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6

THE ACQUISITION OF ENGLISH VOWELS BY BRAZILIAN-PORTUGUESE SPEAKERS

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In *The Acquisition of English Vowels by Brazilian-Portuguese Speakers*, the sixth volume of the Advanced Research in English Series (ARES), Barbara O. Baptista examines the evolution of the English interlanguage (IL) monophthongal vowel systems of eleven Brazilian-Portuguese speakers over a period of six months. The interrelationships between the addition of new English vowels to the IL system and the adjustments in the "old" IL vowels - those with Portuguese counterparts - are investigated within the frameworks of phonetic and cognitive theory.

Based on first and second formant frequency plots of six Portuguese and seven English vowels, as produced monthly by the learners, two types of analysis are carried out: First a comparison is made between the first-month IL vowel systems and the respective native-language (NL) target systems, which leads to the proposal that, after an initial period where the NL schema is used for communication in the target language (TL), an IL schema is generated, patterned on the NL schema (restructuring), but modified as a unit to approximate the TL. Second, the evolution of these newly constructed IL vowel schemata is tracked, resulting in evidence which relates the acquisition or non-acquisition of the new vowels to the appropriate adjustment or lack of adjustment in the old. Baptista proposes that this parallel between acquisition and adjustment is due to the learners' perception of the relative, rather than the absolute, positioning of vowels within the system and to the need for maintenance of sufficient perceptual distance among all the IL vowels. In sum, she suggests that the process of *vowel* acquisition might better be seen as a holistic process of *vowel system* acquisition.

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PÓS-GRADUAÇÃO EM INGLÊS

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PREFACE

This publication is the result of doctoral research carried out at the University of California, Los Angeles, sponsored by CAPES, of the Brazilian Ministry of Education, during the period of 1987 to 1992. Eight years have passed since then, and second language acquisition theory has evolved considerably during this time. At the time of writing, the most important theories orienting the analysis were the general cognitive theories of Rumelhart and Norman (1978) and Karmiloff-Smith (1986a, 1986b, 1986c), among others, the phonetic theories of Ladefoged (1989) and Lindblom (1986), and Flege's theories in the area of second language phonetic acquisition (1986, 1987).

Since then, Flege has developed his theories into a more elaborate model of second language phonetic acquisition, the Speech Learning Model (1992, 1995). This model incorporates his previous theory based on equivalence classification, but acknowledges degrees of similarity between L1 and L2 phones rather than insisting on a new/similar dichotomy, and in this and several other ways does a more thorough job of accounting for apparent inconsistencies in second language speech data. Because Flege's more recent Speech Learning Model is especially suited to offer further insights on the acquisition of second language vowels, I thought it worthwhile to reanalyze the data of this study based on this model and collect and analyze additional data, this time on classroom learners in Brazil, i. e., not living in the country where English is spoken. I am presently involved in a research project with these two objectives.

It is important to point out, however, that the new research project does not invalidate the conclusions drawn from the first study, but rather aims at further validating these results and offering additional insights. The study reported in the remainder of this volume, although concluded eight years ago, is still up-to-date in its treatment of second language vowels as an integrated system, something not done, to my knowledge, in any of the studies published during these last eight years.

The formant frequency data are available in the appendix of the dissertation on which this book is based[1], available at the Biblioteca Central of the Universidade Federal de Santa Catarina, Florianópolis, Santa Catarina, Brazil, or from the author at the Departamento de Língua e Literatura Estrangeiras of the same university, or by e-mail request at baptista@cce.ufsc.br

Barbara O. Baptista
July, 2000

Note

[1] Baptista, B. O. (1992) *The acquisition of English vowels by eleven Brazilian-Portuguese speakers: An acoustic analysis*. Unpublished doctoral dissertation. University of California, Los Angeles, CA.

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ABSTRACT

This study examines the evolution of the non-back portion of the English interlanguage (IL) monophthongal vowel systems of eleven Brazilian-Portuguese speakers over a period of six months. The interrelationships between the addition of new English vowels to the IL system and the adjustments in the "old" IL vowels - those with Portuguese counterparts - are investigated in the framework of phonetic and cognitive theory.

The data consist of the first and second formant frequencies of six Portuguese and seven English vowels, as recorded monthly by the eleven learners and plotted for visual analysis.

In chapter 4, the first-month IL vowel systems are compared with the respective native-language (NL) systems and with data on the assumed target Californian English vowels (Ohnishi, 1991). It is proposed that, after an initial period where the NL schema is used for communication in the target language (TL), an IL schema is generated, patterned on the NL schema (restructuring), but modified as a unit to approximate the TL.

Chapter 5 describes the evolution of these newly constructed IL vowel schemata. Evidence is reported relating the acquisition or non-acquisition of the new vowels to the appropriate adjustment or lack of adjustment in the old. It is proposed that this parallel between acquisition and adjustment is due to the learners' greater preoccupation with the relative than with the absolute positioning of vowels within the system (Ladefoged, 1989), and to their need for maintaining sufficient perceptual distance between the vowels (Lindblom, 1986).

In most cases, it appeared that the accretion of the new vowels could take place only *after* the tuning or restructuring of the IL schema, as would be predicted by Rumelhart and Norman's cognitive learning model (1978). In one case, however, it appeared that partial acquisition may have motivated a reorganization of the schema, as would be predicted by Karmiloff-Smith's success-based learning model (1986a), which would in turn have allowed for the completion of the acquisition process. In sum, the evidence indicates that the process of *vowel* acquisition might better be seen as a holistic process of *vowel system* acquisition.

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1. Introduction

1.1. Context of the problem.

In the last fifteen years, second and foreign-language educators have taken a renewed interest in the sound system of the target language, and many researchers in the field of second-language acquisition (SLA) have discovered the sound system as an exciting new area for research. This renewed interest on the part of educators is evidenced in the increasing number of pronunciation manuals being released (e.g., English, 1988; Morley, 1979; Mortimer, 1985; Orion, 1988; Prator & Robinett, 1985; Roach, 1983, 1989; Rogerson & Gilbert, 1990), and the discovery of this area by researchers, in the publication of the first two anthologies of studies in SLA phonology (Ioup & Weinberger, 1987; James & Leather, 1986).

Still in its infancy, SLA phonology research has many gaps yet to be filled. The following are three areas which I perceive to be particularly in need of attention by researchers.

First, in spite of the importance given to the longitudinal studies carried out in the 1970s by Lonna Dickerson and Wayne Dickerson, and the calls for more longitudinal studies in SLA phonology by people like Tarone (1979) and Beebe (1987), most studies in SLA phonology continue to be cross-sectional. From the proficiency levels of different speakers defined by these studies, implications are made about the *probable* acquisitional stages of a typical learner over time. Although these cross-sectional studies are important, especially because of the possibility of including a statistically significant number of subjects, they should be complementary to, rather than a substitute for, longitudinal studies.

Second, there has been a tendency in SLA phonology to focus on phonemic contrasts, as opposed to phonetic distinctions. Although studies of phonemic contrasts have made important contributions to phonological theory, it should not be forgotten that one of the ultimate goals of applied linguistics is to intercede in second-language (L2) acquisition. With this goal in mind, it is important to remember that, as pointed out by Beebe (1987, p. 168), "phonemic contrasts are a very minor problem for intermediate and advanced learners. Phonetic inaccuracy, compared with a TL norm, is extensive. The phonetic deviance is heard by the teacher/listener as a phonemic error."

Macken and Ferguson (1987, pp. 14-15) also stress the importance of including the phonetic level in SLA research and—toward this end—of using instrumental (spectrographic) techniques to "document phenomena that cannot be detected by the categorically bound perceptual systems of researchers." Although trained phoneticians are capable of detecting phonetic differences not perceived by an untrained person, even they cannot possibly detect the whole continuum of differences picked up by a spectrogram. Even if they could, as pointed out by Flege (1980, p. 120), the limited number of transcription categories would be insufficient to "provide a quantitative estimate of how closely a variant approximates the phonetic norms of the target language." Macken and Ferguson cite a study by Macken and Barton (1980), in which "children were making statistically significant contrasts between adult voiced and voiceless phonemes and yet where all the children's productions fell within the adult perceptual boundaries for a single phoneme."

Macken and Ferguson emphasize the use of instrumental techniques for consonants, presumably because it is consonants which have been found to be categorically perceived, even by infants. However, from the learner's point of view, it is the lack of categorical perception of vowels which makes a gradual approximation of the target more likely than for consonants. This gradual approximation can be most accurately documented by instrumental techniques.

Finally, previous studies of L2 vowel acquisition have generally focussed on the distinction between particular pairs of similar vowels, in isolation from the rest of the vowel system. There is evidence, however, from a classic study by Ladefoged and Broadbent (1957, updated by Ladefoged, 1989) that listeners perceive each vowel in relation to the speaker's total acoustic vowel space, which they calibrate from information in the rest of the ongoing speech. In light of this evidence, it seems reasonable to expect that learners do not acquire each vowel or vowel contrast in isolation, but rather in relation to the rest of their developing vowel system. If this is true, it makes sense to study the L2 learner's vowels as an integrated system.

Most studies in SLA phonology have involved hypotheses based on phonological theory, especially in the area of universal grammar (UG). Dealing with vowels as a system, however, means bringing into SLA research both phonetic theories regarding vowel systems in the world's languages (especially Ladefoged, 1989; Lindblom, 1986) and cognitive theories of the acquisition and storage of knowledge systems, in the form of schemata (e.g., Rumelhart & Norman, 1978) or procedures (Karmiloff-Smith, 1978, 1979, 1981a, 1981b, 1984, 1985, 1986a, 1986b, 1986c).

1.2. Statement of purpose

The main purpose of this study is to contribute to the field of SLA phonology by helping to fill in the three gaps in current research referred to above. This will be done through a longitudinal acoustic analysis, documenting the phonetic and phonemic evolution of the non-back portion of the English interlanguage (IL) vowel system of eleven Brazilian-Portuguese speakers.

The principal research questions of the study are based on two phonetic theories—Ladefoged's theory of the relative nature of vowels and Lindblom's theory of sufficient perceptual distance—and on two cognitive models of learning—Rumelhart and Norman's (1978) model of accretion, tuning, and restructuring, and Karmiloff-Smith's success model (1978, 1979, 1981a, 1981b, 1984, 1985, 1986a, 1986b, 1986c). Thus, a secondary purpose of the study is, through examination of interrelationships among the evolving IL vowels, to supply SLA evidence for or against these theories.

Finally, it is hoped that the knowledge, gained through this study, about the way in which L2 learners acquire the vowel system of the target language, can contribute to the future development of more adequate methodologies for the teaching of the pronunciation of the vowels of a second language.

1.3. Strengths /limitations of the study

The main strength of this study lies in its defining a new area for future studies. I know of no previous longitudinal acoustic analysis of L2 vowel acquisition, nor of any study which looks at IL vowels as an interrelated system. It is innovative in bringing phonetic theory into SLA, and it is up-to-date in drawing from cognitive theory besides.

The main limitations of the study are a result of compromise between the methodologies of the theoretical areas contributing to the study—SLA, phonetics and cognitive psychology.

In recent years, due to the influence of sociolinguists such as Labov and Hymes, there has been an emphasis, in SLA research, on the importance of eliciting speech data that is as natural as possible (Tarone, 1979). Although SLA researchers do not usually use the extreme ethnographic techniques advocated by Hymes (1972), the necessarily formal, but spontaneous interview is commonly used. In SLA phonology, spontaneous speech data has often been elicited together with list and dialogue reading, the results almost always showing that IL variability is influenced by sociolinguistic context (Beebe, 1980; L. Dickerson, 1974, 1975; Gatbonton-Segalowitz, 1975; Tarone, 1979).

Phoneticians, on the other hand, who deal more frequently with first-language (L1) data, and cognitive psychologists, when they deal with human data (as opposed to computers), tend to work under much more controlled conditions. Ideally, for a phonetic study, subjects are recorded in a sound booth, reading words, each contextualized in a single unvarying carrier sentence such as, "Say X again."

The compromise arrived at between the opposing methodologies reflects the objectives of this study. It is not the purpose of this study to contribute to the already considerable body of conflicting data concerning the type, the extent and direction of influence of sociolinguistic context. Rather, the influences to be examined in this study are cognitive and phonetic—the interrelationship of the mental representations of the various vowels of the IL system (what is meant here by mental representation will be discussed later). Therefore, in this study it is recognized that it is important not to mix data from different sociolinguistic contexts, but it is not considered necessary for the context chosen to be that of spontaneous speech.

On the contrary, because of the desire for accurate acoustic measurement of formant frequencies, it is considered more important for this study to control as much as possible the stress (intensity) and pitch (fundamental frequency) of the word containing the target vowel. Lack of control of these variables can not only make accurate acoustic measurement more difficult, but it can lead to actual differences in pronunciation. A vowel with less stress, and therefore shorter duration, is likely to be pronounced with a more economical speech gesture, resulting in a less distinctive acoustic structure. For example, the vowel /i/ in *neat* is likely to have a lower first formant (F1) and higher second formant (F2), and thus be more peripheral, in sentence 1 than in sentence 2 below because of the greater probable stress in the former:

1. She looked really neat.
2. That's a *really* neat idea.

Therefore, the speech analyzed in this study will be that produced by subjects reading words within the context of an invariant carrier sentence.

What *is* considered to be important from SLA methodology is the avoidance, to the extent possible, of inhibitory factors. Because L2 learners are often already somewhat self-conscious about speaking in the L2, it was expected that the laboratory environment would have a greater inhibitory effect on them than on L1 speakers, and thus a detrimental effect on their L2 production. Therefore, strict phonetic recording techniques were rejected in favor of the common SLA practice of recording in the subjects' homes, where they could feel more relaxed. Care was taken to ensure a quiet, though not sound-proof environment, even to the point of turning off noisy refrigerators and heaters.

Another limitation of this study is that diphthongal movement is not being considered. Although it is acknowledged that this is sometimes the principal feature by which a speaker distinguishes two vowels, it is not relevant to the main phonetic and cognitive theories being tested here, and thus can be considered a topic for future study.

A final limitation of this study is the fact that the study was not carried out on a statistically representative sample of the population. This limitation is more than outweighed, however, by the advantages of longitudinal research. Also, the subjects in this study were from a variety of sociolinguistic and academic backgrounds. Thus, the similarities in the acquisitional process found among the eleven subjects can reasonably be assumed to be typical of Brazilians acquiring American English. This is not to say that a future cross-sectional study with statistical tests would not be in order.

2. Review of literature

The review of the literature will deal with the areas of SLA phonology, phonetic theory, and cognitive models of learning.

2.1. SLA Phonology

The following sections support the claims made in 1.1. regarding three areas in which SLA phonology research has been lacking—in longitudinal research, in attention to phonetic distinctions through acoustic analysis, and in the study of IL vowels as a system.

2.1.1. Longitudinal versus cross-sectional studies

It was stated in 1.1. that most studies in SLA phonology are still cross-sectional, in spite of recommendations for longitudinal studies. One of the first and most often cited longitudinal studies is that of Lonna Dickerson (1974, 1975). It was important for Dickerson's study to be longitudinal because of her main objective, that of applying to SLA phonology the Labovian (1972) sociolinguistic model of "ordered decomposition," in which changes take place gradually (a) in more and more environments, (b) through various intermediate phonetic stages, and (c) among more and more members of the community. Her most significant conclusion is that it is only through variable performance that a learner can progress from one stage to the next and eventually reach the target.

Two years later, Wayne Dickerson (1976) replicated part of this study with another longitudinal study, examining the development of /l/ in five Japanese learners of English. From his results, which were similar to Lonna Dickerson's, he used formal notational devices to formulate his subjects' variable rule. In addition, he made stronger claims about the similarities between second language acquisition and language change in communities and applied to Labov's model the name *WAVE mechanism*.

Although the application of the Labovian model to SLA phonology was initially applauded by Tarone (1979), and adopted by Beebe (1980) and by Schmidt (1977), the influence did not carry over to the methodology—none of these studies were longitudinal.

The competing model of the 1970s—the *dynamic paradigm*—which borrowed from Bickerton's L1 research, also called for longitudinal studies. In the area of IL phonology, however, they were not forthcoming. Gatbonton (1978) claims that the acquisitional process is actually accounted for, rather than merely described (as by the Labovian model) by her adaptation of the dynamic paradigm, called the *gradual diffusion* model, which involves "first the acquisition of correct variants into all the relevant contexts and then the replacement of all incorrect variants there" (pp. 336-337). Her study involving the acquisition by French Canadians of the English /ð/ is cross-sectional, however, and one wonders how a cross-sectional study can claim to account for any kind of *process*. The only major *longitudinal* IL study within this model, by Huebner (1983), is not a study of phonology, but of syntax and morphology.

More recent studies of IL phonology have been inspired by Eckman's *markedness differential hypothesis* (MDH) (1977, 1981, 1985, 1986), which incorporates principles of universal grammar (UG) into the contrastive analysis hypothesis (CAH), with the objective of predicting directionality and relative degree of difficulty of linguistic items for second-language learners. The studies inspired by the MDH have, for the most part, tried to prove the dominant influence of either transfer or universal (developmental) factors on difficulty in IL phonology.

Because Eckman speaks about difficulty, rather than process, this hypothesis does not necessarily call for longitudinal studies. Indeed, most of these studies are cross-sectional (J. I. Anderson, 1983; Broselow, 1983, 1984; Fourakis and Iverson, 1985; Karimi, 1987; Major, 1987; Tarone, 1980).

It is interesting to note, however, that of the three major *longitudinal* studies on transfer versus developmental factors (Hecht and Mulford, 1982; Major, 1986b; Sato, 1984), only one (Sato, 1984) makes claims about the supremacy of one factor (transfer, in this case) over the other. The other two have shown, instead, an interaction between the two factors. Hecht and Mulford (1982), from the results of a study of a 6-year-old Icelandic learner of English, claim the relative roles of transfer and developmental processes depend on the phonological item in question, vowels being located on the transfer end of the continuum and affricates and fricatives on the developmental end. Major, from a study of American learners of Spanish, developed the *ontogeny* model, according to which (1986b, p. 455), "chronologically, errors due to transfer processes decrease, but errors due to developmental processes increase and then decrease." A reasonable conjecture might be that the longitudinal studies result in more objective claims because of information generated about *process* which cannot be obtained from the cross-sectional studies.

2.1.2. Phonetic versus phonemic distinctions

Section 1.1. stresses a need, in SLA phonology, for more focus on phonetic differences, in addition to phonemic contrasts, and for greater use of instrumental techniques to document these phonetic differences. SLA phonology research can be divided into four categories with respect to the level of analysis of IL speech sounds: (a) correct versus incorrect, (b) phonemic classification of errors or substitutions, (c) phonetic classification of substitutions, according to the perception of the researcher, (d) description of sounds along an acoustic phonetic continuum, representing *degree* of approximation to the TL norm.

The first category of analysis, the correct/incorrect labeling, is motivated by adherence to Gatbonton's gradual diffusion model (1978) and by the use of Guttman scales (Amastae, 1978; Gatbonton-Segalowitz, 1975), both requiring the categorical judgement of a phonological item as having been acquired or not. It is also motivated by the objective of assessing degree of difficulty of phonological items (Eckman, 1977, 1981), which requires counting errors, and by the use of naive native speaker perception judgements as to the identity of items (Ioup and Tansomboon, 1987; Neufeld, 1980). Finally, it is motivated by the desire to test rule usage (W. Dickerson, 1986), and by the simple objective of testing for the distinction between two phonemes in a learner's IL (Borden et al., 1983).

It is somewhat surprising that all but one of the above error-counting studies, including W. Dickerson (1986, p. 228), have been published since L. Dickerson's (1974) statements concerning the importance of *degree* of correctness and W. Dickerson's (1976) rejection of the notion of error, especially in light of the often expressed agreement of applied linguists with these attitudes.

In phonemic classification, the second category of analysis, the notion of error is still accepted, but not so simplistically. Errors are analyzed as falling into different categories such as the omission, addition, and substitution of particular phonemes or classes of phonemes. One of the principal motivations for this type of analysis is the desire to show the greater influence of either transfer or phonological universals (developmental processes). Errors are classified as having been caused by one or the other; then the numbers in each category are tabulated. Alternatively, relevant structures are classified as present or absent in cued citations, to test the conformity of IL productions to phonological universals. Here the absence of the relevant structure constitutes an error, although the term is not used.

The preferred area for analysis at the level of phonemic classification has been IL syllable structure (J. Anderson, 1978;

Broslow, 1983, 1984; Eckman, 1986, 1991; Hodne, 1985; Karimi, 1987; Sato, 1984; Tarone, 1980; Tropf, 1986), where fine phonetic distinctions are certainly unnecessary. The phonemic categorization of errors has also been used for studies attempting to adduce the reasons for particular phonemic substitutions, either linguistic (Baptista, 1989) or sociolinguistic (Schmidt, 1977).

The third analysis type, phonetic classification of errors, whether or not the word "error" is used by the researcher, is sometimes motivated by the same desire to explain the occurrence of each type of error, but with a finer level of classification (Hecht and Mulford, 1982; Major, 1986b, 1987a), and sometimes to document gradual phonetic approximation of the target (L. Dickerson, 1974, 1975; W. Dickerson, 1976). Approximation to the target can also be evaluated, without the limitations imposed by the notion of error, by native speaker judgements of *degree* of acceptability (Major, 1987b).

The last type of analysis, acoustic description of speech sounds along a continuum, is the only one of the four types of analysis for which the notion of error is totally irrelevant. Acoustic analysis has been used by Caramazza et al. (1973), Flege (1980, 1986, 1987), Flege and Hillenbrand (1987), Major (1989), and Nathan et al. (1987) to demonstrate that speech sounds produced by bilinguals are often intermediate to those found in the two contact languages, although they may be perceived categorically as simply non-native. Flege (1980, p. 117) points out that "language learners frequently produce a *range* of different phonetic variants (including the correct realization) for a single L2 phoneme, sometimes even producing sounds which are not typically found in either L1 or L2."

The acoustic description of speech sounds along a continuum has been especially important to Flege in the development of his theory of "phonetic approximation in second language acquisition"— the title of his 1980 paper. Through acoustic analysis, Flege has documented Saudi English L2 stop voicing intermediate to that of

L1 English speakers and L1 Portuguese speakers (1981), the mutual influence of English and French /t/ in both English-speaking learners of French and French-speaking learners of English (1987), and the mutual influence of English and French /u/ in French-speakers learning English (1987).

These instrumental data have led Flege (1987, p. 50) to conclude (a) that "L2 learners are able to detect auditorily the acoustic differences distinguishing similar L1 and L2 phones" (evidence for this conclusion can be found also in Williams, 1980), and (b) that "the phonetic representations which guide segmental articulation continue to be modifiable throughout life as a result of phonetic input." These capabilities allow L2 learners to *approximate*, but not to achieve accurate production of L2 phones which are similar to those of the L1. This limit on successful production is due to the cognitive process called *equivalence classification*, "a basic cognitive mechanism which permits humans to perceive constant categories in the face of the inherent sensory variability found in the many physical exemplars which may instantiate a category." (Flege, 1987, p. 49).

Whereas equivalence classification allows children learning the L1 to identify acoustically different phones as belonging to the same category, it leads to *phonological translation* by adult L2 learners, who "interpret sounds occurring in a foreign language in terms of sounds found in their native language." (Flege, 1981, p. 448) The result is that L2 phones are produced based on an acoustic model provided by phones occurring in both languages, and thus approximate but rarely reach the L2 target.

Although Flege (1980, 1986, 1987) and Flege and Hillenbrand (1987) provide considerable evidence for the occurrence of phonetic approximation, there is also evidence of cases where it does not occur, apparently inhibited by other unknown influences. Fourakis and Iverson (1985), for example, found voice onset time (VOT) measurements of English consonants produced by Arabic learners to be actually "more Arabic than Arabic itself" (p. 433). In other words, the learners had moved away from the target sound, rather than toward it. This result would probably not have been found by perception alone, and if it had been, there would have been no slot for it in a categorization of errors.

The first three types of analysis described above have their place, depending on the purpose of the study, but we are missing a great deal of information about the phonological acquisition process by not carrying out more instrumental analyses.

2.1.3. The study of IL vowels as a system

Studies of vowels are not particularly widespread in SLA phonology research, when compared to studies of consonants, syllable structure, and even suprasegmentals. Of the few existing studies of IL vowels, I know of none which treat them as an interrelated system.

Amastae (1978) studied the acquisition of five English vowels by speakers of Spanish, but he simply performed a Guttman analysis in an attempt to establish an implicational order. He made no attempt to explain his findings or to relate the acquisition of one vowel to that of another.

Hecht and Mulford (1982, p. 324) refer only briefly to the IL English vowels of their Icelandic subject, though they evidently have enough data to make some generalizations. There is some hint of a system of vowels in their assertion that they "were generally produced slightly higher than their English targets," but no further claims are made.

W. Dickerson (1986) studied the learning of *rules* concerning stress and vowel quality by English-As-a-Second-Language (ESL) students, but rule learning is on another cognitive level, above that of the acoustic images or motor plans involved in the other vowel studies.

Three other studies compared L2 learners' productions of pairs of similar vowels—English speakers' production of French /u/ and /y/ (Flege, 1986; Flege and Hillenbrand, 1987) and Portuguese speakers' production of English /ɛ/ and /æ/ (Major, 1987). The two French IL studies involved a comparison of the acoustic structure of the two vowels, as produced by the L2 learners. Major's study also involved comparison—first of the number of times each IL vowel was correctly identified by NSs, then of NS ratings on degree of foreign accent of each IL vowel.

Major speaks about "the interaction of whole systems," especially in language change, and cites the English Great Vowel Shift. He also considers the possible effect of the acquisition of one vowel on the acquisition of the other, but does not elaborate on this. He claims acoustic analysis would not have been particularly useful without knowing which American English dialect constituted the target. He neglected to consider the possibility, however, that acoustic analysis could have been useful in determining whether the subjects were actually making a distinction between the two vowels, whether or not it was perceived by the NS listeners. Furthermore, if he had tested production of the other neighboring vowels, an acoustic analysis might have been able to show interrelationships in the vowel system as a whole.

2.2. Phonetic theory

2.2.1. The relative nature of vowels

A question intriguing phoneticians for years has been how listeners are able to identify with such accuracy the vowels produced by a variety of speakers, in spite of the variability in acoustic structure of the vowels, not only from one speaker to another, but from one utterance to another by a single speaker.

Ladefoged's answer to this question (1967, p. 97) is that "it may well be that the exact phonetic quality of a vowel sound does not depend on the absolute values of its formant frequencies, but on the relationship between the formant frequencies for that vowel and the formant frequencies of other vowels pronounced by that speaker."

As an illustration, after quoting Fischer-Jorgensen (1958) on the preferability of plotting each person's vowels on a separate chart, Ladefoged plotted 31 separate sets of cardinal vowels spoken by 11 trained phoneticians. He found that, although the absolute formant frequencies were different for each speaker, and from one set to another of the same speaker, the overall patterns were quite similar—”roughly isosceles triangles with [i, a, u] at the apices.”

Ladefoged’s statement concerning the relative nature of vowels is based on the results of a now classic experiment by Ladefoged and Broadbent (1959) using synthetic speech. This experiment demonstrated that listeners’ perception of the vowel in the test word, a word between *bit* and *bet*, depended on the first formant frequency pattern of the introductory sentence. When the frequency pattern was high, the following word was heard as *bit*; when it was low, the word was heard as *bet*.

Thirty years later, controversy over these results prompted Ladefoged (1989) to replicate the experiment using natural speech. Although the percentage of listeners responding to the influence of the introductory sentence was lower for natural speech (75%, compared to 95-97% in the original experiment), it was high enough to confirm the conclusions drawn 30 years before.

The mostly likely explanation for the more modest results of the replication study is that in human speech, as suggested by Ladefoged (ibid.), there are many other factors which also contribute to the perception of vowel quality. There is little doubt, however, that one of the major contributing factors is the relationship of each vowel to the rest of the vowel space utilized by the speaker.

This relative nature of vowels should not be surprising, as many types of human perception are relative. For example, a bluish-green hue will appear greener when placed next to the color blue and bluer when placed next to green. It is much easier to *discriminate* between two similar shades of color presented together than to *identify* a particular shade in isolation. The same is true for vowels. Consonants, however, have been found to be discriminated no better than they are identified.

Psychoacoustic experiments such as Liberman (1970, cited in Lieberman and Blumstein, 1988) have tested human identification and discrimination of the stops [b], [d], and [g], produced synthetically, and varying along a continuum according to the transition of the second formant into the following vowel—from an extreme rising transition to a level transition to an extreme falling transition. These tests have demonstrated (a) that the perceptual boundaries for identification of the stops are quite abrupt, and (b) that listeners are not able to reliably discriminate between any two sounds along the continuum unless they are separated by a category boundary, as determined by their identification of the sounds. In other words, listeners do not discriminate between "shades" of the same consonant, as they do for vowels, colors, and other perceptual stimuli.

This categorical perception cannot be demonstrated in the same way for infants, because infants cannot be shown to identify speech sounds. They can be shown to discriminate between sounds, however, by the variation in their sucking behavior caused by a change in stimulus. Experiments such as Cutting and Eimas (1975, cited in Lieberman & Blumstein, 1988) have shown that infants also discriminate between two consonants, only when the consonants are separated by a category boundary—the same boundary used by adults. Thus, it does not appear that this categorical discrimination is the result of years of exposure to meaningful distinctions signaled by these consonantal differences.

2.2.2. Language acquisition and theories of vowel space

The concept of total vowel space is important, not only for assessing the phonetic quality of individual vowels, but also for accounting for the similarities in the vowel inventories of the world's languages, and actually making predictions as to the vowel inventory of a language, based on the number of vowels in the system.

Two theories which have been proposed for these explanatory and predictive purposes are Stevens' quantal theory and the theory of maximal dispersion or contrast (Martinet, 1955), tested by numerical simulation by Liljencrants and Lindblom (1972). This section will evaluate the main claims made in Stevens (1972), Liljencrants and Lindblom (1972), and Lindblom (1986), in light of research on first and second language acquisition.

Stevens (1972) claims that the vowels [i], [a], and [u] are the most common vowels in the world's languages because of a relative insensitivity to articulatory imprecision within these "preferred", "plateau-like" regions, where "particular acoustic attributes are realized over a range of articulatory configurations " (p. 58). Outside the range of these vowels, however, "there is a pronounced change in the spectral characteristics" (p. 57), causing the vowels "to be perceived in categorial [*sic*] fashion" (p. 65). Because of their facilitation in production and identification, "language seeks out these regions, as it were, and from them assembles an inventory of phonetic elements that are used to form the code for communication by language" (p. 64).

Martinet (1955, p. 99) claimed that the degree of variation among vowel phonemes was due greatly to the number or inventory of the same. Following similar reasoning, Liljencrants and Lindblom (1972) also attributed the universality of [i], [a], and [u] not so much to articulatory factors, as Stevens, but to maximum perceptual contrast. They also went a step farther, constructing a mathematical model by which to predict, according to maximum distance, the ideal vowel system for any number of distinct vowels. In spite of their efforts to turn an acoustic model into a perceptual model by using the Mel Scale, they found their model predicted too many high vowels and introduced mid central vowels too late.

However, because the model made reasonably accurate predictions for systems with 3 to 6 vowels, the authors concluded that it was close enough "to infer that CONTRAST plays an important role as a determinant of the structure of vowel systems," and "should be included among the variables in an explanatory phonological theory" (1972, p. 854). In their own evaluation of their model, Liljencrants and Lindblom hypothesized that their predictions were not more accurate because they treated vowel space as homogeneous—"a given distance r represents the same contribution to the 'magnetic field' wherever we observe it within the space" (p. 856), and suggested that Stevens' "plateaus" might be on the right track for giving more weight to some distances than others.

Lindblom (1986) improved on the above model, making vowel space less homogeneous. He achieved this, however, not by incorporating physiological aspects of vowel production, but by attempting to come closer to auditory reality. He constructed two alternative models, both correcting for the fact that F1 is more intense than F2. In addition, the first one used spectrum-based rather than formant-based distances, following the reasoning that there is "little evidence to suggest that the ear literally tracks formants and discards all other information" (p. 23); and the second one incorporated the effects of an auditory filter with asymmetrical masking characteristics. Both of these models reduced the number of high vowels predicted, and the second model predicted a mid-central vowel in smaller systems, but neither predicted the common 7-vowel system [i, e, ɛ, a, ɔ, o, u].

Lindblom continues to speculate about the possible contributions sensori-motor conditions could make to the model, and he suggests that sequential constraints affect the actual realization of the "possible" vowels. He claims he has shown "that predictions of system type can be made" (1986, p. 34). However, this is qualified when he suggests that both predictions and empirical verification of them would be affected by "language-dependent plasticity," and that "if the space is to a large extent malleable during acquisition, we would perhaps expect social and cultural rather than universal factors to shape vowel systems" (p. 37). Finally, Lindblom suggests that, rather than "maximal perceptual contrast," one possibly should talk about "sufficient perceptual contrast," in which spectral distance plays an important role.

Disner (1983), although she criticizes the unfalsifiability of the notion "sufficient", found some support for this theory in her cross-linguistic vowel study. For example, she found (p. 115) that the Dutch high front and back vowels /i/ and /u/ are farther apart than the corresponding English vowels, presumably because the intervening Dutch vowel /y/ would otherwise leave insufficient perceptual distance between the two adjacent pairs /i/-/y/ and /y/-/u/.

Disner recognized the problems in comparing cross-linguistic data from different speakers, who might have very different-sized vocal tracts, and provided by different researchers, who may have used different methods in data collection as well as in measurement. For this reason, she complemented her monolingual data from the various languages analyzed (much of it from other researchers) with data from bilinguals. The bilingual data lend further, but still far from conclusive, support for a link between dispersion, or acoustic distance, and vowel inventory.

Further illustration of the relation between vowel inventory and acoustic distance can be found in a comparison of distances between corresponding pairs of vowels in American English and Brazilian Portuguese. This comparison will be made below—with caution, because of the problems mentioned above—using data from Peterson and Barney's (1952) and Ohnishi's (1991) studies on General American and Californian English respectively, and data from Godínez's (1978), Pagel's (1985), and Lima's (1991) studies on Brazilian Portuguese.

Peterson and Barney's data (1952) are categorized as General American, but include subjects from several regions of the country. The subjects read lists of non-contextualized monosyllabic words all beginning with /h/ and ending with /d/. The data consist of "sustained" vowels, presumably spoken quite slowly, and measurements were taken of a "practically steady state" section between the influence of the /h/ and that of the /d/.

Ohnishi's data (1991) are limited to Californian English. The words in his study are monosyllabic and begin with /b/ and end with

/d/, except for the word *orange*, because speakers of this dialect do not consistently use the vowel /ɔ/ in any monosyllabic words. The words were read at both slow and natural speeds, and the vowels were measured at a steady state portion. There is little difference between the slow and natural speed frequencies in the female data. In the male data, however, where the difference in vowel duration is greater, the slow speed formant frequencies come somewhat closer to those of Peterson and Barney's study, in which the words were probably spoken even more slowly. Figures 2.1 and 2.2 display the mean first and second formant frequencies (F1 and F2) of the vowels in the two studies produced by males and females respectively. In these figures, as in all the vowel plots in the study, the numeric scales are in reverse order, with the Hertz values set at mel intervals, the F1 intervals set proportionally at greater distances than those of the F2, to correspond more closely to both the traditional articulatory charts and the perceived pitch differences.

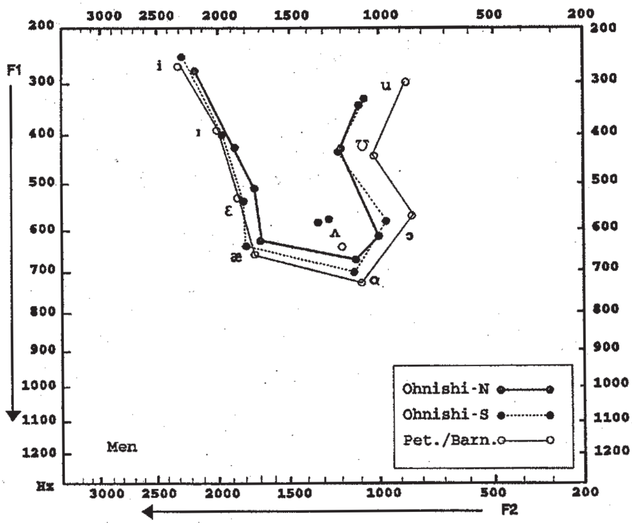

Figure 2.1. Plot of Male Means: General English (Peterson & Barney) and Californian English (Ohnishi - Natural & Slow Speeds).

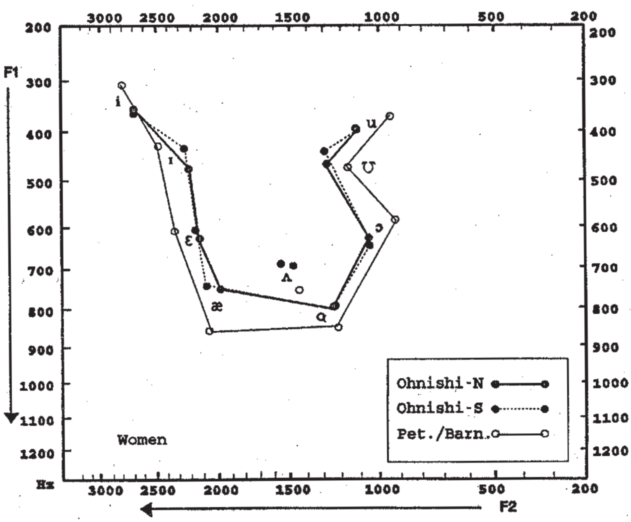

Figure 2.2. Plot of Female Means: General English (Peterson & Barney) and Californian English (Ohnishi - Natural & Slow Speeds).

The Godínez data on Brazilian Portuguese (1978) are from speakers from various regions of Brazil, all residing in the United States at the time recordings were made. The list of seven words, read in the context of a carrier sentence, included words with a variety of phonological structures, four of which were ambiguous as to the vowel elicited. Nothing is said about speed of delivery or about selection of the vowel portion measured. The formant frequencies were measured from spectrograms and confirmed through Linear Predictor Coefficient (LPC) analysis.

The Pagel data (1985) are from German-Portuguese bilinguals from the southern Brazilian town of Blumenau. The vowels in this study were preceded mostly by bilabial, alveolar, and velar stops, contextualized in 112 sentences. We are told nothing about speed of delivery or about the selection of the measured portion of the vowel, but only that formant frequency measurements were taken from spectrographs.

Finally, the Lima data (1991) are from speakers from Florianópolis, also in the south of Brazil. The vowels analyzed were all preceded by bilabial stops, and the words were contextualized. No information is given about speed of delivery. A Fourier analysis was made of a section between transitions.

Because the Ohnishi study includes diphthongs, and because the natural-speed vowels of his study were probably spoken at a speed closer to that of the contextualized vowels of the Portuguese studies, these data are more appropriate for a comparison of acoustic distance between pairs of English and Portuguese vowels. The Ohnishi natural-speed vowels are plotted in Figures 2.3, 2.4, and 2.5 with each of the sets of Portuguese vowels. Although Ohnishi measured the first and second elements of all the American English diphthongs, the plots include only the first element of the pseudo-diphthongs /eɪ/ and /oʊ/, for the purpose of comparison with the Portuguese vowels /e/ and /o/.

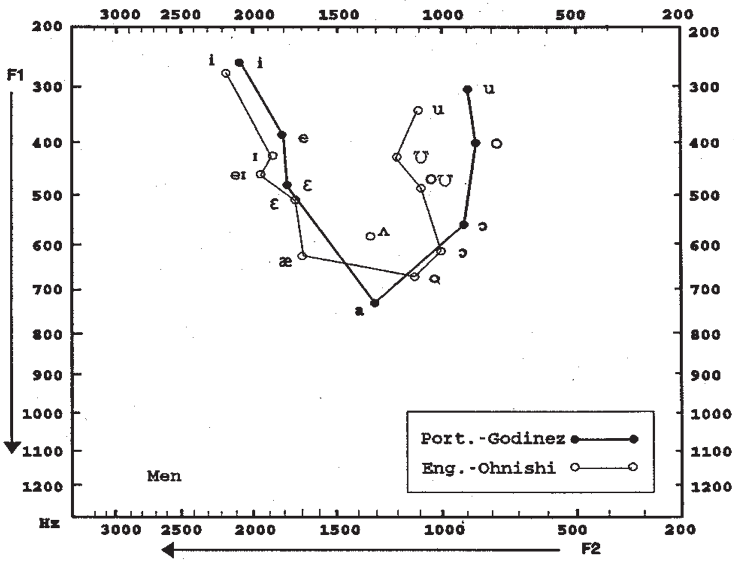

Figure 2.3. Plot of Vowel Means: Californian English (Ohnishi, men, natural speed) & Brazilian Portuguese (Godínez).

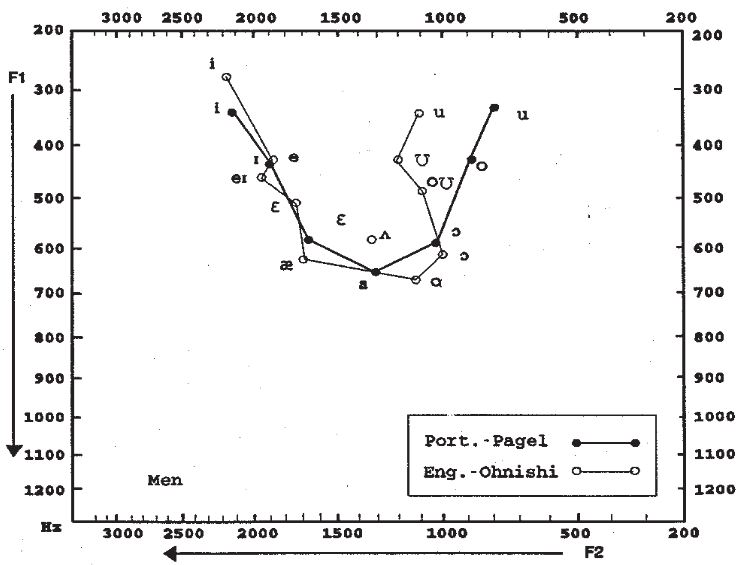

Figure 2.4. Plot of Vowel Means: Californian English (Ohnishi, men, natural speed) & Brazilian Portuguese (Pagel, men).

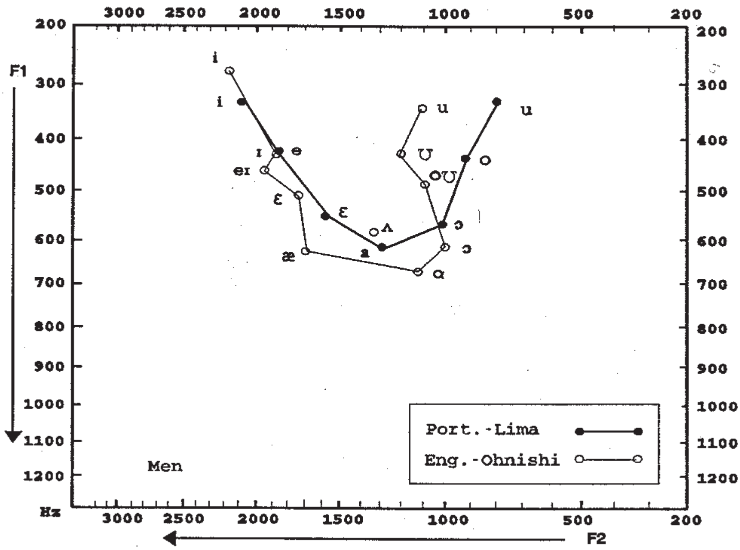

Figure 2.5. Plot of Vowel Means: Californian English (Ohnishi, men, natural speed) & Brazilian Portuguese (Lima).

Justification for including these pseudo-diphthongs in the monophthongal vowel system is found in (a) a correspondence with the Portuguese monophthongs /e/ and /o/ (although Portuguese also has the diphthongs /ei/ and /ou/), (b) the distinction made by Lehiste and Peterson (1961) between these "single-target complex nuclei" and the true "double-target" diphthongs /aɪ/, /aʊ/, and /ɔɪ/, (c) Disner's finding (1983, p. 90) that "these vowels were less diphthongal than one might have imagined," and (d) the fact that there is no English monophthongal /e/ or /o/ which contrasts with /eɪ/ and /oʊ/.

In spite of considerable difference among the three sets of Portuguese data, several similarities can be noted which lend support for a theory of sufficient perceptual distance.

In all three figures there is a greater distance between English /i/ and /eɪ/ than between Portuguese /i/ and /e/ and between English /u/

and /oʊ/ than between Portuguese /u/ and /o/, presumably because of the intervening English vowels /ɪ/ and /ʊ/. In Figures 2.4 and 2.5 there is a greater distance both between English /ɛ/ and /ɔ/ and between English /æ/ and /ɔ/ than between Portuguese /ɛ/ and /ɔ/, which can be attributed to the intervening English central vowel /ʌ/. Although the Portuguese /ɛ/ and /ɔ/ in the Godínez data (Figure 2.3) are more distant than the English pair, this may be simply because they are so much higher, where the vowel space as a whole is wider. Finally, all three figures display the English back vowels as farther forward than the Portuguese back vowels with the exception of English /ɔ/. This vowel is positioned, on the F2 axis, about the same as the corresponding Portuguese vowel in Figures 2.4 and 2.5 and, although forward of the corresponding Portuguese vowel in Figure 2.3, it is much less forward than the other English back vowels. Again, the most obvious reason for this is to leave sufficient perceptual space between English /ɔ/ and /ʌ/.

Assuming there is a relationship between language acquisition and language change, as claimed by W. Dickerson (1976), research on first and second language acquisition should be particularly relevant to an evaluation of theories of vowel space.

