	2O	300.	625.	2600.
DANI	2U	215.	800.	2100.
DANI	3OE	375.	1575.	2125.
DANI	3Ø	260.	1650.	2100.
DANI	3Y	225.	1800.	2100.
DANI	3I	200.	2025.	3200.
DANI	3E	270.	2100.	2950.
DANI	3EH	375.	2100.	2775.
DANI	3AE	625.	1775.	2500.
DANI	3AO	375.	975.	2325.
DANI	3O	300.	650.	2225.
DANI	3U	230.	725.	1925.
DANI	4OE	400.	1725.	2220.
DANI	4Ø	300.	1875.	2250.
DANI	4Y	225.	2050.	2275.
DANI	4I	210.	2400.	3350.
DANI	4E	300.	2625.	3000.
DANI	4EH	390.	2300.	2800.
DANI	4AE	630.	2000.	2650.
DANI	4AO	390.	850.	0.
DANI	4O	310.	625.	0.
DANI	4U	290.	750.	0.
DANI	5OE	375.	1550.	1975.
DANI	5Ø	275.	1650.	2025.
DANI	5Y	250.	1850.	2050.
DANI	5I	225.	2050.	3200.
DANI	5E	260.	2075.	2900.
DANI	5EH	375.	2000.	2725.
DANI	5AE	600.	1750.	2400.
DANI	5AO	385.	950.	2075.
DANI	5O	280.	625.	0.
DANI	5U	250.	700.	0.
DANI	6OE	375.	1550.	1925.
DANI	6Ø	275.	1625.	1925.
DANI	6Y	210.	1825.	2050.
DANI	6I	200.	1975.	3000.
DANI	6E	290.	2050.	2750.
DANI	6EH	375.	1975.	2650.
DANI	6AE	600.	1850.	2500.
DANI	6AO	410.	975.	0.
DANI	6O	300.	650.	0.
DANI	6U	220.	775.	0.
DANI	7OE	380.	1600.	2275.
DANI	7Ø	290.	1625.	2225.
DANI	7Y	260.	2025.	2425.
DANI	7I	230.	2525.	3325.
DANI	7E	300.	2500.	2950.
DANI	7EH	350.	2225.	2775.
DANI	7AE	575.	1850.	2475.
DANI	7AO	350.	850.	2700.
DANI	7O	325.	700.	0.
DANI	7U	275.	775.	0.
DANI	8OE	400.	1600.	2175.
DANI	8Ø	300.	1725.	2150.
DANI	8Y	275.	2000.	2250.
DANI	8I	250.	2125.	3375.
DANI	8E	300.	2100.	2825.
DANI	8EH	375.	1975.	2650.
DANI	8AE	600.	1700.	2450.
DANI	8AO	400.	900.	2100.
DANI	8O	350.	700.	0.
DANI	8U	270.	875.	0.

GERM	1Ø	334.	1582.	2150.
GERM	1Y	260.	1825.	2207.
GERM	1I	254.	2359.	2975.
GERM	1E	308.	2265.	2725.
GERM	1EH	489.	1991.	2427.
GERM	1A	810.	1230.	2915.
GERM	1O	375.	742.	2100.
GERM	1U	268.	608.	2100.
GERM	2Ø	387.	1555.	2140.
GERM	2Y	236.	1840.	2265.
GERM	2I	238.	2411.	2956.
GERM	2E	326.	2398.	2788.
GERM	2EH	550.	1575.	2525.
GERM	2A	738.	1250.	2100.
GERM	2O	404.	1045.	2100.
GERM	2U	277.	710.	2100.
GERM	3Ø	297.	1305.	2035.
GERM	3Y	228.	1571.	1925.
GERM	3I	201.	2222.	2767.
GERM	3E	249.	2253.	2614.
GERM	3EH	425.	1875.	2375.
GERM	3A	700.	1288.	2175.
GERM	3O	326.	597.	2100.
GERM	3U	252.	554.	2100.
GERM	4Ø	314.	1563.	2050.
GERM	4Y	222.	1625.	2021.
GERM	4I	227.	2367.	2904.
GERM	4E	293.	2425.	2800.
GERM	4EH	392.	2238.	2713.
GERM	4A	900.	1421.	2300.
GERM	4O	327.	763.	2100.
GERM	4U	245.	708.	2100.
GERM	5Ø	308.	1367.	1963.
GERM	5Y	231.	1567.	1963.
GERM	5I	228.	2121.	2825.
GERM	5E	308.	2092.	2521.
GERM	5EH	350.	2058.	2521.
GERM	5A	792.	1192.	2375.
GERM	5O	349.	754.	2100.
GERM	5U	238.	733.	2100.
GERM	6Ø	365.	1515.	1955.
GERM	6Y	276.	1621.	1975.
GERM	6I	266.	2004.	2763.
GERM	6E	343.	1900.	2563.
GERM	6EH	504.	1796.	2463.
GERM	6A	833.	1338.	2408.
GERM	6O	383.	817.	2100.
GERM	6U	302.	796.	2100.

