

THE ACQUISITION OF AN L2 VOWEL SYSTEM: A LONGITUDINAL
INVESTIGATION OF CHANGE

by

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Abstract

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To what extent do the vowels systems of L2 learners change over time and what types of changes can be expected? The study reported here is a longitudinal investigation of change in the vowel systems of five adult native Spanish speakers learning English. It focuses on eleven vowels of English as uttered in CVC words and in various sentential contexts. Vowel productions from each speaker were measured for the acoustic parameters of F1, F2 and duration. These acoustic parameters were then analyzed via the classification matrices of discriminant analysis and compared over time.

Change in the nonnative speakers was analyzed in two ways: independently of the target and in direct comparison to the target. Research in L2 acquisition has suggested that *interlanguage* is a system unto itself unlike the native language or the target language (Selinker, 1972). Thus, the nonnative speakers' vowels were first examined independently of the native speakers' vowels. This phase of the analysis showed which vowels were differentiated by a speaker on the three acoustic parameters, which were not, and whether there were changes over time in how vowels were differentiated.

Research in cross-linguistic production has shown that learners may approximate target norms without necessarily achieving them (Flege, 1980). Therefore, in addition to considering the interlanguage of the nonnative speakers, change over time was also examined with respect to the target language. Nonnative speakers' vowels were compared directly to the two native speaker participants in the study. This second phase of the analysis showed whether changes approximated target norms.

Findings indicate that the vowels of nonnative speakers change in ways that reflect dialectal and diachronic changes. Specifically, we see instances of split, merger and shift as described by Labov (1994). It is also the case, however, that changes occur that are unique to L2 acquisition. These changes are undoubtedly related to the learning of orthography and sound-spelling correspondences.

This study provides evidence that intermediate phonological systems arising during L2 acquisition should be viewed not only in terms of the target but as unique systems of contrasts. It also provides evidence that changes are not necessarily unilateral; movement in one aspect of a system can affect other aspects of the system.

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Chapter 1: Introduction

In the study of second language (L2) acquisition and cross-linguistic production, many models have been proposed to account for learners' pronunciation of L2 sounds. In an attempt to determine which model best accounts for the complex facts of L2 production, it is often the case that we focus on particular aspects of pronunciation, on particular subsets of the phoneme inventory, or on particular learning paradigms that will best determine between models or hypotheses.

Taking a historical perspective of the studies of phonological acquisition we can examine this approach beginning with early research on transfer and contrastive analysis. Lado (1957) first proposed the Contrastive Analysis Hypothesis (CAH), which stated that errors in the production of an L2 can be explained or perhaps predicted via a comparison of the first language (L1) and the L2. In response to this proposal, researchers examined the speech of L2 learners by choosing sounds or subset of sounds to test whether transfer could in fact account for learners' successes and errors and to determine the relative difficulty of different types of transfer. An excellent study conducted by Brière (1966) can serve as an example of this methodology. Brière examined several possible types of transfer paradigms. He looked at cases of distributional transfer, convergence, divergence, regrouping and atypical sounds. In Brière's article, distributional transfer referred to the situation in which both languages have a sound but the sound cannot occur in the same position in the two languages. Divergence referred to the situation in which a single phoneme category in the native language must diverge into two separate phonemes in the target language. Convergence referred to the situation in which two separate

phones in the native language must converge into a single category in the target language. Regrouping referred to the situation in which features that exist in the native language, must be regrouped into a completely new combination. The final case, atypical sounds, referred to the situation in which sounds in the target language involve a reduction of features in the native language or require the addition of at least one feature completely new to the native language. In order to test the relative difficulty of each of the transfer types, Brière studied native speakers of American English (AE) on their ability to pronounce words from a composite segmental system based Arabic, French and Vietnamese. These words contained sounds that typified each pattern just described. For example, the sounds /ʒ/ and /ŋ/ were chosen to represent the distributional type because while they exist in AE they do not occur in the same position as they did in the target composite system. He chose the sounds /e/ and /ɛ/ to represent the convergence type because these separate phonemes in AE needed to converge into a single phoneme in the composite system. He chose the sounds /t/ and /t^h/ to represent the divergence type because these allophones in AE needed to diverge into separate phonemes in the composite inventory. Once he chose representative sounds he then placed them on a hierarchy of difficulty based on the mean number of correct testing trials for the AE speakers. From this study we have learned that certain paradigms (such as divergence) present greater difficulty than others (such as distributional differences). It becomes apparent, however, that Brière's conclusions would only hold true if other sounds representing the same paradigm were learned in the same way. That is to say other sounds in a target language that represent convergence, divergence, distributional transfer and so forth, would need show similar ease or difficulty of learning otherwise the

findings could be due to some other factor. Therein lies the problem; we do not in fact have information from all similar cases, only from a small subset.