If one assumes that babbling infants produce all possible speech sounds, as claimed by Jakobson (1940, cited in Lieberman, 1980, p. 141), Stevens' quantal theory would lead to the expectation that /i/, /a/, and /u/ would be the first phonemic distinctions that children would make among the vowel sounds. In fact, Lieberman (1980, p. 141) finds his data "to be more consistent with the alternative hypothesis that the child, during the babbling stage, is attempting to imitate the sounds of his or her linguistic environment." Furthermore, he notes a conspicuous "absence of [i], [u], and [a] from the early vocalizations of children" (p. 119). In Lieberman's figures for subject LS (Figures 2.6-2.9), [i] appears only at 41 weeks, after [ɪ], [ɛ], [æ], [ʊ], and[ʌ]; [a] appears at 62 weeks, and [u] does not appear in the data. The other four children show a similar progression.

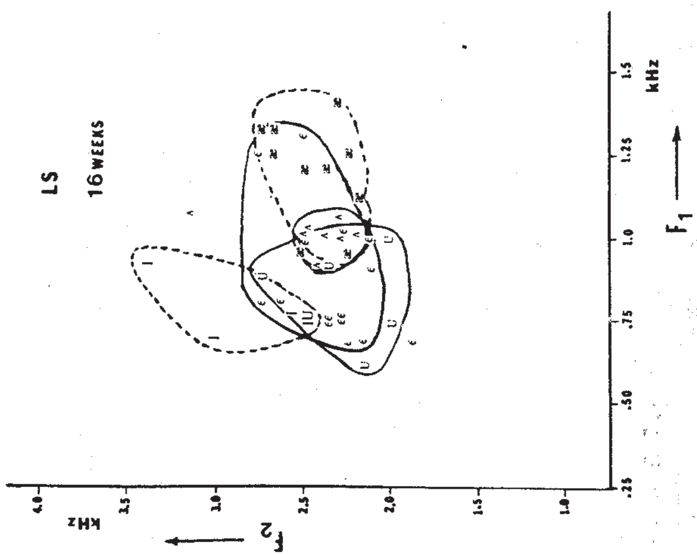

Figure 2.6. LS's vowels at 16 weeks. (Lieberman, 1980)

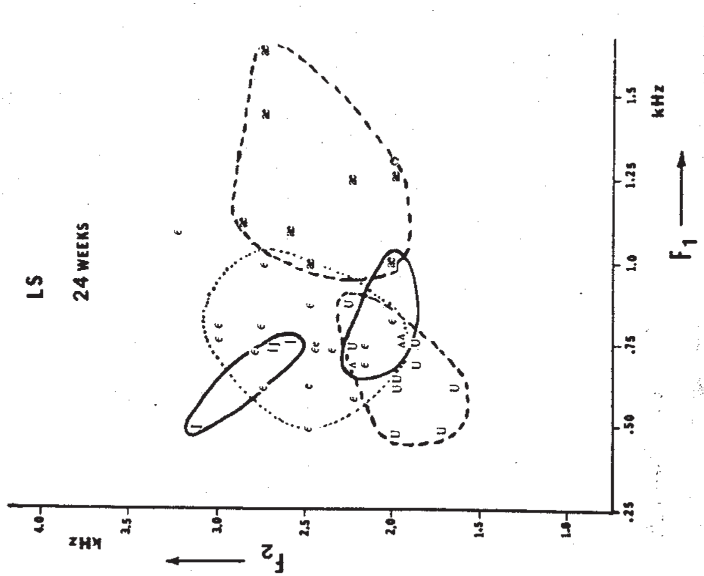

Figure 2.7. LS's vowels at 24 weeks. (Lieberman, 1980)

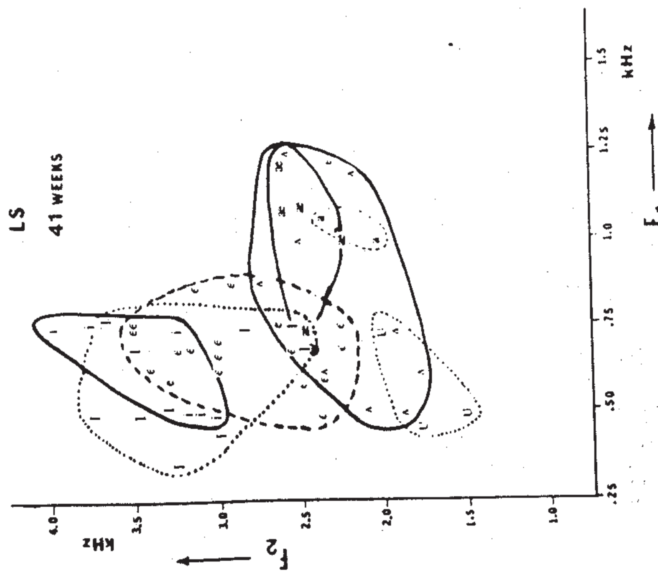

Figure 2.8. LS's vowels at 41 weeks. (Lieberman, 1980)

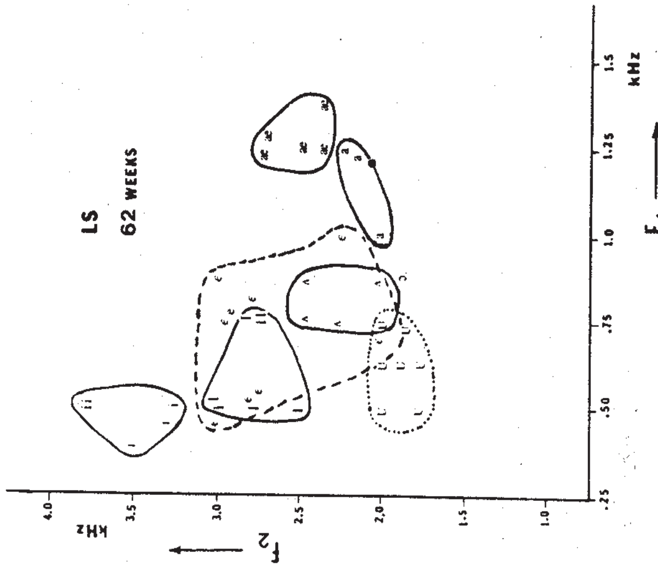

Figure 2.9. LS's vowels at 62 weeks. (Lieberman, 1980)

These children evidently acquired first the vowel articulations closest to neutral position, rather than those whose articulation could be least precise. As to perception, it is possible they were perceiving [i], [a], and [u] before they could produce them, but there is no evidence that they perceived them earlier than the less "quantal" vowels, which they were already *producing* at 16 weeks. Even if one were to claim that children do not really distinguish the vowel sounds until they are actually producing words, "there does not appear to be any 'abrupt' break or discontinuity in their behavior as they go from the babbling to the phonologic stage of language acquisition" (Lieberman, 1980, p. 140). What one does see in this study is a gradual move outward toward a more triangular vowel system, and a gradual decrease in the overlap of the different vowels.[1]

Making an analogy between the gradual development of a child's vowel system and the vowel system of a language, if they both follow the principle of *sufficient* perceptual contrast, one would expect a system containing fewer vowels not to need to occupy the total possible vowel space. This expectation, consistent with the theory of economy of speech gestures, would explain why the extreme vowels were the last to be acquired by the children in Lieberman's study. Lindblom (1983, p. 219) claims that "in normal speech the productive system is rarely driven to its limits"—there is a "tendency toward underexploitation." Lindblom (1986, p. 33) notes that in Crothers' (1979) data, the vowels in the 3-vowel systems which were normalized to [i], [a], and [u] were actually [i, ɪ, e] for [i], [u, o, ʊ, ɯ] for [u], and [a, ɛ , ä, æ, æ̊] for [a]. These variations in real languages do not support the quantal theory any more than Lieberman's child L1 acquisition data does. In both L1 acquisition and in Crothers' language data, there appears to be a trade-off between ease of articulation and sufficient perceptual contrast.

Second language acquisition data (personal experience) does not support Stevens' quantal theory either. If "there is a pronounced change in the spectral characteristics" (1972, p. 57), outside the range of the "quantal" vowels, this categorical quality of /i/ and /u/ should make the English vowels /ɪ/ and /ʊ/ easily distinguishable from them, even for non-native speakers of English. It is my experience as a teacher of English pronunciation that the two latter sounds are very difficult for Brazilian Portuguese speakers to produce accurately, precisely because they have difficulty hearing the difference between the pairs /i, ɪ/ and /u, ʊ/. They appear to cause at least as much difficulty as the /ɛ,æ̂/ pair does, even though the former have the perceptual cues of length and diphthongization, in addition to the supposed boundary of the "plateau-like regions".

Sufficient perceptual contrast, however, can account for the above difficulty. For Portuguese speakers to acquire the English /ɪ/, /ʊ/, or /æ/, it is quite likely that they need to do much more than simply make a contrast between the pairs /i, ɪ/, /u, ʊ/ and /ɛ, æ/. Assuming their IL system is at this point a 7-vowel system modeled after their L1 system, they will need to make adjustments in the "old" vowels of this system in order to make room for the new. Learners beginning with IL vowels modeled on the Portuguese vowels in Figures 2.3, 2.4, and 2.5, for example, would need to lower /e/ and /o/ toward the height of /eɪ/ and /oʊ/ and retract /a/ in the direction of /ɑ/. Learners beginning with IL vowels modeled on the Portuguese vowels in Figures 2.4 and 2.5 would need to raise /i/. Without these adjustments, there would be insufficient perceptual contrast between the adjacent vowels of the new system.

2.3. Cognitive theory

2.3.1. Representation of linguistic knowledge

In applied linguistics today, there is wide acceptance of the cognitive theory that knowledge is stored in long-term memory (LTM) in structures called schemata— interconnected networks of nodes representing complex concepts. For some theorists, it is only declarative knowledge which is represented in schemata. In J.R.

Anderson's model of language production (1983,1985), for example, these schemata contain concepts and the content words which refer to these concepts, with their explicit semantic features. Implicit procedural knowledge about syntax, inflections, and function words is located in production sets, which are internal instructions on how to realize particular structures. The schemata containing concepts and content words can be retrieved from LTM through meaning and inserted in variable slots of productions for both comprehension and production of language.

For Rumelhart and Ortony (1977), on the other hand, all levels of knowledge are stored in schemata—perception, concepts, plans, and the knowledge used to perform actions. An important feature of schemata, in this model, is the characteristic of *flexible variable constraints*. This is the capacity to tolerate "deviations from the typical" (p. 111) without a failure in understanding, and is what distinguishes this theory from semantic feature theories, which require more precise definitions. This flexibility allows a schema to account for a situation encountered "whenever that situation can be interpreted as an instance of the concept the schema represents" (p. 111). Then "what gets stored in memory is, in effect, a copy or partial copy of these instantiated schemata, that is, what gets stored is not the input itself but the interpretation that was given to that input as a result of the comprehension process." (p. 116)

Rumelhart and Ortony's description of knowledge representation is not specific to language, and Anderson's model makes no specific reference to the phonological level in describing the mental representation of language. Presumably the schemata for content words would contain the underlying phonological representation of each word. However, this is not sufficient. If the phonological representation of the concept "cat", for example, is /kæt/, the subject must have a way of knowing what the phonemes /k/, /æ/, and /t/ sound like, how to produce them, and how to combine them.

Assuming that phonemes are actually psychologically real entities (a matter of considerable controversy which will not be explored here, but see Studdert-Kennedy, 1987), I propose that they are also represented in schemata, in a manner similar to the lexicon, grouped and connected according to associations made by features, distribution, etc. For example, a speaker of any language would have separate schemata for vowels and consonants. Each vowel would be stored with its formant structure *relative to the other vowels of the system*, and other relevant prototypical characteristics. This knowledge, just as semantic knowledge, would be explicit, in the sense that a fluent speaker knows at any moment just what an /ɪ/ sounds like.

Just what the other relevant characteristics are which are stored in each vowel schema has been ignored by cognitive psychologists, but has caused controversy among phoneticians. Two schools of thought have been aptly summarized and evaluated by Strange (1989). In the first, the listener (presumably also the speaker) is assumed to store a context-free vowel target, whether in absolute formant frequencies (e.g., Daniloff & Hammarberg, 1973) or in algorithms for normalizing acoustic data (e.g., Syrdal & Gopal, 1986). In the second, adhered to by Strange, the speaker/listener stores, in addition to the canonical target state, the temporal parameters of the vowel trajectory (DiBenedetto, 1989), that is, the changing spectral structure. The latter dynamic information may be more important for the identification of American and Canadian English vowels, where "there is systematic movement within the nucleus even of supposedly monophthongal vowels" (Strange, 1989, p. 2084).

Neary (1989), who takes a more eclectic view of vowel representations, concludes that there are four types of information important for the perception (and presumably for the production) of English vowels,

> (1) static properties, such as steady-state formant frequencies and the fundamental; (2) dynamic properties, including inherent spectral change

> and consonantal context effects; (3) intrinsic (intrasegmental) relational properties, especially relations among the fundamental and formant frequencies within vowels; (4) extrinsic (transsegmental) relational properties, such as relative vowel duration and the relative formant frequencies of a vowel compared to those of other vowels of the same speaker. (p. 2106)

Considering the conflicting evidence from experiments designed to prove one or the other type of information to be more important, Neary's conclusions appear to be the most realistic.

One of the few researchers to concern themselves with the organization of the phonological level of linguistic knowledge, Paradis (1980, 1981) offers a modified version of Weinreich's (1953) distinction between coordinate, compound, and subordinate bilingualism, in which each type of language storage is classified according to acquisitional context. In Paradis's model of neurolinguistic organization, bilinguals may have, on a phonological level, (a) one extended system with all the phonemes from both languages (similar L2 phonemes would be processed as allophones of L1 phonemes, with different distributions); (b) a separate network of neural connections for the phonemes of each language; (c) a tripartite system, with one system for those phonemes common to both languages, plus two different systems for those phonemes which are peculiar to each of the languages.

2.3.2. The acquisition of linguistic knowledge

The question to be asked at this point is how the schemata develop. Rumelhart and Norman (1978) do not deal specifically with language, but offer a model for learning in general, which can easily be applied to the learning of the sound system of a language. In their model, which assumes schemata of the type described by Rumelhart and Ortony (see 2.3.1), there are three types of learning—*accretion*, *tuning* and *restructuring*. Most knowledge is acquired through accretion—the simple addition of data structures to existing schemata. However, when the existing schemata are found to be inadequate for accounting for new input, restructuring or tuning must occur. In restructuring, new schemata are created based on the patterns of the old, either by replacing the variables (nodes referring to general classes of concepts) or constants (nodes referring to specific concepts), or by recombining them. Tuning is similar to restructuring, but less radical, the old schemata being continuously improved upon, rather than re-created.

Since they developed their model of accretion, restructuring, and tuning, Rumelhart and Norman have both embarked upon a different line of cognitive science—*Parallel Distributed Processing* (PDP). This new type of model of information processing involves, according to Norman (1986),

> a major rethinking of the levels at which we must think of cognitive processes, . . . a new form of computational model involving large numbers of highly interconnected parallel computational units, . . . new conceptualizations of cognition that change the emphasis from symbolic processing to states that reflect the quality of the match between the data to be described and the possible configurations of the underlying processing structures, . . . an emphasis on learning. (p. 533)

In spite of the revolution caused in cognitive science by the advent of the PDP models, neither the Rumelhart and Ortony (1977) description of schemata nor the learning model developed by Rumelhart and Norman (1977) has become obsolete, as the greater part of both can be described in the new terms. The schema, for example, still exists in PDP. Norman (1986) describes the new schema as follows:

> Schemas are not fixed structures. Schemas are flexible configurations, mirroring the regularities of experience, providing automatic completion of missing components, automatically generalizing from the past, but also continually in modification, continually adapting to reflect the current state of affairs. Schemas are not fixed, immutable data structures. Schemas are flexible interpretive states that reflect the mixture of past experience and present circumstances. . . . Thus, the system behaves as if there were prototypical schemas, but where the prototype is

> constructed anew for each occasion by combining past experiences with the biases and activation levels resulting from the current experience and the context in which it occurs. (pp. 536-537)

It appears, then, that PDP has not invalidated most of the previous theory on information processing, but rather has added metaphors to describe in more detail the way in which processing takes place. The flexible variable constraints described by Rumelhart and Ortony are reflected in the "automatic completion of missing components" in the above description by Norman. The tuning described by Rumelhart and Norman is reflected in the continual adaptation of the schema "to reflect the current state of affairs." These processes are now described at new, more primitive levels, such as the adjustment of synaptic weights.

One important change alluded to by Norman (ibid.) is that the distinction, in the conventional system, between the information being processed and the processing structures has been abolished by PDP, the changes which take place in learning being in the system itself. This helps to explain why, as pointed out by Fantuzzi (1989, p. 48), Rumelhart and Norman's restructuring "presents a problem for PDP models. Once a schema has been gradually built up, it is not possible to suddenly change its parameters and to create a new one 'by analogy', but only to incrementally fine-tune it." Rumelhart (1989), however, did not disclaim the occurrence of this process, but merely exemplified the difficulty of accounting for it in PDP models, with the failure of his PDP system to learn that a penguin is a bird, after learning that birds fly and fish swim.

Because it is not necessary to think in terms of such primitive levels to relate information-processing theory to the phonetic theories dealt with here, and because Rumelhart and Norman's previous learning model has not been invalidated by PDP, it is their 1977 model which will be applied here. Applying this model to the vowel scenario described at the end of 2.2.2, the English IL vowel schema, based on that of the Portuguese L1, is found to be inadequate for the accretion of the new input—the new L2 vowels /ɪ/, /ʊ/, and /æ/.

Thus, it must be either tuned (altered) or restructured (re-created) *before*, or at least *when* the new vowels are acquired. In the tuned or restructured vowel schema, the old vowels would be adjusted in the appropriate direction to leave sufficient perceptual space for the new ones. In other words, the constraints on the old vowel variables would be made more accurate—closer to those of a native English speaker's system, or the variables would simply be replaced.

Karmiloff-Smith (1978, 1979, 1981a, 1981b, 1984, 1985, 1986a, 1986b, 1986c) describes a process similar to restructuring in her three phases of cognitive and linguistic development. Although she refers to the development of internal representations, these representations do not appear to be in the form of schemata, but rather in the form of procedures. Her emphasis, as she points out, is process-oriented (1981a, p. 152), her model being supported by research on children's verbal and problem-solving behavior. The three phases she describes are the *procedural*, *metaprocedural*, and *conceptual* phases.

The learner starts at the procedural phase, where behavior is data-driven and success-oriented. Any learning taking place during this phase is in the form of isolated but well-functioning procedures, with no attempt at representational change or at a link between procedures.

Motivated by success in phase 1, the learner then progresses to the metaprocedural phase, where the behavior is constrained by top-down control, based on "an internal representation which is imposed on the environment" (1986c, p. 174). Learning taking place in this phase is in the form of an almost compulsive *reorganization*, unification, and simplification of the internal representation. The reorganization is the part which can be compared to Rumelhart and Norman's restructuring, but this reorganization is of procedures, and is not brought about by the inability of current representations to account for the data. On the contrary, in this phase the data are ignored, frequently resulting in a decrease in behavioral success, accounting for the U-shaped curve often found in learning.

Finally the learner enters the conceptual phase, where behavior is again successful, due to the interaction between data-driven and top-down processes, the latter based on the representational reorganization that took place during phase 2. What motivates the return to data-driven processes in this phase, however, remains a mystery. Although Karmiloff-Smith claims her model is success-oriented, it could certainly not be behavioral success, because she affirms that success frequently decreases in the previous phase. It can only be either behavioral failure or success in the development of internal representations, which only become available to consciousness during the third phase.

The most important aspect of this model is that the *reorganization* occurring in phase 2, which appears to be similar to restructuring, is motivated by, and thus occurs *after* behavioral success. Whereas in the first phase the learner is driven by the need for control over the environment, in the second phase the drive is for control over the internal representations, with concern for success being temporarily forgotten.

The ultimate goal of the learner, in Karmiloff-Smith's model, is to progress from an implicit form of knowledge to the most explicit form. In the implicit form (I) of the first phase, procedural components "cannot be accessed and operated on separately." In primary explicitation (E_i), which takes over in phase 2, knowledge is rewritten in the same representational code as the I form, but "the knowledge components of a process can now be operated on internally," and contain "explicitly defined links." Representations are not, however, "directly accessible to consciousness." In secondary explicitation (E_{ii}), knowledge is still represented in the same code, but is now accessible to consciousness. Finally, in tertiary explicitation (E_{iii}), knowledge is still available to conscious access, and is represented in another more abstract code. Knowledge is rewritten in these last two forms only in phase 3 (Karmiloff-Smith, 1986a, pp. 102-103).

There is a contradiction in Karmiloff-Smith's model which is important to point out, especially if it is to be applied to the present vowel study. On the one hand, she claims that phonological procedures are "the last to be rendered explicit" (1978, p. 9) due to their "highly compiled and thus 'automatic'" nature (p. 14). On the other hand, automaticity appears to be the catalyst for advancing to the next phase when she states, "each time a procedure in a representational system is functioning adequately and *automatically* [my italics], the child steps up to a metaprocedural level and considers the procedure as a unit in its own right" (1979, p. 91), and later, "each time a well-functioning procedure becomes *automatized* [my italics], then children work on the *systems* themselves" (1981a, p. 154).

Although the research supporting this model has all been carried out on children, Karmiloff-Smith claims that adults go through the same three phases of learning (1984), and she briefly extends application of the model to adult second-language acquisition as well. (1986a). Applying this model to the IL vowel scenario of 2.2.2, one would expect the new vowels to be acquired, or at least successfully produced, *before* the representation of the system is reorganized, i.e., before the old vowels are adjusted, contrary to the prediction based on Rumelhart and Norman's model of learning.

This may be a simplification, however. Karmiloff-Smith calls her model a success-oriented model because it is success which motivates the passage from the first to the second phase. However, she points out that "failure does have a role to play in creating procedures in the first place and in generating representational adjunctions and behavioural change, since phase 1 procedures are built from both negative and positive feedback" (1986a, p. 106). She further suggests that the sequence of initial failure followed by partial but fragile success and finally robust success described in traditional learning accounts may all take place during phase 1, and thus refer only to behavioral, and not representational change. Thus, in reference to language skills, "by the end of the first phase for a particular linguistic form children have achieved a correct mapping between their output and the adult output. . . , i.e., children have achieved communicative adequacy in their use of the particular linguistic form" (p. 106).

She refrains from claiming that all linguistic development goes through all three stages, and suggests (1986a, p. 118) that "knowledge required as a *means* for another goal is not accessed above $E\text{-}_i$ level, whereas knowledge required for *goals* always involves levels $E\text{-}_{ii}$ or $E\text{-}_{iii}$." It is not clear if this implies that knowledge required as a means will necessarily reach the $E\text{-}_i$ level, or whether it may sometimes stop at the I level of phase 1. The question to ask regarding the vowel scenario of 2.2.2 is whether competency in producing accurate L2 vowels is a means or a goal. Although for some learners it may be a goal in itself, it is likely that for most it is simply a means for the goal of successfully communicating in the second language. Thus, the prediction made regarding the above vowel scenario may be that the new vowel distinctions will be made not only before reorganization of the vowel representation, but possibly even without this reorganization.

A fulfillment of this prediction would preclude fulfillment not only of the prediction made according to Rumelhart and Norman's learning model, but also of the one implied by the theory of sufficient perceptual distance. Sufficient *perceptual* distance means that for vowel distinctions to be perceived, there must be sufficient distance between them in the acoustic vowel space. It can be observed in Figures 2.3, 2.4, and 2.5 above that if the old IL vowels are modeled on the similar L1 vowels, and if the new L2 vowels /ɪ/, /ʊ/, and /æ/ are added between the appropriate pairs of old vowels without a reorganization of the latter, the resulting distance between vowels will be much smaller than in either the L1 or L2 systems. It will most likely be too small for the hearer to adequately distinguish among them. If the goal of being understood is to be successfully met in the first phase without a reorganization of the vowel system representation, the vowels will have to be distinguished by another feature such as formant trajectory or relative intensity of formants. Another possibility, of course, is that learners would choose to maintain sufficient acoustic distance between the new and old vowels simply by adding the new vowels where there already is sufficient space available, in disregard for the appropriate relative position. It is unlikely, based on Ladefoged's (1989) findings, that successful communication would result from this strategy, but the possibility cannot be discounted.

The predictions made in this chapter, based on Ladefoged and Lindblom's phonetic theories and on Rumelhart and Norman's and Karmiloff-Smith's cognitive learning models, will be examined in the following chapters.

Note

1 The transcription of vowels was based on subjective judgement of phonetic quality, even in the phonologic phase, other features of vowels such as length probably accounting for the overlap.

3. Method

3.1. Research questions and scope of the study

The main question to emerge from Ladefoged's theory of the relative nature of vowels and from Lindblom's theory of sufficient perceptual contrast, described in 2.2.1 and 2.2.2 respectively, was whether or not the acquisition of the new English target-language (TL) vowels would involve adjustment of the old vowels of the IL system, i.e., those with Portuguese counterparts. This implies that the IL vowel schema was first modeled on the native-language (NL) schema, an assumption which needed to be examined, rather than accepted *a priori*. Although none of the subjects in this study were absolute beginners at the time of the first observation, an examination of their early stages of acquisition was expected to provide a basis for evaluating the validity of this assumption. Therefore, the following research question was the first to be examined: (1) To what extent and in what ways would the IL vowel systems of the subjects in this study, at the time of the first observation, show signs of having been modeled on their respective NL vowel schemata and/or on the TL vowel input?

This question was examined through a comparison of the plots of the mean formant frequencies of each vowel of the first-month IL vowel systems with the plots of the means of the NL systems and with the plots of the Ohnishi data (1991) on natural-speed Californian English vowels. The comparison will be reported first for the average male and female vowel systems, then for each individual subject's vowel systems. The extent of modeling on the NL schema or on the TL input was evaluated on the basis of similarities between the IL vowel plot and those of the NL and the TL (Ohnishi data), in terms of both the position within the acoustic vowel space of individual vowels, and the size and shape of the whole vowel systems. The findings for this question are reported in Chapter Four.

The second research question examined was the main question posed above: (2) Would the data on the evolving IL vowel systems of the subjects in this study provide evidence for a link between the acquisition of the new TL vowels and the adjustment of the old vowels of the IL systems, i.e., those with Portuguese counterparts? Evidence found for this link would be considered to support Ladefoged's theory of the relative nature of vowels and Lindblom's theory of sufficient perceptual distance, and the importance of these concepts for the acquisition of second-language vowels. This question was investigated through the examination of the monthly plots of each individual subject's IL vowel ellipses, drawn with radii of two standard deviations from the mean formant frequencies. Evidence of a link between vowel acquisition and vowel adjustment was sought in the form of a parallel between the time of total or partial separation of the ellipses of two vowels to be contrasted, and the time of an adjustment in the ellipse of one or more adjacent vowels which opened up the acoustic space for the emerging contrast. Because there was less progress than expected in the developing IL vowel systems, negative evidence was also examined—links between non-acquisition and a lack of appropriate adjustments of adjacent vowels.

Sufficient evidence was found for a link between vowel acquisition and vowel adjustment to justify examination of the third research question: (3) Would adjustment of the old IL vowels of these subjects occur *before* or at the time of acquisition of the new TL vowels, according to the prediction based on Rumelhart and Norman's model, or would it occur *after*, according to the prediction based on Karmiloff-Smith's model? (see section 2.3.2.). It should be remembered that there was also an alternative prediction based on Karmiloff-Smith's model—that the new vowel distinctions might be made without cognitive reorganization (i.e., without adjustment of the old IL vowels), indicating that the learning occurring during the study was taking place in phase 1 at the implicit (I) level of cognition. Because, as we will see in Chapter Five, the emergence of new vowel distinctions was consistently associated with adjustments in old IL vowels, it had to be assumed that the learning documented in this study was not phase-1 learning. This third alternative was thus eliminated, and the first two were investigated through the same type of analysis as question 2, with greater importance given to the order of occurrence of the above-mentioned processes.

Rumelhart and Norman's cognitive model described in 2.3.2 led also to the formulation of question (4): Would adjustments in the subjects' IL vowels be made suddenly and involve major changes in the outline of the vowel system, implying a process like *restructuring*; or would they be made gradually and locally, implying something more like *tuning*? This question was also examined through a visual analysis of the month-by-month changes in the vowel ellipses. The findings to this question, also reported in Chapter Five, were necessarily more subjective than those of the previous questions. The subjectivity was partly due to the difficulty of identifying a sudden occurrence in monthly, rather than continuous, observation, and partly due to the arbitrary nature of the decision as to what constitutes major, as opposed to local, change.

The study lent itself naturally to two other questions which have come up in previous research: (5) Where vowel adjustment occurred gradually, would this mean a gradual linear approximation toward a target, or would there be detours off in another direction? Fourakis and Iverson (1985), for example, as mentioned in section 2.1.2, found voice-onset time (VOT) measurements of the English consonants produced by Arabic learners to be actually "more Arabic than Arabic itself". Evidence for non-linearity was sought not only in the form of English IL vowels which were more Portuguese than Portuguese itself, but also in the form of any IL vowel ellipse at an intermediate observation occurring outside a reasonably straight line drawn between the ellipses for that vowel at the first and last observations.

The final research question examined was a question posed by Beebe (1987, p.172): (6) Would the "phonetic repertoire" (variance) of each phoneme follow the expected tendency of "expanding" (increasing) and then "shrinking" (decreasing) in approximation of the target? Examination of this question involved comparison of the size of the vowel ellipses from month to month, especially at the time of separation of the ellipses of two contrasting vowels. The findings of the last two research questions are also reported in Chapter Five.

It should be made clear that, although I refer above to the storage of linguistic knowledge, this is a study of IL *production*. Although I prefer not to enter into the controversy of competence versus performance, I do assume that the *realization* of a particular vowel by a particular speaker corresponds to some sort of mental *representation*. I make no claims about whether this is a representation of how the speaker believes the vowel should be, or whether it is simply the best motor plan the speaker has come up with so far to approximate his/her mental image of the vowel. The data consist of formant frequencies, which can be thought of as corresponding to a stored plan for an articulatory gesture just as well as to an auditory image of a sound.

This study focused on the acquisition of the three new non-back vowels /ɪ/, /æ/, and /ʌ/, and the adjustment of the old adjacent vowels /i/, /eɪ/,[1] /ɛ/, and /ɑ/. Although the English vowel /ɔ/ is adjacent to /ʌ/ and has a Portuguese counterpart, it was not included because it is generally accepted that no distinction is made between this vowel and /ɑ/ in Southern Californian English, which, because the study was conducted in Los Angeles, should constitute the principal input to which the learners were exposed. Ohnishi (1991) has shown that a Californian /ɔ/ does exist in words such as *orange*. However, because he had to use this word to elicit this sound, when all the other words in his study were monosyllabic words ending in /d/, it can be assumed that this vowel does not contrast with any of the others, and that its inclusion in the present study would not have been productive.

3.2. Subjects

The subjects for this study were 11 Brazilians (5 males, 6 females), aged 18 to 41. All had first arrived in the United States within 6 months of the first recording, and had been living in greater Los Angeles since their arrival. They had had varying amounts of English instruction in Brazil, but none, at the time of the first recording, were able to utter complete sentences in English without considerable hesitation, frequent pauses and backtracking. The subjects were from a variety of academic levels, although all had at least finished high school. They varied also in the amount of exposure to and use of English in the United States—some were working or studying in environments where use of the language was essential, whereas others spent most of the day speaking Portuguese.

Table 1 summarizes the information for each subject, including the number of recordings made, age, sex, the length of time in the United States at the time of the first recording, their state of origin in Brazil, a subjective evaluation of their ability to communicate at the time of the first recording, and whether they were using English socially, at work, for study, or in English classes.

The Brazilian states represented were São Paulo (SP), Ceará (CE), Rio Grande do Sul (RS), and Rio de Janeiro (RJ). Their communicative competence was evaluated subjectively according to the level at which they were able to retell the story: (0) Not at all, (1) with extreme difficulty, (2) with less difficulty, but at a very basic level, and (3) at a low-intermediate level.

Table 3.1

Summary of information on subjects

Subj.	No.Rec.s	Age	Sex	Time in US	Braz. State	Level Comm.	Eng. Use
FR	6	31	M	2 mo.	RS	2	job
MR	6	34	M	3 mo.	RJ	3	job
NR	6	28	M	2 wk.	RS	1	job
NT	6	35	M	4 mo.	RJ	2	class/study
SN	8	26	M	5 mo.	RS	1	job/class
CL	8	21	F	1 mo.	SP	3	job/class
CR	6	18	F	1 wk.	RS	3	job/soc
DN	4	25	F	1 mo.	SP	3	job
MN	6	25	F	6 mo.	RS	2	job
TR	6	30	F	2 mo.	RS	0	class
VN	8	41	F	3 mo.	CE	3	soc/job

Throughout most of the study the eleven subjects are treated, not as a group, but as eleven separate case studies, because of the desire to provide an in-depth description of each evolving IL vowel system. Strong inferences for the general population cannot be made from the subjective evaluation of the vowel systems of eleven learners. However, because the eleven subjects represent a variety of backgrounds in terms of NL dialect, education, and TL exposure, tendencies noted in the majority of the subjects' IL vowel systems are considered to be strong candidates for SLA generalizations, and motivation for future controlled research.

3.3. Materials

Materials were prepared for three different types of language use: modified list reading in English and Portuguese, reading of a story in English, and retelling of the story from memory, also in English.

Forty-two test words (6 for each of the 7 target vowels) were included in the English list reading—all monosyllabic, ending in /t/, and beginning in a non-approximant consonant. In addition, 13 distractors were included, containing various other difficult English phonemes. All words were placed in the same carrier sentence "Say X now." The sentences were printed in large letters on 3 by 5 inch index cards and presented in a different random order to each subject at each recording. Subjects were told that the study concerned their pronunciation, but not that the focus was on vowels. After several recordings, however, most subjects became aware of the focus on vowels, in spite of the distractor words, due to the number of minimal pairs.

The Portuguese list-reading materials were prepared according to a similar format, with 20 test words (4 for each of the 5 vowels /i/, /e/, /ei/,[2] /ɛ/, /a/,), plus 3 distractor words, all presented in the carrier sentence "Fala X de novo." (= "Say X again."). Because Portuguese words do not end in /t/, all test words ended in unstressed /ta/, and all were disyllabic except four, which were trisyllabic. These sentences were printed together on a sheet of normal letter-size paper, in an unvarying order. The list was modified for month five by replacing /ei/, whose first element formant frequencies were only marginally different from those of /e/, with /ɔ/, which was observed to be exerting an unexpected influence on the subjects' English IL /ɑ/.

For the English story reading, a short story was prepared containing four of the six words for each target vowel. The story was printed below illustrative sketches on nine 5 by 8 inch index cards. For the story retelling, 9 additional index cards were prepared containing the sketches as a memory aid, but no text.

3.4. Procedure

Subjects were recorded in their homes (except SN, who was occasionally recorded in a library, due to the difficulty of controlling the noise level at his home), approximately once a month, for at least six months (except DN, who returned to Brazil after only four months). Recordings were made on a stereo cassette recorder with a frequency response of 100 Hz to 10,000 Hz, a signal-to-noise ratio of 35 dB, and a unidirectional electret condenser microphone.

The first recording session began with the Portuguese list reading, followed by an extensive English warm-up. All subsequent sessions began with the warm-up, except the fifth, which began with the second Portuguese list reading, this time with the substitution of /ɔ/ for /ei/ mentioned in 3.3. During the first part of the warm-up, the subjects were asked to talk spontaneously about themselves in English—giving biographical information in the first session, and comments about their daily use of English, or about any other subject, in subsequent sessions. During the second part of the warm-up, subjects were asked to read the story from the cards containing the sketches and text, then to retell the story from the cards containing only the sketches. Those who could not yet produce sentences in English were asked to simply name in English as many objects, people, or actions as they could.

Finally, after the warm-up, the subjects were asked to read the carrier sentences containing the test words, maintaining their intonation as constant as possible. They were asked to repeat any sentence for which they were dissatisfied with their pronunciation. Occasionally, they were asked to repeat a sentence when it appeared the mispronunciation was due to lack of attention, or when they had paused just before the test word. My conversation with the subjects was in Portuguese at all times, because the object was to elicit productions based on the subjects' stored vowel schemata rather than on imitation of the current TL input. The extensive English warm-up was intended to counteract the possible interference which is sometimes caused by a recent switch in codes.

3.5. Analysis

For the acoustic analysis of the test words, the data were 12-bit sampled at a rate of 10 kHz on a real-time digital spectrograph. The first three formants of each vowel were measured at a steady state in the center of the vowel when there was one, and at a 25-millisecond portion just before the greatest diphthongal movement of the second formant (excluding initial and final transitions) when there was not. The window to be measured was identified on a wide-band spectrogram (filter band width 300 Hz. for the male subjects and 400 Hz. for the females). The measurements were taken from power-spectra where possible. Where two formants were too close together to distinguish the peaks in the power spectrum, the formant frequencies were approximated directly from the spectrogram. Figures 3.1 and 3.2 illustrate the method of measurement.

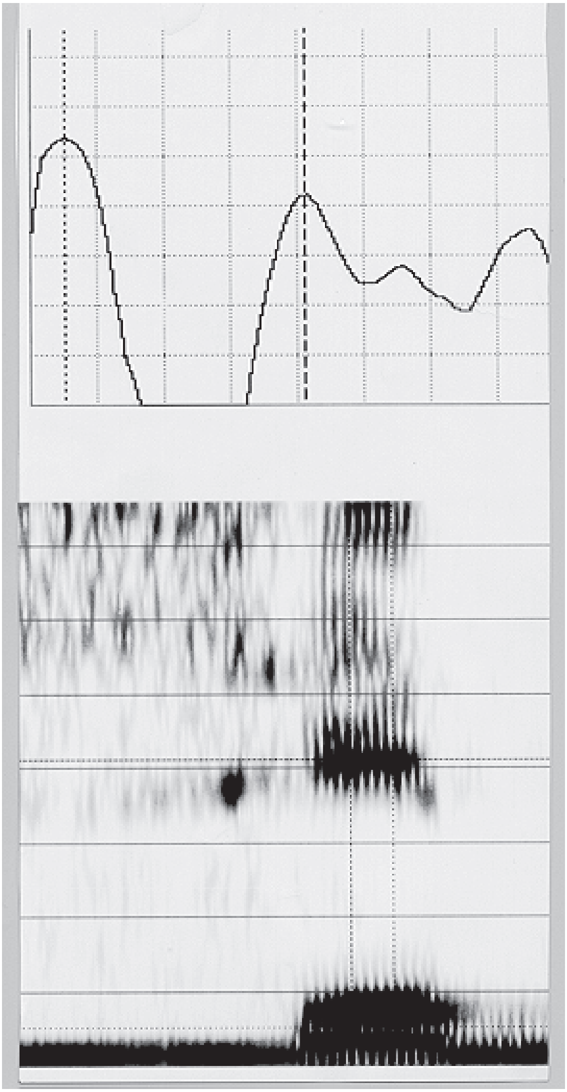

Figure 3.1. The word "sit" spoken by FR in month 2. Cursors in spectogram show 25 ms portion to be measured. Cursors in power spectrum show peak intensity of first two formants.

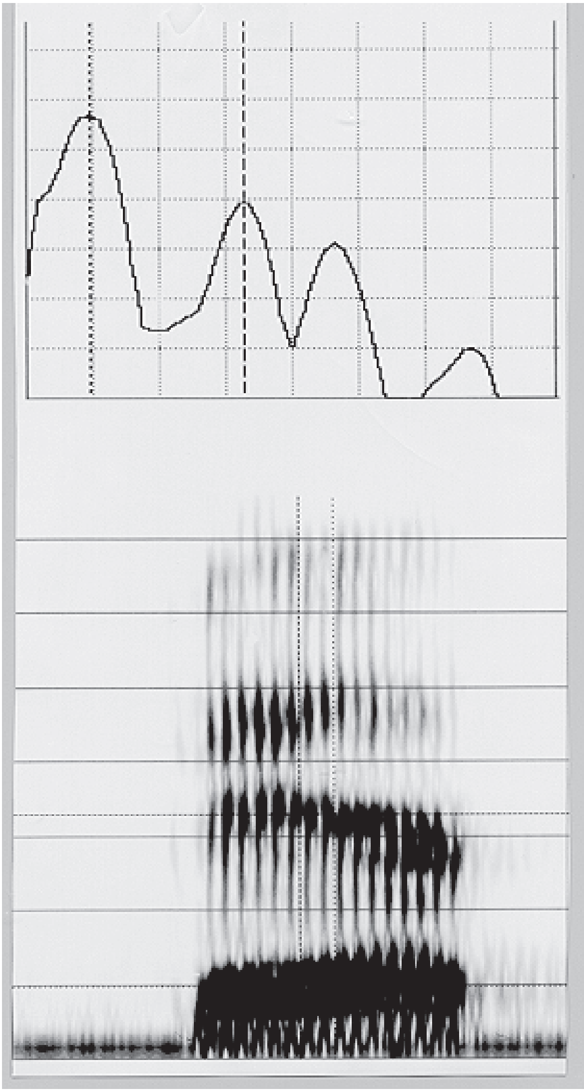

Figure 3.2. The word "pet" spoken by SN in month 7. Cursors in spectogram show 25 ms portion to be measured. Cursors in power spectrum show peak intensity of first two formants.

The inclusion of the second criterion for selection of the vowel portion to be measured was necessary, not only because of the inclusion of the so-called English diphthong /eɪ/ (or "glide" as referred to by Lehiste and Peterson, 1961), but also because several of the English and Portuguese vowels usually considered to be monophthongs (e.g., /ɛ/ of both languages) were often pronounced with considerable diphthongal movement.

Preference was given to the second formant (F2) for two reasons. First, the second formant can be measured more precisely than the first, because there is less interference of the fundamental and of the harmonics. Second, there is generally a greater degree of movement in the second formant, so it is more important to catch it at a relatively static moment. The individual speakers in this study were not always consistent in the degree of diphthongization given to different tokens of the same phoneme. It was observed that, where they were inconsistent, a measurement taken just before the place of greatest diphthongal movement of the tokens of a particular phoneme pronounced without a center steady state generally corresponded closely to steady-state measurements of the more monophthongal utterances of that phoneme.

Vowel plots were made of the first two formants, using a PC program modeled after the UCLA Plot-Formants program for the Macintosh, with the first formant on the ordinate and the second on the abscissa, the frequencies scaled by the Mel Scale, increasing from top to bottom and from right to left, in order to reflect the usual articulatory vowel chart. Location of the vowels on the plots will mostly be described in the usual articulatory terms (i.e., high/low and front/back). However, this imitation of the articulatory vowel charts is only to facilitate the visual analysis. The vowel plots represent the *acoustic* vowel space, and a one-to-one correspondence to articulation is not implied.

For the first research question, the mean formant frequencies of each vowel are represented by single points on the plots, and the points representing the peripheral vowels are joined by straight lines to show the acoustic shape of the vowel system. For the remaining questions, where variance in production was considered to be important, the plots consist of ellipses drawn with radii of two standard deviations from the mean formant frequencies of each vowel. In some cases, especially in the first months, subjects gave spelling pronunciations which were obviously not attempts at the production of the target vowel, i.e., *fight* for *fit* or *Pete* for *pet*. These deviant pronunciations were omitted from the analysis, leaving at times only one or two tokens for a given vowel. For these vowels, and for those whose points fall on a straight line, the plotting program cannot plot the two-standard-deviation ellipses. In these cases, an ellipse shape was drawn close around the points on the graph to facilitate the visual analysis.

Although the statistical measure of standard deviation was used, it is recognized that standard deviations calculated from only six tokens per vowel per month cannot be considered statistically significant, and these ellipses are to be taken as only helpful visual summaries of the vowel qualities. In the case of Portuguese, there are only four tokens for each vowel, but because less variance is expected in the NL, these ellipses should be at least as representative as the English IL ellipses. In most cases, because of the month-to-month consistency observed, it is assumed that the ellipses are reasonable summaries of the vowel qualities, especially when they are small and the points within them relatively evenly distributed. The ellipses assume a normal curve, however, so when the data are skewed or bimodal, they do give a somewhat distorted picture of these data. Therefore, whenever a particular ellipse is unusually large or elongated, the distribution of the points and the reasons for the size or shape are discussed.

Notes

1 For the reasons discussed in 2.2.2., /eɪ/ was treated in this study as a monophthong.

2 Although English /eɪ/ was treated as a monophthong in this study, this did not guarantee that the Brazilian learners would interpret it as such. Thus, both Portuguese /e/ and /ei/ were included because of the equal possibility of subjects' identifying the TL vowel with the NL monophthong or with the NL diphthong.

4. Findings: Models for the Early Interlanguage Vowel System

The first research question asks in what ways and to what extent the English IL vowel systems of the learners in this study, at the time of the first observation, are modeled on their respective NL vowel schemata and/or on the TL input. The vowel plots of the three vowel systems—the learners' first-month IL, the learners' NL, and the assumed TL input (Ohnishi natural speed data, 1991)—based on mean formant frequencies, will be compared in terms of both the position of individual vowels and the overall size, shape, and position of the vowel system.

The first comparison will be of the group mean formant frequencies of the first-month IL vowels of the five male subjects with those of the subjects' NL and with the Ohnishi English averages for men. The second will be of the equivalent sets of female data. Finally, comparisons will be made of the first-month IL means of each subject with his/her NL means and with the appropriate Ohnishi data. Because grouping neutralizes individual physiological differences to some extent, the Ohnishi data can be considered to constitute the approximate target for the groups with greater confidence than for the individuals. However, since the groups are small, the means are vulnerable to the influence of outliers. For this reason, it is important to examine the individual data as well.

4.1. Group means: Males

Comparing first the male NL and TL systems, it can be seen in Figure 4.1 that the average Brazilian Portuguese NL system of the five male subjects is triangular, having only one low vowel in the center, whereas the assumed Californian English TL system (Ohnishi averages for men) is an irregular quadrilateral, with two low vowels forming an almost horizontal lower vowel line.