(German data reprinted from Jørgensen (1969).)

Appendix 3: Data from Chapter 4

283	2257	3080	i
374	2217	2766	e
864	1521	2439	ɛ
244	2186	2572	y
432	1506	2359	ø
276	1625	2192	ʉ
297	1001	2526	u
379	978	2395	ɔ
561	1062	2648	ɑ

Speaker 2: Norwegian

259	2246	2836	i
410	2196	2534	e
498	1793	2579	ɛ
433	1398	2166	ø
908	1355	2494	a
328	959	2254	u
408	1088	2323	o

Speaker 2: German

270	2255	2892	i
387	2088	2706	ɩ
389	2174	2742	e
611	1750	2597	ɛ
334	1730	2203	y
403	1699	2346	ø
412	1551	2312	œ
885	1485	2655	a
275	764	2392	u
418	941	2555	o
530	925	2700	ɔ
759	1102	2853	ɑ

Speaker 6: Dutch

243	2318	2975	i
440	2173	2808	ɩ
457	2240	2858	e
471	2020	2642	ɛ
628	1972	2329	æ
523	1561	2749	ʌ
331	790	2488	u
373	965	2484	ω
424	996	2547	o
530	816	2426	ɔ
875	1036	2709	ɑ

Speaker 6: English

271	2062	2903	i
312	2055	2825	e
266	1926	2425	y
358	1573	1994	ø
290	918	2019	u
484	750	2263	a
312	1603	1999	ʉ

Speaker 7: Swedish

270	2044	2790	i
353	1946	2323	ɩ
421	1766	2170	e
541	1635	2094	ɛ
529	1064	2045	ʌ
308	896	1986	u
375	977	1923	ω
495	968	2060	o
522	937	1869	ɑ

Speaker 7: English

316	2321	3185	i
389	2301	2818	e
555	2097	2483	ɛ
313	2089	2717	y
386	1957	2281	ø
390	1811	2183	ʉ
382	710	2238	u
455	738	2117	o

Speaker 12: Swedish

337	2267	3154	i
442	2164	2571	ɩ
527	2010	2562	e
576	1857	2435	ɛ
730	1673	2183	æ
737	1218	2105	ʌ
369	836	2007	u
392	1160	2179	ω
481	1270	2123	o
490	772	1941	ɔ
696	908	2043	ɑ

Speaker 12: English

225	2060	3102	i
336	2142	2953	e
341	2062	2816	ɛ
474	2035	2574	æ
270	1822	2163	y
323	1458	2079	ø
388	1532	2126	œ
250	645	2222	u
324	752	2412	o
350	780	2268	ɔ

Speaker 13: Danish

233	1963	3113	i
380	1979	2600	ι
488	1967	2641	e
563	1907	2538	ɛ
641	1687	2565	æ
642	1220	2481	ʌ
347	784	2300	u
425	1173	2240	ɷ
453	1040	2394	o
484	732	2576	ɔ
595	1070	2705	ɑ

Speaker 13: English

302	2494	3126	i
435	2157	2900	ι
495	2131	2812	e
545	2003	2524	ɛ
662	1900	2530	æ
672	1523	2335	ʌ
341	889	2315	u
448	1193	2274	ɷ
501	1087	2298	o
626	910	2223	ɔ
724	1318	2202	ɑ

Speaker 14: English

290	2500	3219	i
347	2386	3147	e
428	2161	2590	ɛ
489	2140	2517	æ
295	1796	2181	y
376	1756	2257	ø
471	1681	2202	œ
294	782	2344	u
334	619	2509	o
413	828	2330	ɔ