As theories of phonology began to focus more on features and less on phonemes and as CAH failed to account for all cases of L2 pronunciation errors, researchers proposed new models of L2 phonological acquisition. They proceeded, however, with much the same methodology. That is to say, subsets of the phonology representative of a particular learning paradigm served as primary test cases. As an example, Eckman (1977) proposed the Markedness Differential Hypothesis (MDH) which suggested that areas of the target language that were both different from the L1 and marked would be more difficult to learn. Whereas, areas of the target language that were different from the L1 but not more marked would not be difficult. (Markedness in this case is defined in the following way: A is more marked than B in a language if the presence of A in a language implies B but the presence of B does not imply A). Eckman used the case of voicing contrasts for English speakers learning German and German speakers learning English. Previous studies showed that German speakers have more difficulty learning to voice consonants in word final position than English speakers do having to devoice consonants in word final position. Since CAH does not predict this, Eckman offered the MDH as a possible explanation of the directional differences. Word final voicing contrasts are both *different* and *marked* for German speakers learning English and therefore are predicted to be more difficult. (The presence of final voiced contrasts implies the presence of voiced contrasts in initial and medial position thus word final voiced contrasts are marked). Again, it is

unclear if all sounds that are marked behave the same way throughout a learner's pronunciation since only a small subset of cases¹ were looked at.

Other theories of phonological acquisition that focused on markedness and the status of features in a system followed. One such example is Carlisle's theory of cluster acquisition based on markedness and the sonority hierarchy. Carlisle (1991) suggested that markedness in conjunction with the sonority hierarchy could explain the fact that Spanish speakers had fewer occurrences of epenthesis before /sl/ clusters than before /sm/, /sn/, and /st/ clusters. He suggested that clusters that are unmarked *and* satisfy sonority will be easier than those that are marked *and/or* do not satisfy sonority. He suggested that /sl/ clusters satisfy the sonority principle (sonority must decrease outward from the nucleus) and are also less marked (the presence of obstruent plus nasal clusters in a language implies the presence of obstruent plus liquid clusters).

Theories of underspecification have also been proposed to account for L2 errors. Hancin-Bhatt (1994, 1999) for example proposed the Feature Competition Model (FCM) which incorporated the basic tenets of underspecification and economy of representation to determine which features are most prominent in a system and therefore most likely to be recognized over those with less prominence. Hancin-Bhatt (1994) viewed features in a phonological system as being in competition with each other to be recognized, arguing that prominent features are more likely to be recognized, salient and easier to learn. Prominence is calculated by dividing the number of phonemes for which a feature is

specified by the total number of phonemes in the inventory and rests largely on theories of radical underspecification.

Hancin-Bhatt tested speakers of German, Turkish and Japanese on the production of non-words containing one of eight target sounds (/θ, ð, t, d, s, z, f, v/). The FCM made predictions about the relative ease or difficulty of each these sounds for different L1 speakers based how prominent a feature of the target sound was in the L1. Yet, for all of the studies described, we do not know how the models proposed predict the relative difficulty or ease of learning across an entire system in an individual learner or groups of learners.

Two of the most influential models come from Flege (1987, 1995), the Speech Learning Model (SLM), and from Best (1995), the Perceptual Assimilation Model (PAM). Flege's SLM rests on the classification of sounds into the categories of *new*, *similar* and *different*. New sounds are those in the L2 that have no phonetic counterparts in the L1. Similar sounds are those in the L2 that differ systematically from identifiable counterparts in the L1. Identical sounds are those in the L2 that have identical properties to those in the L1. Flege suggests that identical sounds will pose no problems for L2 learners, but the acquisition of new and similar phones will differ because of the way in which L2 learners set up phonetic categories. Flege proposes a mechanism called Equivalence Classification which prevents learners from establishing new phonetic categories for similar sounds. Since new categories are not established for similar sounds they are not learned authentically (although they will be approximated as the learner gains experience).