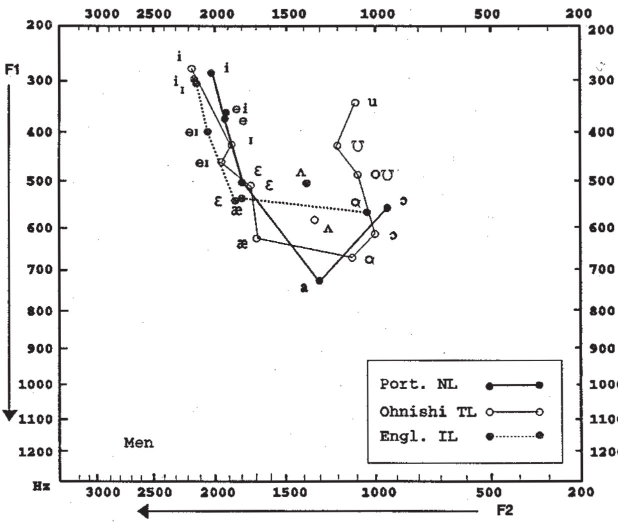

Figure 4.1. Plot of male means: Portuguese NL, English IL, and Ohnishi Californian English (TL).

Although the study included both the /e/ and /ei/ of Portuguese, the NL vowel line is drawn through /e/ in order to represent the outline of the NL monophthongal system. The first element of the diphthong /ei/ was found to be similar to the steady state of /e/ for all of the subjects, and both vowels varied as to the degree of diphthongization observed. However, when /ei/ contained a diphthongal trajectory, it was almost always a rising glide, and when /e/ contained one, it was almost invariably a falling glide, making the vowel sound phonetically like /eə/. As illustrated in Figures 4.1 to 4.13, the IL /eɪ/ was sometimes positioned closer to the NL /e/ and sometimes closer to the NL /ei/. When there was a clear diphthongal trajectory in the IL /eɪ/, it was always a rising glide, indicating that the identification was made with the Portuguese diphthong. However, because the IL vowel was not always diphthongized, variation in the NL model (/e/ or /ei/) is possible. Thus, throughout this section, reference will be made to both NL vowels.

The average TL system is similar, on the F2 axis, to the average NL system (at least the portion of the system included in this study), except for the two low vowels, which are front and back instead of center, and except for the less regular front vowel line (data on the NL back vowel line for these subjects were not collected). Although English and Portuguese are generally considered to contain several corresponding vowels, there is a clear correspondence, on the F1 axis, between only two pairs of vowels of the two languages. The NL and TL /i/ correspond closely in height; the NL /e/ and /ei/ are located between the TL /i/ and /ɪ/, closer to the latter; the NL and TL /ɛ/ are the other pair to correspond closely in height; the NL /a/ is closest to, but lower than the TL /ɑ/; and the NL /ɔ/ is considerably higher than the TL /ɔ/. The TL /æ/ is about midway between the heights of the NL /ɛ/ and /a/, and the central TL /ʌ/ is almost directly above and much higher than the NL low central vowel /a/.

4.1.1. Individual vowels

The male group means for the individual first-month IL vowels plotted in Figure 4.1 exhibit essentially no difference between either /i/ and /ɪ/ or between /ɛ/ and /æ/, so these will considered to be only two rather than four separate IL phonemes.

The IL /i/-/ɪ/ appears to have been influenced by both the NL and the TL. However, although the expected result of the influence of both a NL and a TL vowel would be an IL vowel located midway between the two in the vowel space (Flege, 1980, 1981, 1986), the position of this vowel indicates that its height (F1) has been modeled on the NL /i/ and its backness (F2) influenced by the TL /i/.

The IL /eɪ/ is positioned, in relation to the NL /e/ and /ei/, about the same as the IL /i/-/ɪ/ in relation to the NL /i/. This puts it closest to, but even higher than the TL /ɪ/, which would be a strange model for this IL vowel. An explanation for the position of this vowel will have to await the comparison of the whole vowel systems.

The IL /ɛ/-/æ/ is located slightly below and forward of both the NL and the TL /ɛ/, and thus, in a position relative to the NL /ɛ/ similar to that of the two previous IL vowels in relation to the NL /i/ and to the NL /e/ and /ei/.

The IL /ɑ/ is located nowhere near what one would take to be the corresponding NL vowel /a/, but instead, appears to have been identified with the NL /ɔ/. There is little indication of influence from the appropriate TL /ɑ/, and if the TL /ɔ/ has had an influence, it is only on the F2 axis, just as the TL influence on the /i/-/ɪ/. It should also be noted, however, that the IL /ɑ/ is located forward and slightly below the NL /ɔ/, similar to the position of the three IL front vowels relative to the NL front vowels. This amounts to a surprising consistency in the data—four IL vowels located in almost the same position relative to four NL vowels.

The most obvious explanation for the apparent identification of this IL vowel with the NL /ɔ/, rather than with the acoustically closer NL /a/, is orthographic interference—the letter *o*, which represents the /ɑ/ phoneme in American English stressed syllables, represents the /ɔ/ phoneme in Portuguese stressed syllables. But if this were the cause, one would expect to see a phonetic approximation between the NL /ɔ/ and the TL /ɔ/. The orthographic interference explanation will prove to be simplistic upon examination of the vowel system as a whole in 4.1.2.

Finally, the IL /ʌ/ is located right in the center of the vowel space, very far above and slightly forward of the target, and not very near any other NL or TL vowel. If the representation for this vowel was not based on identification with any NL or TL vowel, the only other conceivable possibility is for it to have been positioned according to the IL vowel system as a whole. This possibility will be examined below in 4.1.2.

The above comparison was based on the usual assumption that each vowel is learned individually. At this point in the analysis, the data indicate that four of the five average male IL vowels may have been modeled after NL vowels, and all four modified from the original models in basically the same manner, regardless of the relative location of the target. The latter part of this finding is curious, and the analysis of individual vowels appears to offer no explanation. The fifth vowel /ʌ/ does not appear to have any relation at all to the NL, and its similarity to the TL may be in its relative, rather than absolute positioning.

4.1.2. The vowel systems

For the following comparison, the group NL and first-month IL formant frequency means plotted in Figure 4.1 will be treated as outlining the NL and IL vowel systems of an average Brazilian male learner of English as a second language in the early stages of acquisition, and the Ohnishi data as the outline of the TL system.

There are four points to note in judging the degree of similarity of this average male IL vowel system to that of the NL or of the TL. (a) The IL front vowel line down to /ɛ/-/æ/ is straight like that of the NL, and is almost parallel to the NL line down to /ɛ/, but farther forward of both the NL line and most of the TL line, intersecting the fronted TL /eɪ/. (b) The lower IL vowel line—the one linking the IL /ɛ/-/æ/ to /ɑ/— is almost at the height of the NL /ɛ/ and /ɔ/, and almost parallel to a straight line linking these two vowels. (c) The /ʌ/ is the only IL vowel which does not appear to be modeled after any NL or TL vowel. (d) The whole IL vowel system is much smaller, on the F1 axis, than the NL and TL systems. Because three of these four characteristics refer to the system as a whole, they can be expected to be related, and this is precisely what will be seen below.

Beginning with the front vowel line, it was noted in 4.1.1 that the location of the IL /i/-/ɪ/ indicated that it had been modeled on the NL /i/ in terms of height, then influenced by the TL /i/ in terms of backness. If the position of this IL vowel were really due to a process based on single dimension modeling, one would expect this process to be productive, at least for other vowels of the same category, i.e., for the other front vowels. Allowing for a larger margin of error, it could be argued that /eɪ/ is also closer to the NL model in height (whether /e/ or /ei/) and to the TL /eɪ/ in backness. The IL /ɛ/-/æ/, however, is farther forward (has a higher F2) than the NL /ɛ/, the TL /ɛ/, or even the TL /æ/, and cannot have been positioned by this process. There is also no evidence, among the three IL front vowels, of the expected phonetic approximation described by Flege. None of these vowels are positioned between NL and TL models in the acoustic space.

If we assume, however, that the L2 learner acquires the vowels as a system, as suggested in 2.1.3, rather than vowel by vowel, the shape and position of the front vowel line can be explained. Rather than try to match five TL front vowels with only three NL front vowels, the learner identifies the TL front vowel line with the front vowel line of the NL. He does not notice the irregular shape of the TL vowel line (especially the relatively retracted position of /ɪ/ and /ɛ/), but perceives all of the TL front vowel line as being somewhat forward and slightly lower than the NL line. He then constructs an IL front vowel line, with vowels modeled on those of the NL, and displaced in a fairly uniform manner in the general direction of the TL vowel line. Thus, it is the entire IL front vowel line which is positioned just forward and slightly lower than that of the NL. In other words, what may be occurring is a phonetic approximation of the entire IL front vowel line, rather than of individual vowels. Each vowel is modeled after a NL vowel and moved into the appropriate position on the new IL vowel line, which explains the similarity in position of each IL front vowel relative to the NL model. It is as if the learner were trying to develop a more forward base of articulation for the English vowels.

The next point in need of an explanation is the similarity between the lower IL vowel line and the NL line linking /ɛ/ and /ɔ/, when these vowels are relatively distant from the target vowels, and there is a NL vowel—/a/—which is acoustically closer to TL /ɑ/. Still assuming that the learner interprets the TL vowel input in terms of the NL vowel system, the TL /æ/ and /ɑ/ are heard by the learner as the lowest front and back vowels of the TL system, and are therefore identified with the lowest front and back vowels of the NL system—/ɛ/ and /ɔ/. Although the TL /ɑ/ is acoustically closer to the NL /a/, this NL vowel is not a back vowel, so the identification is not made. Because the TL /ɛ/ is also identified with the NL /ɛ/, no distinction is made between /ɛ/ and /æ/ in the IL system.

Although the NL vowels chosen as models are acoustically rather distant from the actual TL vowels, they probably do not sound so distant to the Brazilian ear. Because the auditory system of the Brazilian learner of English is unaccustomed to hearing vowels from these two unfamiliar corners of the vowel space, the higher F1 frequencies of these vowels may be heard as being within the range of the NL front and back vowels, causing TL /æ/ and /ɑ/ to sound, to the Brazilian ear, quite similar to NL /ɛ/ and /ɔ/.

When no systemic match-up is found for the NL /a/, it is ignored in the construction of the IL vowel system, and the IL lower vowel line is modeled after the line linking the lowest front and back vowels of the NL. Although the height of the TL vowel line may not be perceived accurately, it *is* perceived as lower and forward, so the IL lower vowel line is constructed slightly below and forward of the NL line, in phonetic approximation of the TL lower vowel line. Whereas the IL front vowel line was located as far forward of the NL line as the TL vowels /i/ and /eɪ/, the lower vowel line did not come as close to the target line. This is to be expected because of the difficulty of entering the unfamiliar low front and back corners of the vowel space, and simply because the TL lower vowel line is at a much greater distance from the NL line on which it was modeled.

The third point mentioned above was that the IL /ʌ/ apparently lacked a NL or TL model. If the IL system were constructed vowel by vowel, one would expect the IL /ʌ/ to be modeled after the NL vowel closest to the target vowel—the /a/. However, if the IL system is constructed as a system, as proposed, /ʌ/ cannot be modeled after the NL /a/, because this would put the IL /ʌ/ below the two low vowels, and thus alter the shape of the IL system. In fact, the IL /ʌ/ *is* modeled after TL /ʌ/, although not in terms of the absolute acoustic position in the vowel space. The similarity is in its relative positioning. It is located, relative to the lower IL vowels /ɛ/-/æ/ and /ɑ/, in a position similar to that of the TL /ʌ/ relative to the lower TL vowels /æ/ and /ɑ/—between these vowels on the F2 axis and slightly above them in height.

The fourth and last point noted above is the fact that the IL vowel system is quite reduced in size, on the F1 axis, compared to the NL and TL systems. The reason for this is now clear. The learner perceives that the TL system is quadrilateral, as opposed to the triangular system of the NL, and therefore without a match for the lower NL /a/, even though this vowel is acoustically the closest NL vowel to two of the TL vowels. The IL vowel system is then modeled on the NL with the exclusion of /a/, the only NL vowel occupying the lower extreme of the total vowel space, and is thus left with a much reduced total vowel space.

Summing up the analysis of the male group data, the average English IL vowel system of the Brazilian males in this study—at least that part of the system analyzed—appears to be a model of the NL vowel system, modified to approximate the TL system. The most important modifications are (a) the exclusion of the low vowel /a/, leaving the IL system shaped more like the TL, but smaller on the F1 axis than the NL or the TL; (b) the inclusion of the vowel /ʌ/, positioned within the IL system according to the relative position of the target vowel within the TL; and (c) the dislocation of the whole system (or at least the front and lower vowel lines) down and forward, in approximation of the TL front and lower vowel lines.

4.2. Group means: Females

The female NL and TL systems in Figure 4.2 are similar to the male systems. The average Brazilian Portuguese NL system of the six female subjects is triangular with approximately the same relative positions among the vowels as the average male system, except that there is a greater difference in the heights of the female /ɛ/ and /ɔ/. The average Californian English TL system (Ohnishi means for women), has a very irregular quadrilateral shape similar to that of the average male system, except for the centered /oʊ/. (As the Ohnishi slow speech means for both men and women also show a centered /oʊ/, possibly this vowel should not be considered to be peripheral.)

Like the male systems, the female NL and TL systems are similar on the F2 axis, except for the existence of front and back low vowels in the TL, compared to a centered low vowel in the NL, and except for the irregular shape of the TL front vowel line.

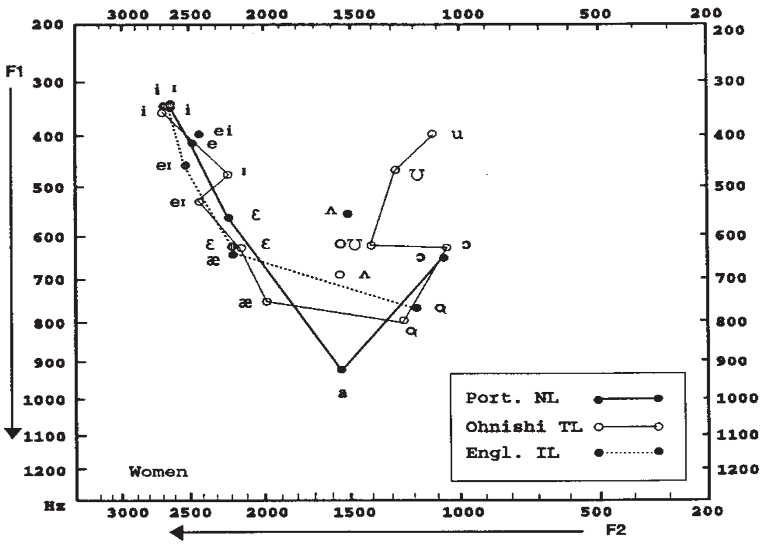

Figure 4.2. **Plot of female means: Portuguese NL, English IL, and Ohnishi Californian English (TL).**

On the F1 axis, the vowels of the two female native language systems are lacking in clear correspondences, as are those of the male systems. The NL and TL /i/ are at almost the same height; the NL /e/ and /ei/ are located between the TL /i/ and /ɪ/ ; the NL /ɛ/ is located almost midway between the TL /eɪ/ and /ɛ/; the NL /a/ is closest to, but much lower than the TL /ɑ/; and the NL /ɔ/ is just below the TL /ɔ/. The TL /æ/ is almost midway between the heights of the NL /ɛ/ and /a/, and the TL central /ʌ/ is almost directly above and considerably higher than the NL /a/ .

4.2.1. Individual vowels

The female group means for individual first-month IL vowels in Figure 4.2, just as those for males, demonstrate essentially no difference between /i/ and /ɪ/ or between /ɛ/ and /æ/. Thus, these will be considered to be only two, rather than four separate phonemes, as they were for the male group analysis.

The average female /i/-/ɪ/ occupies about the same space as the NL and TL /i/, which is what would be expected, because the difference between the NL and TL vowels is minimal.

The average female IL /eɪ/ is positioned in a similar manner to that of the average male IL system, below and slightly forward of the NL /e/ and /ei/. Also consistent with the male data, this puts the IL vowel just above but quite a bit forward of the TL /ɪ/.

The average female IL /ɛ/-/æ/ is located almost right on target for the TL /ɛ/, directly below the NL /ɛ/, but forward of the NL vowel line linking /ɛ/ and /a/. Its position relative to the NL vowel is similar to the position of the IL /eɪ/ relative to the NL /e/ and /ei/.

Whereas the average male IL /ɑ/ appeared not to have been influenced at all by the appropriate TL vowel, the average female IL /ɑ/ is located between the NL /ɔ/ and the TL /ɑ/, closer to the latter, an apparent example of Flege's phonetic approximation. However, although at a greater distance, it is also below and forward of the NL vowel, just like the average female IL /eɪ/ and all of the average male IL vowels.

Finally, the female IL /ʌ/ is located in the center of the vowel space, just like that of the males, very far above and almost in line with the target vowel, and far from any other NL or TL vowel.

The above comparison of the female group means of the individual IL vowels with those of the NL and TL vowels reveals less consistency in the positioning of the IL vowels relative to those of the NL than was observed in the male group data. Because of the similarity between the NL and TL models, the IL /i/-/ɪ/ has not been displaced from the position of the NL vowel. Although, as in the male systems, a similarity can be noted in the positioning of the female IL /eɪ/, /ɛ/-/æ/, and /ɑ/ relative to the NL /e/ and /ei/, /ɛ/, and /ɔ/, the average female IL /ɑ/ exhibits a much greater apparent TL influence than that of the males. The average female /ʌ/, just as that of the males, exhibits no similarity to any NL vowel, and its similarity to the TL vowel is in relative rather than absolute positioning.

4.2.2. The vowel systems

The following comparison will treat the female group formant frequency means plotted in Figure 4.2 as though they belonged to the NL and IL vowel systems of an average Brazilian female learner of English as a second language. This average female IL vowel system will be examined, in light of the four observations made about the average male system, to discover whether it has been constructed by similar processes.

The first point noted about the average male vowel systems was the fact that the male IL front vowel line is straight and almost parallel to that of the NL, but displaced uniformly in apparent approximation to that of the TL. Although the relationship between the *individual* IL vowels and those of the NL is not as consistent for the female systems as it is for the male systems, the female IL front vowel *line* is also almost straight, like that of the NL, and almost as uniformly forward of the NL vowel line as that of the males. The fact that the female TL /ɪ/ is farther back than the NL front vowel line has had no effect at all on the positioning of the female IL front vowel line. What has had an effect is the fact that the TL front vowel line is much longer than the NL line from /i/ to /ɛ/. The displacement of the female IL /eɪ/ and /ɛ/-/æ/ from their NL models was more down than forward, having the effect of lengthening the IL front vowel line. Thus, it appears that the average female IL front vowel line was constructed, like that of the males, as a model of the NL front vowel line down to the /ɛ/, displaced forward in phonetic approximation to the TL front vowel line. The female IL vowel line, contrary to that of the males, was also extended down to approximate the length of the TL line.

The second observation made about the male system was that the IL lower vowel line appeared to be modeled after the line linking the NL /ɛ/ and /ɔ/, then lowered and fronted in approximation to the TL lower vowel line. This can be seen even more clearly in the female vowel system, because of the greater angle of the NL line linking /ɛ/ and /ɔ/. The IL lower vowel line is set at a similar, but even greater angle, and is positioned between the NL and TL lines.

Just as for the male IL system, it is proposed that /æ/ and /ɑ/ are heard respectively, by the average female learner, as the lowest front and back vowels of the TL system, and identified with lowest front and back vowels of the NL. The IL lower vowel line is therefore modeled after the line linking the NL /ɛ/ and /ɔ/, and lowered in the direction of the TL vowel line. It is because the lower vowel line is lowered as a unit, maintaining the approximate angle of the NL line, that the IL /ɑ/ approximates the TL vowel more closely than does the IL /ɛ/-/æ/.

The third point made about the average male IL vowel system was that /ʌ/ is the only IL vowel which does not appear to have been modeled, in terms of absolute position, after any NL or TL vowel; but that it does appear to have been modeled, in terms of its relative positioning, on the TL /ʌ/. The same observation can be made about the average female IL vowel system: the IL /ʌ/ is located in a position relative to the IL lower vowels /ɛ/-/æ/ and /ɑ/ similar to, but somewhat higher than, the TL /ʌ/ relative to the TL /æ/ and /ɔ/.

The last point made about the average male IL vowel system was the fact that it is quite reduced in size, on the F1 axis, compared to the NL and TL systems. This is true also for the female IL vowel system, although the difference in size is proportionally smaller. The explanation is the same: the average English IL vowel system of the female learners in this study, just like that of the males, is a model of the NL system, modified to approximate the TL system. Just as for the male system, this claim has been supported only for that part of the system included in the study, but one would expect the remainder of the vowel system to be acquired in a similar manner. The most important modifications from the NL are also the same: (a) the exclusion of the low vowel /a/, making the IL system smaller and shaped more like the TL; (b) the inclusion of the vowel /ʌ/, positioned within the new system, according to the position of the target vowel in the TL; and (c) the dislocation of the whole system in the direction of the TL front and lower vowel lines.

The male and female group data lead to the following proposal concerning the construction of the IL vowel schema. It appears most learners are aware of a difference, from early on, between the NL and TL systems. However, they are unable to base their new IL vowel schema directly on the unfamiliar TL. Rather, they use the familiar NL vowels as a starting point, and then "aim" in the direction of the TL vowel system, rather than toward the individual vowels.

The data have provided important clues also regarding the form of the vowel schema. It does not appear to be simply a set of vowels, each one specified individually as to position in the total vowel space, but rather an outline of the portion of the total acoustic vowel space occupied by the particular vowel system, with the individual vowels specified according to their position relative to the rest of the vowel system. Thus, when learners construct an IL schema based on their NL schema, but with modifications to approximate the TL system, the modifications are not simply of the specifications of individual vowels, but of the outline of the whole system.

4.3. Individual subject means: Males

The above proposals concerning the form of vowel schemata and the construction of the IL vowel schema will be further supported if the data from the individual subjects exhibit the same tendencies as the group data. In this section, a comparison will be made of the first-month IL vowel system of each individual male subject with his Portuguese NL vowel system, and with the Ohnishi averages for men. Just as with the group data, each subject's vowel systems will be represented by the means of the first and second formant frequencies plotted on the graphs, with straight lines linking the points. The comparison with the Ohnishi data is made with caution, however. Because of physiological differences, these means may not accurately represent the target for each subject.

4.3.1. FR

FR's NL vowel triangle, in Figure 4.3, is quite similar to that of the average male system (Figure 4.1), except that all his vowels are higher (forward) on the F2 axis. If this is due to physiological differences, as indicated by the consistency, then his TL system should be proportionally forward of the Ohnishi plotted data as well.

Contrary to the average male IL tendency, however, FR's IL front vowel line is not located forward of that of the NL, nor is the lower vowel line in the expected relationship to the NL line linking /ɛ/ and /ɔ/. FR's peripheral IL vowels, with the exception of /ɛ/-/æ/, are near duplicates of the corresponding NL vowels. Even his /ɛ/-/æ/, although lower than the NL /ɛ/, falls right on the NL vowel line linking /ɛ/ and /a/, indicating a dependence on the NL for this vowel also.

FR's /ʌ/ also exhibits no similarity to the TL vowel, except in relative height. The two points for this vowel in Figure 4.3 represent the two separate means which were calculated because of the bimodal nature of the data. The fact that FR has realized this vowel alternately close to the front and back vowel lines, rather than near the center of the vowel space, suggests that he has been constrained by the NL system, which does not occupy this center area of the vowel space.

In sum, FR's first-month vowel system is not a good illustration of the process of IL vowel-schema construction proposed at the end of 4.2.2. Although FR was about average among the eleven subjects in his communicative competence at the first observation, his IL vowel system was still surprisingly primitive. In fact, it is possible that FR had not yet even constructed a separate IL schema, but had simply added an allophone for his NL /ɛ/, and was attempting to append the new vowel /ʌ/ to the NL system. This may be an early learner strategy which persisted unusually long for this particular learner.

4.3.2. MR

MR's NL vowel triangle, in Figure 4.4, is also slightly forward of the average male NL system (Figure 4.1), but the difference is much smaller. Thus, his target vowels can also be expected to be just slightly forward of the Ohnishi data. MR's English IL front vowel line follows the tendency of the average male IL system: it is similar to the NL front vowel line in size and shape, and in distances between the vowels, but displaced forward of the NL line. As with the average male IL system, this apparent phonetic approximation to the average TL front vowel line did not move the individual vowels in the direction of the individual targets.

MR's IL lower vowel line, although apparently modeled on the NL line linking /ɛ/ and /ɔ/, is not in a uniform position in relation to this NL line. Whereas /ɛ/ is positioned more or less in accord with the rest of the front vowel line, the IL /ɑ/ is farther back than both the NL and TL back vowel lines, as though MR's assessment of the new vowel system was that it occupied more acoustic space overall than that of the NL.

MR's IL /ʌ/, although at the same approximate height relative to the IL lower vowel line as the TL vowel in relation to the average TL lower vowel line, is also farther back than would be expected. As the bimodal /ʌ/ of FR's IL system, this may indicate a reluctance or inability to enter the unfamiliar center of the vowel space.

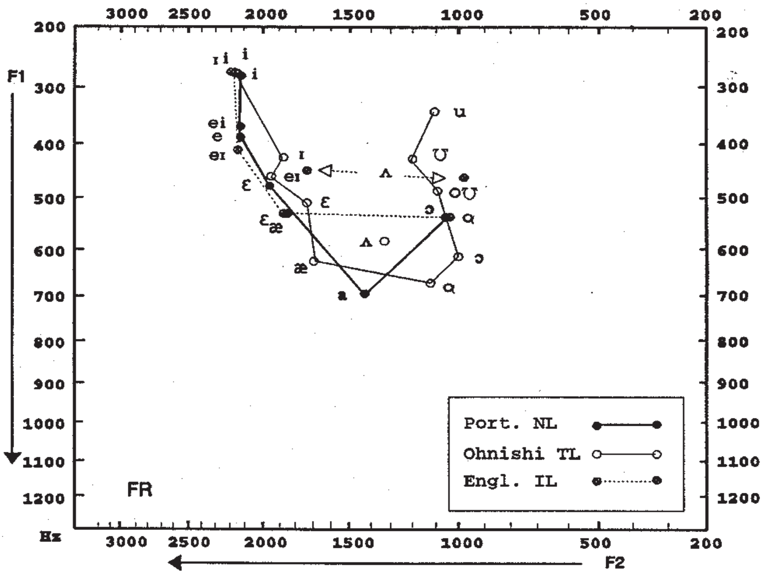

Figure 4.3. Plot of FR's means: Portuguese NL, English IL, and Ohnishi Californian English TL.

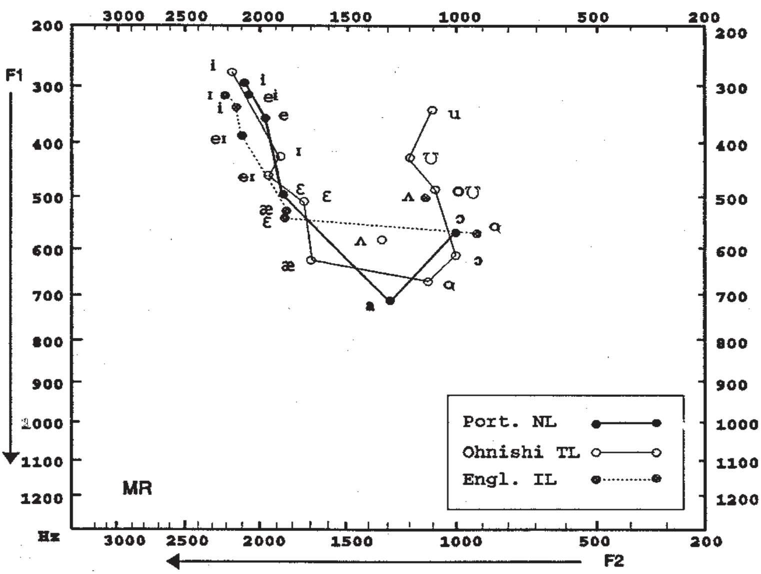

Figure 4.4. Plot of MR's means: Portuguese NL, English IL, and Ohnishi Californian English (TL).

Overall, MR’s IL system appears to follow the tendencies of the average male system: the peripheral vowels are modeled on NL vowels, according to their position in the system; his /ʌ/ is modeled on the TL vowel in terms of relative position; and the front vowel line appears to be undergoing phonetic approximation to the TL vowel line.

4.3.3. NR

NR’s NL triangle, in Figure 4.5, is larger than the average male NL on both axes, especially on the F1; thus, his target system would also be expected to be somewhat larger than the plotted Ohnishi quadrilateral. NR’s IL system follows closely the tendency of the average male IL, in being similar to the NL (with the exclusion of the NL /a/) in size and shape, and in distances between the vowels. Also like the average IL, NR’s IL front and lower vowel lines are forward and lower than the corresponding NL front and /ɛ/-/ɔ/ vowel lines, but the IL /ɑ/ is much farther forward than in the average IL, almost in the position of TL /ʌ/.

NR’s IL /ʌ/, although at the appropriate height relative to the IL lower vowel line, is, like his IL /ɑ/, quite a bit forward of the assumed target, but only slightly forward of the appropriate position relative to the two lower IL vowels.

In sum, NR’s IL vowel system lends support to the proposals that the early IL vowel schema is constructed by using the NL vowels as models, then approximating the outline of the TL system, rather than the individual TL vowels, and that the IL /ʌ/ is modeled on the relative position of the TL vowel.

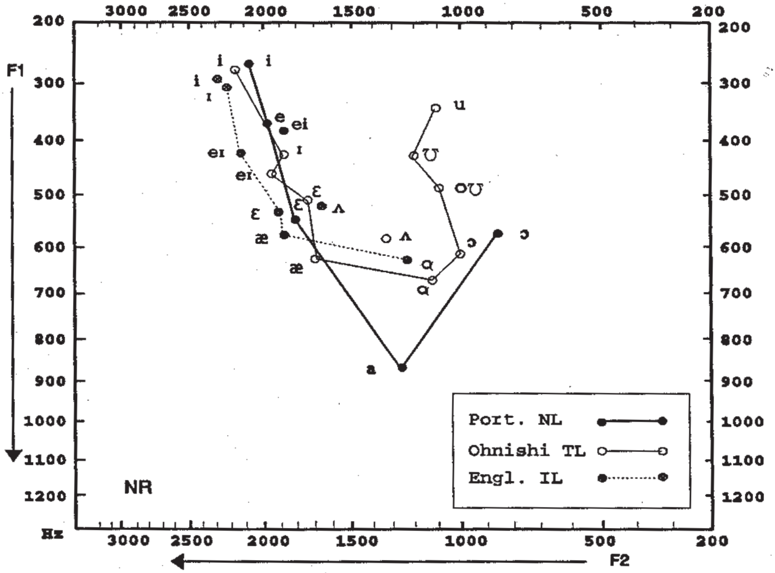

Figure 4.5. Plot of NR's means: Portuguese NL, English IL, and Ohnishi Californian English (TL).

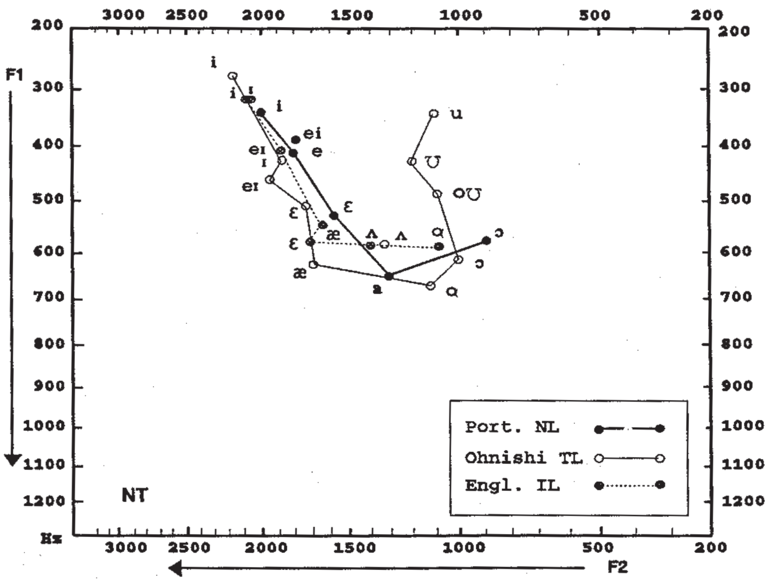

Figure 4.6. Plot of NT's means: Portuguese NL, English IL, and Ohnishi Californian English (TL).

4.3.4. NT

NT's NL vowel system is quite different from that of the other male subjects, in that it is much smaller along the F1 axis and proportionally larger on the F2 axis. The uniformity of this difference suggests that it may be due to physiological differences. In spite of this difference, his IL vowel system mostly follows the tendencies of the average male IL vowel system. Figure 4.6 displays NT's IL front vowel line slightly forward of the NL and appropriately somewhat longer than the NL line down to /ɛ/. The individual vowels, as usual, remain closely identified with their NL counterparts.

NT's IL lower vowel line, as that of the average male IL system, appears to have been modeled on the line linking his NL /ɛ/ and /ɔ/, but the IL /ɑ/ is only forward of, and not lower than, the NL /ɔ/.The IL /ʌ/ of this subject is located appropriately between the IL /ɛ/-/æ/ and /ɑ/ on the F2 axis, but at the same height rather than raised above the lower vowels. This may be the result of a conflict between an attempt to approximate the absolute TL position and an attempt to maintain the relative TL position. Although the result is a vowel which is lower than the appropriate *relative* position, this vowel does not fall below the lower vowel line of the IL system.

Overall, the NT first-month IL vowel system demonstrates the usual dependence on the NL as a point of departure, with the usual exception of /ʌ/, and the usual phonetic approximation of the TL system as a whole.

4.3.5. SN

SN's NL vowel system is slightly smaller than the average on the F2 axis, and about the same size on the F1 axis, but with consistently lower F1 frequencies. His English IL was the most basic of the five male ILs at the beginning of the study. Having only recently begun English language classes, he had a very limited knowledge of the English spelling system. Therefore, some of the means plotted in Figure 4.7 have been calculated from very few tokens (e.g., three for /i/ and two for /ɪ/), and no valid tokens were produced for /ɛ/. Where SN did not know the correct English pronunciation, his most frequent strategy was to give the vowels the sound of the English grapheme name (e.g., *bite* for *bit*).

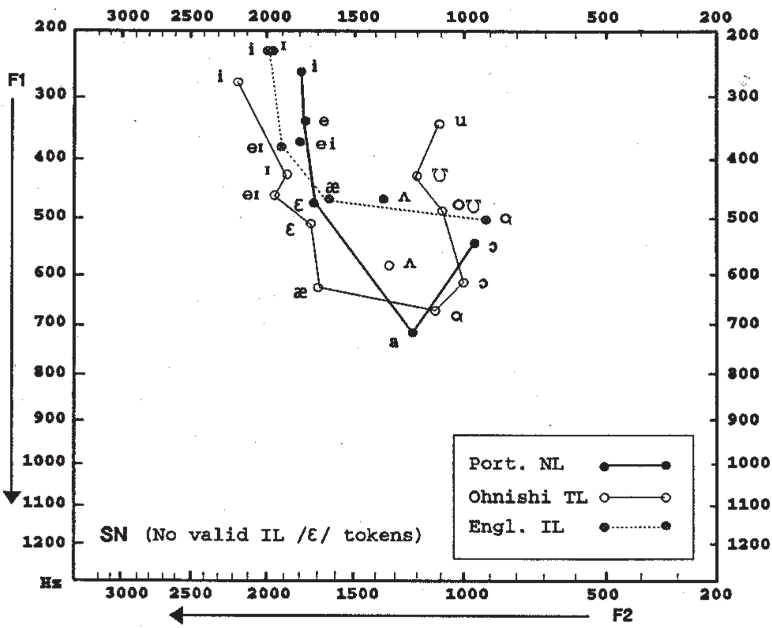

Figure 4.7. Plot of SN's means: Portuguese NL, English IL, and Ohnishi Californian English (TL).

Following the tendency of the average male system, all of SN's IL vowels except /ʌ/ appear to have been based on NL vowels. His /i/-/ɪ/ and /eɪ/, like those of the average male IL, are forward of the NL vowels, in apparent phonetic approximation to the TL vowel line. His /i/-/ɪ/, however, is higher than both the NL and TL vowels, possibly because of an awareness that the TL front vowel line is longer. Although SN has made the same identification of the TL lower vowels with the lower front and back vowels of the NL, he has not lowered and fronted his IL lower vowel line as the other subjects. Apparently ignoring the input from the TL /æ/, the IL /æ/ is located in the probable position of his TL /ɛ/, based on his narrower than average NL system. It is possibly because of the association of these two lower vowels that /ɑ/ is actually higher, rather than lower, than the NL /ɔ/.

The IL /ʌ/ is in the appropriate position relative to the IL lower vowel line only on the F2 axis, the height being almost identical to that of the two lower vowels. As suggested for NT, there may be a conflict here between the sense that the target /ʌ/ is lower and the knowledge that IL /ʌ/ cannot be lower than the two low vowels of the IL system.

In sum, at this primitive stage of acquisition of SN's IL vowel system, dependence on the NL is clear, but there are already signs that the IL vowels are being acquired as a system: the displacement of /i/-/ɪ/ and /eɪ/ (though not /æ/) in the direction of the TL front vowel line, the identification of the IL low vowels with the lower front and back vowels of the NL, and the reluctance to lower the IL /ʌ/ below /æ/ and /ɑ/.

4.3.6. Summary of individual male vowel systems

The relationships observed above between the individual male subjects' IL and NL vowel systems are not as uniform as the relationship between the two average male systems, but several consistencies can be observed.

The IL front vowel lines of four of the five subjects have the approximate size, shape, and relative vowel heights of their respective NL vowel lines down to /ɛ/, rather than the irregular shape and extended length of the TL vowel line. FR's front vowel line is almost identical to that of his NL, and the front vowel lines of MR, NR, and NT all appear to be models of the

NL line moved forward. Only SN's has a different shape from that of the NL, because of lack of fronting of his IL /æ/. None of the subjects have extended their IL vowel line down near the target /æ/, nor have any of them displaced their IL /eɪ/ forward and down in relation to the rest of the IL front vowels, according to the relative position of the TL vowel. Thus, it appears that in every case the IL front vowel line has been constructed by using the NL line as a model, and for at least three of the subjects, this line has been modified through a change in the overall position within the acoustic space.

The construction of the IL lower vowel lines of the five male subjects has not occurred in such a uniform manner. All five subjects do appear to have modeled their IL lower vowels on the lower front and back vowels of the NL, rather than on the closer in height NL /a/. However, although /ɛ/-/æ/ and /ɑ/ of the average male IL system are in approximately the same positions relative to the NL /ɛ/ and /ɔ/, this is true for the individual systems of only NR and NT. Possibly the other three subjects identified the IL /ɑ/ more as part of a back line unit than as part of a lower vowel line. Unfortunately, data on the other back vowels were not collected.

The individual subjects also varied in their relative placement of the IL /ʌ/. Although in the average male IL system this vowel is located in approximately the same relative position as that of the TL vowel, this is not true for the individual systems. FR and MR's /ʌ/s are at the appropriate relative height, but closely identified with the front and/or back vowel lines. NR's is at the appropriate relative height, but somewhat fronted. NT and SN's /ʌ/s are positioned in the appropriate relative position on the F2 axis, but almost right on the IL lower vowel line. Although the subjects varied considerably in their perception of the appropriate relative position of this vowel, they all appear to have been aware that it could not be placed below /ɛ/-/æ/ or /ɑ/, as these vowels define the lower limits of the vowel system.

In spite of the variation noted above, the analysis of the individual male subjects leads to basically the same conclusions reached in 4.1.2. The IL vowel system is modeled on that of the NL, the individual vowel models chosen for their position in the overall system, rather than for acoustic proximity. The resulting system is modified to exclude the low vowel /a/, to include the central vowel /ʌ/, and to approximate the outline of the TL system. The inconsistent positioning of /ʌ/ indicates that the learners have difficulty identifying relative position in the unfamiliar center of the vowel space, but that they recognize that /ɛ/-/æ/ and /ɑ/ define the lower limits of the system. The male subjects were more consistent, and successful, in the phonetic approximation to the front vowel line than to the lower vowel line.

4.4. Individual subject means: Females

In this section, a comparison will be made of the first-month IL vowel system of each individual female subject with her Portuguese NL vowel system, and with the Ohnishi averages for women. As above, each subject's vowel systems will be represented by the means of the first and second formant frequencies plotted on the graphs, with straight lines linking the points. As was emphasized in the individual male analysis, the Ohnishi means may not accurately represent the target for each subject, because of physiological differences. Comparisons are, therefore, made with caution.

4.4.1. CL

CL's NL vowel system, plotted in Figure 4.8, is similar in overall shape to the average female NL system, but slightly larger on the F2 axis and smaller on the F1. Also, her /i/ and /e/ appear to be distinguished mainly by length, and the F2 of her vowels is consistently slightly lower, making her whole vowel system appear farther back. Her TL vowels are likely to correspond closely to the average female Ohnishi data, adjusted in the same direction.

Figure 4.8 demonstrates that CL's IL front vowel line is even more forward in relation to her NL vowel line than the average female IL front vowel line in relation to the average female NL. Even more important, although CL's IL front vowel line still includes as distinct vowels only the vowels with Portuguese counterparts, these vowels are closer to the heights of the corresponding TL vowels.[1] In particular, CL was the only one of the eleven subjects to place her first-month IL /eɪ/ at the approximate target height.

CL's IL lower vowel line is on a slightly greater slant than either her NL line linking /ɛ/ and /ɔ/ or the TL lower vowel line, and is positioned approximately midway between the two. The length of the IL line, however, is an indication that the NL line was probably the model. It appears to have undergone phonetic approximation more or less as a unit, stopping when /ɛ/-/æ/ reached the approximate height of TL /ɛ/, which prevented /ɑ/ from coming closer to its assumed target.

Finally, CL's IL /ʌ/ follows the tendency of the average male and female systems, in its appropriate positioning relative to the IL lower vowel line, rather than in absolute terms.

In sum, CL's IL vowel system, because it is at a more advanced stage of acquisition than the systems of the other subjects, exhibits less dependency on the NL vowel schema. However, evidence of the IL system having been modeled on that of the NL can be seen in the total number of vowels (the absence of the new vowels /ɪ/ and /æ/) and in the length and positioning of the lower vowel line.

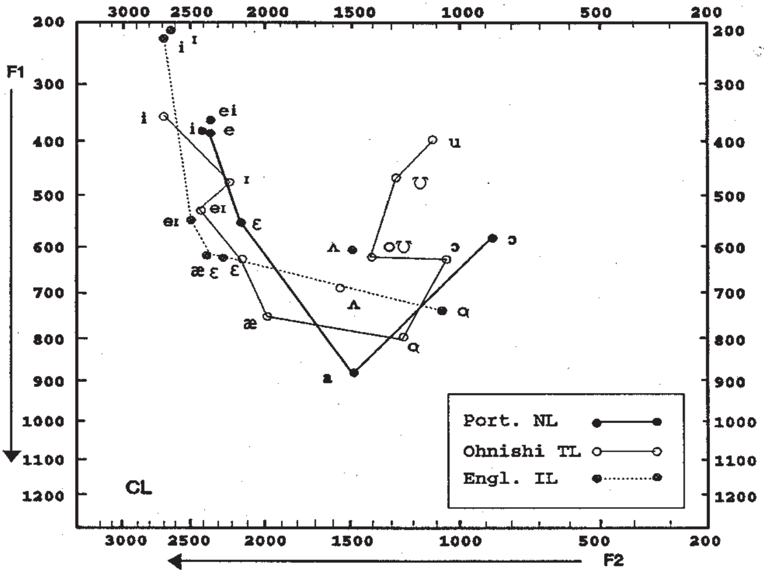

Figure 4.8. Plot of CL's means: Portuguese NL, English TL, and Ohnishi Californian English (TL).

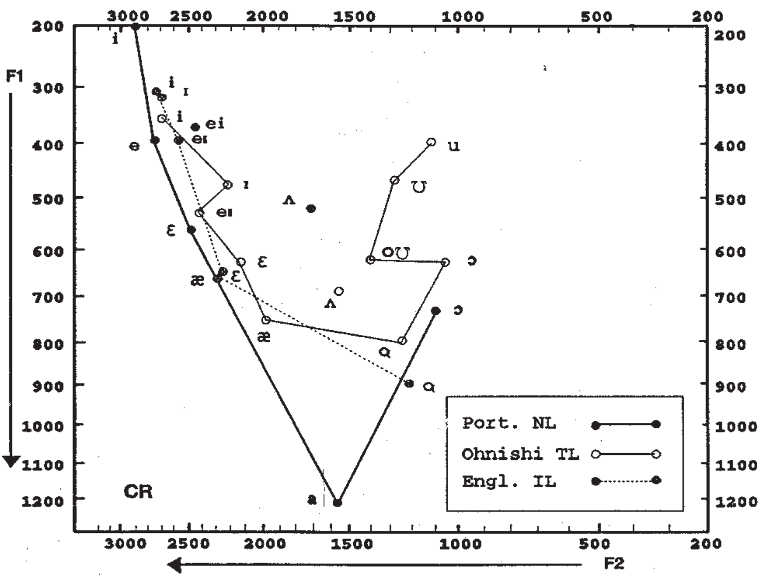

Figure 4.9. Plot of CR's means: Portuguese NL, English IL, and Ohnishi Californian English (TL).

4.4.2. CR

CR's NL vowel system, plotted in Figure 4.9, is unusually large on the F1 axis[2] and larger than the average female NL on the F2 axis, her front vowels being positioned considerably farther forward than those of the other subjects. Despite such a difference between CR's NL and the average female system, her first-month IL vowel system, with the exception of the especially low /ɑ/, does not deviate much from the average female IL, making CR the only one of the eleven subjects besides TR (see 4.4.5) whose entire IL front vowel line is farther back, rather than forward of her NL vowel line. The only other subject to produce an IL /ɑ/ lower than the average TL vowel was MN (Figure 4.11), whose NL /ɔ/ and /a/ are also lower than average. This is an indication that, with the exception of the extension of the lower half of the vowel system, much of the deviance of CR's NL vowel system from the NL norm is probably due to idiolect rather than size of the vocal apparatus. Thus, it is probably safe to assume that her target system would be similar to the average TL system, except that it would extend somewhat lower, on the F1 axis.