Speaker 14: Danish

286	1969	2815	i
305	2187	2762	e
514	1941	2567	ɛ
289	1916	2603	y
443	1530	2065	ø
354	1842	2487	ʉ
374	889	2335	u
375	963	2103	o
558	891	2310	ɑ

Speaker 16: Swedish

307	2206	3110	i
364	2011	2456	e
477	1879	2399	ɛ
302	1880	2281	y
407	1408	1955	ø
793	1127	2302	a
338	867	1995	u
398	1122	1880	o

Speaker 16: German

327	2244	2583	i
442	1888	2593	ι
422	1838	2489	e
504	1608	2400	ɛ
821	1527	2571	æ
761	1218	2428	ʌ
364	1058	2115	u
424	1079	1969	ɷ
446	1173	1876	o
426	1097	2097	ɔ
579	921	2460	ɒ

Speaker 16: English.

318	2264	3170	i
342	2126	2646	e
615	1319	2310	æ
309	1853	2193	y
406	1427	2231	ø
306	917	2028	u
464	1060	2314	ɔ
551	987	2492	ɑ
283	1585	2043	ʉ

Speaker 16: Norwegian

263	2176	3024	i
560	2172	2989	e
319	1946	2354	y
451	1482	2111	ø
725	1292	2776	a
307	921	2349	u
411	1064	2378	o

Speaker 19: German

301	2154	2903	i
444	2059	2777	ɩ
431	2214	2835	e
510	1898	2627	ɛ
772	1335	2305	ʌ
336	967	2200	u
484	1168	2383	ω
437	1136	2120	o
470	1171	2306	ɔ
694	1261	2671	ɑ

Speaker 19: English

302	2290	2798	i
356	1959	2501	ɩ
372	2256	2461	e
484	1763	2531	ɛ
276	1656	2204	y
365	1546	2427	ø
361	1432	2292	œ
971	1265	2507	a
287	796	2569	u
409	861	2538	o
444	834	2557	ɔ
552	1025	2562	ɑ

Speaker 20: Dutch

272	2317	2838	i
358	1886	2631	ɩ
375	2138	2577	e
815	1712	2473	æ
526	1380	2501	ʌ
304	1053	2429	u
376	1198	2373	ω
391	949	2439	o
501	878	2356	ɔ
779	1076	2416	ɑ

Speaker 20: English

257	2313	2905	i
355	2232	2577	e
395	2072	2534	ɛ
298	1676	2280	y
360	1506	2228	ø
907	1317	2413	a
298	847	2473	u
403	823	2526	o

Speaker 20: German

313	2386	2684	i
415	2233	2758	ɩ
499	2174	2624	e
603	1859	2578	ɛ
695	1849	2522	æ
349	724	1816	u
427	909	2283	ω
510	902	2428	o
713	884	2681	ɑ

Speaker 23: English

319	2374	3226	i
345	2326	2655	e
593	1973	2521	ɛ
298	1705	2210	y
384	1589	2280	ø
478	669	2641	o
675	1187	2721	a

Speaker 23: German

281	2013	3009	i
325	2010	2400	e
500	1800	2300	ɛ
291	1921	2556	y
472	1562	1992	ø
334	680	2376	u
374	659	2409	o
553	876	2445	ɑ

Speaker 24: Swedish

298	2082	2981	i
344	1862	2554	ɩ
424	1850	2323	e
503	1736	2481	ɛ
573	1575	2351	æ
536	1296	2602	ʌ
303	1059	1951	u
326	1128	2192	ω
521	926	2617	ɔ

Speaker 24: English

266	2058	3104	i
386	1943	2545	e
502	1765	2191	æ
272	1934	2323	y
384	1506	2106	ø
278	703	2460	u
440	679	2650	ɔ
622	1065	2595	ɑ
306	1659	1990	ʉ

Speaker 24: Norwegian

310	2188	2897	i
385	2273	2794	e
538	1912	2582	ɛ
324	2028	2586	y
401	1841	2368	ø
368	1802	2460	ʉ
330	746	2483	u
379	686	2518	o
566	772	2623	ɑ