Learners are able to set up phonetic categories for new sounds so they will be produced authentically. In order to test the predictions of SLM, researchers have selected sounds between L1s and L2s that represent the difference between new and similar. For example, Flege applied the SLM to the case of English speakers acquiring French /u/ and French /t/, which are both found in English but show systematic phonetic differences in French (Flege, 1987). Likewise the acquisition of VOT (Riney, 2006) and /r/ and /l/ (Aoyama, et al., 2004) by Japanese speakers learning English have been examined under the SLM.

The Perceptual Assimilation Model (PAM) as proposed by Best (1995) is a theory of perception, not production, but has obvious relevance to the acquisition of an L2 vowel system. The underlying premise of PAM is that segments in the L2 will be perceived according to how similar or different they are from the L1 sounds that are closest to them in the phonological space (defined by the structure of the vocal tract and characteristics of articulatory gestures). Best (1995) posits six assimilation patterns between L1 and L2 contrasts and predicts how well they will be discriminated perceptually. For example, a Two-Category assimilation type is when each non-native segment in a contrast is assimilated to a different category. Discrimination for this type is expected to be good. Single-Category Assimilation is where both L2 sounds in a contrast are assimilated to the same L1 category and both members of the contrast are unacceptable matches for the L2 norm. Discrimination for this type is expected to be poor. Each of the six categories proposed by PAM specifies an assimilation pattern and makes a prediction for the relative ease of perceptual discrimination. In order to test the predictions of PAM and to see if perceptual discrimination patterns can be extended to production, researchers have

selected sounds that represent the categories set forth in the model. Escudero (2000) examined PAM with respect to Spanish speakers learning the English /i/ -/ɪ/ continuum. Morrison (2006) examined PAM with respect to Spanish speakers learning English /i/ -/ɪ/ and /e/ and/ɛ/. Komaki et al. (2000) examined the predictions of PAM with respect to Korean and Japanese speakers learning English /r/ and /l².

Yet, we are still left with the same question. Do all the sounds or sound contrasts that fall into the same production or perceptual pattern behave the same way within an individual speaker? Escudero (2000) suggests several directions for future research at the end her own study of L2 perception. She specifically mentions the need to study category formation and perception of other sounds in the system. She also suggests the need for longitudinal studies of one year or more to determine the stability of the patterns and the sequence of development.

It is not my intention to criticize the studies mentioned above. Like most research on L2 production, this study relies heavily on the findings of those that have come before.

What I am suggesting is the need for an additional line of research to fill in gaps in our collective knowledge. Primarily, we do not know if the behavior of individual sounds or classes of sounds is representative of the phonological system as a whole. We have failed to determine if what is true of one area of a learner's system is also true of other areas that share the same characteristics. We also need longitudinal evidence to see how these learners' productions develop over time.

The present study seeks to observe and describe a system and how the parts of that system interact and change during the course of L2 acquisition. No single study can reasonably examine all aspects of a phonological system in its entirety, so this study examines the acquisition of the vowel systems of L2 learners because they are significant subsystems of the overall phonological system. In doing so, it cannot necessarily select between competing hypotheses of L2 acquisition nor can it explain why some areas are more difficult to acquire than others. It can however make a useful contribution by providing much needed information about systemic patterns. During the course of the study, changes emerged that were both similar to general patterns of linguistic change (Labov, 1994) and unique to L2 acquisition. These changes were not unilateral but affected other areas of the system. The interlanguage systems in this study indicated conflict between change that created contrasts and change that maintained the size of the L1 inventory.

In order to examine contrasts and change in the vowel systems of non-native speakers, a longitudinal study was conducted. Over the period of one year, recorded samples were collected from five Spanish speakers learning American English who represented various stages of acquisition. Some speakers were new to the country and were just beginning to learn English, while others had been living in the United States for as many as twelve years. Samples were collected through a sentence-reading task. Three acoustic parameters (F1/F2 and duration) of eleven vowels were measured and compared across time via discriminant analysis. Phonemic contrasts were discussed in both native and

nonnative speakers with respect to which pairs were differentiated, which parameters were primarily responsible for the differentiation, and which pairs changed over time.