Although CR's /eɪ/ is the only IL vowel located at the same height as the corresponding NL vowels, the fact that the IL front vowel line is almost straight and fairly uniformly farther back than the NL line is an indication that the IL front vowel line is developing as a unit.

CR's IL lower vowel line is at a similar angle to that of the NL /ɛ/-/ɔ/ line, and thus at an extreme angle relative to the average TL line, a strong indication of having been modeled on the NL. The fact that this IL line is considerably lower and somewhat shorter than the NL line indicates a phonetic approximation toward the TL lower vowel line. Although her IL /ɑ/ is actually lower than the average TL vowel, the target for this subject, as explained above, is likely to be lower still.

Finally, CR's /ʌ/ is not as appropriately placed relative to the lower vowel line as CL's. It is rather high, but it is located in the center of the IL vowel system, and above the IL lower vowel line, apparently not modeled on any other NL or TL vowel.

In sum, although CR's IL first-month vowel system does not exhibit an extreme dependence on the NL system, NL influence is apparent in the height of her /eɪ/, and in the angle of the lower vowel line. Both the IL front and lower vowel lines show signs of undergoing phonetic approximation to the TL vowel lines, rather than of individual vowels, and the IL /ʌ/ appears to be modeled, though without precision, on the relative position of the TL vowel.

4.4.3. DN

The plot of DN's NL vowel system (Figure 4.10) does not include /ɔ/. This vowel was included only in the fifth-month recording session, when DN was no longer participating. The portion of DN's NL vowel system plotted is similar in distribution to that of the average female NL system, but it is all farther forward, and the /i/ is fronted further still. Her TL vowels can therefore be expected to be close to those of the Ohnishi data, adjusted in the same direction. DN's IL /ɛ/ and /æ/, positioned in reverse order, will be considered to be one IL phoneme, with the mean somewhere between the two plotted points, as will her /i/ and /ɪ/.

DN's first-month IL front vowel line, like that of the average female IL system, is approximately parallel to the NL vowel line and slightly forward, but the three IL vowels are not in a uniform relationship to their assumed NL models. Her /i/-/ɪ/ occupies the same space as her NL /i/, and /eɪ/ is forward and lower than the NL vowel (when the means for this vowel are calculated without the one low outlier, /eɪ/ appears only minimally different from her NL /e/). Her /ɛ/-/æ/, in contrast to those of all the other female subjects, which were all close to the height of the TL /ɛ/, is actually closer to the TL /æ/. This has made the length of her IL front vowel line closer to that of the TL line than that of any of the other female subjects. It has also made her IL lower vowel line slant in the opposite direction from that of the line connecting her NL /ɛ/ and /ɔ/ (assuming her NL /ɔ/ is also similar to the average NL /ɔ/) and from that of the TL line. In fact, it is not clear if this subject's IL /ɛ/-/æ/ was modeled on the NL /ɛ/, as the other subjects, nor is it clear that the lower vowel line is lowering as a unit.

Finally, DN's /ʌ/, as that of the average female IL system, is placed in an appropriate position relative to her IL lower vowel line.

In sum, DN's IL vowel system exhibits an approximately equal influence from the NL and the TL, and is counter to the general tendency of the female subjects (and more similar to the males), in that her front vowel line exhibits stronger evidence than the lower vowel line of having been modeled on the NL and of developing as a unit. Although her IL /ɛ/-/æ/ and /ɑ/ may be undergoing phonetic approximation of the TL vowels individually, the models for these vowels cannot be clearly determined. Her /ʌ/ is modeled, in terms of relative position, on the TL vowel, constituting further evidence that the IL vowels form an integrated system.

4.4.4. MN

Figure 4.11 shows that MN's overall NL vowel system is similar in shape and position to the average female NL system, but her /i/ and /e/ are slightly fronted and her /a/ and /ɔ/ are slightly lower than average. Although the difference in the latter two vowels may be physiological, the fronted /i/ and /e/, because they change the shape of the vowel system, are more likely idiolectal. Thus, her target system can be expected to be similar to the Ohnishi data, except for a possible extended lower portion.

It was observed in 4.2 that the front vowel line of both the male and female average TL systems is quite irregular compared

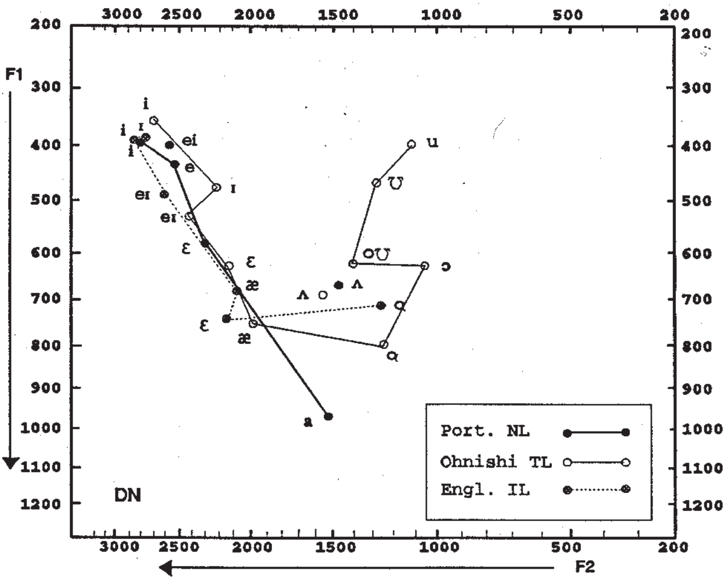

Figure 4.10. Plot of DN's means: Portuguese NL, English IL, and Ohnishi Californian English (TL).

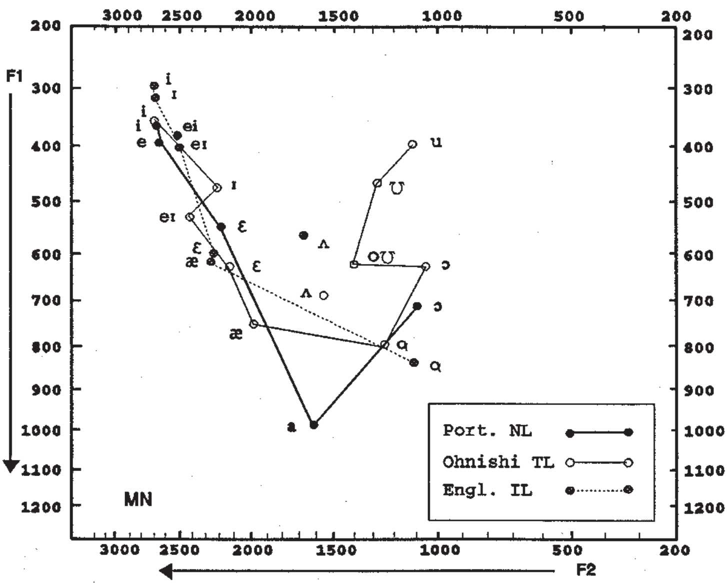

Figure 4.11. Plot of MN's means: Portuguese NL, English IL, and Ohnishi Californian English (TL).

to that of the average NL. In the average female TL, most of the irregularity is due to the retracted nature of /ɪ/, which puts this vowel behind the NL front vowel lines of CL, TR, VN (Figures 4.8, 4.12, and 4.13), and MN, whereas all the other TL front vowels are forward of these subjects' NL lines. For CL, TR, and VN, however, it is only a small fraction of the entire TL front vowel line which is behind that of the NL, and this small fraction does not appear to have influenced at all the formation of their IL vowel lines. They all displaced their IL front vowel lines uniformly forward of their NL lines. In MN's case, her fronted NL /i/ and /e/ leave more than one-third of the entire TL front vowel line behind that of her NL, apparently enough to influence the IL system, which developed in two different directions from the NL model. The IL /i/-/ɪ/ was displaced up and back, and the /ɛ/-/æ/ down and forward, thus lengthening and changing the angle of the IL front vowel line, vis-à-vis that of the NL. A height adjustment of the mid IL vowel /eɪ/ was unnecessary for correcting the length of the IL vowel line. This vowel was moved only back, in the direction of the overall TL vowel line, although the TL /eɪ/ is much lower and forward of the NL vowel line.

Apparently the retracted position of the average TL /ɪ/ had little or no influence on the construction of the IL vowel systems, as long as it had only a minimal effect on the overall position of the TL front vowel line, relative to that of the NL. However, the position of this TL vowel, added to the fronted position of MN's NL /i/ and /e/, had a considerable effect on the relative position of the NL and TL front vowel lines, and thus an influence on the formation of the IL front vowel line. This constitutes further evidence that the phonetic approximation occurring in the IL vowel systems is in the direction of the TL *vowel line*, rather than toward individual TL vowels.

MN's IL lower vowel line follows the tendency of the average female IL system in being almost parallel to the NL /ɛ/-

/ɔ/ line, and thus at an extreme angle relative to the average TL line, but lowered in phonetic approximation to the TL. MN's IL /ɑ/ has passed the height of the average female TL /ɑ/, supporting the suggestion at the beginning of this section that her target system might extend somewhat lower than the Ohnishi data. Her IL /ɛ/-/æ/ has reached the height of TL /ɛ/, and may be blocked from lowering further in the direction of /æ/ as long as the lower vowel line is modeled on the NL line and maintains this angle, because /ɑ/ has reached its lower limit.

MN's IL /ʌ/ is at an appropriate height relative to the IL lower vowel line, but slightly forward of the average TL vowel.

In sum, MN's first-month IL vowel system exhibits a dependency on the NL system in the height of /eɪ/ and in the angle of the lower vowel line. It also provides support for the proposal that the vowel system is acquired as a whole, in the apparent phonetic approximation of the front and lower vowel lines, and in the appropriate relative location of IL /ʌ/.

4.4.5. TR

TR's NL vowel system, in Figure 4.12, is peculiar in that her /a/ is not the lowest vowel of the system, but rather between the heights of /ɛ/ and /ɔ/, resulting in a quadrilateral system, rather than the usual Portuguese triangle.

TR, as SN, was still having difficulty decoding the English spelling system at this stage. Thus, there were no valid tokens for the IL /eɪ/, and the point for /i/ in Figure 4.12 represents the only valid token produced for this vowel. This /i/ token, which is in a reversed relationship with /ɪ/, is likely to have been a rather random pronunciation, there being probably no difference yet between /i/ and /ɪ/. Although the location of points gives the impression of a distinction between /ɛ/ and /æ/, the higher mean for /ɛ/ was due to only one particularly high realization of this vowel.

TR’s first-month IL vowel system does not appear to be based on TL input at all. Rather, it appears she has simply taken the NL vowel system and decreased the overall vowel space, the IL front vowel line being more centered than that of the NL, the IL /ɑ/ being even higher than the NL /ɔ/, and /ʌ/ up at the height of the high vowels. The only exception to this tendency to move to the center of the vowel space is the IL /ɛ/-/æ/.

TR had the least developed English IL of the eleven subjects, and this may very well be an early defensive strategy, related to the theory of economy of speech gestures: doubt as to the quality of a vowel causes smaller speech gestures, resulting in vowels which are closer to the center of the acoustic vowel space.

4.4.6. VN

VN’s NL vowel system is similar to the average female NL system, but narrower on the F2 axis, and her /i/, /e/, and /eɪ/ are lower, making her system shorter at the top on the F1 axis. This latter difference may be idiolectal, in which case her TL system would differ little from the average.

Whereas the average female IL front vowel line is parallel to, forward of, and longer than the average female NL line, VN’s IL front vowel line is parallel to, forward of, slightly lower than, and approximately the same length as her NL line, which is already shorter than average. This makes her IL /i/-/ɪ/ even lower than the NL model, and leaves little room for the extra TL vowels. Although it has placed /ɛ/-/æ/ between the NL model and the TL /ɛ/, it has left no room for an appropriately placed IL /i/, and placed both /i/-/ɪ/ and /eɪ/ at the height of, but quite a bit forward of the approximate TL /ɪ/. Thus, VN’s IL front vowel line appears to be undergoing phonetic approximation to the TL vowel line, but VN has failed to notice the difference in length, which has thrown the mid /eɪ/ and high /i/-/ɪ/ together. The distinction between /eɪ/ and /i/-/ɪ/ is maintained by the rising glide of the former.

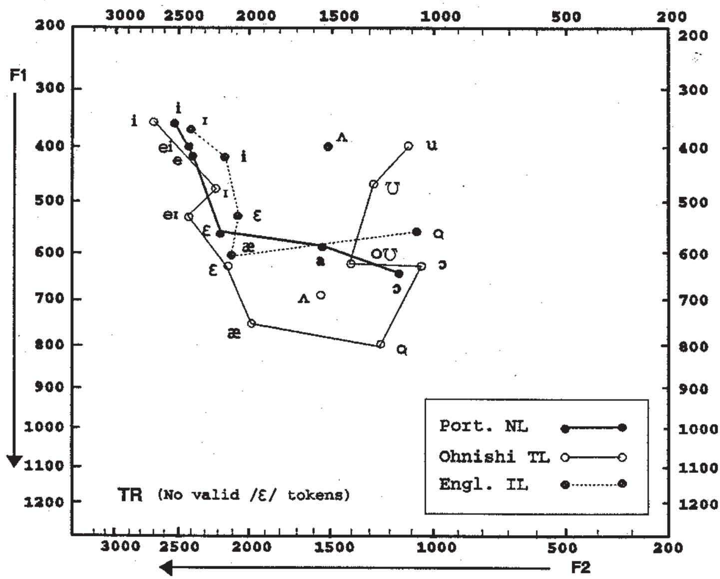

Figure 4.12. Plot of TR's means: Portuguese NL, English IL, and Ohnishi Californian English (TL).

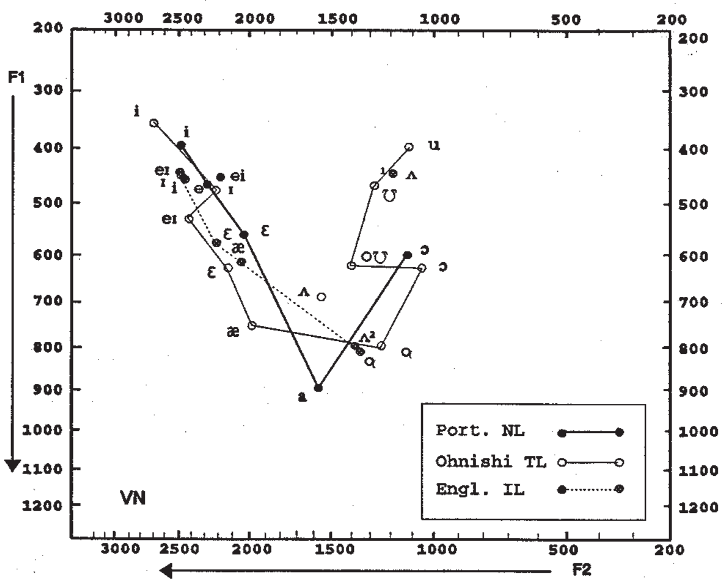

Figure 4.13. Plot of VN's means: Portuguese NL, English IL, and Ohnishi Californian English (TL).

Contrary to that of the average female IL system, VN's IL lower vowel line does not appear to be evolving as a unit. Her IL /ɑ/, with its mean almost right on target, is much lower than her IL /ɛ/-/æ/, making the angle of the IL lower vowel line quite different from those of both her NL and the average female TL. Although the target-like mean position of /ɑ/ appears to indicate a lack of any NL influence on this IL vowel, the actual realizations of this vowel in month one stretched from the position of her NL /a/ to that of her NL /ɔ/ (see Figure 5.63 in Chapter 5). It may be that the IL vowel is modeled on the two NL vowels, and that it is merely coincidental that the means coincide with the target.

The two points for VN's first-month /ʌ/ in Figure 4.13 represent the two sets of means that were calculated for this vowel, due to the bimodal nature of the data. For the two realizations corresponding to the lower point, the vowel was apparently identified with the TL /ɑ/, and the four realizations corresponding to the higher one were very close to the average female TL /ʊ/, possibly in analogy with the extremely common but exceptionally spelled *put*. VN was the only one of the six female subjects whose first-month IL system did not appear to contain a distinct /ʌ/. Possibly the inconsistency in her choice of NL model for her IL /ɑ/ and the fact that she apparently did not acquire the lower vowel line as a unit, as the other subjects, prevented her from ascertaining the position of /ʌ/ relative to the lower portion of the IL system. Because the identification of this central vowel with any of her NL vowels was also unviable, she simply failed to create a node for /ʌ/ in her IL vowel schema, realizing it alternately as /ɑ/ and /ʊ/.

In sum, NL influence is apparent in the angle and length of VN's IL front vowel line, and in the actual realizations, but not the mean of /ɑ/. The IL front vowel line, but not the lower vowel line, appears to have developed as a unit. The lack of a consistent model for /ɑ/ and the fact that the lower vowel line did not develop as a unit appear to have contributed to VN's failure, by month one, to acquire an IL /ʌ/.

4.4.7. Summary of individual female vowel systems

The individual female first-month IL vowel systems vary in the degree to which they provide support for the proposals made in 4.2.2, possibly, in part, because they are not all at the same stage of development.

In particular, the female subjects appear to have varied considerably in the process of construction of the IL front vowel line. Except for the mid vowel /eɪ/, they were not consistent in maintaining the relative heights of the NL model vowels, as were the males. Two of the women, CR and DN, lowered their IL /ɛ/-/æ/ past even the average TL /ɛ/, in the direction of the TL /æ/. All except for TR, however, have, as the males, maintained a straight front vowel line, without the retracted /ɪ/ of the TL system. Thus, although NL influence is apparent, it is not as strong as it was in the male systems. The individual female IL front vowel lines do appear to have developed as integrated units—they have mostly maintained the overall shape and angle of the NL front vowel line—but the phonetic approximation toward the TL vowel line has been not only in terms of position within the acoustic vowel space, but also in terms of length.

Although the female subjects were less consistent than the males in the construction of their IL front vowel lines, they were more consistent in the construction of their lower vowel lines. All except DN and VN have clearly modeled their IL lower vowel lines on their NL lines linking /ɛ/ and /ɔ/. TR, who has the least developed first-month IL system, has not lowered this line at all. CL, CR, and MN have moved their IL vowel lines in the direction of the target, without changing the angle from that of the NL lines. The models for DN and VN's lower vowels are unclear.

Although there was considerable subject-to-subject variation in the height of the first-month IL /ʌ/, in all five female IL systems in which /ʌ/ existed as a distinct vowel (it was not a distinct vowel in VN's system), it was positioned somewhere above the IL lower vowel line, and in the approximate center of the IL vowel space. Thus, although their perception of position within the unfamiliar center of the vowel space may not be too precise at this stage of acquisition, five of the six female subjects apparently attempted to model the placement of this IL vowel on the relative position of the TL vowel, perceiving that /ʌ/ had to be approximately centered and above the IL lower vowel line. Only in DN's system, in which the lower vowel line approached the target, did this relative position coincide closely with the absolute target position.

The analysis of the first-month IL vowel systems of the individual female subjects supports the basic proposal that the IL vowel system is modeled on that of the NL, with the individual vowel models chosen by their position in the overall system, rather than by acoustic proximity. The female IL systems, as those of the males, appear to have been modified from the NL model to exclude the low vowel /a/, to include the central vowel /ʌ/, and to approximate the outline of the TL system. The female subjects were more accurate in approximating the TL front vowel line than the lower vowel line, the latter exhibiting more dependence on the NL, in both shape and location.

4.5. Discussion

In this chapter, a detailed analysis has been carried out of the early IL vowel systems of eleven Brazilian learners of English as a second language, from the first of four to eight recordings for each subject. Considerable variability has been demonstrated among the early IL systems of these eleven learners, partly because they were not all at the same stage of acquisition at the time of the first recording, and partly because of individual variation in the path and rate of acquisition.

In spite of the inherent variability among different learners, many similarities have been noted. From these similarities, the following proposal has been developed to describe the manner in which a typical English IL vowel schema is constructed by speakers of Brazilian Portuguese. Although this is the only group of learners analyzed in this study, it appears likely that the process of IL vowel schema construction described is typical of any learner of a second language whose vowels cannot all be identified one-to-one with those of the NL system.

It was suggested in 2.3 that a speaker of any language has separate schemata for vowels and consonants, and that each vowel is stored with a prototype of its formant structure relative to the other vowels, its spectral shape, relative length, and other important characteristics. The above analysis has indicated that speakers appear to have a notion of the limits of the vowel system, and of the position of each vowel within those limits. Evidence for this is found in (a) the reluctance or inability of the subjects to enter unfamiliar vowel space; (b) the identification of NL vowels with TL vowels according to relative position, rather than by acoustic proximity; and (c) the consistent positioning of the IL /ʌ/ according to the established limits of the IL system. Thus, it is proposed here that the knowledge stored in a speaker's vowel schema includes an outline of the vowel space occupied by the particular vowel system, which defines the size and shape, and thus the limits, of this system.

When learners are first confronted with the task of acquiring a second language phonology, they cannot instantly construct a new vowel schema to accommodate the vowels of the new language, even if they are aware that there are differences. Thus, initially the NL vowel schema will have to be used to make sense of the new vowels heard. Individual learners probably vary considerably in the length of time they continue to use the NL vowel schema, and this probably depends on many factors, including the similarity between the two languages. Some learners may leave this stage before they begin production, accounting for the fact that not one subject in this study produced all IL vowels exactly like those of the NL.

For some extremely timid learners, the first realization that the vowels of the TL are not like those of the NL may produce insecurity, to which the reaction might be to reduce the size of the speech gestures, causing a reduction in the overall size of the vowel system. This appears to be what occurred with TR (see Figure 4.12), who frequently commented on her apprehensions about having to learn a new language.

For less timid learners, however, the first realization that one or more of the TL vowels are different from those of the NL will cause the addition of allophones of NL vowels, the TL being treated as simply a different context for these old familiar vowels. Those TL vowels which are not similar to any NL vowel may also be appended to the NL schema, by the process called accretion by Rumelhart and Norman (1978), as long as this does not require a change in the overall shape (limits) of the system. A good example is FR, who in his first recording (Figure 4.3), appeared to be still at the stage of using the NL vowel schema, to which he had added an allophone of the NL /ɛ/, which although lower, was still right on the outline of the NL system. He also appended two versions of /ʌ/, one just behind his NL /ɛ/, and one near his probable NL back vowel line. Because it is the relative position of the vowel which is important, the accretion of a new vowel to an old and inadequate vowel schema does not provide the necessary conditions for accuracy, accounting for the lack of precision and consistency in FR's IL /ʌ/.

As demonstrated by the nine other subjects of this study, most learners are not long in discovering the inadequacy of the NL vowel schema to account for the TL. Restructuring occurs; i.e., a new schema is constructed, based on the pattern of the old NL schema. This means that the NL nodes (vowels) which can be matched up with TL vowels in terms of relative position define the shape of the new IL vowel schema. For Brazilian learners of English, those vowels are /i/, /e/ or /ei/, /ɛ/, and /ɔ/ (and possibly /o/ or /ou/ and /u/, but this portion of the vowel system cannot be commented on from the data in this study). Those which cannot—/a/ for the learners in this study—are excluded from the new vowel schema.

Most L2 learners are sensitive to the acoustic differences between the vowel systems, so these matched nodes take on a new position in the new vowel system. However, the position of each IL vowel is apparently not determined, as suggested by Flege, through phonetic approximation from the position of the NL vowel toward the position of the TL vowel. Because of the different number of TL vowels and the different realization of each one, it is difficult for learners to identify each sound in the TL input with the appropriate vowel phoneme. For this reason, the positioning of the IL vowels involves a phonetic approximation from the position of the NL vowels vaguely toward the TL vowel line defining the outer limits of the TL system. Thus, the overall limits of the new IL schema are extended (or reduced) in the direction of the overall TL input, but the relative position of each vowel in the early IL system is only minimally different from the corresponding NL vowel.

Finally, any TL vowel which is within the acoustic limits of the new IL schema but has not been identified with a NL vowel—/ʌ/ for the learners of this study—is added to the new IL schema, positioned according to its relative position in the TL, though perhaps without precision. In the case of the English /ʌ/, the most important aspects of its relative positioning are generally adhered to in the IL—it cannot be lower than the lower vowel line, and it must be between the two lower vowels on the F2 axis.

The above account of the process of construction of the IL vowel schema necessitates a revision in the three types of bilingual phonological organization proposed by Paradis (1981, see 2.3.1). The first type, in which bilinguals have one extended system with all the phonemes from both languages, corresponds to the early stage described above where new vowel phonemes or allophones are appended to the NL schema. The second type, in which bilinguals have a separate network of neural connections for the phonemes of each language, would be the type of phonological storage employed by bilinguals with absolutely no L1 or L2 phonological interference. Although there are certainly proficient bilinguals who have no *noticeable* L1 or L2 interference, many applied linguists (e.g., Scovel, 1969, 1989) believe that a thorough analysis would demonstrate some degree of phonological interference in all bilinguals. Whether or not this is true, it certainly is true that many *apparently* "perfect" bilinguals will demonstrate interference under conditions of fatigue or stress.

The third type, the tripartite system, in which bilinguals have one system for those phonemes common to both languages, plus two different systems for those phonemes which are peculiar to each of the languages, would not allow for vowels to be positioned in relation to the rest of the vowel system. It is thus incompatible with the construction process proposed above, and with the evidence presented in the previous sections. To account for the process of IL vowel schema construction proposed above, what is needed as the third type of division of phonological systems is one almost like the second, in which there is a distinct network of neural connections for the phonemes of each language, but in which there are also some connections between the two distinct networks.

This type of neurolinguistic organization would allow for the relative positioning of IL vowels. It is also consistent with evidence presented by both Flege (1981) and Major (1989), that in the phonological systems of proficient bilinguals, there is both influence from the L1 on L2 phonemes and influence from the

L2 on L1 phonemes. The phoneme prototypes of each language would be based to a large degree on the average input from the appropriate language. However, the connections between the networks would allow also for some influence of stored or new input on the phonemes of the wrong language. The more proficient the bilingual, the less frequently the inter-system connections would be activated, and thus the less interference would occur. In fact, since the frequency of activation of inter-system connections would determine the level of bilingual proficiency, these separate but connected systems could account for the perfect or near-perfect bilingual, making Paradis's second type of organization unnecessary. We are left, then, with two types of organization: that of one extended system, and that of two systems with connections between them.

Notes

1 The possibility of measurement inaccuracy must be considered here. This is the only month in which measurements of the F1 of CL's /i/-/ɪ/ were so low, and it is difficult to determine F1 values in the lower ranges when the fundamental frequency is high.

2 This is true even if the measurements for CR's NL /i/ are inaccurate. They are unusually low, like those of CL's first month IL /i/-/ɪ/, and might be inaccurate, for the same reasons given in note 4.

5. Findings: The Evolving Interlanguage Vowel System

The previous chapter examined the first research question, describing the manner in which the early IL vowel systems of eleven Brazilian learners of English were first constructed and the extent to which they were modeled on the NL and assumed TL vowel systems. It was proposed that, after an initial period during which the NL vowel schema is used for communication in the TL, an IL schema is constructed, modeled on the NL schema, and modified as a unit to approximate the TL.

This chapter reports the findings of the remaining five research questions posed in 3.1, which were investigated through the tracing of the subsequent development of these newly constructed IL vowel schemata. This part of the analysis was based on an examination of each individual subject's IL vowel system, plotted month by month with his or her NL vowel system and the Ohnishi data representing the assumed TL system. The vowels of the NL and IL systems are represented in the figures of this chapter by ellipses drawn with radii of two standard deviations from the mean F1 and F2 frequencies of each vowel. Points for individual IL tokens are included where needed for clarification. The TL vowels are represented by points designating mean formant frequencies from the Ohnishi natural-speed data, joined by straight lines.

The second research question asks whether the data would provide evidence for a link between acquisition of the new TL vowels and adjustment of the old vowels of the IL systems (i.e., those with Portuguese counterparts). Evidence of vowel acquisition, in this and the following research question, was considered to be the separation of the ellipses of two vowels to be contrasted. A relevant vowel adjustment was an adjustment of the ellipse of one or more adjacent vowels which opened up acoustic space for the emerging contrast. It will be seen in this chapter that there were only a few cases of actual separation of two vowels to be contrasted, but these cases did appear to require adjustments in adjacent vowels. The bulk of the evidence for this question was found in the form of vowel distinctions *not* acquired, due to the *failure* to open up the necessary acoustic space.

The third research question asks whether adjustment of the old IL vowels would occur *before or at the time of* acquisition of the new TL vowels, according to the prediction based on Rumelhart and Norman's model, or *after*, according to the prediction based on Karmiloff-Smith's model. As stated in 3.1, references to Karmiloff-Smith's model are necessarily to processes occurring *after* phase 1, because of evidence of reorganization of the vowel system (see 2.3.2). In general, the acquisition of the new TL vowels was found to require the previous or simultaneous adjustment of the old IL vowels. However, there was one case where separation of two vowels began, the adjacent vowels were adjusted, then vowel separation was concluded. Possibly the processes described by the two cognitive models can sometimes work together.

The fourth, fifth, and sixth research questions involve the manner of vowel adjustment, i.e., the direction and degree of change in the position of the ellipses, and related changes in size. The fourth research question asks whether adjustments in the subjects' IL vowels would be made suddenly and involve major changes in the outline of the vowel system, implying a process like *restructuring*, or gradually and locally, implying something more like *tuning*. Both types of adjustments were found, apparently depending on the particular vowels to be distinguished. The fifth research question asks whether, where vowel adjustments occurred gradually, this would mean a gradual linear approximation toward a target or there would be detours off in other directions. Subjects were found to be inconsistent in this respect also, but non-linearity was widespread. The sixth research question asks whether the "phonetic repertoire" (variance) of each phoneme would follow the expected tendency of "expanding" (increasing) and then "shrinking" (decreasing) in approximation of the target. Because of the small number of tokens per vowel per month for each subject, and because of the relatively short time period of the study, this question was difficult to answer with confidence, but change in size of variance did appear to be an important factor in vowel adjustments.

As is often the case when dealing with human behavioral data, the findings on the above research questions are not as clear-cut as might be desired. One of the main problems in the analysis was the fact that the subjects did not make as much progress as was hoped for in the acquisition of the relevant vowel distinctions. In spite of their limited progress, however, some important similarities were observed in the process of acquisition.

Findings are reported for each subject separately, then summarized for the male subjects and for the female subjects. Conclusions are drawn regarding the research questions, and finally, in the discussion section, a proposed model of the process of vowel acquisition is outlined, which completes the model begun in Chapter Four.

As the following analysis will demonstrate, the position of /eɪ/ appeared to be a key factor in the IL systems of all the subjects, influencing the acquisition or non-acquisition of the two difficult front vowel distinctions—the /ɪ/ from /i/ and, to a lesser extent, the /æ/ from /ɛ/. The positions of /i/-/ɪ/ and /eɪ/ appeared to be mutually dependent in all eleven IL systems, whether or not progress toward separation of the higher vowel pair was made. In the IL systems of several subjects, the position of /eɪ/ appeared to be virtually blocking the acquisition of the /i/-/ɪ/ distinction. In the IL systems where acquisition of the distinction occurred—only those of CL and CR—it clearly seemed to be dependent on the position of the lower vowel. The inappropriately high position of /eɪ/ may also have initiated the process of separation of /ɛ/ from /æ/ in the IL systems of NR, SN, and TR, by allowing the temporary but equally inappropriate raising of /ɛ/. Only in SN's system was this strategy subsequently replaced by the more appropriate strategy of lowering /æ/.

Another key relationship which will be demonstrated in the following analysis is the relationship among the three lower IL vowels /ɛ/-/æ/, /ɔ/, and /ʌ/. For the male subjects, whose *relative* positioning of these vowels was mostly almost target-like from the beginning because of a greater similarity between the NL and TL systems, there appeared to be an attempt to maintain those relative positions. This is an indication that the acquisition of the /ɛ/-/æ/ distinction would depend on adjustments in the other two vowels. This dependence was actually born out for only one subject—SN—who was the only one to begin separating /æ/ from /ɛ/. For the female subjects, whose relative positioning of the three lower IL vowels was mostly non-target-like in the beginning, the acquisition of the /ɛ/-/æ/ distinction would be expected to be more difficult. Although none of the female subjects actually began to separate these two vowels by the end of the study, CL and VN did make progress toward improving the relative positioning of the three lower vowels by lowering the /ɛ/-/æ/ and making simultaneous adjustments in the other two. For both the male and female subjects, because of the interrelationship among the three lower vowels, the appearance of a distinct /æ/, as well as a target-like realization of /ʌ/, appeared to necessitate an extension of the overall lower vowel space.

A final similarity among ten of the eleven IL vowel systems is that, from the second month on, the new English vowel /ʌ/ was a distinct vowel in all but VN's IL system. Although this English vowel is acoustically quite close to the Portuguese /a/, the IL version was kept distinct from the lower IL vowels by its inappropriately high position.

In the following account of the development of the eleven individual IL vowel systems, research questions 2 to 6 are thoroughly investigated, and the interrelationships among the vowels of each IL system can be observed more clearly.

5.1. Male subjects

5.1.1. FR

FR's first to sixth-month IL vowel systems are plotted in Figures 5.1 to 5.6. As demonstrated in these plots, FR did not learn to produce a distinction between English /i/ and /ɪ/ during the course of the study. On the contrary, the two vowels appeared to be produced according to a single representation throughout the six-month period. This /i/-/ɪ/ phoneme gradually lowered from above the target area of /i/ to midway between the target areas for /i/ and /ɪ/ by month six. Apparently, FR was becoming gradually more receptive to the input from /ɪ/ over the six-month period, but this input contributed to the readjustment of the old vowel representation, rather than to the creation of a new one.

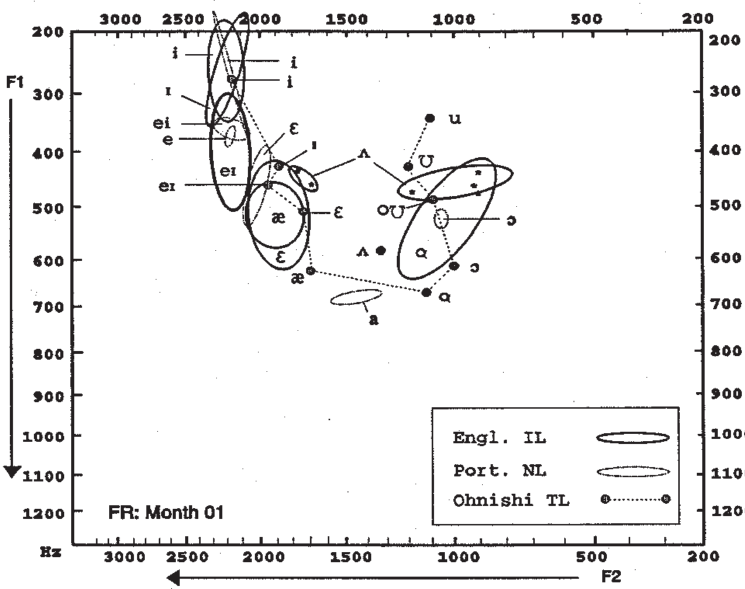

Figure 5.1. Plot of FR: English IL Vowels - Month 01.

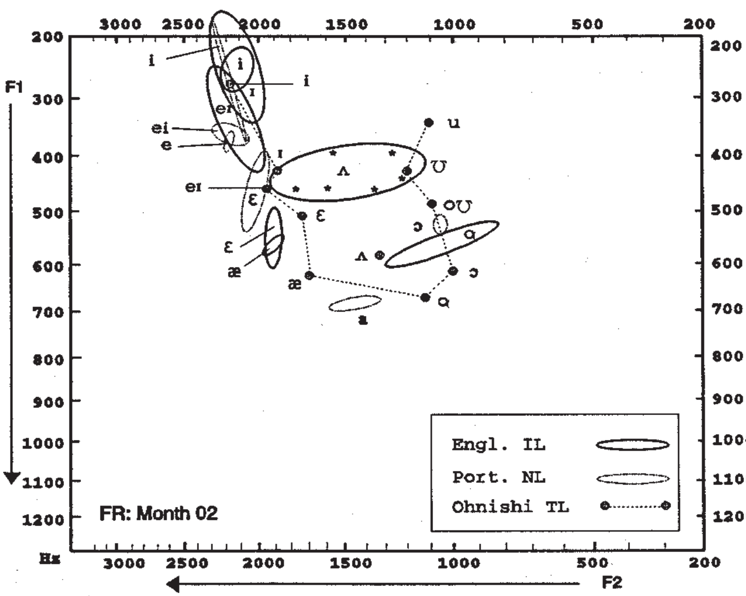

Figure 5.2. Plot of FR: English IL Vowels - Month 02.

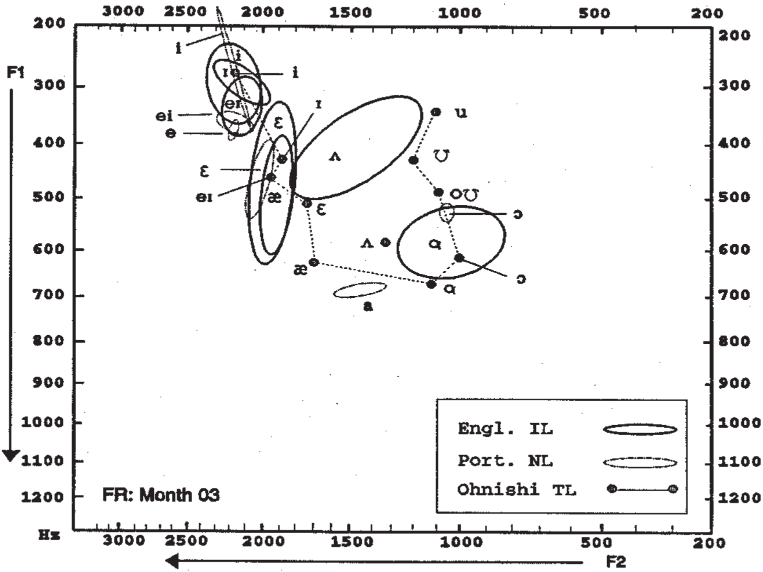

Figure 5.3. Plot of FR: English IL Vowels - Month 03.

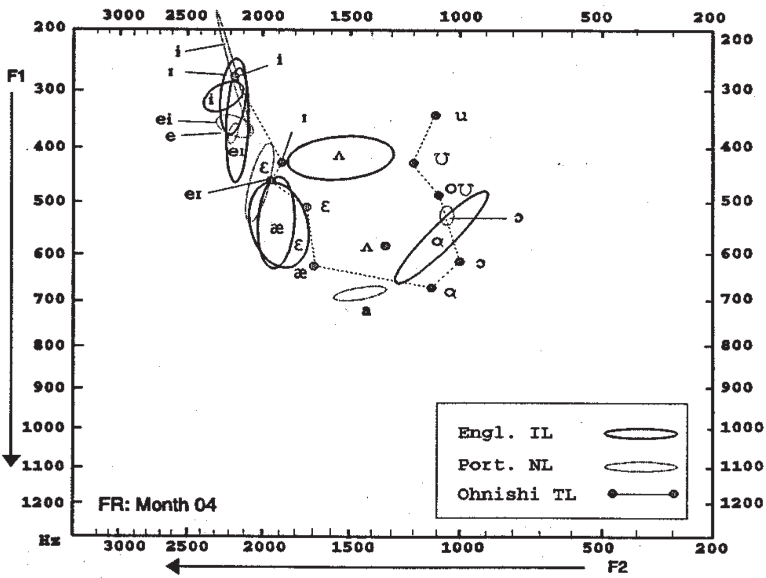

Figure 5.4. Plot of FR: English IL Vowels - Month 04.

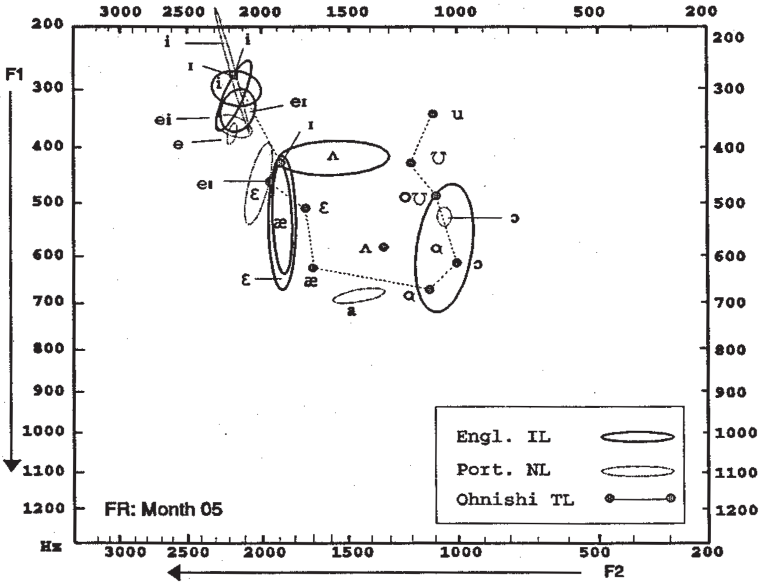

Figure 5.5. Plot of FR: English IL Vowels - Month 05.

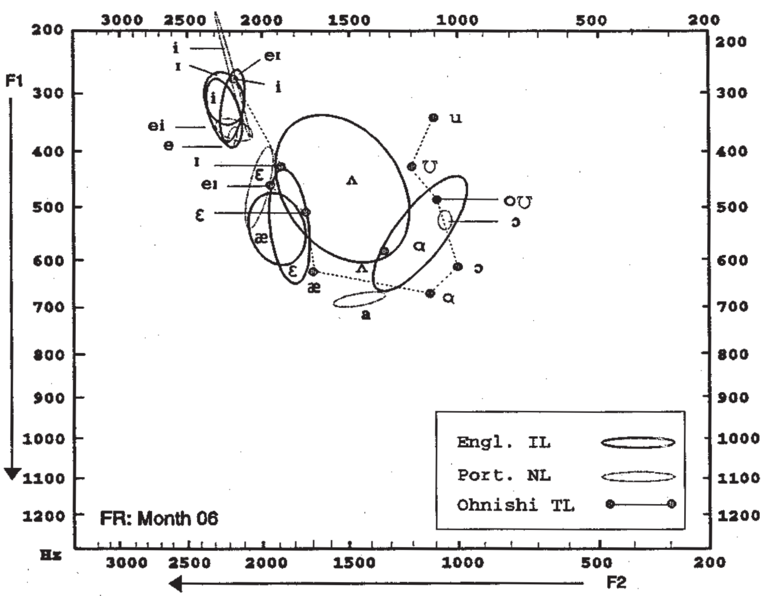

Figure 5.6. Plot of FR: English IL Vowels - Month 06.

The further lowering of the IL /i/-/ɪ/ phoneme and the eventual distinction between these two vowels appear to have been inhibited by the location of FR's IL /eɪ/. The ellipse of this vowel began between the heights of NL /e/ and /ei/ and TL /ɪ/, with only a slight overlap with /i/-/ɪ/. It raised gradually during subsequent months, until totally overlapping /i/-/ɪ/ in month six and becoming higher than the NL vowels, that is, "more Portuguese than Portuguese itself," adapting Fourakis and Iverson's phrase (see 2.1.2) to the present study. While the creation of an /ɪ/ would have required the opening up of a space between /i/ and /eɪ/, what occurred was just the opposite—that space closed even further. FR's /i/ and /ɪ/ were essentially identical in both formant structure and duration throughout the study, but his /eɪ/ was consistently distinguished by its longer duration, and sometimes by its diphthongal trajectory.

This subject also did not learn to produce a distinction between English /ɛ/ and /æ/. What appeared to be lacking for the creation of an /æ/ phoneme was not space between two vowels, but simply a greater *total acoustic vowel space*, despite the fact that this subject could have made a more open vowel, as demonstrated by his NL /a/.

It was noted in 4.3.1 that FR's /ʌ/ was realized alternately as a front or as a back vowel in the first month. Its two ellipses can be seen in Figure 5.1 to overlap with both /ɛ/-/æ/ and /ɑ/. FR did learn, after the first month, to centralize this vowel and thus distinguish it from his /ɛ/-/æ/ and his /ɑ/, but he was inhibited from lowering this vowel to the appropriate height because his /æ/ and /ɑ/ were also too high, and an appropriate realization of /ʌ/ would have interfered with the position of this vowel relative to the other two.

Only in the last month of the study did FR begin to lower his /ʌ/ somewhat, by considerably increasing the variance. He could not lower it any farther, however, and continue to maintain its distinction from /ɛ/-/æ/ and /ɑ/, because his /ɑ/, by the sixth month, had moved forward, diminishing the distance between the lower front and back vowels. Most likely, FR will need to lower /ɑ/ and possibly even acquire /æ/ before he can produce a more accurate /ʌ/. In other words, what appears to be necessary is a greater *total acoustic vowel space*.

In sum, because FR had acquired only one of the three new vowels (and that one inaccurately) by the end of the six months of the study, the data do not provide positive evidence for a link between vowel acquisition and adjustment. However, they do provide negative evidence for this link. It was demonstrated in two cases that vowel B could not be distinguished from vowel A, or made more accurate, because vowel C was occupying at least part of the acoustic space to which vowel B needed to move. There was *no* space between his IL /i/-/ɪ/ and /eɪ/ for the creation of a distinct /ɪ/, and there was insufficient space between his /ɑ/ and his /ɛ/-/æ/ to lower his IL /ʌ/. For the creation of an /æ/ phoneme, however, all that was lacking was the ability to enter unfamiliar vowel space.

With no distinction having been made between /i/ and /ɪ/ or between /ɛ/ and /æ/ by the end of the study, the third research question regarding order of occurrence of acquisition and adjustment is not applicable for this subject.

Vowel adjustment did occur, however, and the last three questions will now be examined. FR's /eɪ/ raised gradually, in non-linear fashion, mostly by a decrease in variance, although the first raise, in the second month, involved essentially no change in variance. The "backsliding" which occurred in the fourth month involved a return to the larger variance. (The term "backsliding" usually refers to a return to a less accurate realization; but here, because the overall adjustment is in the wrong direction, it refers to the return of a more accurate realization.) Unless the subject fossilizes, this vowel can be expected to lower again, making the overall adjustment even less linear.