Speaker 25: Swedish

331	2246	2950	i
417	1853	2607	ɪ
436	2061	2624	e
548	1794	2542	ɛ
694	1551	2629	æ
678	1388	2625	ʌ
339	1031	2552	u
411	1147	2367	ʊ
433	1240	2325	o
488	701	2651	ʊ
552	836	2651	ɔ

Speaker 25: English

299	2262	2909	i
341	2179	2679	e
487	2005	2555	ɛ
319	1685	2123	y
410	1414	2212	ø
772	1237	2781	a
326	708	2290	u
387	697	2615	o

Speaker 25: German

305	2088	2706	i
361	2060	2753	e
432	1997	2415	ɛ
332	1722	2120	y
649	1214	2011	a
353	879	2147	u
441	813	2115	o

Speaker 26: German

319	2086	2835	i
457	1887	2514	ɪ
444	1985	2481	e
526	1750	2407	ɛ
722	1592	2273	æ
593	1311	2073	ʌ
339	1102	2004	u
478	1192	2067	ʊ
453	1059	1872	o
617	1016	1977	ɔ

Speaker 26: English

281	2085	2873	i
327	2068	2746	e
413	2000	2485	ɛ
510	1895	2456	æ
311	1663	2089	y
375	1561	2058	ø
434	1543	2104	œ
331	867	2037	u
390	710	1905	o
410	844	1945	ɔ

Speaker 26: Danish

341	2520	3265	i
395	2155	2939	ɪ
476	2208	2883	e
579	1927	2756	ɛ
838	1831	2825	æ
600	1556	2535	ʌ
361	934	2497	u
432	1196	2463	ʊ
479	905	2242	o
804	1142	2216	ɑ

Speaker 27: English

298	2450	3325	i
376	2373	2888	e
639	1756	2693	ɛ
348	1789	2260	y
418	1534	2276	ø
839	1371	2487	a
315	655	2460	u
423	700	2362	o

Speaker 27: German

275	2333	2960	i
353	2388	2832	e
599	2007	2590	ɛ
283	1676	2098	y
377	1389	1810	ø
311	724	2247	u
370	737	2228	o
839	1369	2608	a

Speaker 29: German

290	2437	2749	i
413	2085	2650	ɪ
484	2124	2640	e
520	1955	2609	ɛ
604	1898	2580	æ
688	1243	2337	ʌ
314	917	2173	u
433	1015	2246	ʊ
493	926	2292	o
615	901	2480	ɔ
636	965	2416	ɑ

Speaker 29: English

289	2228	3154	i
376	2410	2737	e
554	2050	2614	ɛ
398	1915	2668	y
522	1496	2566	ø
329	1832	2722	ʉ
351	1107	2333	u
400	744	2343	o
567	894	2257	ɑ

Speaker 31: Swedish

368	2274	2996	i
389	2330	2827	ɪ
585	2021	2711	e
544	2003	2614	ɛ
709	1500	2499	æ
399	1120	2380	u
421	1223	2419	ʊ
453	1393	2322	o
455	730	2301	ɔ
514	816	2183	ɑ

Speaker 31: English

288	1927	2685	i
349	1903	2650	ɪ
452	2059	2722	e
515	1869	2611	ɛ
638	1768	2648	æ
705	1260	2124	ʌ
317	933	2394	u
442	1136	2464	ʊ
472	722	2561	ɔ
615	995	2639	ɑ

Speaker 32: English

271	2195	3087	i
289	2201	2837	e
615	2038	2675	ɛ
300	2050	2825	y
357	1867	2254	ø
288	1723	2301	ʉ
318	743	2477	u
450	654	2386	o
564	805	2272	ɑ

Speaker 32: Swedish

278	2249	2897	i
355	2133	2610	e
283	1898	2347	y
448	1489	2324	ø
787	1401	2388	a
317	939	2387	u
378	1096	2455	o

Speaker 33: German

299	2293	2899	i
388	1949	2563	ɪ
484	1876	2521	e
542	1818	2467	ɛ
649	1727	2524	æ
726	1248	2442	ʌ
316	1000	2439	u
405	1017	2459	ʊ
428	1370	2188	o
467	1074	2545	ɔ
596	964	2314	ɒ