In the present study, **Chapter two** addresses the patterns of change observed in prior linguistic research and is couched primarily in the framework of William Labov's study of linguistic change. Specifically Labov (1994) identifies three types of changes (Splits, Shifts and Mergers) each serving a unique function with respect to creating, eliminating and maintaining phonemic distinctions within a linguistic system. The primary issues addressed are those regarding the observations of change in real time, restrictions of direction and types of movement and whether the way in which L2 systems behave can be compared to diachronic changes observed in languages and their dialects.

Additionally, Chapter two discusses the vowel systems of both English and Spanish in terms of their inventory, phonemic contrasts, allophonic variation and acoustic properties. Once the nature of linguistic change and the structure of the relevant vowel systems have been discussed, hypotheses are made regarding what changes can be expected in the speech of L2 learners.

Chapter three explains the methodology for the study. It begins by describing the two native speakers and the five nonnative speakers who participated in a longitudinal study. It goes on to explain the materials used to elicit eleven target vowels of English and discusses the benefits and limitations of the sentence reading tasks. Chapter three also discusses the acoustic analysis used to measure the vowels and the statistical analysis used to determine change over time.

Chapter four describes the vowels systems of the two native speakers in this study, one male and one female, both monolingual. This chapter explores the changes across time in native English speakers and the degree to which vowels overlap and encroach on the acoustic space of each other. This chapter also examines the effects of allophonic variation and dialectal variation on how systems are structured and change.

Chapters five through nine focus on the five nonnative speakers, each one treated as a separate case study. The vowel systems of the nonnative speakers were evaluated in two ways. First, they were considered as entities unto themselves with respect to which phonemic contrasts were made and how these changed over time. Second, they were considered in direct comparison to the native speakers' systems to gauge acquisition and direction of change.

Chapter ten summarizes the changes in vowels systems of L2 learners, discusses the limitations of the study and proposes areas for future research.

Chapter 1: Notes

1. Eckman (1977) also applied the MDH to the /ʃ/-/ʒ/ contrasts as it differs in French and English and to subsets of other components of the grammar. This of course is one of the appeals of the hypothesis; it can account for paradigms across the all areas of language.
2. This is not to suggest that all research is conducted on small subsets of sounds. Strange et al. (1998), for example, examined perceptual assimilation for Japanese listeners on the entire vowel system of English. Many other studies have measured the acoustic properties of the English vowel system and of the vowel systems of other languages/

Chapter 2: Vowel Systems and Patterns of Change

2.1. Introduction

The purpose of this study was to examine patterns of change in the vowel systems of Spanish speakers learning English. As such, it is necessary to first address how change is to be defined and considered in linguistic research. We can begin by asking how natural languages change over time and then by asking whether change in L2 acquisition mirrors those patterns.

In addition to the nature of linguistic change, the nature of the vowels systems of English and Spanish must also be discussed. Although not all L2 pronunciations can be attributed directly to transfer from the first language the L2 literature recognizes the role of the L1 in L2 acquisition. The evidence for transfer is strong enough that we can assume that many (if not all) L2 learners will be influenced by the L1. This means that during the acquisition of an L2 vowel system, the phonetic and phonemic properties of the L1 system will play a crucial role in how the system changes. The phonetic and phonemic properties of the target language will also ultimately play a role in defining change.

This chapter provides a general discussion of patterns of linguistic change as presented in Labov (1994) and offers several hypotheses about the types of changes one might expect in the acquisition of an L2 vowel system. Once patterns of change have been addressed, patterns of phonemic contrasts and phonetic differences in the vowel systems of Spanish and English are presented.

2.2. Patterns of Phonological Change

Conceivably, one can look at sound change from the perspective of the feature, from the perspective of the segment, from the perspective of phonemic contrasts, from the perspective of the entire vowel system, or from some combination of these. This particular study focuses largely on changes in phonemic contrasts and how changes in one contrast affect others in the system. Given this perspective, it is useful to identify three patterns of change discussed in Labov (1994), which serve to create, eliminate and maintain phonemic distinction in language. The three patterns of change are Splits, Mergers and Shifts.