FR's /i/-/ɪ/ was also adjusted by a decrease in variance, the higher realizations of this vowel being gradually eliminated. Adjustment of this IL phoneme was linear during the six-month period, but if the two vowels are eventually distinguished, this will involve adjustment of /i/ in the opposite direction.

FR's /ʌ/ was first changed in month two by the sudden fronting of the three posterior realizations. It remained stable during four months, with only a slight decrease in variance, then was adjusted again in month six by an increase in variance—a considerable lowering of two of the six realizations. Thus, although rather abrupt changes have occurred in the vowels of individual words, the overall change has been gradual in the sense that it has affected only part of the lexicon at a time. The adjustments in this vowel have not been linear in the sense of a constant move in a single direction, but there has not been any backsliding.

Overall, FR's vowel adjustments have been minimal, gradual, non-linear, and inconsistent as to the increase or decrease in variance. It was suggested in 4.3.1 that FR may have been still using his NL vowel schema, with the appended vowel phoneme /ʌ/ and an additional allophone for /ɛ/. This may be the reason for such minimal change over the six-month period of the study.

5.1.2. MR

Figures 5.7 to 5.12 demonstrate that MR did not begin to produce the /i/-/ɪ/ distinction or the /ɛ/-/æ/ distinction during the course of the study. Always mostly overlapping, his /i/ and /ɪ/ were most likely produced according to a single representation. This IL /i/-/ɪ/, in month one, was about midway between the target heights for the two vowels, indicating that the input from TL /ɪ/ may have been strong enough to influence the old vowel representation, but not to bring about the creation of a new one.

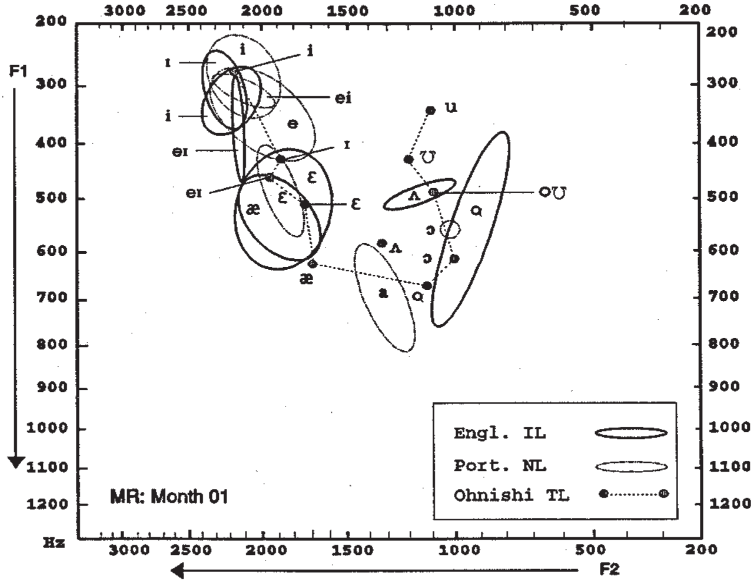

Figure 5.7. Plot of MR: English IL Vowels - Month 01.

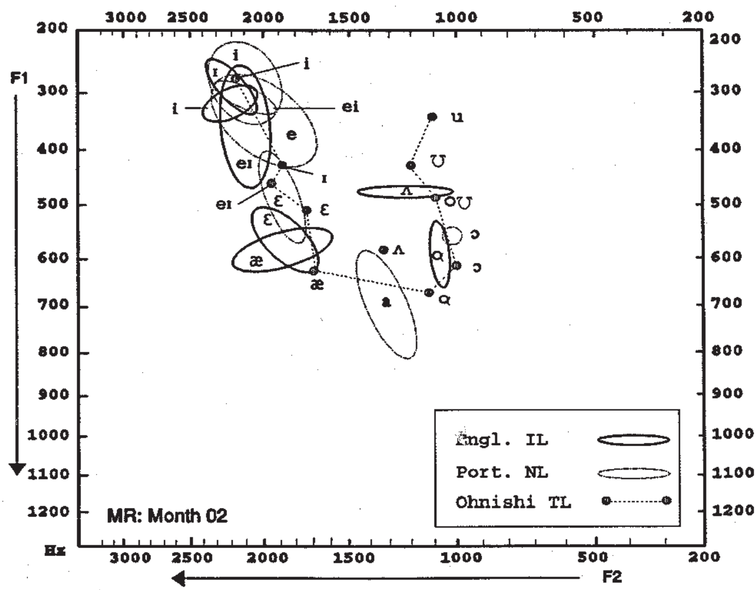

Figure 5.8. Plot of MR: English IL Vowels - Month 02.

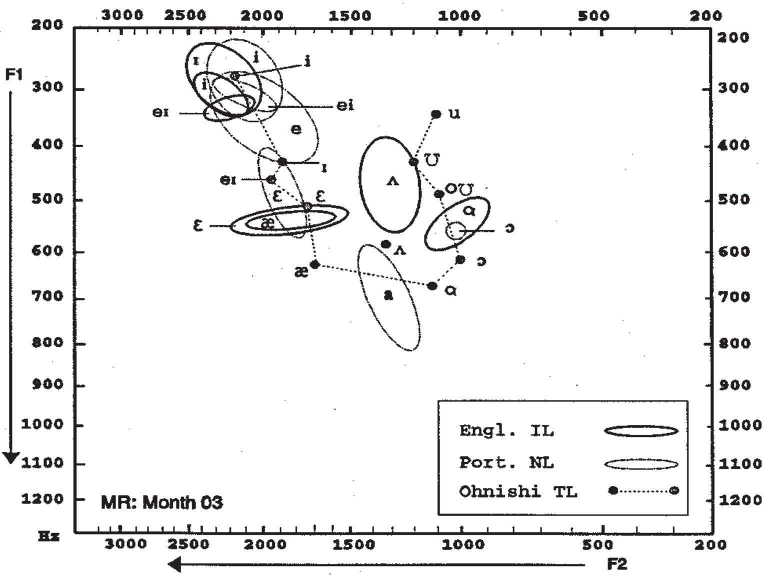

Figure 5.9. Plot of MR: English IL Vowels - Month 03.

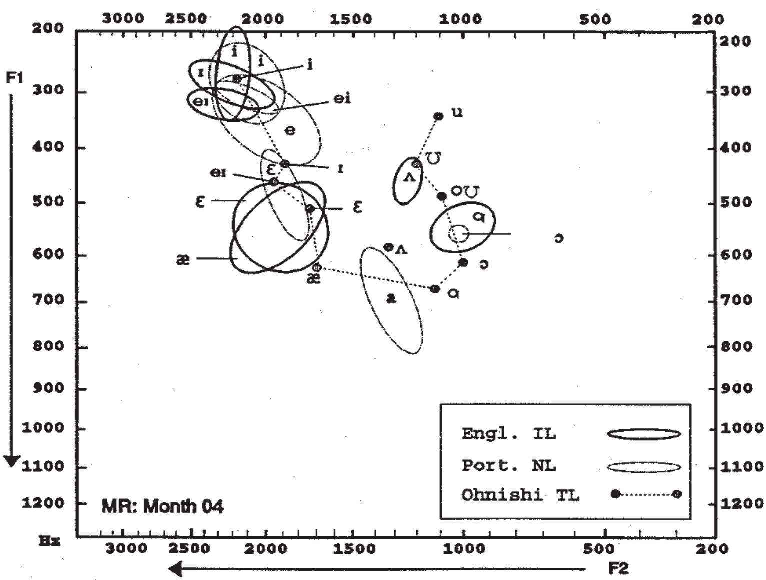

Figure 5.10. Plot of MR: English IL Vowels - Month 04.

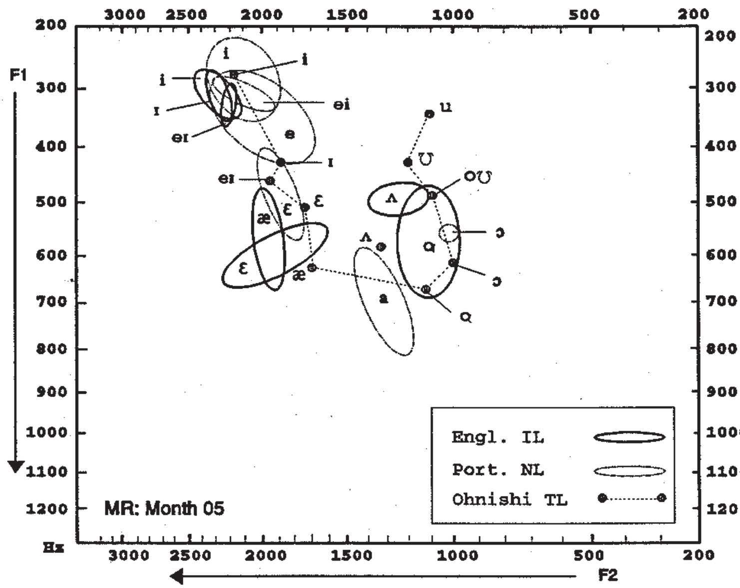

Figure 5.11. Plot of MR: English IL Vowels - Month 05.

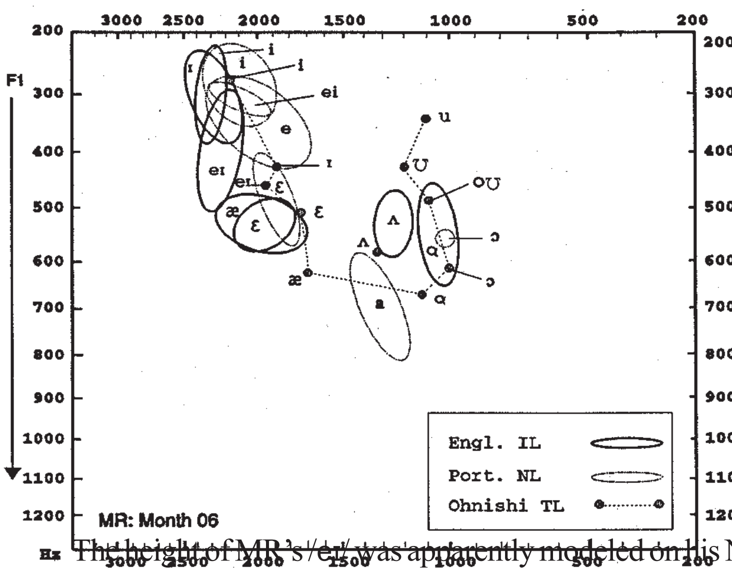

Figure 5.12. Plot of MR: English IL Vowels - Month 06.

The height of MR's /eɪ/ was apparently modeled on his NL /e/, which, contrary to that of the other subjects, was distinguished from /ei/ more by height than by degree of diphthongization. This IL vowel extended from his /i/-/ɪ/ to his /ɛ/-/æ/ in the first two months, thus occupying the target space for /ɪ/. Then, instead of lowering and fronting to make room for a distinct /ɪ/, his /eɪ/ raised during the following three months, by decreasing the variance, becoming more similar to his NL /ei/. This raising of /eɪ/ appeared to force his /i/-/ɪ/ even higher.

In month six, MR's /eɪ/ lowered again, this time by increasing the variance, and moved slightly forward as well. Interestingly, in the same month, /i/ and /ɪ/ also lowered again, still as one, by increasing their variance. Throughout the six months, the /i/-/ɪ/ representation was always located as low as possible without taking over the area occupied by /eɪ/. Because /eɪ/ never lowered past the target area for /ɪ/, the creation of a representation for this new IL vowel was not possible. The lowering of /eɪ/ begun in month six, however, may, in subsequent months, have continued far enough to leave space for a distinct /ɪ/, since in moving forward as well this time, it would not infringe upon the space of /ɛ/. Unfortunately, the study did not continue long enough to confirm this possibility.

MR's IL /ɛ/ and /æ/ underwent no noticeable change during the course of the study, and were always essentially identical, most likely produced according to a single representation. As with FR, what appeared to be lacking for the creation of an /æ/ phoneme was a greater *total acoustic vowel space*.

The relationship between MR's /ʌ/ (already a distinct IL vowel from month one on) and his IL /ɑ/ shows some interesting developments. Although the changes in each vowel over the six-month period were slight, they were apparently not in isolation. The realization of MR's /ɑ/ was quite consistent after the first month, except for a slight movement forward. His /ʌ/ ellipse, which was centered above and only slightly forward of his /ɑ/ in months one and two, moved farther forward of the latter vowel in months three and four, allowing it to lower in the following two months until reaching the same height as /ɑ/ in month six without overlapping. This lowering of /ʌ/ in month six gave the vowel system three low vowels instead of two. This may be the path MR needs to follow in order to lower /æ/ and /ɑ/—his /ʌ/ has lowered as far as possible without reversing the position of this vowel in relation to the other two, which could now be "pushed" into lowering further in subsequent months.

The developments described above constitute both negative and positive evidence in support of a link between vowel acquisition and adjustment. The creation of a distinct IL /ɪ/ and the further lowering of the IL /ʌ/ both appeared to be blocked by the position of adjacent vowels. Although none of the new vowels were acquired during the study, the adjustments to MR's IL /i/-/ɪ/, whether lowering toward the target height for /ɪ/ or raising to the /i/ area, occurred always in parallel with adjustments in the adjacent /eɪ/, indicating the lowering of the former was only allowed by the lowering of the latter. The creation of a third low vowel in month six indicates that MR's IL vowel system needs to occupy a greater total acoustic vowel space, in order to restore the appropriate relative positioning of these three vowels.

Because no new vowel distinctions were acquired by MR during the six months of the study, the third research question, regarding the order of vowel acquisition and adjustment is, as for FR, not applicable.

As to the manner of vowel adjustment in MR's IL system, the adjustment of /eɪ/ was rather sudden, but non-linear; the adjustment of /i/-/ɪ/ was more gradual, and also non-linear; the sequential fronting and lowering of /ʌ/ were gradual and non-linear. His /eɪ/ and /i/-/ɪ/ both raised by decreasing their variance, and lowered by increasing the variance. His /ʌ/ adjusted its position without any noticeable change in variance.

5.1.3. NR

NR, whose first to sixth-month IL vowel systems are plotted in Figures 5.13 to 5.18, also did not produce the /i/-/ɪ/ or the /ɛ/-/æ/ distinction during the study, and the development of his /i/-/ɪ/ appeared to be influenced by that of his /eɪ/. NR's /eɪ/ began with a small ellipse in month one, located just below and forward of his NL /e/ and /ei/, and thus at the target height but forward of English /ɪ/. It raised steadily over the six-month period, by increasing, then decreasing its variance. By months five and six, it was located even higher than his NL /e/ and /ei/, and thus had become, just like FR's IL vowel, "more Portuguese than Portuguese itself."

NR's /i/ and /ɪ/ appeared to be produced according to a single IL representation, the ellipses varying in unison (there was only one valid /ɪ/ token in the second month—two were pronounced as /aɪ/, i.e., *knight* for *knit* and *fight* for *fit*, and three were inadvertently erased). This /i/-/ɪ/ vowel phoneme began near the target height of English /i/, and raised steadily during the six months, apparently "pushed" up by his /eɪ/. At no time during the study was there ever any space between /i/ and /eɪ/ for the creation of a separate IL /ɪ/.

NR's /ɛ/ and /æ/ were similar throughout the study, but the /ɛ/ ellipse extended somewhat higher in months one, five and six. In month one, it extended up and back, avoiding the space occupied by /eɪ/. By months five and six, /eɪ/ had raised, leaving room for /ɛ/ to extend up and forward along the IL front vowel line. It appears NR was attempting to produce a distinction between the two vowels, but rather than create a new, lower IL representation for /æ/ in an unfamiliar corner of the vowel space, he took advantage of the space left open by the raising of /eɪ/ and make /ɛ/ the new IL vowel.

This partially bears out, for this subject, the prediction made in Baptista (1990), a preliminary report of the first four months

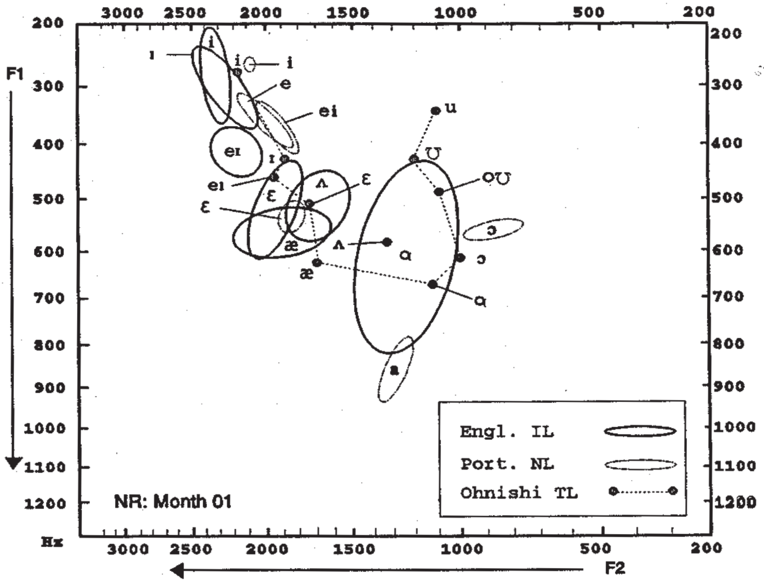

Figure 5.13. Plot of NR: English IL Vowels - Month 01.

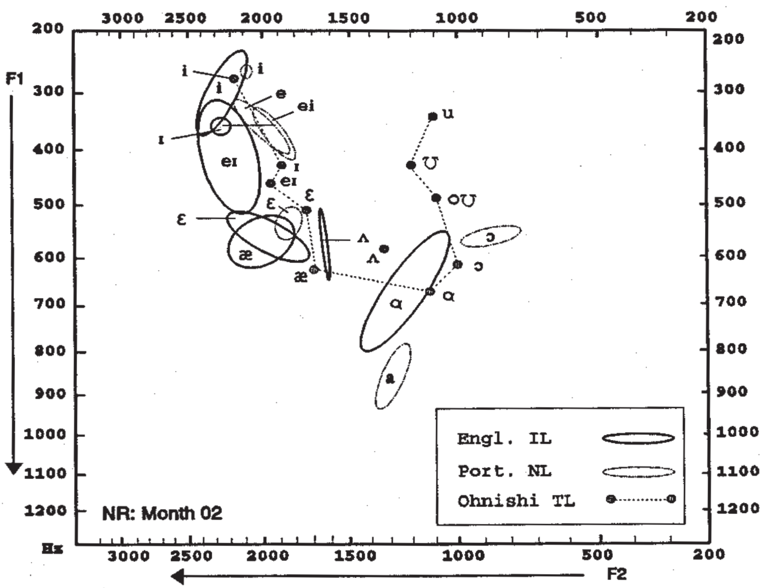

Figure 5.14. Plot of NR: English IL Vowels - Month 02.

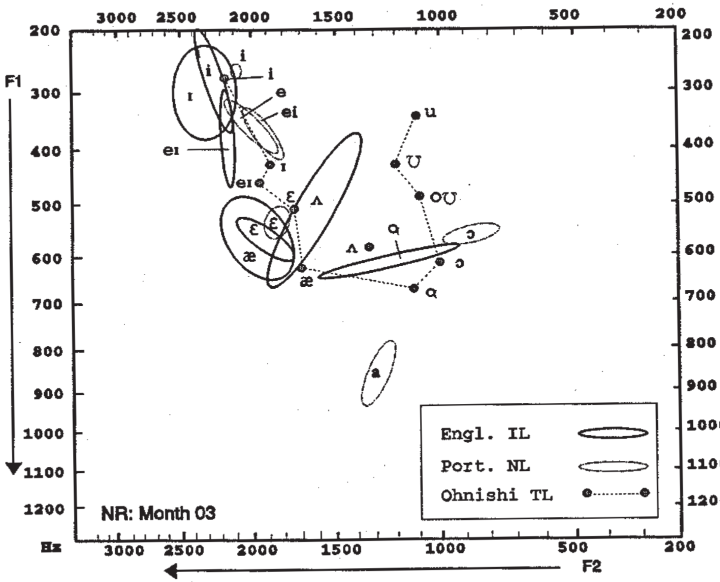

Figure 5.15. Plot of NR: English IL Vowels - Month 03.

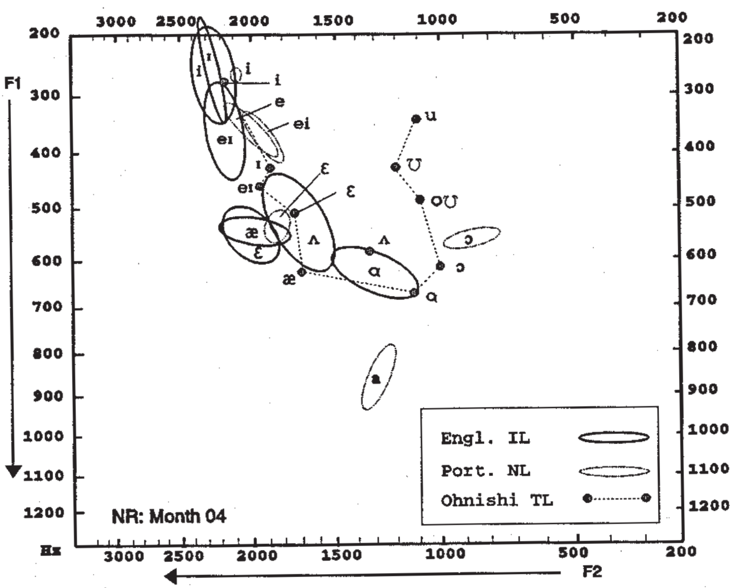

Figure 5.16. Plot of NR: English IL Vowels - Month 04.

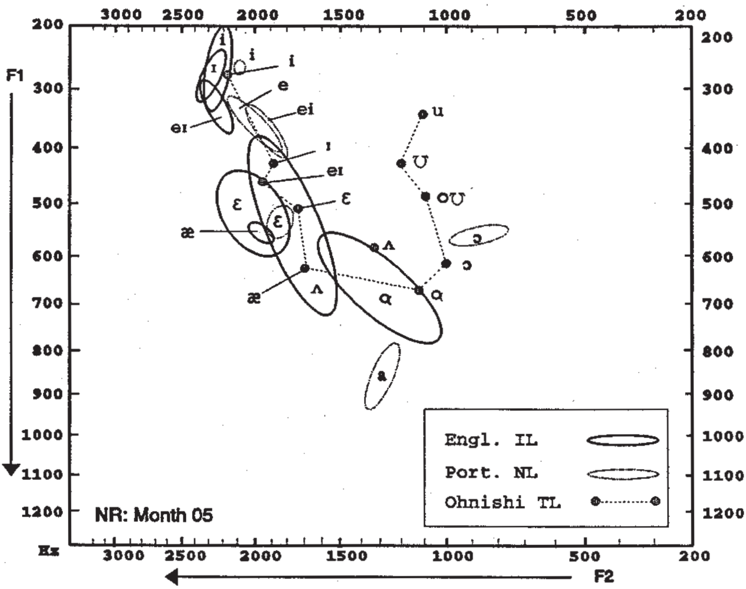

Figure 5.17. Plot of NR: English IL Vowels - Month 05.

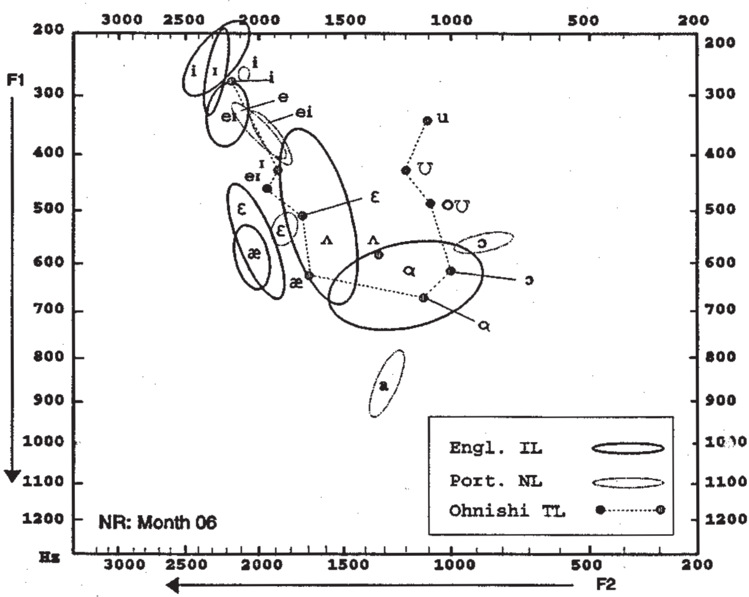

Figure 5.18. Plot of NR: English IL Vowels - Month 06.

of this study, that the acquisition of the /ɛ/-/æ/ distinction by NR and SN would occur before the acquisition of the /i/-/ɪ/ distinction, because of the space left by the raising of IL /eɪ/. A distinction between /ɛ/ and /æ/ arrived at in this manner, however, may not be perceived by native speakers (and English Language teachers), who may hear both sounds as /ɛ/.

NR's /ɑ/ and /ʌ/ varied considerably from month to month, but except for the elimination of a couple of especially high realizations of /ɑ/ after the first month, this variation appeared to be random, making it difficult to identify a tendency to adjust in a particular direction. Both vowels were forward of their target areas throughout, and somewhat high, though not as high as FR and MR's. NR's /ɑ/ consistently occupied the approximate target area for /ʌ/, leaving the latter inappropriately just back of /ɛ/, and sounding somewhat like a French or European Portuguese /ə/.

Once again negative evidence has emerged supporting a link between vowel acquisition and adjustment. NR was not able to acquire /ɪ/ for lack of space between his IL /i/ and /eɪ/, and he was unable to produce an accurate /ʌ/ because his /ɑ/ occupied the target area for this vowel. NR's data supply also some tentative but positive evidence for the link: /ɛ/ began to separate from /æ/ at the culmination of a gradual upward adjustment of /eɪ/. Although in this case, both the adjustment of /eɪ/ and the separation of /ɛ/ from /æ/ began in an inappropriate direction, it still appears to be a case where the adjustment of one vowel allowed the beginnings of a distinction between two others. This is the first piece of evidence which bears upon the third research question. Because the adjustments in /eɪ/ and the partial separation of /ɛ/ occurred simultaneously each time, it appears the tuning of the vowel schemata is necessary for the addition of the new vowel structure, as predicted by Rumelhart and Norman's cognitive model, rather than the reorganization being a product of success, as predicted by Karmiloff-Smith's model.

Like that of the other subjects, NR's vowel adjustment was mostly gradual. The adjustments in NR's /eɪ/ and /i/-/ɪ/ have been linear so far, but unless fossilization occurs, future adjustments will have to be in the opposite direction, to lower /eɪ/ and distinguish /ɪ/. The adjustment of /eɪ/ occurred as predicted by Beebe, by an increase, then a decrease in variance. NR's /i/-/ɪ/ began with a rather large variance, and raised by decreasing this variance. The separation of /ɛ/ from /æ/ appears to be occurring in a non-linear manner, beginning in month one, becoming indistinct again, then beginning again in month five.

5.1.4. NT

NT, whose first to sixth-month IL vowel systems are plotted in Figures 5.19 to 5.24, also did not produce the /i/-/ɪ/ distinction or the /ɛ/-/æ/ distinction during the study. Continuing to follow the trend, the creation of a new IL /ɪ/ appeared to be inhibited by lack of space between his /i/-/ɪ/ and /eɪ/. As that of the other subjects, NT's /eɪ/ occupied an area at the approximate target height for /ɪ/ in months one and two. It raised further in the following months, by increasing then decreasing its variance, becoming again "more Portuguese than Portuguese itself", and lowered slightly again in month six, by increasing its variance.

In contrast to that of MR and NR, NT's /i/-/ɪ/ was not forced upward with the raising of /eɪ/. Instead, his /eɪ/, after totally overlapping his /i/-/ɪ/ in months three and five, separated again with a slight lowering in month six. NT's IL /i/-/ɪ/, already higher than that of his NL, may have reached a physiological upper limit. It should be noted that the separation of /eɪ/ in the acoustic space was not necessary for the purpose of auditory discrimination. Whereas his IL /i/ and /ɪ/ were virtually identical, not only in formant structure, but also in duration and direction of diphthongal trajectory (when there was a glide, it was always a falling glide); his /eɪ/ was consistently much longer, and any diphthongization was always with a rising glide. In spite of the

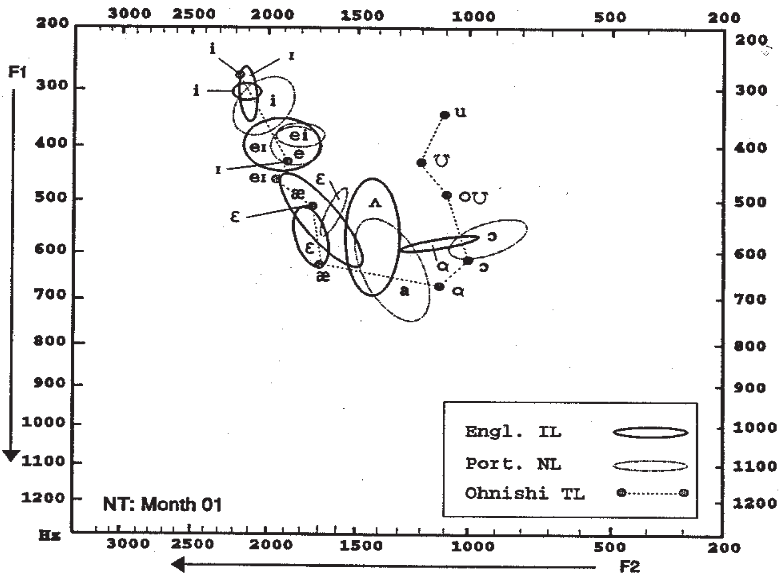

Figure 5.19. Plot of NT: English IL Vowels - Month 01.

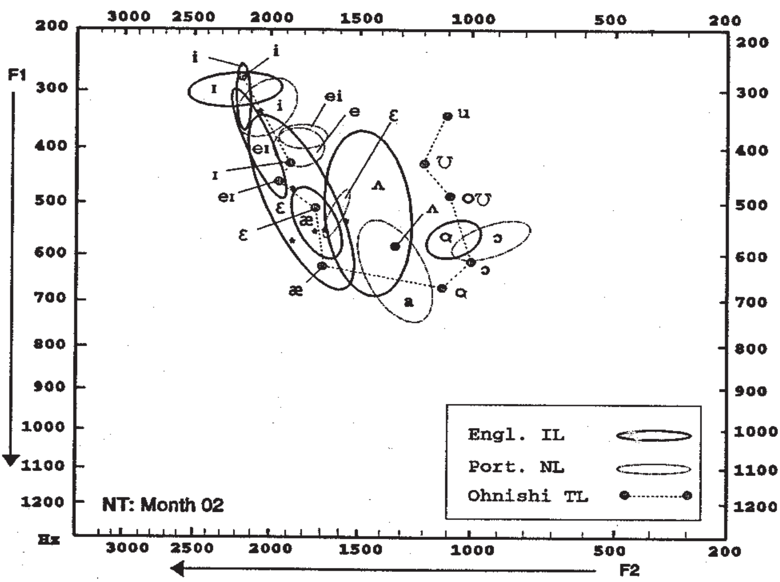

Figure 5.20. Plot of NT: English IL Vowels - Month 02.

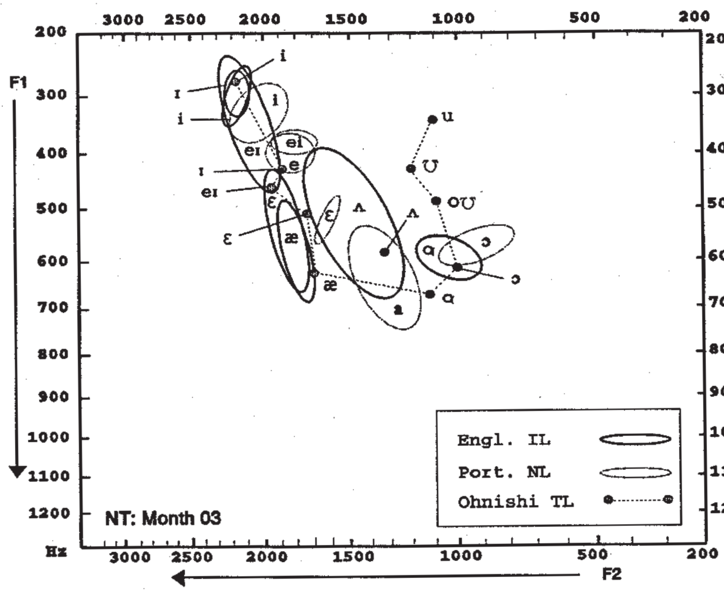

Figure 5.21. Plot of NR: English IL Vowels - Month 03.

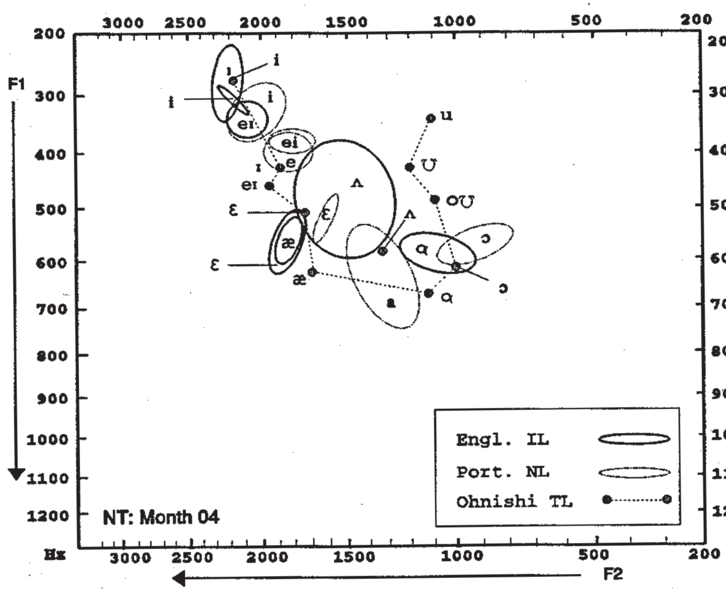

Figure 5.22. Plot of NT: English IL Vowels - Month 04.

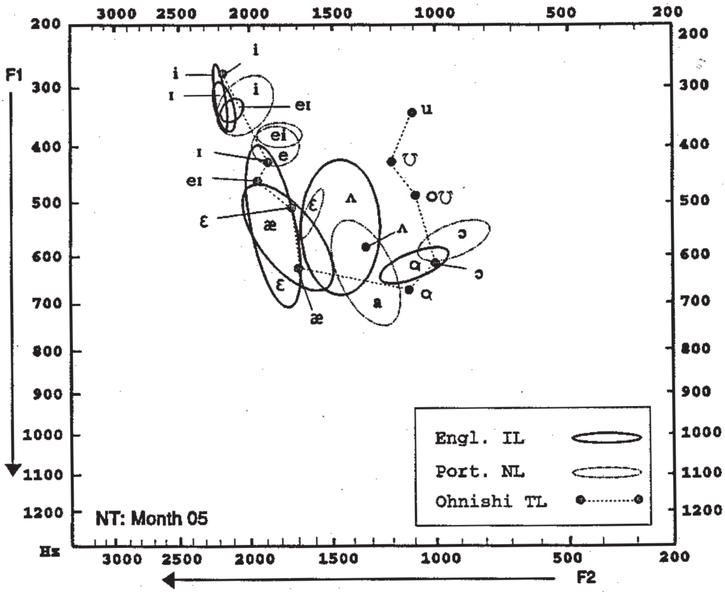

Figure 5.23. Plot of NT: English IL Vowels - Month 05.

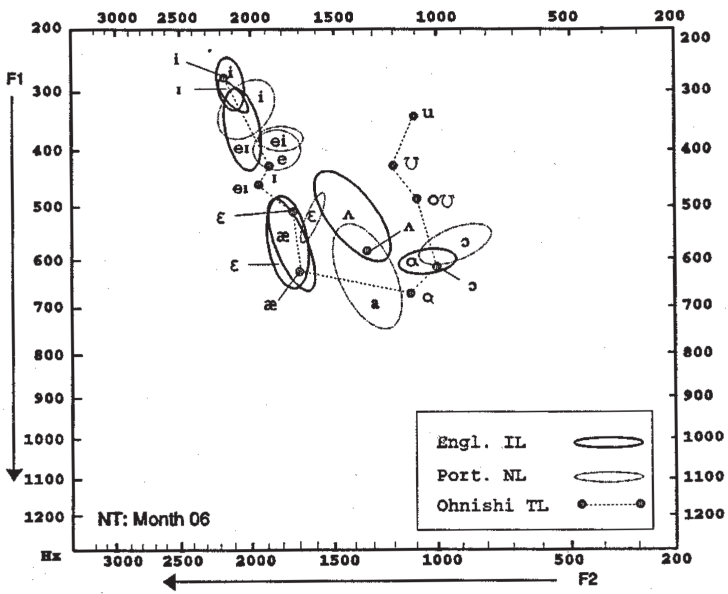

Figure 5.24. Plot of NT: English IL Vowels - Month 06.

lack of auditory confusion between /eɪ/ and /i/-/ɪ/, NT appeared to be compelled to separate them when they reached the point of total overlap.

NT's IL /ɛ/ and /æ/ also appeared to be produced according to a single representation. They were essentially identical throughout the course of the study, and varied little from month to month, located mostly between the approximate target heights for the two English vowels. Only in month two did /ɛ/ appear to raise somewhat, overlapping with /eɪ/, but it was only one stray token responsible for the upper extension of this ellipse.

NT's IL /ʌ/ and /ɑ/, in month one, were at the same approximate height as his /ɛ/-/æ/. His /ɑ/, with a consistently small variance each month, remained at this height throughout the study. His /ʌ/, whose ellipses were mostly quite large, underwent a gradual raising over the six-month period, by an increase, then a decrease in variance. By month six, this vowel was in an almost appropriate position relative to the two lower vowels, but farther from the absolute target position.

There were two apparent motivations for the raising of NT's /ʌ/. Not only was there very little perceptual distance among the three lower IL vowels when /ʌ/ was at the same height as the other two, but the raising was necessary to obtain the appropriate relative positions of these three vowels. Once again, the situation is one of a reduced total vowel space. Because the lowering of any one of these three vowels without the other two would interfere with the relative positioning of the three, the creation of an /æ/ and the accurate realization of /ʌ/ depend, in a sense, on the adjustment of the old vowel /ɑ/.

NT's data have provided us with further negative evidence for a link between vowel acquisition and adjustment: (a) The creation of an IL /ɪ/ was blocked by the inappropriate positioning of /eɪ/; and (b) the creation of an IL /æ/ and the lowering of /ʌ/, although not actually blocked, could not occur without upsetting the overall relative positions of the lower three IL vowels. With the analysis of each additional subject's vowel system, the notion of total vowel space gains importance. For this subject also, the third research question is non-applicable because no new vowel distinctions were acquired.

Overall, NT's IL vowel system underwent very little change during the course of the study. The non-linear adjustments in his /eɪ/ amounted to almost no change overall, because the vowel returned almost to its first-month position. The adjustments in his /ʌ/ were almost linear, but minor. Both vowels were adjusted gradually, by an increase followed by a decrease in variance.

5.1.5. SN

SN's first to eighth-month IL vowel systems are plotted in Figures 5.25 to 5.32. Although SN participated in the study during two extra months, he did not come any closer to acquiring the /i/-/ɪ/ distinction than any of the other subjects. On the contrary, his ellipses for these two vowels were almost identical during all eight months, indicating that a single representation was responsible for the realization of both vowels.

This representation did not remain stable, however, and the adjustments made occurred simultaneously with those made for /eɪ/. In month one, SN's /eɪ/ appeared to be modeled on his NL /ei/, which put it just above the target height of /ɪ/. His /i/-/ɪ/ phoneme was at the height of his NL /i/, and thus above the TL /i/. His /eɪ/ and /i/-/ɪ/ both lowered somewhat in month two, then raised in months three and four, the /eɪ/ closing the space that had existed between them, and remained relatively stable for the last four months. In month four the IL /eɪ/ was slightly higher than his NL /e/ and /ei/, once more "more Portuguese than Portuguese itself." The space that had separated these vowels in the first two months failed to open up again, thus blocking the creation of a separate IL /ɪ/ between /i/ and /eɪ/.

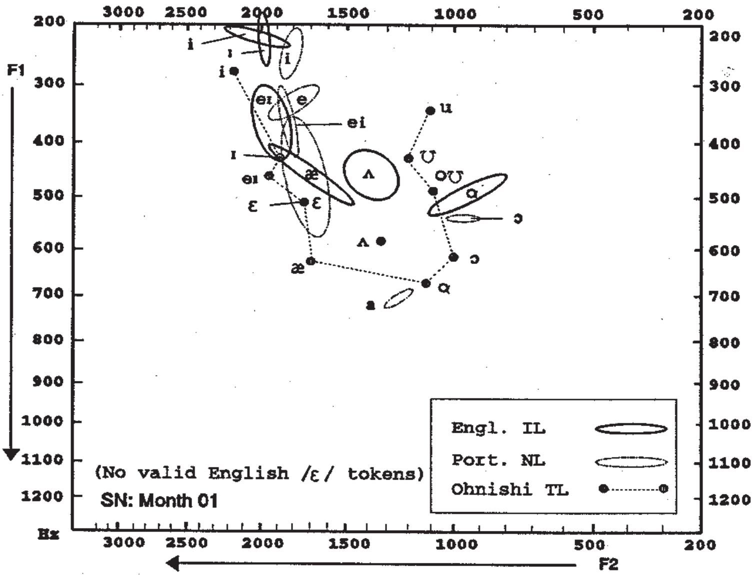

Figure 5.25. Plot of SN: English IL Vowels - Month 01.

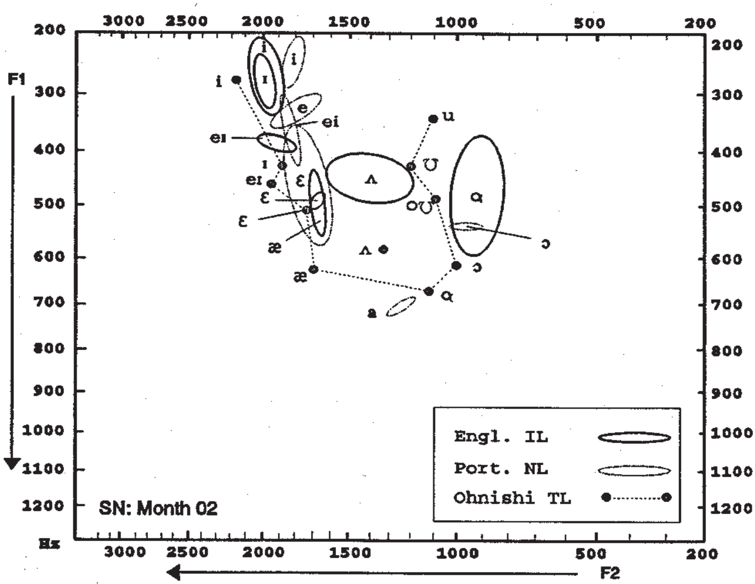

Figure 5.26. Plot of SN: English IL Vowels - Month 02.

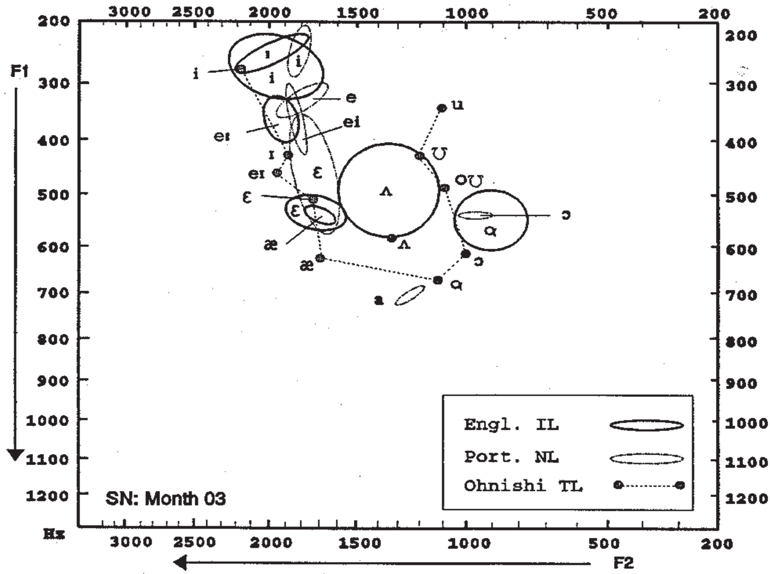

Figure 5.27. Plot of SN: English IL Vowels - Month 03.

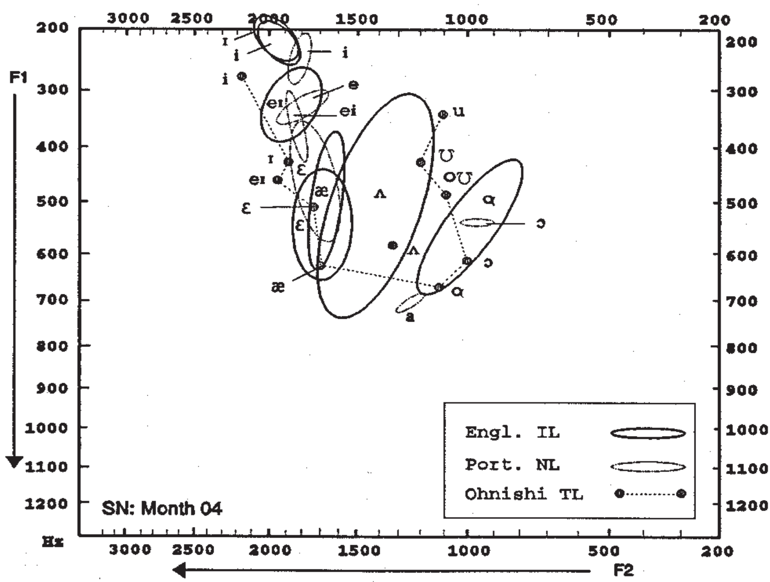

Figure 5.28. Plot of SN: English IL Vowels - Month 04.