Speaker 33: English

245	2196	2939	i
339	1979	2551	ɪ
372	1985	2590	e
405	1919	2550	ɛ
723	1551	2356	æ
715	1346	2595	ʌ
267	1093	1925	u
409	1088	2258	ʊ
398	1405	2238	o
390	732	2617	ɔ
591	946	2869	ɑ

Speaker 34: English

254	2040	2799	i
337	1919	2518	ɪ
344	2022	2592	e
602	1697	2495	ɛ
248	1895	2413	y
341	1659	2197	ø
356	1658	2356	œ
667	1361	2609	a
287	876	2231	u
375	951	2372	o
372	766	2721	ɔ
652	1080	2737	ɑ

Speaker 34: Dutch

281	2271	2837	i
357	1994	2619	ɩ
367	2025	2608	e
458	1866	2614	ɛ
940	1634	2570	æ
753	1347	2385	ʌ
328	1118	2413	u
442	1260	2309	ɷ
415	1294	2289	o
427	849	2495	ɔ
765	1073	2642	ɑ

Speaker 36: English

277	2131	2891	i
345	2177	2761	e
416	1879	2589	ɛ
297	1812	2338	y
364	1308	2024	ø
902	1376	2352	a
317	879	2452	u
373	847	2387	o

Speaker 36: German

285	2108	2801	i
359	1990	2578	ɩ
372	2080	2704	e
843	1748	2463	ɛ
308	1806	2435	y
395	1654	2348	ø
383	1594	2375	œ
963	1560	2507	a
324	974	1817	u
395	937	2408	o
401	853	2764	ɔ
741	1062	2785	ɑ

Speaker 36: Dutch

Appendix 4:

Instructions for Listening Test

This is a test of selected speakers' mastery of the sounds of English. Each speaker will pronounce nine words. These words are written on the grading sheet. You will be asked to listen carefully to the speaker's pronunciation and then to rate your overall impression of his performance compared with the way an educated native speaker of English would say the same words under similar conditions. A six-point rating scale is provided for this purpose (see page 2); it ranges from zero (entirely foreign pronunciation) to five (entirely native pronunciation).

Please note the following:

(1) There are some native speakers of English in the sample.

(2) Some of the speakers -- those marked with an asterisk (*) -- were asked to say the target words in a sentence context ("Now say _______ again"). The words you will hear from them have been edited out of the sentences. They are of shorter duration, and exhibit a less appropriate intonation contour than similar words uttered in isolation. The sentence-context readings were assigned randomly, and they bear <u>no</u> relation to the individual's language skills. Please do not let this influence your assessment.

(3) The word-lists will vary slightly from speaker to speaker. This, too, is random and should not influence your assessment.

(4) You will be listening primarily for mastery of the <u>vowel</u> sounds of English. Some of the "errors" you may hear in the consonantal portions of the test words may be due to boundary conditions (e.g. coarticulation with a following segment) rather than to a lack of proficiency on the part of the speaker. As much as possible, try to confine your assessment to the quality of the vowels you hear.

(5) All regional varieties of English -- U.S., U.K., New Zealand, etc. -- are to be considered equally correct. "Prestige" is not a factor here. Please just rate how close a speaker seems to be to mastery of any native English accent.

Foreign Service Institute Scale of Language Proficiency

You are to rate your overall impression of the subject's performance compared to that which an educated native speaker would produce under similar conditions. Please give a single score for each speaker you hear (not for each individual word) in the spaces provided at the right-hand edge of the scoring sheet.

Rate the speaker's accent on a six-point scale (0 to 5) from "foreign" to "native":

Foreign ___ ___ ___ ___ ___ ___ Native
0 1 2 3 4 5

i.e. truly foreign 0; truly native, 5
quite foreign 1; quite native, 4
more foreign than native, 2; more native than foreign, 3

You might find the following guidelines more useful:

0 = pronunciation frequently unintelligible
1 = very heavy accent; difficult to understand
2 = marked "foreign accent"; requires concentrated listening
3 = occasional mispronunciations which do not interfere with understanding
4 = no conspicuous mispronunciations, but would not be taken for a native spkr.
5 = native pronunciation, with no trace of "foreign accent"

You may use plus (+) or minus (-) to make finer distinctions.

Do not hesitate to add written comments alongside the numerical scores.

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