2.2.1. Split and Subtypes in L2 Acquisition

The first type of change is a *split*. According to Labov (1994) split is the process whereby a preexisting phoneme divides into distinct phonemes. This can occur when two allophones become distinctive upon the loss of a conditioning environment or it can occur when existing word classes divide in what Labov refers to as a *lexical split*¹. It should be noted that split is not the only way for new phonemes to enter a system. New phonemes can also be introduced through borrowing, in which a new sound is introduced through the borrowing of words from other languages (as in the case of English /ʒ/).

It is easy to see the role that split would play in the acquisition of an L2 vowel system². If in fact the result of split is the creation of new phonemic contrasts, then successful acquisition of English by Spanish speakers would require split on several dimensions. Minimally for those speakers who are transferring L1 vowels when speaking the L2, each

of the five vowels of Spanish would need to be split in order to create additional phoneme contrasts. To illustrate, consider a subset of English words containing the vowel /i/ and a subset of words containing the vowel /ɪ/. If an L2 learner initially pronounces all words in the two subsets with a single vowel, such as /i/, then a split must occur in order for the target to be acquired; a new phoneme must be created. Clearly, the new vowel that results from the split must then be distributed correctly in the corresponding target words. It should be clear however, that the term split is reserved for those cases in which a new phoneme distinction is created. It is not used to refer to redistribution of lexical items into other preexisting vowel categories. Such redistributions will be addressed shortly

It is useful to show at this point what split may look like in L2 acquisition. The typical split would likely have three properties:

1. a single phoneme separates into two phonemes
2. one of the resulting phonemes did not previously exist for the speaker and has new phonetic properties
3. one of the phonemes retains the phonetic characteristic of the original category

Figure 2.1 illustrates this using the phoneme /i/ as an example. It indicates that lexical items initially produced with the vowel /i/, regardless of the actual target phoneme, have separated over time into two groups: one produced with the vowel /i/ and the other produced with the vowel /ɪ/.

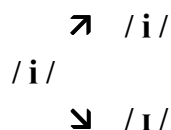


Figure 2.1 Split in which the original phoneme is maintained and a new one is added

Other types of splits are also logically possible. One such case would be a split in which a phoneme separates but the phonetic properties of the original category are not maintained. Let's take the hypothetical example involving Spanish /a/. We will soon see that Spanish /a/ is higher and more centralized than English /æ/ and /ɑ/ but not phonetically identical to English /ʌ/ either. If at some initial point in acquisition, a learner pronounces English words containing the target vowels /æ/, /ɑ/ and /ʌ/ with the single Spanish vowel /a/, then a more complex split would be necessary. Figure 2.2 illustrates such a split in which more than one new phoneme is created and the original category is not maintained. In this scenario, English lexical items produced with the Spanish vowel /a/ split into three phonemes that previously did not exist for the speaker but no phonetic evidence of a category for /a/ remains.

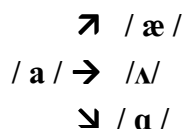


Figure 2.2 Split in which original phoneme is not maintained

Of course, the types of splits illustrated above are idealized, especially when placed in the context of actual language production and second language learning, both of which are complex and defy such neat categorizations. It is unlikely that in this study we will see perfect splits such as the ones illustrated above. But we will see evidence of movement towards the separation of phonemes and we will see evidence of the creation of new phonemic categories that did not previously exist. The definitions and illustrations merely provide a framework to identify the types of change we will potentially see.

2.2.2. Mergers and Subtypes in L2 Acquisition

The second type of change is a *merger*. According to Labov (1994) merger is the process whereby a phoneme moves in the F1/ F2 space but surrounding vowels do not move.

The vowel that is moving essentially encroaches into the space of another vowel and the two become one. Labov contrasts splits and mergers in the following way: Splits involve movement into an *unoccupied* space and *create* distinction, mergers involve movement into an *occupied* space and eliminate distinction.

One can also envision mergers taking place during the acquisition process. In the typical case of merger, two separate vowel groupings become one. Let's say, for example, that an L2 learner is pronouncing two separate vowels /ʌ/ and /ɑ/ in subsets of English target words that contain these vowels (such as *cup* and *top*). If over time all attempts at these target words fall into the range of /ɑ/, we would say that /ʌ/ has merged with /ɑ/. Such a merger is illustrated figure 2.3.