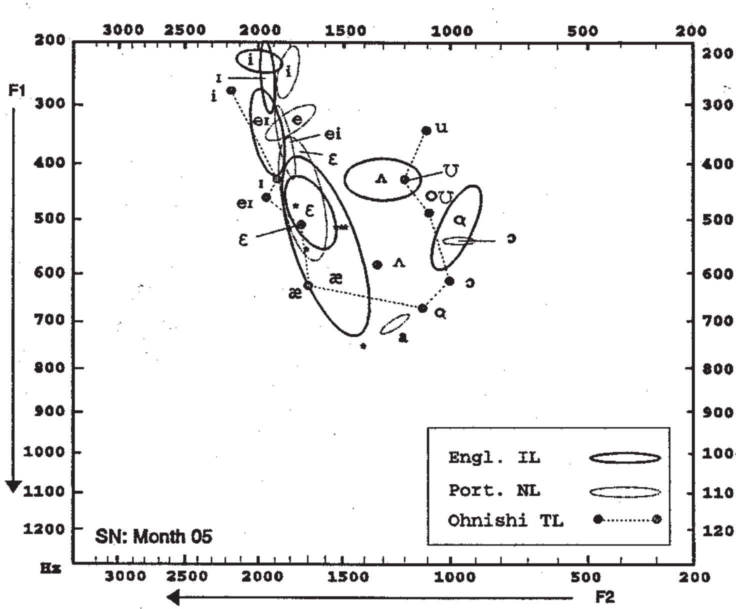

Figure 5.29. Plot of SN: English IL Vowels - Month 05.

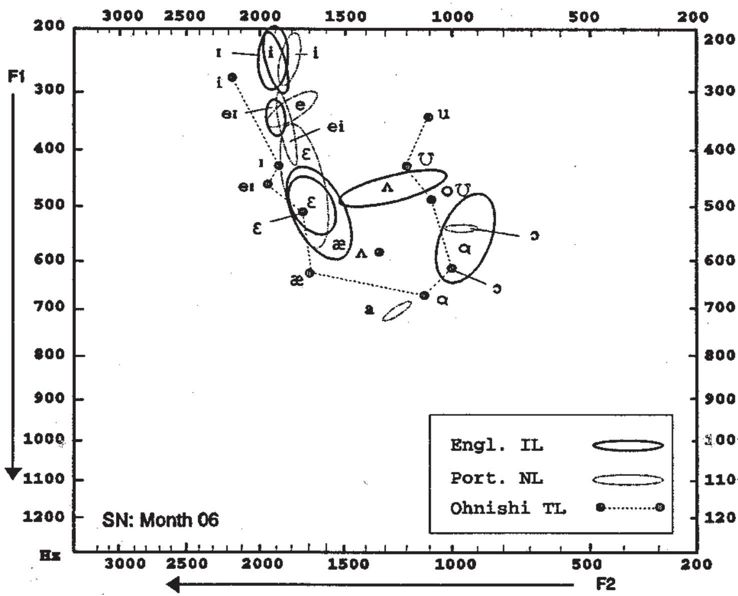

Figure 5.30. Plot of SN: English IL Vowels - Month 06.

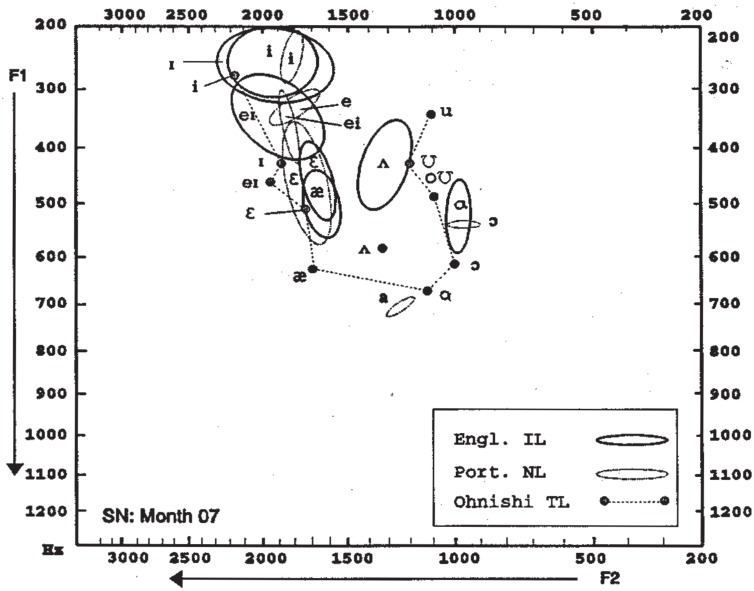

Figure 5.31. Plot of SN: English IL Vowels - Month 07.

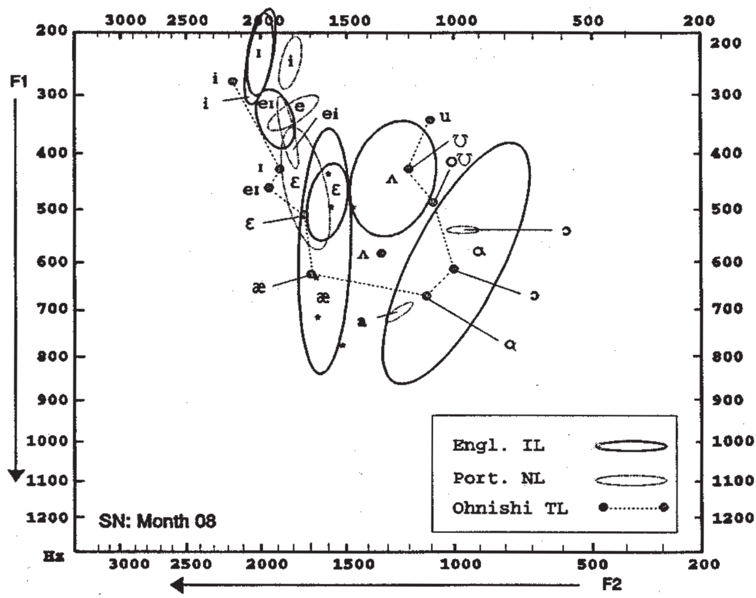

Figure 5.32. Plot of SN: English IL Vowels - Month 08.

SN did not fully acquire the /ɛ/-/æ/ distinction during these eight months, but there are clear signs that he was on his way to doing so. In month one, there were no valid tokens for /ɛ/. His /æ/ was almost identical to his NL /ɛ/, and thus slightly above the TL /ɛ/. Having identified English /æ/ with his Portuguese /ɛ/, he had no idea how to pronounce the words spelled with the letter *e*, which he realized variously as /eɪ/ (*gate* for *get*), /ɪ/ (*knit* for *net*), and /i/ (*Pete* for *pet*). In month two, SN still pronounced four of the six /ɛ/ tokens as /i/, but the other two apparently according to the same vowel representation as that of his IL /æ/. The IL /ɛ/ and /æ/ ellipses were now occupying the lower half of the area of his NL /ɛ/, and thus the appropriate area for the English /ɛ/. In month three, with four of the six /ɛ/ tokens valid, this IL /ɛ/-/æ/ phoneme lowered slightly below the target height for English /ɛ/. By month four, all /ɛ/ tokens were valid, and the /ɛ/-/æ/ phoneme increased its variance, now occupying the areas of both TL vowels.

In month five SN gave the first sign of trying to create separate representations for the two IL vowels. The /ɛ/ ellipse began to occupy only the area of the appropriate TL vowel, and the /æ/ ellipse increased its variance, extending down past the TL height for this vowel, and slightly farther back. In month six, his /æ/ decreased its variance, but still extended somewhat lower than his /ɛ/. In month seven, both vowels raised slightly, but maintained their relative positions. In month eight, the /æ/ ellipse extended down again—straight down this time, even farther past the TL /æ/ than in month five. Although the adjustments made in months five to eight were not linear, it appears that real progress was being made—the lower extension of the /æ/ ellipse in month five was the result of only one lower token out of the six, whereas the similar extension in month eight was the result of three, distributed evenly across the lower half of the ellipse.

In Baptista (1990) it was predicted that the /ɛ/-/æ/ distinction would be acquired by NR and SN by the inappropriate raising of /ɛ/ to the space left vacant by /eɪ/. Both subjects did indeed begin separation of these two vowels by the raising of /ɛ/, but SN's raising of /ɛ/ was minor, probably because his /eɪ/ returned to its lower position in month five. His lowering of /æ/ was ultimately a more significant adjustment.

SN's IL /ɛ/-/æ/, /ʌ/, and /ɑ/, in months one and two, were much higher than their respective English targets, but in approximately the appropriate positions relative to each other, the /ʌ/ slightly higher than the other two. The adjustments that occurred in these three vowels in subsequent months seemed to show a desire to maintain these relative positions, but complications were caused by the beginning of a separation of /æ/ from /ɛ/. All three vowels (/ɛ/-/æ/ still as one) lowered gradually in months three and four, increasing their variance in month four. In month five, when /ɛ/ and /æ/ were beginning to separate, /ʌ/ and /ɑ/ moved back up with /ɛ/. Then in months six and seven, as /æ/ decreased its variance but remained partially separate from /ɛ/, /ɑ/ began to lower again, this time without the company of /ʌ/. Finally, in month eight, /æ/ was radically lowered by an increase in variance, accompanied by an equally radical lowering of /ɑ/.

It seems clear that there is a connection between the adjustments of SN's /ʌ/ and /ɑ/ and the partial separation of his /ɛ/ and /æ/, but the cause-and-effect relationships are not so clear. The following interpretation seems reasonable. When /ɛ/ and /æ/ began to separate, SN was unsure as to which vowel his /ʌ/ and /ɑ/ should accompany to maintain the relative positioning of the first four months. In month five, both /ʌ/ and /ɑ/ raised along with /ɛ/. Then in month six, his /ɑ/ began to accompany his /æ/, suggesting an awareness of their complementary positions along the front and back vowel lines. His /ʌ/ was left behind either because of a continued association with /ɛ/ or because it simply was "squeezed out", as /ɑ/ approached /æ/ at the lower extreme of the ellipse, centralizing a bit too much. The separation of /æ/ by lowering was not literally blocked by another vowel in its way, but it did seem that it would have required the accompanying lowering of /ɑ/, with which it had maintained its relative positioning from the beginning. In other words, what was necessary was again an increase in the total vowel space.

Probably the most significant aspect of the development of SN's IL vowel system is that, not only did he come the closest, among the male subjects, to acquiring one of the two key vowel distinctions, but he was the only one to significantly increase his total vowel space during the study, after having begun with the smallest total vowel space of the five males. Whereas the Ohnishi data for men exhibit a range in F1 mean frequencies from about 260 hz for /i/ to about 680 hz for /ɑ/, SN's F1 frequencies varied in month one from 200 hz—the highest realization of /ɪ/—to only 540 hz—the lowest realization of /ɑ/. By month eight, although the mean F1 for SN's IL /ɑ/ and /æ/ had not reached the Ohnishi means, his lowest token for /ɑ/ was produced with an F1 frequency of 810 hz, and his lowest token for /æ/ with an F1 frequency of 780 hz.

SN's data provided the usual negative evidence for a link between vowel acquisition and vowel adjustment in the parallel adjustments of the IL /i/-/ɪ/ and /eɪ/, and in the blocking, by the position of /eɪ/, of the creation of a distinct IL /ɪ/. SN made the most progress, among the male subjects, toward the acquisition of a new English vowel distinction, and his data offer the strongest positive evidence for this link. It is pretty clear that the gradual separation of /ɛ/ and /æ/ was not occurring in isolation, but was linked to adjustments in other vowels of the system. Interestingly, however, the effect of the adjustments in the other vowels was not just to open up the vowel space to allow for the new vowel, but to maintain the relationship between the lower point vowels, and thus increase the total vowel space.

The developments in SN's three lower vowels also bear on the third research question. Every step toward the separation of his /æ/ was accompanied by a simultaneous adjustment in /ɑ/ and/or /ʌ/. Thus, SN's partial acquisition of /æ/, as that of NR, provides support for the need for tuning or restructuring of the IL vowel schema in order to add the new vowel structures, as predicted by Rumelhart and Norman's model. It does not support the prediction made by Karmiloff-Smith's model, that success in the acquisition of the new vowel will motivate the reorganization of the vowel schema.

While NR's IL vowel schema appeared to have undergone only a gradual and rather minor tuning in the raising of /eɪ/ to allow for the distinction between /ɛ/ and /æ/, there are two differences between the changes in NR's vowel system and those of SN's which justify labeling the latter as restructuring. NR's raising of /eɪ/ was gradual and linear, and always along the IL front vowel line, thus not involving any change in the overall size or shape of the vowel system. The changes in SN's vowel system began in a gradual and non-linear fashion in months three to seven, but led up to an extremely radical change in month eight. The change in month eight was radical both in magnitude and in the fact that it changed the outline of the IL vowel system. It was also the first time that SN ventured into the unfamiliar lower front corner of the vowel space. Thus, it is proposed that a tuning occurred in SN's IL vowel schema during months three to seven, followed by a restructuring of the whole lower part of the system in month eight. Although the distinction between /ɛ/ and /ɑ/ began during the "preparatory" tuning, it was only with the restructuring, and the resulting increase in total vowel space, that /æ/ actually began to emerge as a separate IL phoneme.

As for the manner of adjustment of the IL vowels, it was observed above that adjustments in all vowels occurred mostly gradually, except for the sudden and radical changes of the last month. Adjustments were definitely not linear—both the higher and lower vowels began changing in one direction, and returned to their original positions. Whereas most minor vowel adjustments occurred without much change in variance, the major changes of month eight involved a considerable increase in variance, which can be expected to be followed by a decrease in subsequent months, when these changes stabilize.

5.1.6. Summary of male subjects

There are many similarities in the developing IL vowel systems of the five male subjects. The first concern the three highest front vowels. Without exception, the IL /eɪ/ representation of each of these subjects was located near the target height of /ɪ/ or higher at the beginning of the study, apparently modeled on the NL /e/ or /ei/, and raised higher still in subsequent months. For every subject except MR, this raising of /eɪ/ made the IL vowel "more Portuguese than Portuguese itself," i.e., higher than the particular subject's Portuguese /e/ and /ei/.

With the IL /eɪ/ located near the target height of /ɪ/ or higher, the vowel schemas of these subjects were all left without space between /i/ and /eɪ/ for the creation of a new IL /ɪ/. In fact, for FR and NT, this raising of /eɪ/ caused a temporary overlapping with the IL /i/-/ɪ/, but the identity of /eɪ/ was always maintained by its greater duration and/or distinct diphthongal trajectory. For the other three male subjects, the adjustments of /i/-/ɪ/ and /eɪ/ were simultaneous, whether raising or lowering. It appears that any raising of /eɪ/ caused a raising of /i/-/ɪ/ for these subjects, and a lowering of the higher vowel was possible only when accompanied by the lowering of /eɪ/. Given this interdependence, it is reasonable to conclude that the location of IL /eɪ/ was responsible for inhibiting the acquisition of /ɪ/ by any of the five male subjects.

An intriguing question is why, in the IL vowel schema of all five subjects, the /eɪ/ would raise, instead of lower, making it higher than the subjects' Portuguese /e/. As observed in 2.1.2, this is not the first study to document changes in IL phonemes occurring in precisely the opposite direction of the target. Fourakis and Iverson do not speculate on the reasons for this occurrence in their study, and there is no reason to expect the motivation to be the same in each case. In the case of the IL /eɪ/ of this study, the subjects evidently perceived that the NL model was not accurate for the TL, but did not know in which direction to move it. They may have tended to raise, rather than lower the vowel, because in the Portuguese diphthong /ei/ the second element is much higher, or because of the greater association, in Portuguese, between /e/ and /i/ than between /e/ and /ɛ/. There are contexts in which vowel harmony occurs between these two vowels, and /e/ is, for most of the subjects in the study, acoustically closer to /i/ than to /ɛ/. One male and two of the female subjects in this study have a considerable overlap in their NL /e/ and /i/, which are then distinguished more by duration.

The changes taking place among the lower vowels in the study were not so uniform among the five male subjects, but the relationships maintained among these vowels were. All five subjects apparently began with a single representation for /ɛ/ and /æ/, and only two of the subjects had begun to produce a distinction between these vowels by the last month of the study. In both NR's and SN's vowel systems the beginnings of this distinction were due to the inappropriate raising of /ɛ/ into the space left by the raising of /eɪ/. Only in SN's vowel system, however, was this raising of /ɛ/ accompanied by the appropriate lowering of /æ/.

It was noted in 5.1.5. that the lowering of SN's /ɛ/-/æ/ in month four was accompanied by the lowering of /ʌ/ and /ɑ/, but the lowering of an almost distinct /æ/ in months six to eight was accompanied by the lowering of only /ɑ/. The explanation given hinged upon SN's apparent desire to maintain the relative positions of the three lower vowels, which included /ɛ/ until month five, when /ɛ/ and /æ/ began to separate. The relative positioning of the lower vowels was also given as an inhibiting factor for the lowering of /ʌ/ in the vowel systems of the other subjects.

It is important to note that the *relative* positions of the IL lower vowels were target-like from early on, and remained fairly stable throughout the study for all five subjects. Each subject's IL /ʌ/ was always either at the same height as or, more often, slightly higher than his IL lower front vowel, which corresponds to the appropriate relative TL positioning of /ʌ/ and /æ/. Each subject's IL /ɑ/ was always at the same height as or slightly lower than /ɛ/-/æ/, or than /æ/ when there was a difference between these two. This corresponds to the relative TL positioning of /ɑ/ and /æ/. The only exception to the latter relationship was in SN's month five, at the beginning of the separation between /ɛ/ and /æ/. In this month, SN's IL /ɑ/ was still maintaining this relationship with /ɛ/ rather than with /æ/, but this changed in the very next month.

Although the target-like relative positions of the IL lower vowels may be due to the similarity with the NL /ɛ/-/ɔ/ line, and thus to NL transfer, it is likely that the learners would avoid adjustments which would interfere with these relative positions, such as the isolated lowering of /æ/. The problem for these learners, then, is not simply to distinguish /æ/ from /ɛ/, but to lower the three vowels /æ/, /ʌ/ and /ɑ/. This is extremely difficult because of the notion of total vowel space mentioned earlier. The average Portuguese vowel system of these five male subjects extends down to between 700 and 800 hz. on the F2 axis, which is actually slightly lower than the mean lower limit of the Ohnishi data for men. However, the key to the difficulty lies in the fact that the Portuguese system is approximately triangular, with the lower limit reached only by the central vowel /a/, whereas the English system is a somewhat irregular trapezoid, with the lower limit reached by the front and back vowels. Thus, lowering the

IL /æ/ and /ɑ/ means venturing into two corners of the total vowel space which are entirely unfamiliar to the Brazilian Portuguese speaker.

In sum, although the data on the male subjects of this study do not include a single instance of total separation of a new IL vowel from an old, the two examples of partial separation do demonstrate a parallel with adjustments in the adjacent vowels. Also, the separation of new vowels from the old was consistently demonstrated to have been inhibited by the positioning of the adjacent vowels—the appearance of an IL /ɪ/ was literally blocked by the position of /eɪ/, and the appearance of an IL /æ/ was more subtly inhibited by the desire to maintain the relative positions of the lower vowels, and thus by the inability to increase the size of the total vowel space. Most important, the vowel systems of these subjects have been demonstrated to be true *systems*, with a very intricate network of interrelationships, where it is doubtful that any vowel undergoes significant change without affecting or being affected by changes in other vowels of the system.

The findings regarding the *sequence* of vowel acquisition and adjustment by the male subjects have been less significant, because there were only two instances of partial acquisition. However, in the partial separation of IL /æ/ by both NR and SN, the adjustments in the adjacent vowels occurred simultaneously. This indicates that, at least for these subjects, the reorganization of the IL vowel schema was not motivated by success in producing a new IL vowel, as predicted by Karmiloff-Smith's model of cognitive development. Rather, it appeared to be data-driven, i.e., necessary for successful acquisition of the new IL vowel to take place, as predicted by Rumelhart and Norman's model.

In NR's case, the reorganization appeared to take the form of tuning—a minor modification of one of the constants of the IL vowel schema. It was noted that although this tuning allowed for the partial separation of the new IL vowel, it did not allow for its accurate realization. In SN's case, the initial moderate tuning of the vowel schema also allowed only for the partial separation of the new vowel, and not for its accurate production. The accurate production of SN's new IL vowel, which occurred only in the eighth month, appeared to require a much more radical restructuring of his IL vowel schema; that is, a new vowel schema was created to replace the old one, on which it was patterned. This new schema was of a similar shape to the old one, but the general outline extended much farther down into the vowel space.

Finally, the five male subjects were fairly consistent in the manner of adjustments made in the IL vowels. The adjustments made were mostly gradual, the principal exception being the changes in SN's lower point vowels in the eighth month. A strong tendency for non-linearity in vowel adjustments has been noted, with total reversals in direction of change being quite frequent. Although some adjustments made during the course of the study appeared to be linear so far, many of these were in the wrong direction, indicating that a reversal could be expected in subsequent months. There were also some apparently random changes, indicating simply a "wandering around" in the vowel space, in a search for the appropriate realization.

Vowel adjustments were frequently accompanied by increases and/or decreases in variance. The only clear instances observed of vowel adjustment in the sequence expected by Beebe—of an increase followed by a decrease in variance—were in NR's raising of /eɪ/ and NT's raising of /eɪ/ and /ʌ/. However, because this study covered only six to eight months of each subject's development, it is quite possible that some decreases in variance noted in the first months were preceded by increases before the study had begun, and that increases occurring in the last months (notably SN's lower point vowels) were followed by decreases after the study had concluded.

5.2. Female subjects

5.2.1. CL

It was noted in 4.4.1 that CL was the only one of the eleven subjects whose IL /eɪ/, in the first month, was already at the approximate TL height. However, as demonstrated by Figures 5.33 to 5.40, this position was not yet stable. In month one, the variance for her /eɪ/ was quite large. In month two, a sudden decrease in variance brought this vowel back up almost to the position of her NL /e/ and /ei/, where it remained for three months. The first-month realizations of this vowel proved to be predictive of future developments, however, for the vowel lowered again in month five, by another increase in variance. The new position for this vowel was not quite as low as that of the first month, but it stayed relatively stable in the last four months, with a gradual decrease in variance—a sign of CL's greater confidence that this was the appropriate position.

As observed with the male subjects, there was a definite parallel between the above described developments of CL's IL /eɪ/ and those of her /i/ and / ɪ/. However, whereas the position of the IL /eɪ/ of the male subjects appeared to block the acquisition of /ɪ/, the adjusted position of CL's /eɪ/ apparently facilitated it. Her /i/ and /ɪ/, with a consistently small variance, were virtually identical during the first six months, most likely produced according to a single IL representation, in spite of the lower position of /eɪ/ in months one, five, and six. This /i/-/ɪ/ phoneme underwent very little change during this period, except for the sudden apparent lowering in month two (see Footnote 4 in 4.4.1) and a slight and temporary rise in month three. This rise was possibly an attempt to distance /i/-/ɪ/ from /eɪ/, with which it consistently overlapped, although no auditory confusion resulted, due to the longer duration

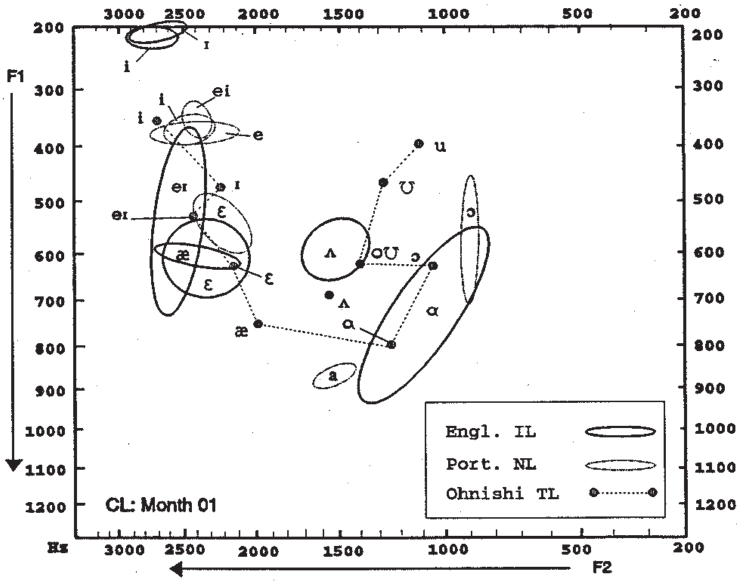

Figure 5.33. Plot of CL: English IL Vowels - Month 01.

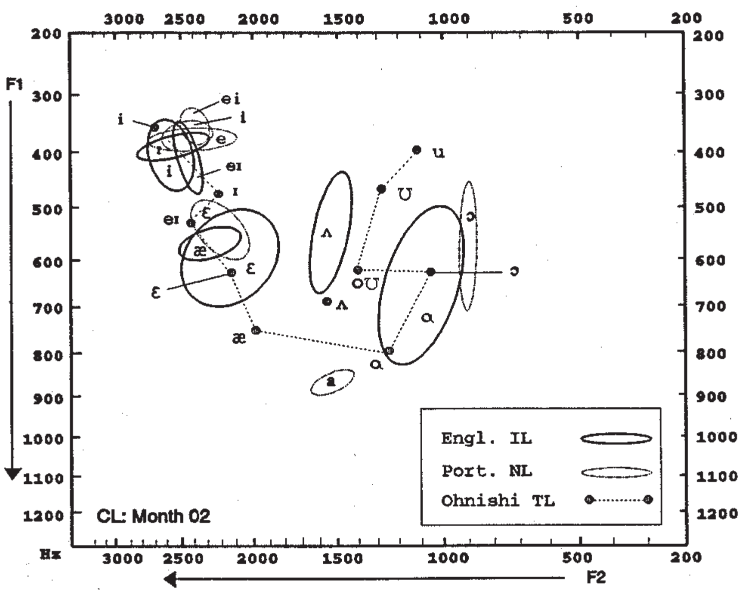

Figure 5.34. Plot of CL: English IL Vowels - Month 02.

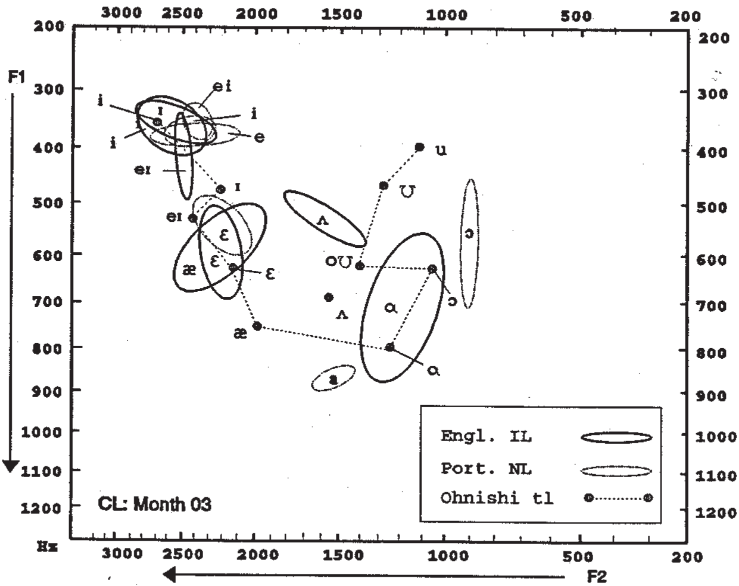

Figure 5.35. Plot of CL: English IL Vowels - Month 03.

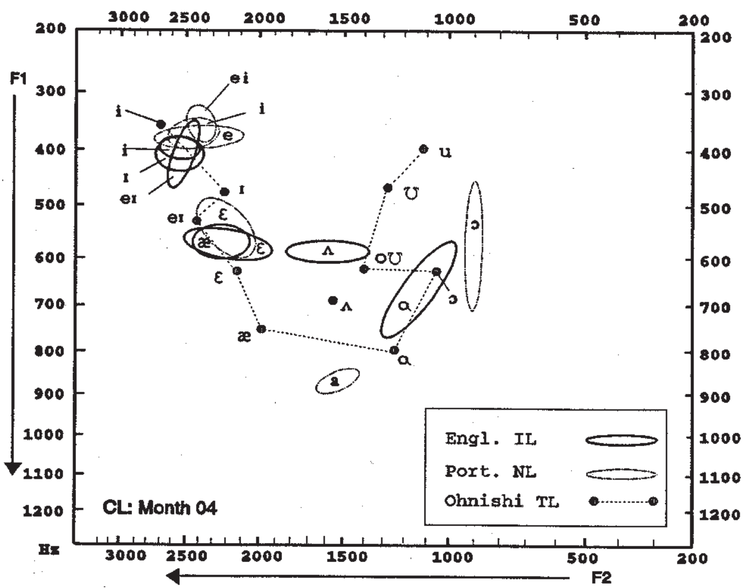

Figure 5.36. Plot of CL: English IL Vowels - Month 04.

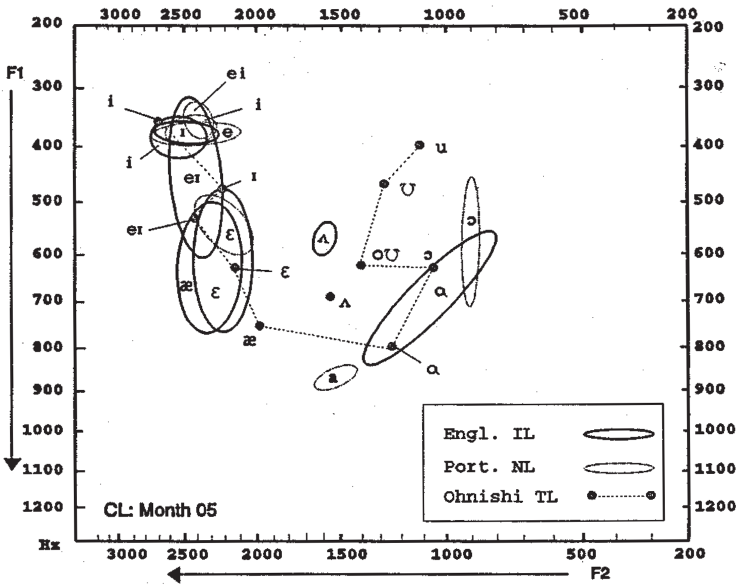

Figure 5.37. Plot of CL: English IL Vowels - Month 05.

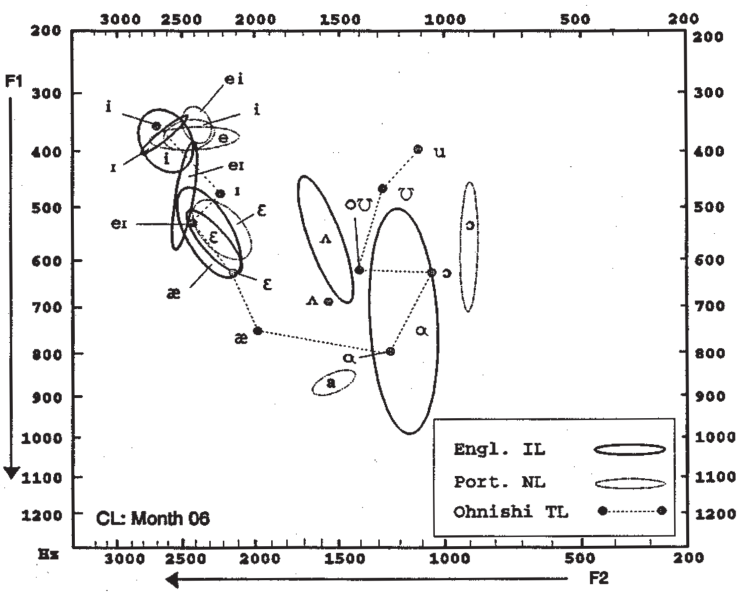

Figure 5.38. Plot of CL: English IL Vowels - Month 06.

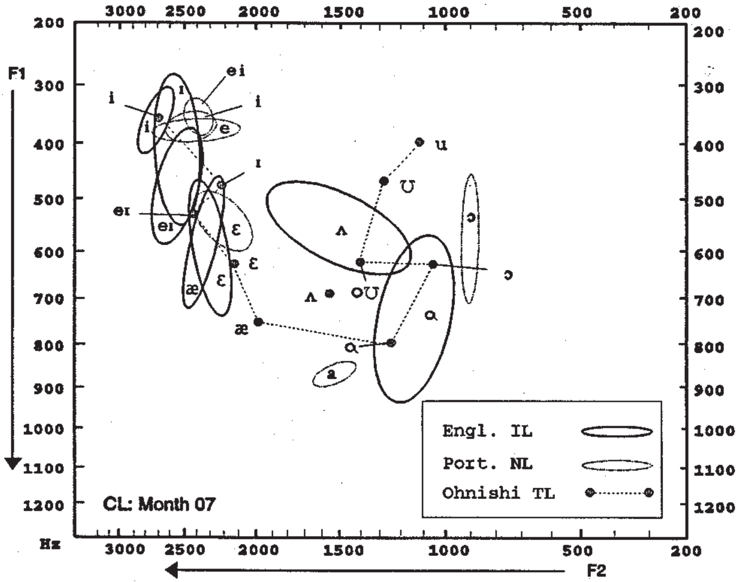

Figure 5.39. Plot of CL: English IL Vowels - Month 07.

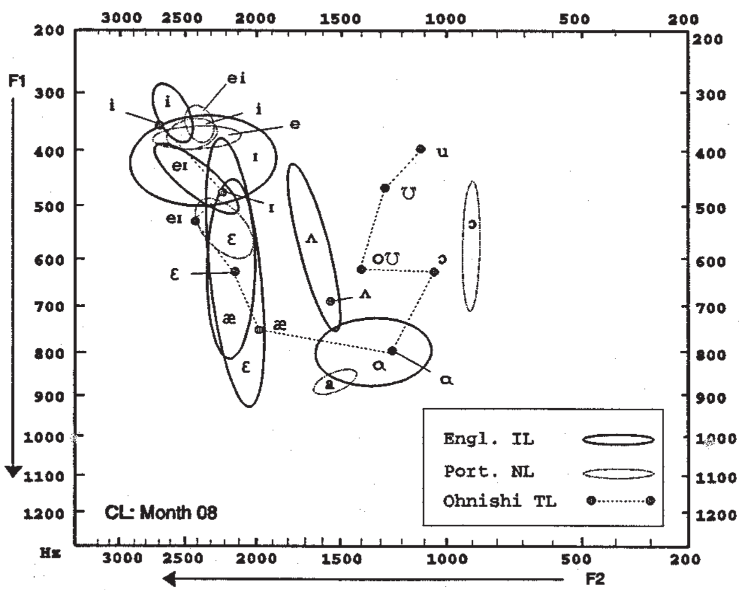

Figure 5.40. Plot of CL: English IL Vowels - Month 08.

and rising glide of the latter (CL's NL /i/ and /e/ were also distinguished principally by duration, and her /ei/ from the other two by diphthongal trajectory). In the seventh month, when the lower position of /eɪ/ was beginning to appear stable, /i/ and /ɪ/ suddenly began to separate, and by month eight /ɪ/ had essentially emerged as a new IL phoneme.

CL's IL /ɛ/ and /æ/ were virtually identical throughout the eight months that she participated in the study, and can thus be considered to be the result of a single representation. This /ɛ/-/æ/ phoneme did not undergo any significant changes in mean formant frequencies during this period, but the F1 variance increased considerably in the last four months, causing it, especially in the last month, to extend farther into the lower front corner of the vowel space.

A parallel can be seen between the developments in CL's /ɛ/-/æ/ and those of the two other lower vowels. Her /ʌ/, which exhibited a consistently small variance during the first five months of the study, also increased its variance in the last three months, extending lower in the vowel space in months six and eight. Her /ɑ/, whose F1 variance was large throughout the study, and whose lowest realizations were consistently in the appropriate target area, underwent a sudden decrease in variance in the last month, bringing all the tokens, and thus the mean, also into the target area. Thus, with the increased variance of /ɛ/-/æ/ and /ʌ/ and the decreased variance of /ɑ/, the overall effect, during the last few months, was for the IL vowel system as a whole to extend lower into the vowel space.

Although CL's month-eight means still show /ɛ/-/æ/ higher in the vowel space than /ɑ/, the lowest realizations of /ɛ/-/æ/, /ɑ/, and /ʌ/ are in the appropriate relative and absolute target positions of the three lower TL vowels. This appears to be where she is heading. It was observed in 5.1.5 that it appeared to be necessary for SN to increase his total IL vowel space in order to begin to separate /æ/ from /ɛ/. CL has increased her total vowel space, indicating she may be ready in the following months to begin to separate her IL /æ/ from /ɛ/. Her /ɛ/-/æ/ is occupying the space for both of these vowels now, so all that is necessary is to identify each realization with the appropriate vowel phoneme. Unfortunately, because the study ended after CL's eighth month, this prediction will remain only a prediction.

In sum, the developments in CL's IL vowel system have provided a strong indication that the individual IL vowels do not evolve in isolation. A parallel was observed between the adjustments of the lower vowels /ɛ/-/æ/, /ʌ/ and /ɑ/, and between the acquisition of /ɪ/ and the adjustment of /eɪ/. These parallels provide evidence for the constant preoccupation of the subjects not only with maintaining sufficient perceptual distance, but also with attaining the appropriate relative positions among the vowels.

It is clear from the order of occurrence that the reorganization of CL's IL vowel schema (the lowering of /eɪ/) was not motivated by the successful acquisition of /ɪ/, as predicted by Karmiloff-Smith's model of cognition. On the contrary, the lowering of /eɪ/ appears to have been the *prerequisite* for the creation of the new IL vowel representation, thus bearing out the prediction made according to Rumelhart and Norman's model, that the tuning or restructuring of the vowel schema would make way for the acquisition of the new vowel.

The adjustments in CL's /eɪ/ were rather sudden, but did not change the whole outline of the system, as those permitting SN's acquisition of /æ/. Because restructuring, as described by Rumelhart and Norman, not only is sudden, but also involves the creation of a new schema, it appears that these changes would have to be classified as tuning. Thus, it seems that both tuning and restructuring can prepare the IL vowel schema for the creation of an additional vowel.

The changes observed above in CL's IL vowel system were all rather sudden, as opposed to those of the male subjects described in 5.2. They were also non-linear—her IL /eɪ/ was lower than the NL /e/ and /ei/ in month one, raised in month two, then lowered in month five; and /i/-/ɪ/ raised slightly in month three, lowered again slightly in month four, then separated in months seven and eight. The non-linearity in each case appeared to have been due to some experimental and temporary adjustments leading up to the more permanent changes. The most significant changes—the lowering of /eɪ/ and /ɪ/—occurred by a noticeable increase in variance, followed in the case of the former vowel by a slight decrease, as predicted by Beebe. The extension of the vowel system into the lower portion of the vowel space occurred by a decrease in variance of /ɑ/ and an increase in variance of /ɛ/-/æ/ and of /ʌ/. The increase in the variance of /ɛ/ -/æ/ and /ʌ/ is likely to be followed by a decrease (an elimination of the higher realizations) as CL becomes more confident of the new outline of the vowel system.

5.2.2. CR

The development of CR's English IL vowel system, as that of CL, exhibited a parallel between the gradual separation of /i/ and /ɪ/ and the adjustment of /eɪ/. As demonstrated in Figures 5.41 to 5.46, however, the order of occurrence was different for CR. In the first month of the study, there were already signs of the beginning of a separation of /i/ and /ɪ/, facilitated by the higher position of her IL /i/, compared to that of the other female subjects. Although the /i/ ellipse was located almost in the center of the ellipse for /ɪ/, the upper extreme of the /ɪ/ ellipse was the result of skewed data—there were four points for /ɪ/ within the /i/ ellipse, none above, and two below. In the second month, the separation had progressed further, with four of the six points for /ɪ/ below and back of the ellipse for /i/, and in the last four months there was never more than one point for /ɪ/ overlapping with /i/.

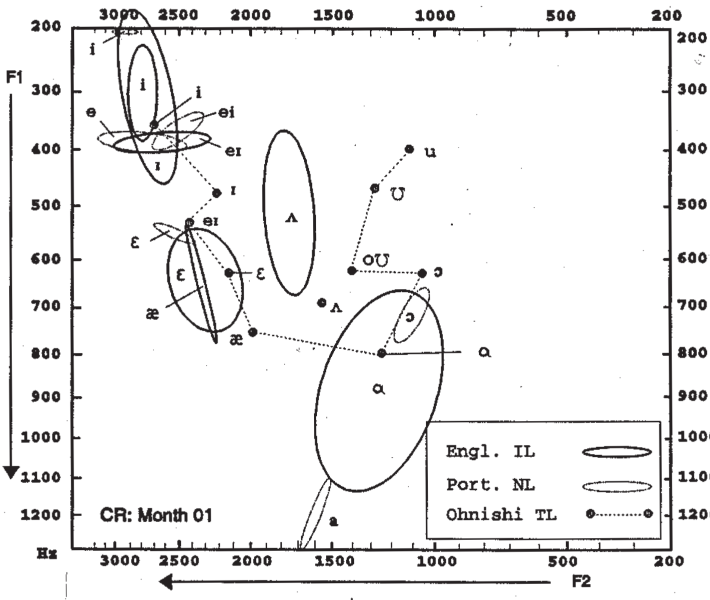

Figure 5.41. Plot of CR: English IL Vowels - Month 01.

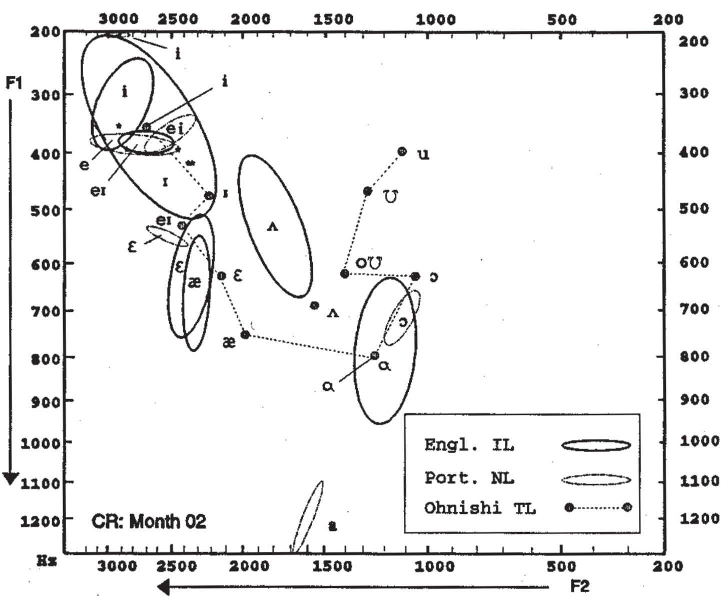

Figure 5.42. Plot of CR: English IL Vowels - Month 02.

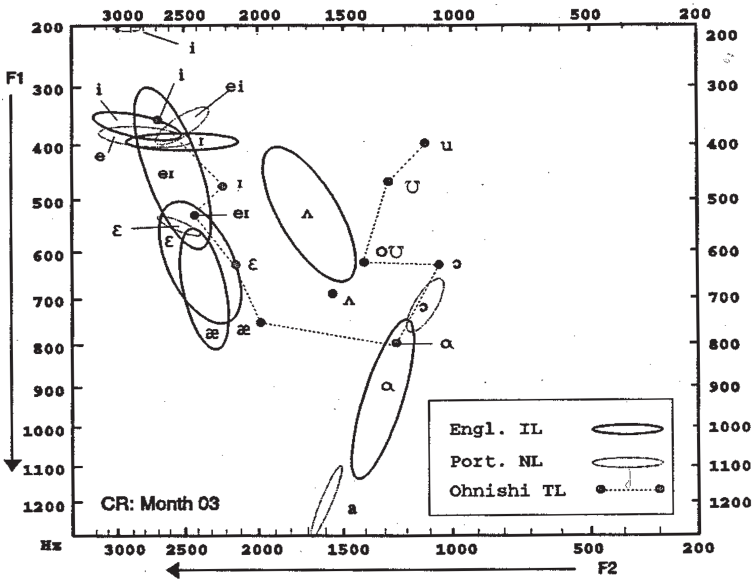

Figure 5.43. Plot of CR: English IL Vowels - Month 03.

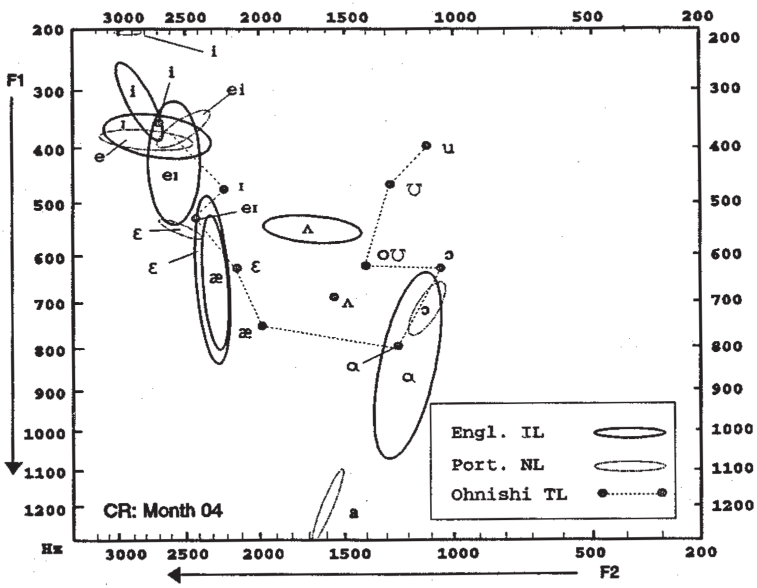

Figure 5.44. Plot of CR: English IL Vowels - Month 04.