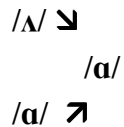


Figure 2.3 Merger in which one phoneme absorbs the other

This simple case of merger involves one vowel moving into the space occupied by another vowel (which in turn remains stable). Labov refers to the elements in this type of merger as the *merging* element and the *absorbing* element. In the example just described, /ʌ/ would be the merging element and /ɑ/ would be the absorbing element.

Other types of mergers are likely to occur as well in L2 acquisition as well. In discussing the mechanisms of change, Labov refers to *Merger by Approximation*. He defines Merger by Approximation as ...*the gradual approximation of the phonetic targets of two phonemes until they are non-distinct* (p.321). Labov describes this type of merger as more of a *coalescence* of two vowels that creates a new vowel as opposed to one vowel absorbing another. Figure 2.4 illustrates this using the vowels /æ/ and /ɑ/ showing that /æ/ and /ɑ/ gradually move closer to each other until the new phoneme is created eliminating the contrast originally present.



Figure 2.4 Merger in which two phonemes coalesce to form a new phoneme

The new vowel may have formant means somewhere between the two original vowels. Although a new vowel is created, this type of merger should not be confused with split. Merger may create new vowels but only because a phonemic contrast has been eliminated elsewhere. Split on the other hand creates new phonemic contrasts.

The question remains as to why mergers might occur in L2 acquisition at all. In studying nonnative speakers learning English, we can temporarily view the five vowel system as the starting point for many Spanish speakers. This five vowel system must be expanded to accommodate the phonemes of the target language. The process which would accomplish this expansion would be split and it is therefore easy to understand why split would occur; in this case it moves the learner towards the target of acquisition. But under what circumstances would an L2 learner merge learned contrasts? Before answering this question we should clarify the difference between having only one phoneme where two are necessary and merging two phonemes into one as the result of change over time. Merger is not simply the production of separate contrasting phonemes in the L2 as a single phoneme from the L1 because they must have first been separate in order to merge. We cannot, for example assume that a Spanish speaker who pronounces target words containing /i/ and /ɪ/ with only the vowel /i/ has merged those phonemes because two phonemes never existed for that speaker. Rather, this is a case of transfer from L1, not a case of merger as defined here. Mergers in L2 acquisition will be viewed in terms of change over time, not in terms of the initial state.

So then what about our question? Understanding why two separate phonemes would collapse is not as easy as understanding why phonemes would split. The first reason why merger may occur in L2 acquisition is because the process of learning a second language does not always move from one to many but also from many to one. Some learners are faced with the task of suppressing phonemic and phonetic contrasts that exist in the native but do not exist in the target language. Likewise, since not all L2 errors are attributed to transfer, an L2 learner may have formed contrasts that don't exist in either the native language or the target language phonology. Merger might be triggered in such a case in order to eliminate an unnecessary or non-target contrast. Although the Spanish speakers in the study are faced with expansion of a system in order to acquire English, we can certainly see why merger might be necessary in other language learning situations.

The second reason mergers might occur in L2 acquisition would be the case of backsliding. We can loosely define backsliding here as the reemergence of non-target forms (see Selinker, 1972, Adjemian, 1976, Klein, 1986, and Schachter 1988, for a comprehensive discussion). In the case of the acquisition of L2 phonemic contrasts, backsliding could be seen in the failure to produce a contrast that had been consistently produced in the past. In the context of this study it is possible to look at backsliding as a case of merger where two phonemes that were evident in the learner's productions have ultimately collapsed over time or reverted back to an earlier state where the learner is simply transferring vowels from the from L1. It is beyond the scope of this study to explain the *causes* of backsliding, but one can imagine many practical reasons why learning might regress, ranging from communicative stress to an extended visit home.

Other reasons for merger will become evident as we look at the results of the L2 learners in this study but for now we move on to the third type of change.

2.2.3. Shifts and Subtypes in L2 Acquisition

The third type of change is shift. Shift refers to a simple movement of a vowel in the F1/F2 space which neither creates nor eliminates phonemic distinction. We recognize the possibility of simple shifts occurring in L2 acquisition. Since vowels of any L1 may not be phonetically identical to the vowels of the L2, the process of acquisition would require vowels to make simple shifts to approximate the targets. For example, if Spanish /i/ is higher and more centralized than English /i/, we may in fact see a lowering and/or a fronting of that vowel. If in fact we see movement into an unoccupied space that neither creates a new distinction nor eliminates an existing distinction we would consider this movement to be a simple shift.