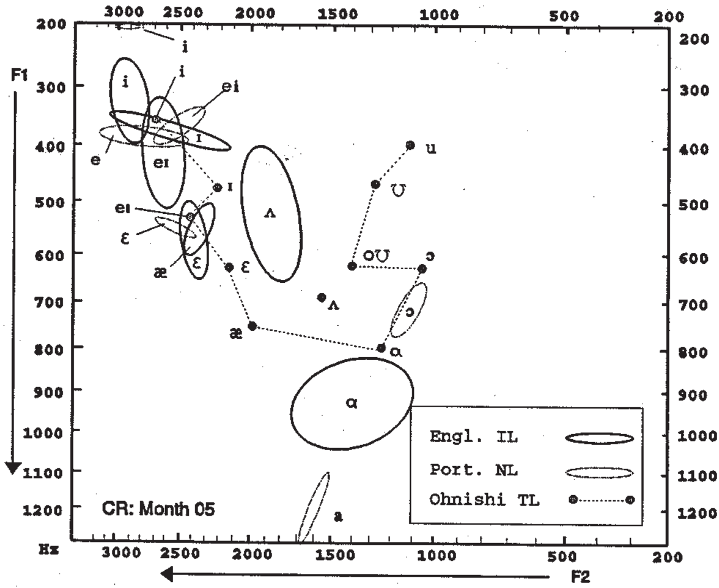

Figure 5.45. Plot of CR: English IL Vowels - Month 05.

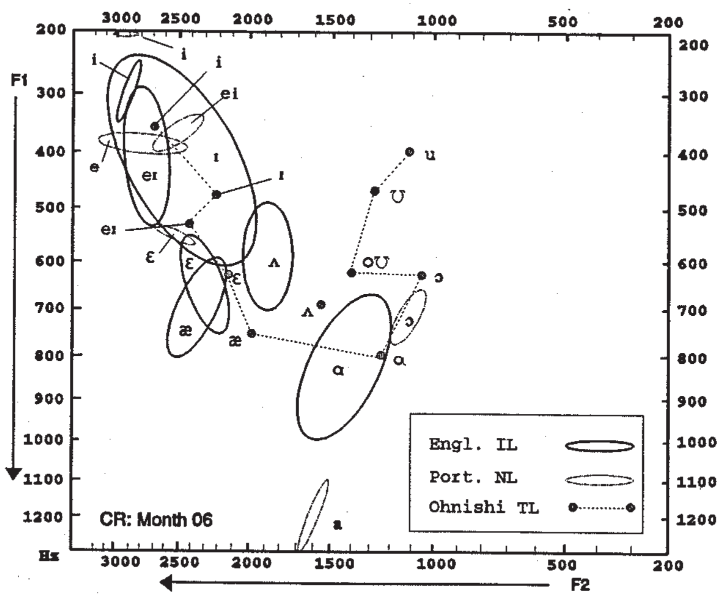

Figure 5.46. Plot of CR: English IL Vowels - Month 06.

CR's IL /eɪ/, on the other hand, was located in the position of her NL /e/ and /ei/ in the first two months, with a very small variance, and did not lower to open additional space for /ɪ/ until month three. The result was two points for /ɪ/ lower than the entire /eɪ/ ellipse in the first month and four below it in the second, in clear violation of the TL relative positioning along the IL front vowel line. This extreme overlap did not cause any perceptual confusion, as /eɪ/ was consistently longer and contained a rising off-glide, whereas /ɪ/, as well as /i/, were either steady or contained a falling off-glide (as opposed to that of the TL /i/). Still, CR was not long in rectifying the positions of these vowels. Her IL /eɪ/ lowered in the third month, with a sudden increase in variance, and remained stable throughout the rest of the study. Her newly created IL /ɪ/, although almost totally distinct from /i/ during the last four months, was in various positions in the vowel space, demonstrating an apparent uncertainty as to the precise target position.

The other vowels of CR's IL system underwent very little change during the six months of the study. Her /ɛ/ and /æ/ were essentially identical throughout, evidently produced according to a single IL representation. Only the mostly large variance of this IL phoneme on the F1 axis and the slight fronting and lowering of /æ/ in month six indicate an awareness of the need to extend lower in the vowel space. The only change noted in /ʌ/ and /ɑ/ was a counterproductive fronting of both vowels in the last two months, which moved CL's IL /ɑ/ from the approximate target area closer to the area of her NL /a/, and made the future appearance of a distinct IL /æ/ more difficult. The creation of this new IL vowel would involve a move both down and back from the present position of /ɛ/-/æ/. With the new forward position of /ʌ/ and /ɑ/, this would cause both a very small perceptual distance between /æ/ and /ɑ/ and the inappropriate relative positioning of /æ/ directly below /ʌ/.

In sum, the developments described in /i/, /ɪ/, and /eɪ/ were the only substantial changes which took place in CR's IL vowel system during the study, but these changes provide strong support for a link between vowel acquisition and vowel adjustment. Contrary to the development of CL's IL system, the conclusions to be drawn from the order of occurrence of these modifications are not so clear-cut. On the one hand, the fact that the separation of /ɪ/ from /i/, which began in the first two months, was only completed after the lowering of /eɪ/ in month three, bears out the prediction made according to Rumelhart and Norman's model of cognition—that tuning of the vowel schema must occur before accretion of the new vowel. On the other hand, the fact that the separation of /ɪ/ from /i/ had already made considerable progress by month two, although /eɪ/ only lowered in month three, could be interpreted to support the prediction based on Karmiloff-Smith's model—that success in producing the new vowel distinction (if partial success is valid) would motivate the reorganization of the IL vowel system, i.e., the adjustment in /eɪ/.

One thing that does seem clear is that, whether a prerequisite or a result, the acquisition of the IL /ɪ/ required an adjustment of the adjacent vowel /eɪ/ in order to maintain sufficient acoustic distance between the two vowels, even though they were already distinguished by duration and by the direction of formant trajectory. The acquisition of /æ/ is probably inherently more difficult than the acquisition of /ɪ/ because it involves entering unfamiliar vowel space, and thus a restructuring of the overall outline of the IL vowel system. In CR's case, it was made even more difficult by the backsliding of /ɑ/ toward the space of the NL /a/ and by the backsliding of /ʌ/ toward the front vowel line.

The adjustment observed in CR's IL /eɪ/ was linear and sudden, but because it did not involve a very radical change in the whole vowel system, it can be considered to constitute a tuning, rather than a restructuring. The adjustment of /eɪ/ involved an increase in variance, followed by a slight decrease as the new position became stable. The separation of /ɪ/ from /i/ was gradual and approximately linear, with some wavering to the sides of an otherwise straight line. It involved an initial increase in variance, followed by a decrease and another increase several months later. The adjustments of /ɑ/ and /ʌ/ appeared to involve a temporary decrease in the F1 variance and an increase in the F2 variance, as both vowels extended forward.

5.2.3. DN

DN's English IL vowel system, plotted in Figures 5.47 to 5.50, underwent very little change during the four months that she participated in the study. There was no distinction made between her /i/ and /ɪ/ or between her /ɛ/ and /æ/ during the study, each pair apparently being realized according to a single IL phoneme.

DN's IL /i/-/ɪ/, somewhat lower and forward of the TL /i/, appeared to be modeled on her NL /i/ at the beginning of the study. Her /eɪ/ remained consistently very similar to her NL /e/ and /ei/ during the four months, except for one low outlier each in months one and four, which increased the variance for these two months. The position of this vowel higher than TL /ɪ/ may have been blocking the lowering and separation of IL /ɪ/, as was observed in the vowel systems of the male subjects. The only overall change in /eɪ/ was a slight move back. Although this move was not in the direction of the target, it did open enough space for a slight lowering of /i/-/ɪ/. It was in the fourth month, when DN's /eɪ/ moved farthest back, that her /i/, rather than her /ɪ/, underwent a slight lowering by an increase in variance. Although none of these developments led to a more accurate IL vowel system, there does appear to have been a link between the adjustment of /eɪ/ and an attempt at separation of /i/-/ɪ/.

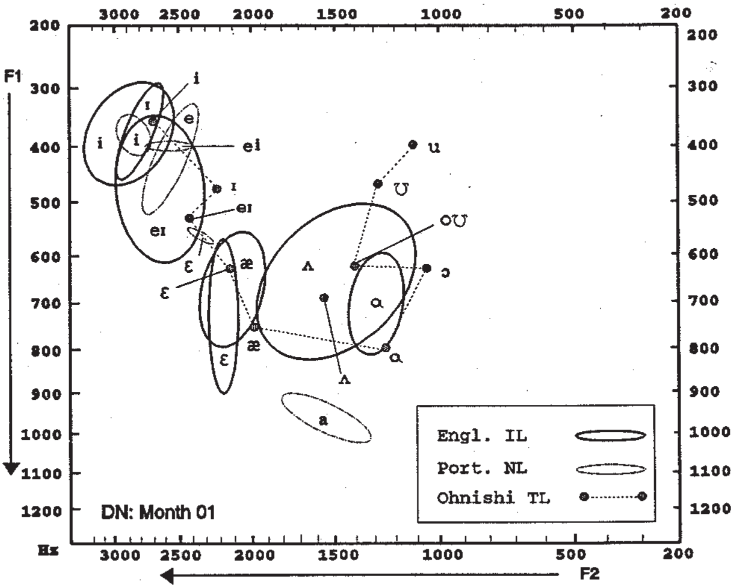

Figure 5.47. Plot of DN: English IL Vowels - Month 01.

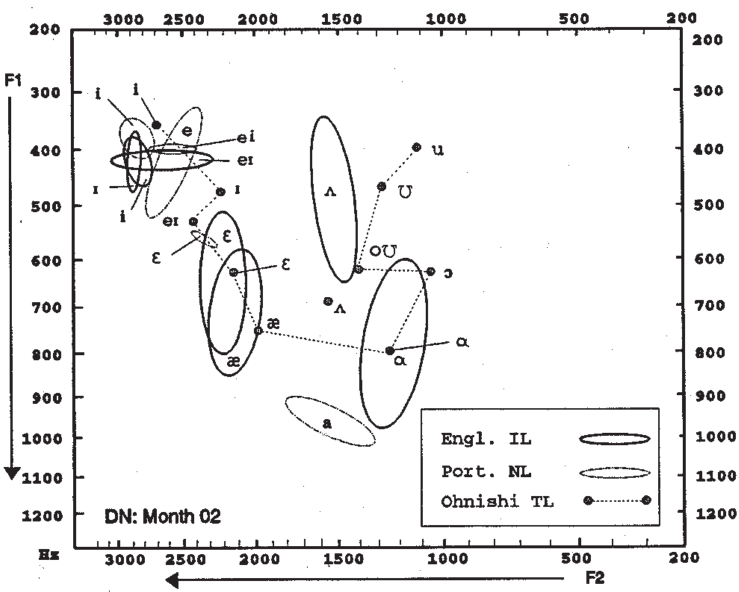

Figure 5.48. Plot of DN: English IL Vowels - Month 02.

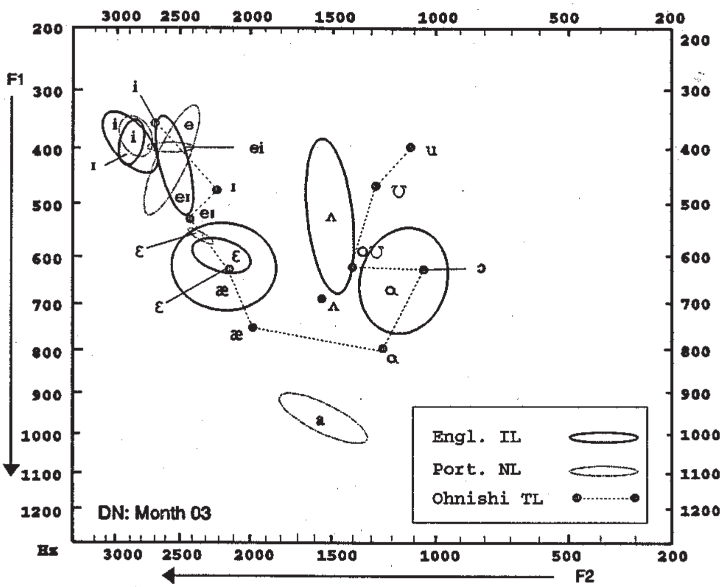

Figure 5.49. Plot of DN: English IL Vowels - Month 03.

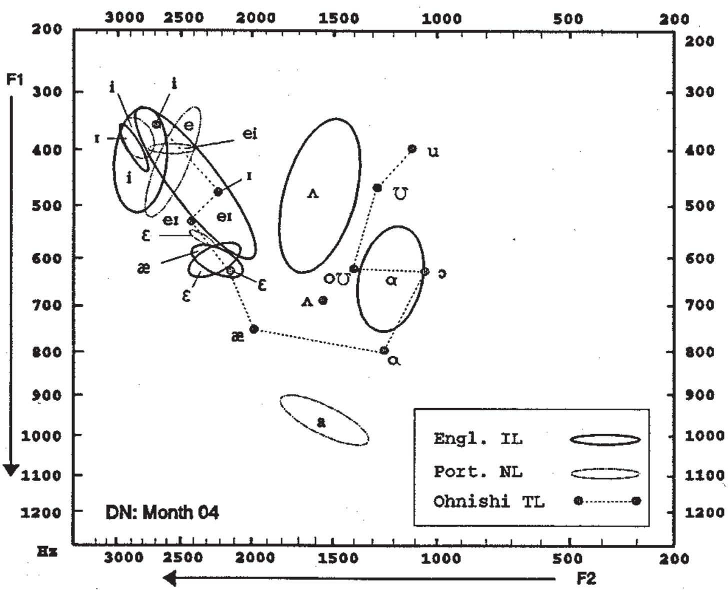

Figure 5.50. Plot of DN: English IL Vowels - Month 04.

Whereas four of the six female subjects began the study with their lower vowel line parallel to the /ɛ/-/a/ line of the NL, DN's lower vowel line was parallel to that of the TL vowel system from the beginning. This means that, as in the male IL vowel systems, any move toward separation of her IL /æ/ which involved an appropriate lowering of /æ/ would upset the relative positions of the three lower vowels, unless /ʌ/ and /ɑ/ moved in unison with the new vowel.

There was, in fact, a parallel in the adjustments of the three lower IL vowels, but the move was in the other direction. DN's /ɛ/-/æ/ raised slightly over the four months until it was virtually identical to her NL /ɛ/ by month four. After the second-month raising of /ʌ/ and lowering of /ɑ/, which accomplished the distinction of these two vowels, /ɑ/ raised with /ɛ/-/æ/ in months three and four, resulting in a considerably smaller total acoustic vowel space than in the first month. It has already been observed that the creation of an IL /æ/ appears to require either an increase in the total acoustic vowel space, as was occurring in the IL systems of CL and SN, or the inappropriate raising of /ɛ/, which requires the equally inappropriate raising of /eɪ/, as occurred in NR's IL system. Neither of these changes is occurring in DN's system, which has been left with neither space below /eɪ/ for /ɛ/ to raise nor space for /æ/ to lower, without upsetting the relative positions of the lower vowels. Thus, DN cannot be expected to acquire the /ɛ/-/æ/ distinction in the near future.

In sum, the changes which took place in this subject's IL vowel system were minimal, and moved three of the five IL vowels closer to the NL model, indicating an overall regression. There appeared to be a connection between the adjustment of /eɪ/ and /i/-/ɪ/ in the fourth month, but there was no progress toward a target-like distinction between the latter vowels, making the third research question inapplicable. Although the distinction of /ʌ/ from /ɑ/ was acquired at the beginning of the study, this move did not appear to require any adjustments in the adjacent vowels, as there was more open vowel space in the new position for this vowel than in the old. In the four months of DN's participation in the study, her vowel adjustments were too slight to be judged as linear or not. However, because her vowels did not adjust in the proper direction, any positive future developments will necessarily involve non-linearity.

5.2.4. MN

MN's English IL vowel system, plotted in Figures 5.51 to 5.56, also changed very little during the six months of the study. She made no distinction between her /i/ and /ɪ/ or between her /ɛ/ and /æ/, which will be considered to constitute only two IL phonemes.

MN's /i/-/ɪ/, somewhat higher than her NL /i/ in the first two months, lowered to about the same height as the NL vowel in month three, where it remained during the last four months. Her IL /eɪ/ remained at the height of her NL /e/ and /ei/ throughout the six months. The larger ellipses in months one, two, four, and five are due to only one low token each, the other tokens being positioned at the same height as her NL vowels. As was observed for all the male subjects, at no time during the six months was there any space between MN's /eɪ/ and /i/-/ɪ/ for the creation of an IL /ɪ/ phoneme.

No noticeable change occurred in MN's other IL vowels. Her /ɛ/-/æ/ remained consistently in the area of the TL /ɛ/ during the course of the study, except for a temporary raise to the height of TL /eɪ/ in month four. Her IL /ɑ/ remained consistently target-like, and her /ʌ/ remained central and slightly higher than /ɛ/-/æ/. The most noticeable month-to-month variation in these vowels was in the degree of variance, which appeared to be random, but almost always greater on the F1 axis, the only indication of possible future change. On the one hand, MN's IL vowel system can be described as having acquired a very target-like /ɛ/ and /ɑ/ early in development, and as having failed to acquire an /æ/ during the

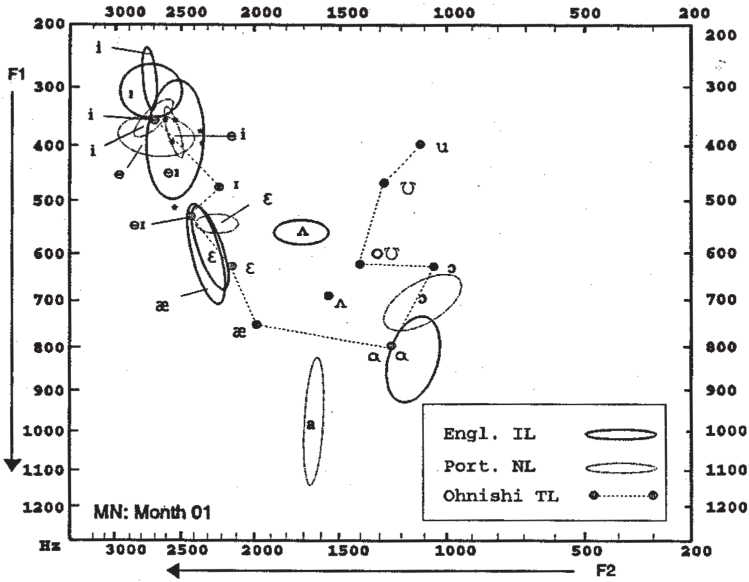

Figure 5.51. Plot of MN: English IL Vowels - Month 01.

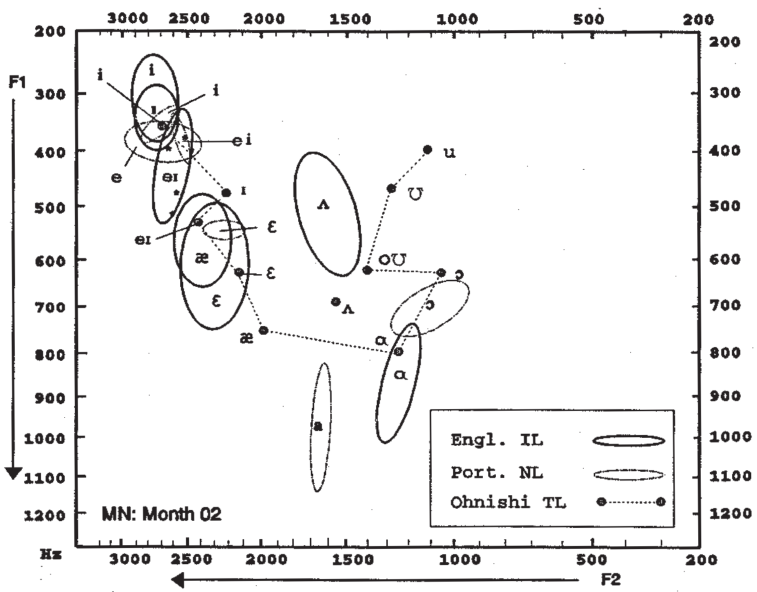

Figure 5.52. Plot of MN: English IL Vowels - Month 02.

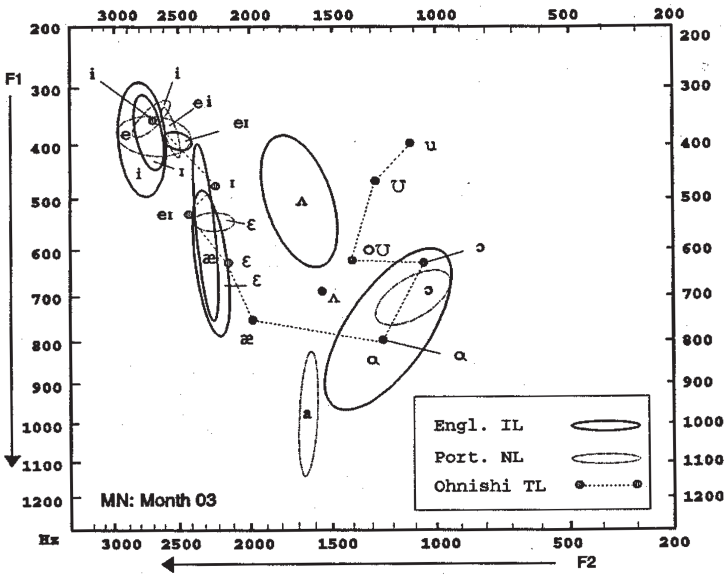

Figure 5.53. Plot of MN: English IL Vowels - Month 03.

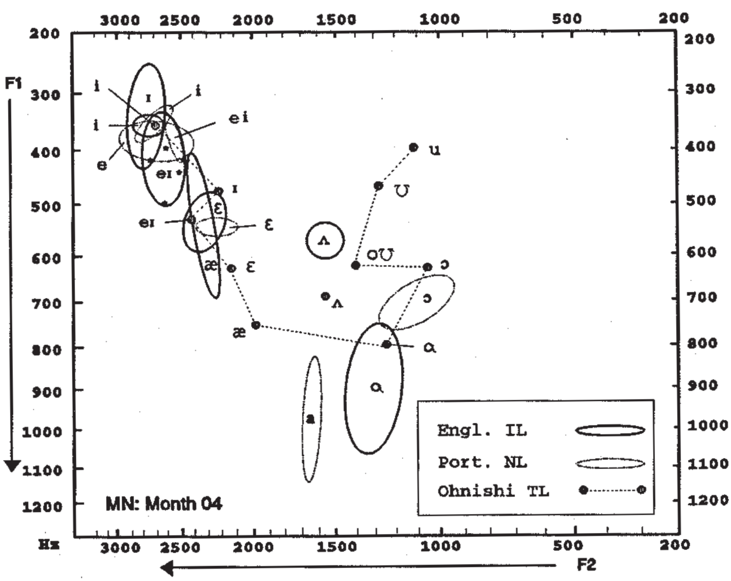

Figure 5.54. Plot of MN: English IL Vowels - Month 04.

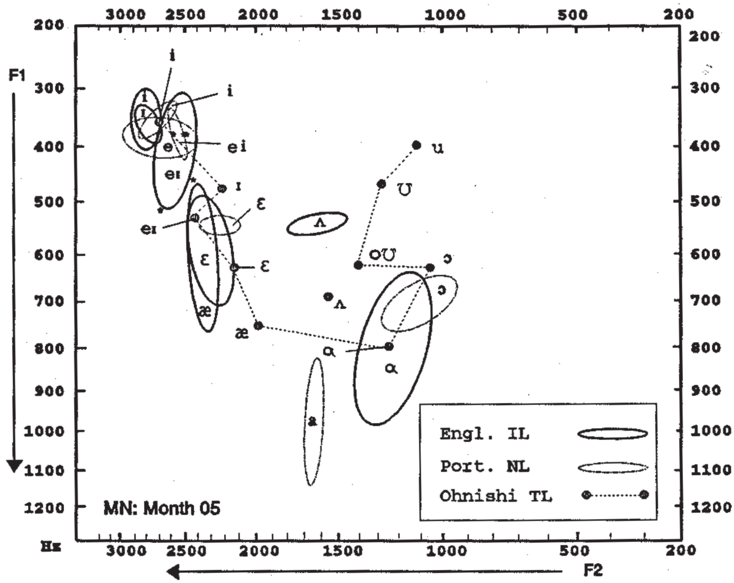

Figure 5.55. Plot of MN: English IL Vowels - Month 05.

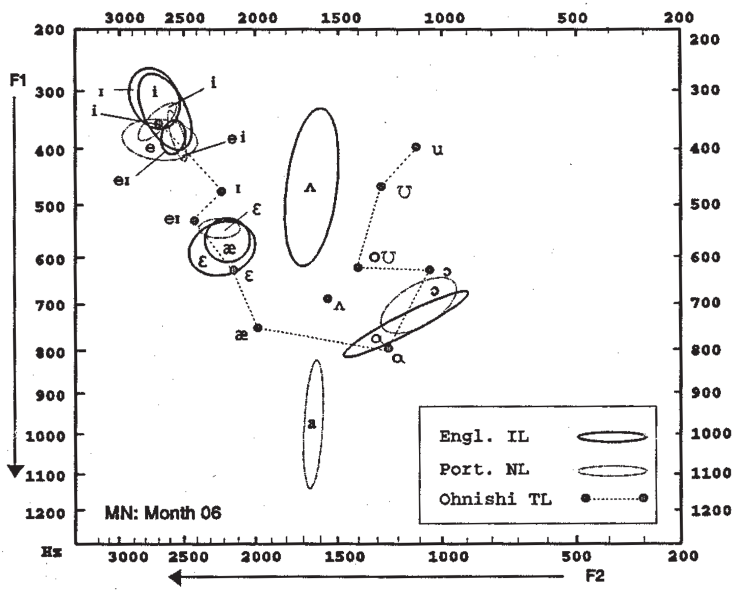

Figure 5.56. Plot of MN: English IL Vowels - Month 06.

course of the study. On the other hand, if the IL system is considered to be a model of the NL, it can be described as having extended the lower outline early on in the direction of the TL, but without changing the overall shape of the vowel system, which would require a more radical restructuring.

In sum, MN's data provide only negative evidence for the link between vowel acquisition and vowel adjustment, her IL /eɪ/ remaining throughout the study in a position which appeared to block the emergence of a distinct IL /ɪ/. There was also insufficient change in the overall outline of the vowel system to allow for the separation of /æ/ from /ɛ/. Overall, the changes in MN's IL vowel system have been slight, non-linear, and have not brought the system any closer to the TL system.

5.2.5. TR

The development of TR's English IL vowel system, the most basic of the eleven in the study, is plotted in Figures 5.57 to 5.62. As noted in 4.4.5, TR, the only true beginner of the study, was having difficulty decoding the English spelling system, which resulted in the production of only one and two valid tokens for /i/ in months one and two respectively, and no valid tokens for /eɪ/ until the third month. Although she decoded /ɛ/ and /æ/ without difficulty in the first two months, hypercorrection in the third and fourth months caused many invalid tokens, which were pronounced mostly like the name of the letter which represented the particular vowel phoneme (e.g., *Kate* for *cat*, *meet* for *met*).

TR's IL /i/ and /ɪ/ appeared to be distinct in the first two months, but with a total of only three valid /i/ tokens for the two months, and with these three positioned inappropriately relative to /ɪ/, it is more likely that these three realizations constituted random variation of an /i/-/ɪ/ phoneme. From the time the subject learned the spelling code for /i/ in the third month, it no longer appeared distinct from /ɪ/. Her IL /eɪ/, when it first appeared in

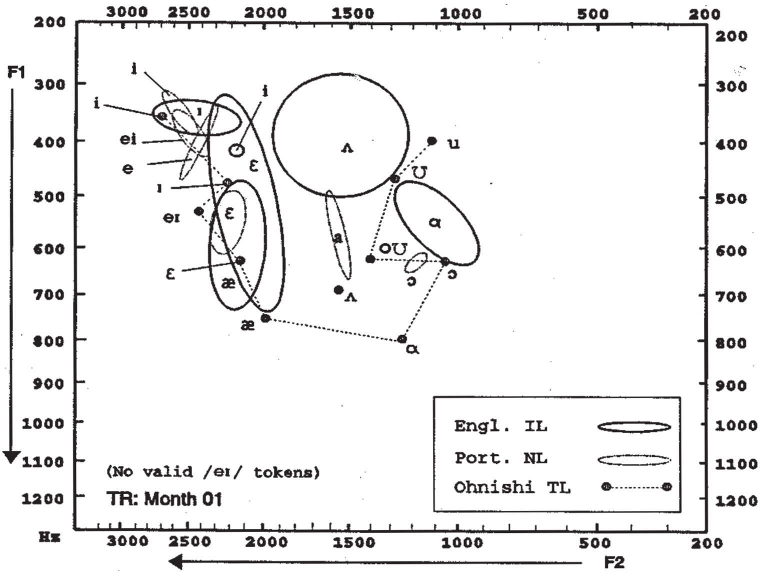

Figure 5.57. Plot of TR: English IL Vowels - Month 01.

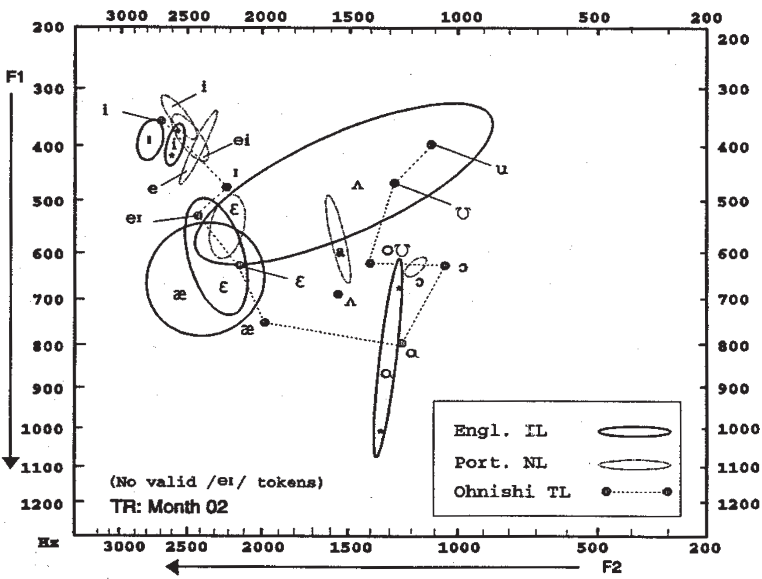

Figure 5.58. Plot of TR: English IL Vowels - Month 02.

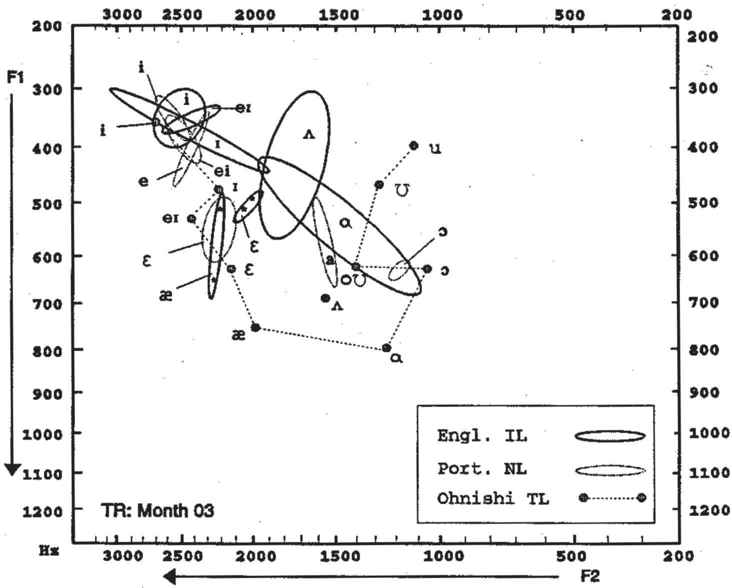

Figure 5.59. Plot of TR: English IL Vowels - Month 03.

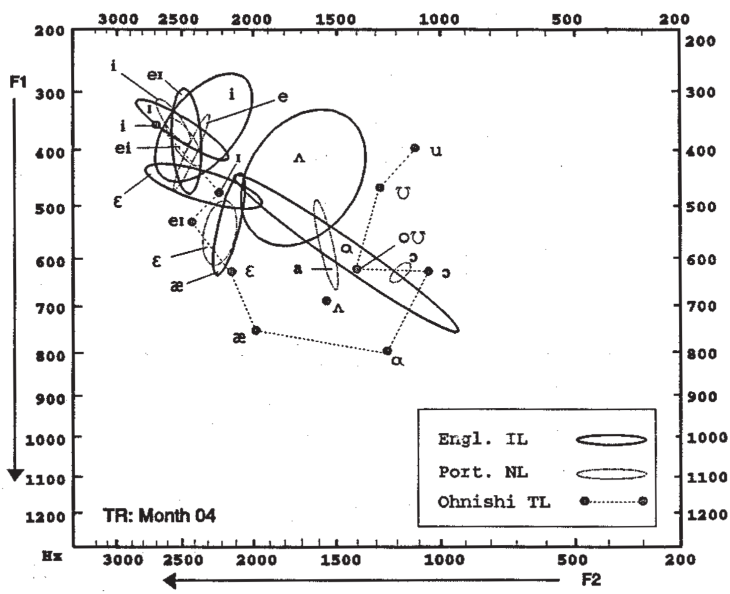

Figure 5.60. Plot of TR: English IL Vowels - Month 04.

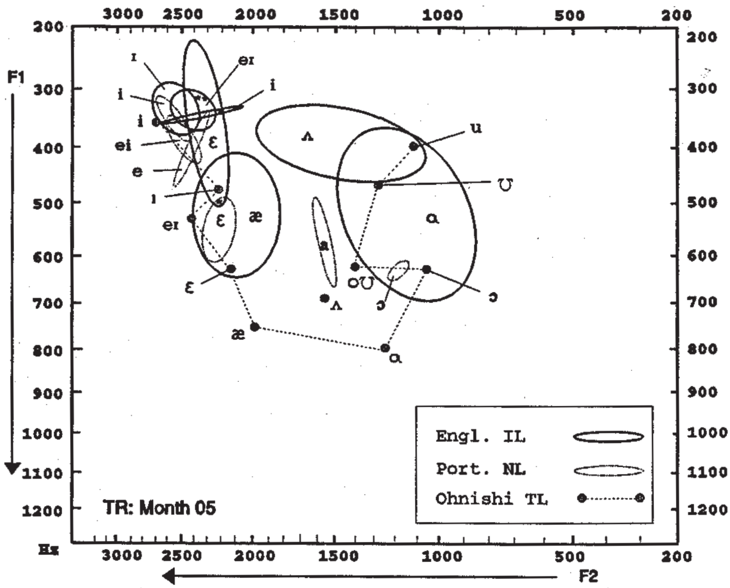

Figure 5.61. Plot of TR: English IL Vowels - Month 05.

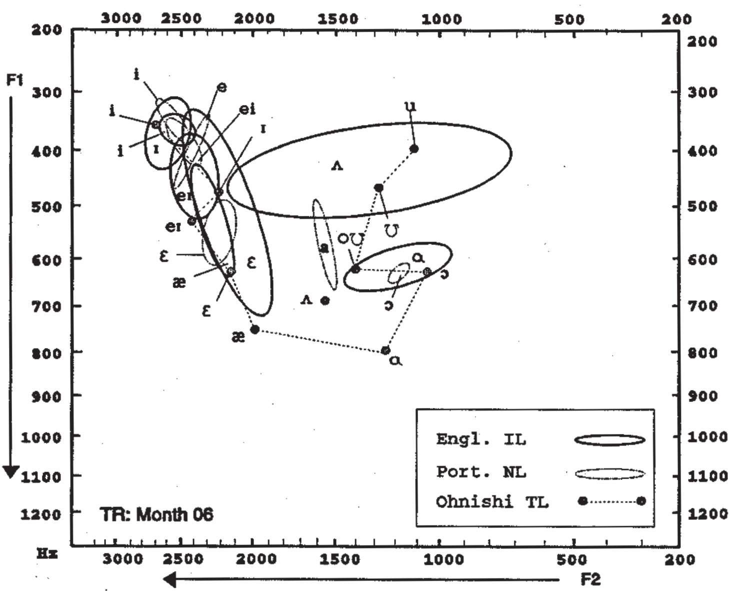

Figure 5.62. Plot of TR: English IL Vowels - Month 06.

the third month, was positioned together with /i/-/ɪ/, distinguished mostly by duration (contrary to the other subjects, TR did not consistently pronounce /eɪ/ with a rising glide). Her /eɪ/ lowered slightly in month four, by an increase in variance, but this was only temporary. In month six /eɪ/ lowered enough to separate from /i/-/ɪ/—again by an increase in variance—but not enough to leave space for the distinction of /ɪ/.

TR's IL /ɛ/ and /æ/ overlapped during all six months, but there was a tendency to raise /ɛ/ above /æ/ throughout, culminating in month five, when three of the four valid tokens for /ɛ/ overlapped with /eɪ/. When /eɪ/ lowered in month six, /ɛ/ also lowered to its initial position, becoming less distinguishable from /æ/ than in any of the other months. It appears TR realized she had been moving /ɛ/ in the wrong direction, and it became one with /æ/ again.

TR's /ʌ/ and especially /ɑ/ varied considerably throughout the six months, in an apparently almost random search for the appropriate position. Her /ʌ/ began in a high central position in month one, extended forward almost to the front vowel line from months two to four, returned to the approximate initial position in month five, and extended to the back vowel line in month six. Her /ɑ/ began just above her NL /ɔ/ in the first month, extended down in the second month when there were only two valid tokens, moved back up and extended forward in months three and four, and returned to the approximate initial position in months five and six.

TR's IL vowel system was in a very early and unstable stage, and the changes noted above may have been part of a random search for the appropriate realization of the IL vowels. However, because of similarities between developments in TR's IL system and those of other subjects, these developments might also be considered very tentative evidence for a link between vowel acquisition and vowel adjustment. There was no space for the creation of a distinct IL /ɪ/ because /eɪ/ was always in the same vowel space with /i/-/ɪ/ or just below it. On the other hand, the position of /eɪ/ did allow a temporary separation of /ɛ/-/æ/, by the inappropriate raising of /ɛ/, as was observed in the development of NR's IL vowel system. Apparently, the vowel schema could account for the accretion of the new vowel /ɛ/, as long as both /ɛ/ and the adjacent vowel /eɪ/ were inappropriately high. As soon as the appropriate tuning of the vowel schema lowered /eɪ/, the new vowel could no longer be accounted for, and merged again with /æ/.

It was observed in 4.4.5 that TR's NL vowel system was quadrilateral, contrary to the norm, and much smaller than average on the F1 axis. Her IL vowel system, even smaller than that of the NL, was barely large enough for the three front vowels that she acquired by the end of the six months, let alone the five of the target system. Thus, TR can be expected to have a much greater difficulty than the other subjects in acquiring the new vowel distinctions. If she does acquire them in the future, they are likely to be distinguished more by the F2 than by the F1, as the vowels of her NL system.

The adjustments in TR's vowel system were both gradual—the separation of /ɛ/—and sudden—the lowering of /eɪ/ and the merging of /ɛ/ and /æ/—and may well have been simply random changes. All adjustments, without exception, were non-linear. Every lowering of the front vowels occurred by an increase in variance, and the back vowels increased in variance every time they adjusted toward a different extreme of the vowel space, and decreased when they returned to their original positions.

5.2.6. VN

VN's IL /i/ and /ɪ/, as demonstrated in Figures 5.63 to 5.70, were virtually indistinguishable throughout the eight months that she participated in the study, most likely produced according to a single IL representation, which underwent no lasting changes. Her IL /eɪ/ was located consistently in a position similar to that of /i/-/ɪ/, extending slightly farther back in months two, four, and six, and slightly lower in months three, four, and seven. In addition to these slight deviations in position, /eɪ/ was distinguished from /i/-/ɪ/ by its longer duration and its rising off-glide, which contrasted with the falling off-glide of /i/-/ɪ/. As long as /eɪ/ was positioned together with /i/-/ɪ/, there was no space for the creation of a distinct IL /ɪ/, without upsetting the relative positions of the vowels along the front vowel line. These relative positions came close to being upset in months two and six, when most of the productions of /i/-/ɪ/ were lower than those of /eɪ/ but this partial upset was corrected in the immediately following months three and seven by the extension of /eɪ/ toward the lower vowel space.

VN's /ɛ/ and /æ/ also appeared to be produced according to a single IL representation throughout the study. This /ɛ/-/æ/ phoneme began with an extremely large variance in month one, with several tokens produced within the space of her NL /ɛ/, and the rest below it. After the first month, the variance decreased considerably, and the IL vowel remained below her NL /ɛ/, occupying the target areas of both /ɛ/ and /æ/. Although there appeared to be attempts to separate these vowels in months three, five, and eight, the separation was always slight and temporary. This partial separation occurred by a decrease in the variance of /æ/ in months three and five, and by an increase in the variance of /ɛ/ in month eight. In month eight this attempt at separation occurred through the extension of the IL system farther than before into the lower front vowel space, but this extension involved tokens of both /æ/ and /ɛ/.

VN's IL /ɑ/ and /ʌ/ each had a consistently large variance throughout the study, and varied considerably from month to month besides. Although the two vowels overlapped throughout, their means were always quite distinct.

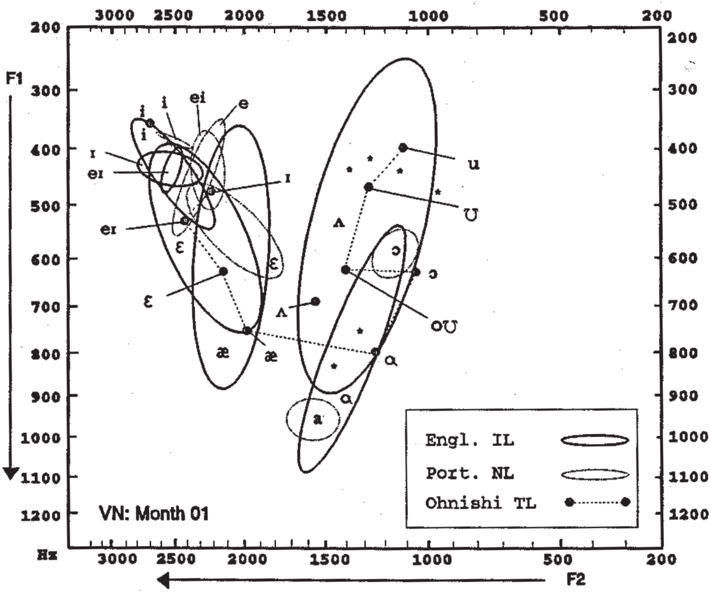

Figure 5.63. Plot of VN: English IL Vowels - Month 01.

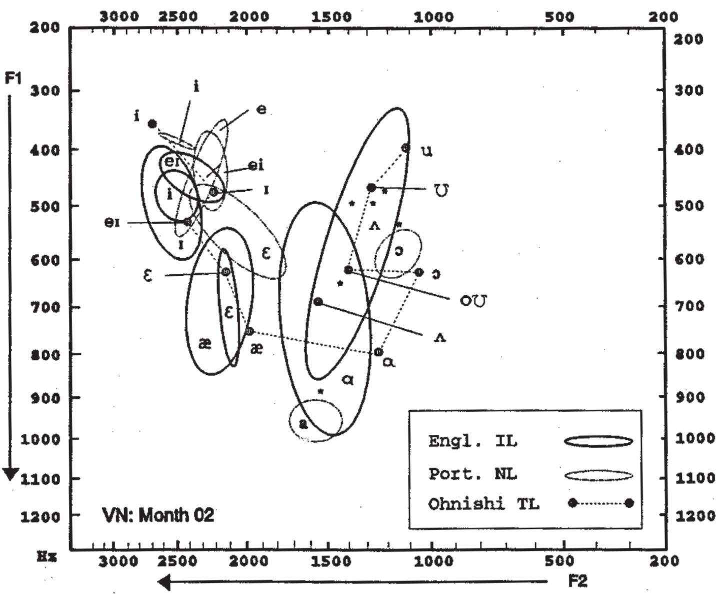

Figure 5.64. Plot of VN: English IL Vowels - Month 02.

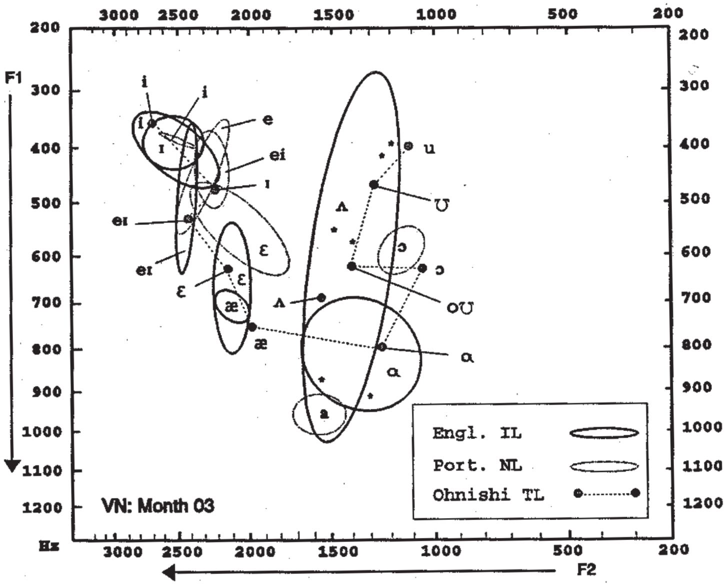

Figure 5.65. Plot of VN: English IL Vowels - Month 03.

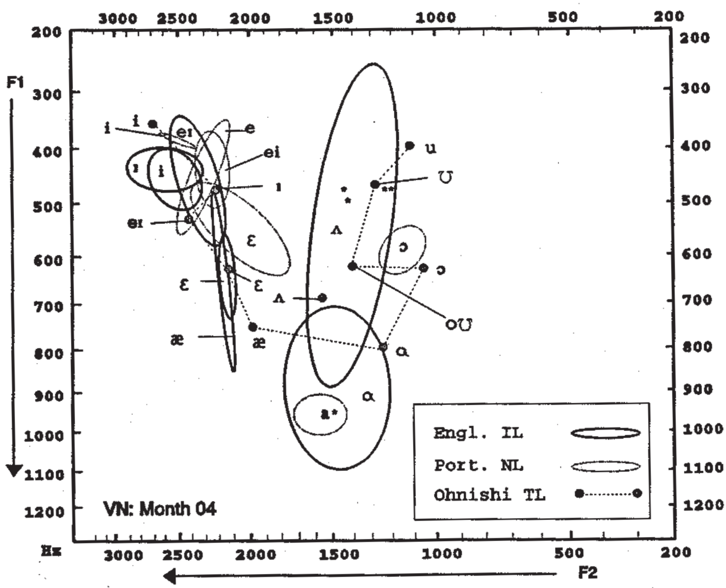

Figure 5.66. Plot of VN: English IL Vowels - Month 04.

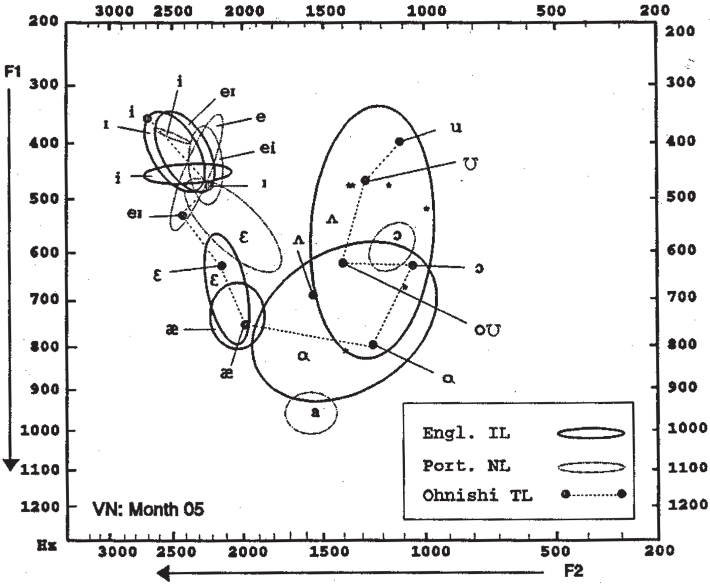

Figure 5.67. Plot of VN: English IL Vowels - Month 05.

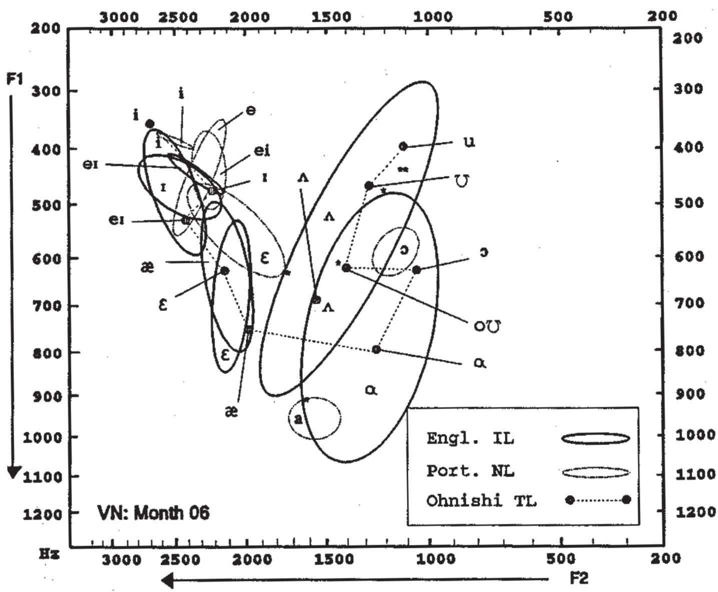

Figure 5.68. Plot of VN: English IL Vowels - Month 06.

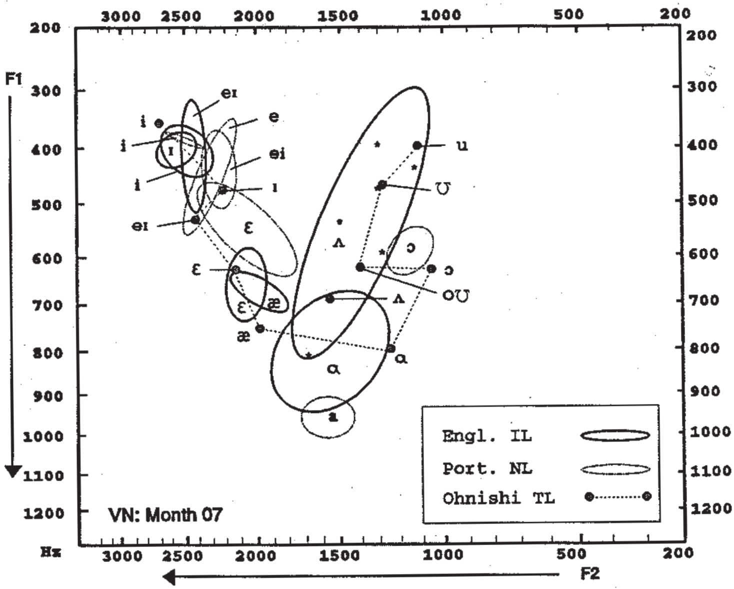

Figure 5.69. Plot of VN: English IL Vowels - Month 07.

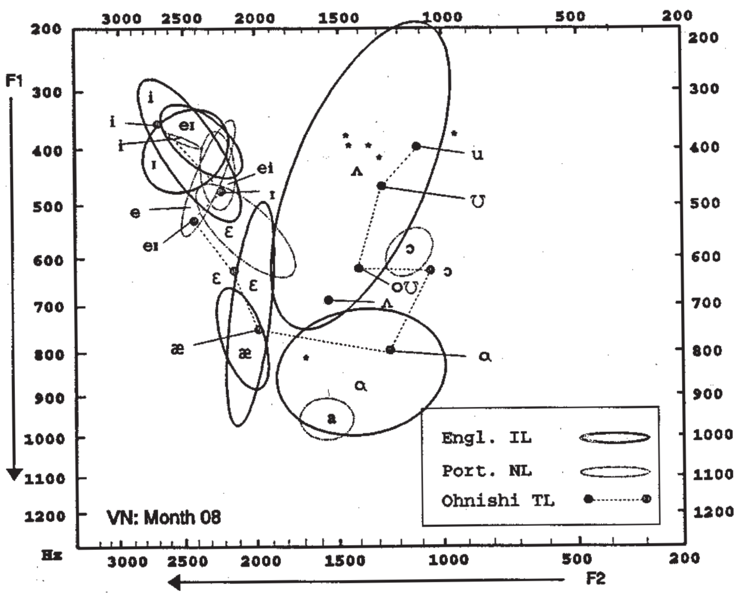

Figure 5.70. Plot of VN: English IL Vowels - Month 08.

VN's /ɑ/ began in month one extending from the area of her NL /a/ to the area of her NL /ɔ/. Her NL /ɔ/ appeared to lose its influence after the first month, however, except in months five and six, where there was evidence of backsliding. From the third month on, the IL vowel exhibited a much decreased F1 variance and a stronger influence from her NL /a/, though it vacillated between the areas of this vowel, the mean TL /ɑ/, and the mean TL /ʌ/. VN was the only subject whose IL /ɑ/ exhibited a greater influence from her NL /a/ than from her NL /ɔ/, and thus the only subject whose IL vowel system appeared to be triangular (as far as can be judged without data on the back vowels), like that of the NL, throughout most of the study. This shape changed almost to quadrilateral only in the last month, when /ɛ/-/æ/ extended down to the height of /ɑ/, and /ɑ/ moved back, apparently to leave sufficient acoustic space between them.

The means of VN's /ɛ/-/æ/ in month eight are still higher than those of her /ɑ/. However, month eight is the first month in which the lowest realizations of these two IL vowels were at approximately the same height, and in almost the appropriate relative and absolute target positions of /æ/ and /ɑ/, although /ɑ/ was still a bit too far forward. As CL and SN, VN has increased her total vowel space, indicating she may be ready to separate her IL /æ/ from /ɛ/ in the following months. Also as CL, her /ɛ/-/æ/ ended the study occupying the space for both of these vowels, so all that is necessary is to identify each realization with the appropriate vowel phoneme.

It was noted in 4.4.6 that the data for VN's IL /ʌ/ in the first month were bimodal, coinciding with the positions of her IL /ɑ/ and the average female TL /ʊ/, indicating the absence of the central vowel in her IL vowel schema. The inconsistent realization of this vowel continued throughout the eight months, but after the third month there was only one token at the lower extreme of the ellipse—always the extremely common word *but*. In months two and five there was one realization at a height midway between the areas of /ɛ/ and /ɑ/; in months three, six and seven there were two mid-height realizations; and in the fourth and eighth months, all realizations were in the area of TL /ʊ/ except *but*. Although the data were bimodal in three of the eight months, separate ellipses for the higher and lower realizations were not drawn because of the mid-height productions of the intermediate months. Instead, the individual points were plotted in each month's /ʌ/ ellipse to show the spread.

Although the mid-height realizations in the intermediate months may indicate sporadic attempts to create a distinct IL /ʌ/, by the end of the study, VN was the only subject who still had not acquired this vowel. It was suggested in 4.4.6. that whereas the other subjects appeared to have positioned their first-month IL /ʌ/ relative to their IL lower vowel lines, this was difficult for VN, due to her inconsistent choice of model for her IL /ɑ/ and to the fact that her lower vowel line did not appear to be developing as a unit. It has been observed in this section that VN's IL /ɑ/, during most of the study, appeared to be modeled more on her NL /a/ than on her NL /ɔ/, making her IL vowel system more triangular than quadrilateral. In a triangular vowel system there is no lower vowel line at all, making the relative positioning of an IL /ʌ/ in this manner totally impossible.

VN's English IL vowel system provides the usual negative evidence for a link between vowel acquisition and vowel adjustment. With her IL /eɪ/ occupying almost the same acoustic space as /i/-/ɪ/ throughout the study, there was no space between these vowels for the creation of a distinct IL /ɪ/. The fact that VN did not allow her /i/-/ɪ/ to extend below /eɪ/ without extending /eɪ/ farther down in the very next month (even though the vowels were already distinguished by duration and formant trajectory) provides additional evidence that relative positions are important to the L2 learner, and thus that further adjustments in /eɪ/ would be necessary for the emergence of a distinct IL /ɪ/.

The development of VN's IL vowel system also provided some tentative positive evidence for a link between vowel acquisition and vowel adjustment. Although no new vowel distinctions were acquired during the eight-month period, the last apparent attempt to separate /æ/ from /ɛ/ was accompanied by an adjustment in /ɑ/ toward the back of the vowel space. Because this occurred in the last month, there is no way of knowing if the adjustment allowed this last attempt to succeed in subsequent months, but the timing of the two occurrences does indicate a relationship between them. It is also clear that the previous attempts at the separation of /æ/, without the adjustment of /ɑ/, were unsuccessful.

The adjustments in VN's IL vowel system were mostly gradual and always non-linear. All five IL vowels adjusted toward the target position and back several times, and /ɛ/ and /æ/ twice began to move apart only to move right back together again. Every lowering of /i/-/ɪ/ and /eɪ/ occurred by an increase in the F1 variance; the partial separations of /ɛ/ from /æ/ occurred both by a decrease in the variance of /æ/ and an increase in the variance of /ɛ/. The lowering of /ɑ/ occurred by a decrease in variance, and the move back by a slight increase.

5.2.7. Summary of female subjects

Although the female subjects were less uniform than the males in the development of their English IL vowel systems, several similarities were observed. The first concern the three highest front vowels. All except CR began the study with their IL /i/ and /ɪ/ virtually identical, and all except CL began with their IL /eɪ/ at the same height as their NL /e/ and /ei/ or only slightly below (DN), and thus in the approximate target position for /ɪ/. As long as /eɪ/ remained at this height, it appeared to have prevented the appearance of a distinct /ɪ/. Although the IL vowel systems of CL, CR, TR, and VN demonstrated that /eɪ/ could be distinguished from the other two vowels by both duration and formant trajectory, all subjects appeared compelled to adhere to the appropriate relative positioning of these vowels.

CL and CR were the only two of the eleven subjects to manage an almost total separation of their IL /ɪ/ from /i/ during the course of the study. CL's /eɪ/ lowered slightly several times, but her /ɪ/ lowered and separated from /i/ only after /eɪ/ appeared to have stabilized in its lower position. CR's /i/ and /ɪ/ were partially separated already in the first month, facilitated by the higher position of her /i/, but reached almost total separation only after a lowering of her IL /eɪ/. These developments in CL's and CR's three highest front vowels provide strong positive evidence for a link between vowel acquisition and vowel adjustment.

In DN's IL system, a parallel was observed in the backward adjustment of /eɪ/ and the lowering of /i/, although both of these adjustments were inappropriate. In VN's IL system, each time /i/-/ɪ/ lowered into an inappropriate position relative to /eɪ/, the latter vowel lowered in the subsequent month, restoring the proper relationship between the two vowels. Although no separation of /ɪ/ from /i/ occurred in either of these two IL vowel systems, the parallel adjustments of the IL vowels provide tentative support for a link between vowel acquisition and vowel adjustment, in that these adjustments may constitute preparation for the vowel acquisition which is yet to occur. Both the lowering of the wrong vowel and the lowering of both vowels indicate that the learners were becoming aware of the need to lower the realizations of at least one of these vowels, and that this would be possible only when there was acoustic space available.

There was minimal adjustment of /eɪ/ or /i/-/ɪ/ in the IL systems of MN and TR. In both of these vowel systems, /eɪ/ was always in the space that /ɪ/ needed to occupy to separate from /i/, adding negative evidence for the link between vowel acquisition and vowel adjustment.

Although only two female subjects and not a single male acquired the distinction between /i/ and /ɪ/ in their IL vowel systems, it has been observed that, in the six female and five male developing IL vowel systems in this study, not a single separation of /ɪ/ from /i/ has occurred without a substantial lowering of /eɪ/; not a single IL /eɪ/ has approximated the target position without the separation of /ɪ/ from /i/ occurring in parallel; and no noticeable adjustments have occurred in either /i/-/ɪ/ or in /eɪ/ without parallel adjustments in the other vowel. All in all, the study has accumulated considerable evidence for a link between the acquisition of a distinct IL /ɪ/ and the adjustment of /eɪ/.

Not as much progress was made in the lower vowel distinctions of the female IL vowel systems. This may be related to the fact that, whereas the lower vowels of the male IL systems were in the appropriate relative positions from early on, the lower vowel line of the female IL systems was at an inappropriate angle, apparently modeled on the /ɛ/-/ɔ/ line of the NL. This angle was especially pronounced in the NL vowel systems of CR and MN, and in the first-month IL systems of CL, CR, MN, and VN (although VN's first-month /ɑ/ appeared to have been modeled on both /a/ and /ɔ/). Although SN's lowering of /æ/ and /ɑ/ together was labeled in 5.1.5. as restructuring, because it involved a change in the overall outline of the system, it was a restructuring which followed the general learner tendency of moving the vowel line as a unit. In the female systems which have the lower vowel line set at an angle, a lowering of this vowel line as a unit can occur only until the IL /ɑ/ reaches the approximate target height. The continued lowering of /ɛ/-/æ/ or the separation of /æ/ means altering the angle of the lower vowel line, a restructuring which changes more radically the shape of the lower portion of the IL vowel schema. Thus, although restructuring is a difficult process in both cases, for the female learners it may be even more complicated.

In spite of the difficulties involved, both CL and VN managed to extend their IL /ɛ/-/æ/ into the lower front vowel space by the end of the study, possibly in preparation for an ultimate separation of these vowels in subsequent months. The extension of CL's /ɛ/-/æ/ into the lower vowel space involved adjustments in all three lower vowels. The extension of VN's /ɛ/-/æ/ involved a slight retraction of /ɑ/ and an ultimately more radical restructuring of the lower outline of the IL system—the creation of a quadrilateral, as opposed to the previously triangular system. Although neither subject had actually begun a separation of /æ/ from /ɛ/ by the end of the study, it appears likely that these are preliminary steps to increase the total vowel space to make room for the new vowel. Thus, this can be considered tentative evidence for a link between vowel adjustment and vowel acquisition.

Further evidence for a link between vowel adjustment and vowel acquisition was seen in TR's attempt to distinguish between /ɛ/ and /æ/ by the raising of /ɛ/, which failed when she began to lower /eɪ/, forcing /ɛ/ to rejoin /æ/. It is interesting that the same strategy of distinguishing /ɛ/ and /æ/ by the raising of /ɛ/ was observed in the IL systems of NR and SN, although SN switched quickly to the strategy of increasing his vowel space. The fact that these three subjects had the least developed English ILs of the eleven subjects suggests that this may be an early strategy, which necessarily fails because of the eventual need to lower /eɪ/. The strategy of increasing the lower vowel space may be the only one which leads to a long-term successful distinction between these vowels, but this strategy is much more difficult, and is probably applied by most learners only later, if at all.

The other three female subjects made no progress whatsoever toward the distinction of /ɛ/ and /æ/. MN's IL system simply underwent very little change at all. CR and DN's IL systems underwent adjustments which would make the /ɛ/-/æ/ distinction more difficult. In CR's, there was a fronting of /ʌ/ and /ɑ/, which left very little space for the creation of a distinct /æ/ phoneme. In DN's system, there was a raising of all three lower vowels, resulting in a smaller total vowel space, and thus, no room for the appearance of an /æ/.

Finally, it is significant that of the three English vowels without Portuguese equivalents, /ʌ/ was the only one which, by the end of the study (by the first month for several subjects), had appeared as a distinct vowel in all of the eleven IL vowel systems except VN's. Although not accurately realized by most of the subjects, it was distinguished from the other IL vowels because there was ample space in the center of the vowel system for the learners to position this vowel appropriately relative to the lower vowel line of the system, maintaining sufficient perceptual distance from the other vowels.

In sum, this study documented adjustments in the adjacent vowels occurring parallel to CL and CR's acquisition of the /i/-/ɪ/ distinction, and sufficient adjustment was seen to be lacking in the IL systems where the new vowel did not appear. The beginnings of an /ɛ/-/æ/ distinction in TR's IL system were apparently stifled because the appropriate adjustments did not occur. The appropriate adjustments were observed in CL and VN's IL systems parallel to a lowering of /ɛ/-/æ/, which was expected to lead to the separation of these vowels. Either no lower vowel adjustments or adjustments which decreased the vowel space were observed in the IL systems of the subjects who showed no signs of acquiring these two vowels. Finally, the only vowel which did not require an opening up of the vowel space was acquired by all but one of the subjects by the end of the study. Thus, the developing IL vowel systems of the female subjects in this study have contributed considerable, if sometimes tentative, evidence that, because of the need for maintaining sufficient perceptual distance in the developing IL vowel system, the acquisition of new vowel distinctions requires adjustments in the adjacent vowels of the IL system. The developing IL systems have also provided evidence of the learner's need to maintain, in addition to sufficient perceptual distance between adjacent vowels, the appropriate relative positions of the vowels, indicating that new vowels are not acquired one by one, but as part of an integrated system.

The order of occurrence of the events in CL's system clearly offers support for the application of Rumelhart and Norman's cognitive model to the acquisition of TL vowels. The tuning of the IL vowel schema, i.e., the adjustment of the adjacent /eɪ/, is what made the vowel schema adequate for the accretion of the new vowel /ɪ/. This same account could be given for the events occurring in CR's system, because the total separation of /i/ and /ɪ/ occurred only after the adjustment of /eɪ/. However, in CR's vowel system the situation was not so clear-cut. Because there was already considerable progress made toward the separation of the two higher vowels before the lowering of /eɪ/, it could also be argued that partial success was the motivation for the reorganization of the schema, i.e., the adjustment of /eɪ/, as in Karmiloff-Smith's model, which then allowed the further separation of /i/ and /ɪ/. In other words, the learning processes described by Rumelhart and Norman and by Karmiloff-Smith may have been working together.

The events occurring in the lower portion of the vowel system of CL and VN, if they are actually laying the ground for the acquisition of the /ɛ/-/æ/ distinction, as suggested, support the predictions made on the basis of Rumelhart and Norman's model—that the vowel schema, because of insufficient perceptual distance, would be seen as inadequate to account for the new vowel, and that tuning or restructuring of the lower portion of the vowel schema would have to occur before or simultaneously with the accretion of the new vowel. In this case, the adjustments occurred first, but the study did not continue long enough to document the actual accretion of the new vowel, if it occurred.

Finally, the apparently easy task (for ten of the eleven subjects) of acquiring a distinct, if not accurate IL /ʌ/ illustrates the case where, according to Rumelhart and Norman's model, the vowel schema is seen as adequate for the accretion of the new vowel, and no previous tuning or restructuring is required. Subsequent tuning or restructuring, however, can allow for a more accurate representation of this vowel, as it did in CL's system. In VN's IL vowel schema, the only one whose triangular shape did not provide adequate conditions for the accretion of /ʌ/, this new vowel had not yet been acquired by the end of the study.

The manner of vowel adjustment occurring in the female IL vowel systems of this study was less consistent than in the male systems in that adjustments were both gradual and sudden. There was, however, just as in the male systems, a strong tendency toward non-linearity, with the exception of CR's system. Adjustments rarely occurred without a change in the degree of variance. The study documented many adjustments which involved either an increase or a decrease in the variance, but not both. The study was relatively short, however, and most of the adjustments were either incomplete at the end of the study, or appeared to have begun before the first month of the study. In CL's IL vowel system, which progressed the most among the female subjects, adjustments involved the expected sequence. The most basic vowel systems did not contain vowels with an abnormally large variance. It can be expected, then, that a longer longitudinal study would bear out Beebe's expectation that most vowel adjustments involve an increase, followed by a decrease, in the variance or "phonetic repertoire". Where adjustments are non-linear, this sequence is likely to be repeated.

5.3. Conclusions

Chapter Four examined the first-month English IL vowel systems of the eleven Brazilian learners of this study and the first research question—the extent to which these IL systems were modeled on the respective NL vowel schemas and on the TL vowel input. Evidence was presented for the claim that the early IL vowel systems of these L2 learners were modeled on the NL systems, but were already moving in phonetic approximation toward the perceived outline of the TL system.

This chapter has documented the development of these IL systems in the subsequent months of the study. Although less progress was made than expected toward the acquisition of the new TL vowels, some interesting developments were observed which shed light on research questions two through six and allow the formulation of a coherent model of the evolving interlanguage vowel system.

The second research question, based on Lindblom's theory of sufficient perceptual contrast, asked whether the data would provide evidence for a link between the acquisition of the new TL vowels and the adjustment of the old vowels of the IL systems, in an attempt by the learners to maintain sufficient perceptual distance. The data from this study have provided evidence for this link between acquisition and adjustment (a) in the acquisition by CR and CL of the new vowel /ɪ/, which involved the lowering of /eɪ/; (b) in the partial acquisition by NR and SN of the new vowel /æ/, which involved the inappropriate adjustment of /eɪ/ by the former and the appropriate adjustment of /ɑ/ and /ʌ/ by the latter; and (c) in the extension of the lower portion of CL and VN's vowel systems, in apparent preparation for the acquisition of /æ/. The adjustments in the lower portion of the IL system have shown that sufficient space is required for the acquisition of a new vowel not only between two old vowels, but also on the periphery of the vowel system. In other words, if the system contains insufficient vowel space overall, this space must be increased for the acquisition of a new point vowel to occur.

The data have provided, in addition, evidence for a link between non-acquisition and insufficient adjustment, (a) in the blocking by /eɪ/ of the lowering of /ɪ/ in the IL vowel systems of nine of the eleven subjects, and (b) in the lack of adjustments of the lower vowel line in the IL systems of all subjects except SN, CL, and VN. The data have contributed evidence also for a link between the adjustment of each vowel with that of the adjacent vowels, even when this does not involve the acquisition of a new vowel. The most frequent case was the simultaneous adjustments of /i/-/ɪ/ and /eɪ/, whether in the appropriate or inappropriate direction. Finally, the data have shown, by the early acquisition of /ʌ/, that the earliest new TL vowel to be acquired is likely to be one whose appropriate relative position can be realized without impinging on the space of adjacent IL vowels.

Liljencrants and Lindblom (1972) and Lindblom (1986), in their work on perceptual contrast, refer only to the monophthongal vowels in each language's vowel system. This is presumably because the diphthongs are distinguished by their diphthongal trajectory, and thus theoretically do not need to maintain perceptual distance within the vowel space. Ladefoged and Broadbent (1957) and Ladefoged (1989), in demonstrating the importance, for the perception of a vowel, of the relationship between its formant frequencies and those of the other vowels in the same speaker's system, used monophthongs as the vowels to be distinguished. However, the introductory phrase in their experiments—"Please say what this word is"—contains monophthongs and the pseudo-diphthong /eɪ/. Although the English /eɪ/ was included in this study because of its doubtful status as a diphthong, it was observed in 4.1 that most of the subjects apparently identified it with the Portuguese diphthong /ei/ rather than with the monophthong /e/.

In spite of the apparent classification of English IL /eɪ/ as a diphthong by most of the learners and its consistent distinction from the other IL vowels by length and diphthongal trajectory, the position of this vowel was a key factor affecting the evolution of the subjects' /ɪ/ and even of their /ɛ/. This finding should not be surprising. It has been shown that both Lindblom's theory of sufficient perceptual contrast and Ladefoged's theory of the relative nature of vowels played a part in the evolution of the eleven subject's vowel systems. Although sufficient distance in the vowel space between diphthongs from monophthongs may not be necessary for their distinction, it makes sense that the relative position of diphthongs to monophthongs is just as important as the relative position among monophthongs. The diphthongs are composed of vowel movements which must be in the appropriate relative part of the vowel space to be accurately identified. If the components are not identifiable, the diphthong will not be either.

In the case of the three highest English front vowels, the learner needs to create sufficient perceptual distance between /i/ and /ɪ/ in order to contrast these two vowels. If the IL /ɪ/ is lowered enough to create that distance without the appropriate adjustment of /eɪ/, these two vowels will still be in contrast because of the diphthongization of the latter, but they will be in inappropriate positions relative to each other. Inappropriate relative vowel positioning is apparently less acceptable to the learner than insufficient perceptual distance, and is avoided at all cost.

The third research question asked whether adjustment of the old IL vowels of the subjects would occur before or at the time of acquisition of the new TL vowels, according to the prediction based on Rumelhart and Norman's model, or after, according to the prediction based on Karmiloff-Smith's model. Most of the evidence from this study indicates that adjustment of adjacent old vowels occurs first or simultaneously with the acquisition of the new vowel: (a) the motivation for the extension into the lower vowel space of the IL systems of CL and VN is likely to have been to prepare the IL vowel schema for the acquisition of /æ/; (b) the acquisition of /ɪ/ by nine of the eleven subjects appears to have been blocked by the non-occurrence of the necessary adjustments in /eɪ/; (c) the partial acquisition of /æ/ by NR and SN occurred simultaneous to adjustments in the adjacent vowels; and (d) the acquisition of /ɪ/ by CL occurred only after the necessary adjustments in /eɪ/. However, because acquisition is generally gradual and non-linear, it is possible that the learning processes described by Rumelhart and Norman's model of learning work together with those described by Karmiloff-Smith. For example, in CR's acquisition of /ɪ/, the partial success in the separation of this vowel from /i/ may have been the motivating force for the adjustments in /eɪ/, which then allowed for the completion of the separation process.

The fourth research question asked whether adjustments in the subjects' IL vowels would be made suddenly and involve major changes in the outline of the vowel system, implying a process like restructuring, or gradually and locally, implying something more like tuning. This is a difficult question to answer, not only because of the subjective nature of the data collected, but also because of the vagueness in the definitions which distinguish these two processes. This vagueness is admitted by Rumelhart and Norman, when they propose talking "as if we could indeed classify learning into these three categories : *accretion, tuning, and restructuring*" (1978, p. 38). The distinction initially sounds clear, when they specify that "restructuring involves the creation of entirely new memory structures, whereas tuning involves the evolution of old memory structures into new ones" (1978, p. 40). However, they claim later in the same paper that restructuring can occur by "patterned generation", in which variables of the old schemata can be replaced by constants and vice-versa, which is one of the ways in which tuning can take place besides. In summing up (1978, p. 50), they state that tuning should be sufficient when the arriving information "is only mildly discrepant", and that restructuring may be necessary when this input "is more discrepant." The obvious questions are (a) how discrepant does the input have to be to require restructuring and (b) how many variables must be replaced with constants or vice-versa to label the modifications as restructuring, rather than tuning?

In 4.5 the creation of the IL vowel schemata, modeled or patterned after those of the NL, was labeled restructuring. This categorization was necessary to specify that new schema structures had been created—tuning of the NL schemata in the direction of the TL might imply that the learners had lost the ability to accurately produce the vowels of their first language. After the creation of the IL vowel schemata, most of the adjustments in the vowels of these schemata have been gradual and non-linear, making the labeling of these adjustments as anything except tuning counterintuitive—one would not expect the repeated creation and subsequent disappearance of new vowel schemata. The one exception to this tendency was in the eighth month of SN's vowel schema, when sudden and radical changes occurred in the lower portion of the system, including a much larger step toward separation of /ɛ/ and /æ/ than in previous months. These are very few data on which to base any strong conclusions. However, because SN was the only subject to come this close to acquiring a distinct /æ/, it might tentatively be suggested that whereas tuning is sufficient for the acquisition of a mid vowel like /eɪ/, the acquisition of a new point vowel requires a more radical restructuring.

Questions five and six asked whether vowel adjustment would be linear and whether the "phonetic repertoire" or variance of each vowel phoneme would follow the tendency of increasing and then decreasing. The first of these questions can be answered simply—there was definitely a strong tendency toward non-linearity, mostly in the form of back-and-forth adjustments, but also in the form of vowels "wandering" in different directions within the vowel space. As to the increasing and decreasing sequence of the variance, part of this question can be answered with confidence. That is, noticeable adjustments in vowel realization rarely occurred without an equally noticeable increase or decrease in variance. In the case of non-linear adjustments, it was often the case that if the move in one direction involved an increase, then the return to the previous position would involve a return also to the previous approximate variance. Because of the limited time of the study, the sequence of increases and decreases in variance cannot be determined with certainty. It is likely that the sequence repeats itself, thus making the order of occurrence irrelevant.

Throughout this chapter the term variance has been used in place of Beebe's expression "phonetic repertoire" because of the use of the statistical measure of standard deviation in the drawing of the ellipses. However, because the limited number of six tokens per vowel per month for each subject limits the validity of this statistical measure, it cannot be claimed that the month-to-month differences in variance are significant. Rather, conclusions are based upon the subjective evaluation that the changes occurring among the eleven subjects have been similar. Thus, the conclusion would be more accurately stated using the original expression—vowel adjustments involved both the expansion and shrinking of the phonetic repertoire, probably more than once and not in any particular order.

5.4. Discussion

The conclusions formed above can now be put together to complete the model of vowel acquisition begun in Chapter Four. It was suggested in 4.5 that most L2 learners are sensitive to the overall acoustic differences between the NL and the TL, which allows all but a few, who never pass the stage of using their NL vowel schema in the TL, to generate early on an IL vowel schema to account for the TL vowels. However, because of the different number and realization of the TL vowels and the cognitive mechanism called equivalence classification (see 2.1.2 on Flege), few if any learners are able, at this stage, to identify each TL vowel sound in the input with the appropriate TL vowel phoneme. Therefore, the individual vowels in this new IL vowel schema are initially patterned on those of the NL schema, but positioned in the acoustic space between the NL model and the perceived overall outline of the TL vowel system, in a phonetic approximation more general than that described by Flege.

Any NL vowel not associated with vowel sounds from the TL input is dropped from the new system, as occurred with Portuguese /a/ in the present study. Any TL vowel sound which is within the acoustic limits of the new IL system, but which is too different to be associated with a NL vowel and will not create a problem of insufficient perceptual contrast, is incorporated as a new node in the IL schema, positioned according to the approximate relative position in the TL. This was the case of the English vowel /ʌ/ in this study. A TL vowel positioned well outside the range of the NL vowel space is likely to be associated with the NL vowel in the most similar relative (as opposed to absolute) position and interpreted acoustically as being only slightly more peripheral. This was the case, in this study, of the English vowels /æ/ and /ɑ/. Thus, the IL vowel schema is created, in Rumelhart and Norman's terms, by a restructuring process involving patterned generation of schemata, with a change in the constraints on the variable terms (i.e., the relative range of positions of each vowel within the acoustic space), and the possible omission and/or addition of variables.

Some learners probably end their acquisition process at this stage. The IL vowel schemas which continue to evolve, however, undergo constant tuning and occasional restructuring in their attempts to reshape the outline of the total IL vowel space and to realign the individual vowels along and within this outline, to conform more closely to the TL. This tuning and restructuring usually occurs through a sequence of increases and decreases in the phonetic repertoire, meaning that learners first realize only a few tokens of a particular vowel in the new manner, and gradually decrease the frequency of the realizations in the old manner. Although most L2 learners, even adults, may maintain the acoustic sensitivity which enabled them to acquire their NL, this sensitivity is constrained in two ways.

First, their experience with the NL has given them practice in identifying and producing vowels in only certain areas of the vowel space. The newly constructed IL may have increased this space, but only slightly. Because new data are interpreted according to the existing IL schema, learners may interpret the data as being outside the existing vowel space, but cannot compute accurately how far outside. Since it is not the data which are stored in memory, but the interpretation of these data (see 2.3.1 on Rumelhart and Ortony), the inaccurate perception of TL vowel sounds perpetuates itself, continually limiting the total vowel space of the overall schema on which new vowels are interpreted. This helps to explain why learners who have not acquired the TL vowel distinctions after several years of exposure to the language are unlikely to acquire them later. They have by then stored a large quantity of inaccurately interpreted data.

The second constraint on the acoustic sensitivity of L2 learners may or may not be due also to NL experience. An awareness of the importance of both relative vowel positioning and sufficient perceptual distance makes both the initial acquisition and the later evolution of each vowel dependent on that of the surrounding vowels. It appears that in most cases learners must adjust the surrounding vowels, i.e., tune or restructure the IL vowel schema, to maintain relative positioning and sufficient perceptual distance, before or at the time of accretion of the new TL vowel. It may be that in some cases, however, the process of vowel separation begins before adjustment of the adjacent vowels, and thus serves as motivation for this adjustment, but can only be completed when the necessary tuning or restructuring takes place.

Whatever the order of occurrence, the dependence of each IL vowel on the others may be an advantage to the learners in one sense: given the evidence provided by Ladefoged (1989) and by Ladefoged and Broadbent (1957) that the listener depends heavily on *relative* formant frequencies for vowel identification, it might confuse the listeners if English L2 learners learned to produce, for example, a distinction between /i/ and /ɪ/ which left /eɪ/ positioned between them.

On the other hand, this interdependence of the IL vowels makes the whole acquisition process more complicated, especially if the TL has a greater number of vowels than the NL. It means that the task of acquiring each new vowel involves much more than learning to distinguish it from its closest neighbor. It involves making adjustments in several surrounding vowels, which may each in turn require adjustments in their adjacent vowels. In sum, the process of *vowel* acquisition might better be seen as a holistic process of *vowel system* acquisition.

6. Discussion

6.1. Theoretical significance of findings

Like most studies in second language acquisition, the findings of the present study are not as conclusive as one would like them to be. The study has, however, contributed considerable SLA evidence toward both phonetic theories of vowel space and cognitive theories of learning. Previously contributed evidence for the phonetic theories dealt with here has, as far as I know, come exclusively from first language and fluent bilingual data. Previous evidence for the cognitive models has come from first language data, from data on other areas of learning, and from SLA reading data. None of the theories or models has accumulated any substantial supporting evidence from the area of second language phonological acquisition.

6.1.1. Significance for phonetic theory

The two studies which provided the basis for the theory of the relative nature of vowels (Ladefoged & Broadbent, 1959; Ladefoged, 1989) both involved the perception of native language vowels (albeit produced by a synthesizer in the former). The listener, according to these studies, perceives each vowel in relation to the other vowels produced by the same speaker. The study reported in this dissertation provides evidence that the second-language learner also produces each IL vowel in relation to the other vowels in his IL vowel inventory.

Lindblom's theory of sufficient perceptual distance is based on a large body of first language data reported by Crothers regarding vowel inventories of many of the world's languages, in addition to evidence from his (1986) and Liljencrants and Lindblom's (1972) mathematical models. It has been supported by a study by Disner, on both first-language data from several mostly Germanic languages, and on more-easily compared bilingual data on several pairs of languages. This dissertation contributes SLA data which indicates that second-language learners are also constrained by the need to provide their listeners with vowels which are sufficiently distant in the acoustic vowel space.

6.1.2. Significance for cognitive theory

Rumelhart and Norman's (1978) model of accretion, tuning, and restructuring is supported by examples in the areas of concept and skill learning. Since their abandonment of their learning model in favor of PDP models, the learning model has been applied to second-language reading by McLaughlin, Rossman and McLeod (1983), McLeod and McLaughlin (1986), and others. Studies in SLA phonology, to my knowledge, have not concerned themselves with cognitive learning models. This study has added evidence from the area of SLA phonology to the evidence in the area of second-language reading, to support the hypothesized processes of accretion, tuning, and restructuring.

Karmiloff-Smith has accumulated a wealth of data to support her success-based learning model, from a variety of child learning tasks, including tasks involving first-language acquisition. She has not, as far as I know, looked at second-language learning (except hypothetically - 1986a), and she has dealt with first-language phonology only to the extent that phonological procedures affect other types of linguistic learning, such as gender (1978). There was one case in the present study which could be interpreted to support the functioning of success-motivated learning, in conjunction with a tuning in the mold of Rumelhart and Norman's model. There is little indication in the rest of the data, however, that success-motivated learning, as described by Karmiloff-Smith, occurs in the area of second-language phonological acquisition.

6.2. Methodological significance of findings

In the area of SLA research methodology, the present study has illustrated the importance of carrying out longitudinal studies, studies which include the phonetic level and use instrumental (acoustic analysis) techniques, and studies which treat vowels as a system.

Although the importance of longitudinal studies has been recognized by many in the field of SLA research, most researchers still prefer cross-sectional studies, which involve a much shorter time commitment, and which lend themselves more easily to statistical tests. The present study has shown the importance of longitudinal studies in at least three ways. First is the fact that phonological acquisition is not linear, making it difficult in a cross-sectional study to identify the stage of the learner. Realizations of IL phonemes occurring at one stage, whether accurate or not, frequently disappear and reappear at a later stage. Second is the fact that a cross-sectional study cannot show the connection between the acquisition of one item and the acquisition of another—the presence of two different items at the same stage of learning does not necessarily mean they have been acquired together. This second reason leads into the third—that it is only through a longitudinal study that one can reasonably make claims about the cognitive *processes* occurring during acquisition. In the present study, these processes have been implied from parallels observed between the acquisition of different linguistic items.

It is true that for some areas of SLA phonology, especially those involving syllable structure, the phonological level of analysis is sufficient. However, a total neglect of the phonetic level means missing a good deal of information about the acquisition process. In the case of second-language vowels, for example, a narrow phonetic transcription based on careful listening by an experienced phonetician can identify several different native or non-native variations of a particular target vowel sound. It could not, however, have demonstrated, with the same level of precision as the acoustic analysis of this study, (a) the degree to which a particular IL vowel approximates the NL or TL norm, (b) the degree to which a particular IL vowel is distinct from adjacent IL vowels, (c) the degree of variance of a particular IL vowel from month to month, or (d) the size of a learner's total acoustic vowel space relative to the total space of the NL or TL norm.

Finally, the present study has demonstrated the importance of treating IL vowels as belonging to an integrated system of vowels. Many SLA researchers today emphasize the importance of recognizing that a learner's interlanguage at any particular stage is an integrated (if not entirely stable) system with its own set of rules. Yet researchers in the area of SLA phonology continue to study pairs of IL vowels to discover, for example, which is acquired with greater precision, the vowel with a NL counterpart or the one which is totally new. A study limited to comparing pairs of IL vowels will necessarily fail to make the types of discovery made in the present study, including (a) connections between the development of one IL vowel and that of another (e.g., the lowering of /eɪ/ and the acquisition of /ɪ/); (b) a connection between the ease or difficulty of acquisition of a particular vowel and its position relative to the total NL vowel space (e.g., /ʌ/, which is positioned within the total vowel space of the Portuguese vowel system, and /æ/, which is positioned outside the limits of the Portuguese system); (c) the similarity in size and shape of the total IL vowel system and that of the NL and TL norms.

6.3. Pedagogical significance of findings

Just as SLA phonology researchers have persisted in studying pairs of IL vowels, L2 pronunciation teachers and materials writers have persisted in drilling distinctions between pairs of TL vowels, in isolation from the rest of the system. In English classes in Brazil, for example, the emphasis is on distinguishing /ɪ/ from /i/, /ʊ/ from /u/, and /æ/ from /ɛ/. English /eɪ/ and /oʊ/ are often ignored in pronunciation exercises because the substitution of a Portuguese /e/ or /ei/ for English /eɪ/ or a Portuguese /o/ or /ou/ for English /oʊ/ will not usually cause problems of comprehension. What the present study has shown is that if Brazilian learners continue to produce, for example, English /eɪ/ at the height of the Portuguese counterpart, they will probably fail to acquire the distinction between English /i/ and /ɪ/, because Portuguese /e/ and /eɪ/ are usually realized at almost the same height as the latter English vowel. This study was limited to the front vowels, but it is quite likely that a Portuguese pronunciation of the English /oʊ/ would interfere with the acquisition of English /ʊ/ in the same manner. The obvious conclusion is that all the vowels of the TL system need to be taught, and drills should not be limited to similar pairs, but should cover entire sequences of vowels. Vowel practice could include exercises similar to the practice of scales in singing or piano classes, and the practice of vowels in context should always include sentences containing sequences of vowels.

Another important pedagogical implication of the present study is that, as pointed out by Dickerson (1973), the language teacher often perceives only that a student is not adequately distinguishing between two different vowels (or consonants or suprasegmentals), even after considerable drilling. It may often be the case, however, that progress is being made, if not in the approximation to the specific vowel sound, at least in opening up the vowel space around the target position. Although many foreign/second language institutions do not have the resources to consider computerized language labs at this point, those that do should be looking into this possibility. It is only through a visual presentation of the acoustic quality of IL vowel realizations (see Edney, 1990 and Molholt, 1988) that teachers and students can obtain precise information about the direction and degree of progress made and progress yet to be made.

6.4. Suggestions for future research

It was stated in the introduction that this dissertation was limited to studying the steady-state formant structure of IL vowels. Although the steady-state formant structure is an important, possibly the most important, feature for the identification of vowels, it was recognized in 2.3.1 that other features, such as duration, diphthongal trajectory, and relative intensity of formants, are also important. It is hoped that future SLA vowel studies will include the study of these features.

Although the present study has made discoveries about the process of vowel acquisition that were possible only because of its longitudinal nature, the progress documented in this study has been limited. Further studies are needed which follow the progress of second-language learners from the absolute beginning until they have reached a greater degree of proficiency in pronunciation than the learners in this study. This will most likely mean continuing the study for a longer period than six months. It is also preferable to find subjects who are both enrolled in language courses and who have sufficient opportunities to interact with native speakers. The three subjects in the present study who made the greatest progress were the only three who were enrolled in English language classes during most of the duration of the study.

Finally, it would be insightful to follow up a study like the present one with perception tests to discover just how distant in the acoustic space pairs of IL vowels need to be for native speakers of the TL to identify the intended vowel, and how much other features can compensate for insufficient acoustic distance.

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Appendix A: Portuguese Corpus

Month 01

Fala libra de novo.
Fala respeita de novo.
Fala reta de novo.
Fala meta de novo.
Fala preta de novo.
Fala aceita de novo.
Fala cita de novo.
Fala nata de novo.
Fala rita de novo.
Fala mata de novo.
Fala rata de novo.
Fala caneta de novo.
Fala neta de novo.
Fala fita de novo.
Fala chupeta de novo.
Fala seta de novo.
Fala brita de novo.
Fala mêta de novo.
Fala pata de novo.
Fala deita de novo.
Fala enfeita de novo.
Fala cinta de novo.
Fala pausa de novo.

Month 05

Fala libra de novo.
Fala reta de novo.
Fala meta de novo.
Fala cita de novo.
Fala bota de novo.
Fala preta de novo.
Fala vota de novo.
Fala nata de novo.
Fala cota de novo.
Fala Rita de novo.
Fala rota de novo.
Fala mata de novo.
Fala rata de novo.
Fala caneta de novo.
Fala mêta de novo.
Fala fita de novo.
Fala chupeta de novo.
Fala seta de novo.
Fala brita de novo.
Fala neta de novo.
Fala pata de novo.
Fala cinta de novo.
Fala pausa de novo.

Appendix B: English Warm-Up Story

It was hot.
Pat planned to meet Kate and go fishing.

He met her at the hut.
Kate wore a straw hat, to protect her head from the heat.
She looked very neat, but Pat did not.
He wore nothing on his feet.
They went out and shut the gate.
Then they went to get some squid for bait.
While Kate cut the squid, Pat bet ten dollars he could catch the biggest fish.
Now they sat down on a mat to wait.
Pat offered Kate a nut, and he ate some himself.
A gnat landed on Kate's nose.
"I really hate these gnats," she said.
"Next time I'll sit at home and relax, or maybe (k)nit.
Suddenly a fish bit on Kate's line.
She reeled it in, while Pat got the net.
Kate put the fish in the pot, but it didn't fit.
She smiled and said, "Ten dollars, please."

Appendix C: English Corpus

Forty-two test words plus thirteen distractor words, all contextualized in the carrier sentence: *Say* _____ *now*.

Test Words

meet	mitt	mate	met	mat	not	nut
neat	knit	bait	net	gnat	pot	but
beet	bit	fate	bet	bat	shot	shut
feet	fit	gate	pet	Pat	cot	cut
seat	sit	Kate	set	sat	got	gut
heat	hit	hate	get	cat	hot	hut

Distractor Words

fish	nose	reel	thing	wore
head	plan	smile	ten	
home	please	straw	they	

The Acquisition of English Vowels by Brazilian-Portuguese Speakers is the sixth volume of the Advanced Research in English Series (ARES), published by the Graduate Program in English Language and Literature of the Universidade Federal de Santa Catarina (UFSC), Brazil. It is the result of doctoral research carried out by the author, Barbara O. Baptista, at the University of California, Los Angeles (UCLA), sponsored by CAPES, of the Brazilian Ministry of Education, during the period of 1987 to 1992.

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