We must at this point differentiate *shifts* from *chain shifts*. A chain shift involves multiple vowels and is the process whereby a phoneme moves into the space left empty by the movement of another vowel. According to Labov (1994) there are *Minimal Chain Shifts* and *Extended Chain Shifts*. *A Minimal Chain Shift is a change in the position of two phonemes in which one moves away from an original position which is then occupied by the other*. Labov refers to the two phonemes of a minimal chain shift as the *entering* and *leaving* elements. *An Extended Chain Shift is any combination of minimal chain shifts in which the entering element of one minimal chain shift replaces the leaving element of a*

second. Labov considers chain shifts movements that involve *interlocking sets* and claims that ...*by definition chain shifts preserve the capacity of the phonemic system to make distinctions* (Labov, 1994:33). So, if some triggering event causes a phoneme to move, other phonemes respond by moving as well in order to maintain distance and phonemic contrasts.

It is also reasonable to expect chain shifts in L2 acquisition. As stated earlier, a chain shift is when one phoneme moves in the vowel space and another moves to fill in the space that is left empty. It is reasonable to assume that in L2 acquisition vowels move to approximate the target norms; it is therefore also reasonable to assume that other vowels may move to fill the space left empty by that vowel. As an example, let's say that a Spanish speaker is producing target words containing /ɑ/ (which is low for English speakers) as /a/ which is higher in the F1/F2 space. As /a/ lowers to /ɑ/, it is possible that other vowels might move into the space that was left by /a/. So, for example, words containing /æ/ might move more towards the center to fill the vacant space thereby creating a minimal chain shift.

2.2.4. Dispersion and Concentration in L2 Acquisition

As we discuss the types of changes that occur in language and potentially occur in L2 acquisition it is important to understand the role of lexical items in these changes.

Speakers do not utter vowels; they utter words that contain vowels. Thus when we talk about sound changes, we are talking about movement in the pronunciation of a set or

subset of lexical items. A fundamental difference between the speakers who are studied in sociolinguistics and the people who are studied in L2 acquisition is that the former have acquired the language and presumably know what vowels lexical items contain. The L2 learner on the other hand is in the process of learning these facts about a language. Thus in acquisition we should expect to see widespread reorganization of vowels in some lexical groupings as learners discover what target vowel these groupings should contain. Movements of vowels resulting from this reorganization often look like splits and mergers (and in fact may be subtypes of these) but will be given separate classifications for now.

Two such changes likely to occur are what we will refer to as *dispersion* and *concentration*. Dispersion will be defined here as the scattering of lexical items containing a single target vowel into multiple preexisting vowel categories. Concentration will be defined as the gradual movement of lexical items that have been scattered among multiple vowel categories into a single preexisting vowel category. To understand these types of changes we can think about the process of acquiring an L2 vowel system in the simplest terms. Most would agree that several things need to happen to successfully acquire an L2 vowel system. These are listed here but it is not my intention to imply that there is a particular order, just that all these must happen. First, the learner must recognize that new phonemes exist. Second, the learner must identify which phonetic or phonological features distinguish the new phonemes. Third, the learner must physically articulate the new phones. And finally the learner must determine how the phoneme is distributed in the lexicon. It is this last step that concerns us for the moment.

As the learner is trying to determine where the vowels belong, dispersion and concentration are likely. Dispersion is essentially when the learner doesn't know what vowel a particular item or group of items should contain and scatters that word among many categories in successive attempts to find the right category. For example, we can consider a speaker who initially pronounced all instances of English /e/ and /ɛ/ as a single category. As the speaker learns that there is a distinction to be made between these two vowels he or she might disperse words containing these vowels into other preexisting categories. Thus words may be pronounced with vowels that match English /e/, /ɪ/ and /æ/. This dispersion may make it look as though the phoneme /e/ is being split, but if the phoneme categories for /ɪ/ and /æ/ already exist then the lexical items have simply been dispersed into preexisting categories and no new contrast has been created.

We can also look at a case where the speaker begins with lexical items containing a single target vowel scattered among several phoneme categories. In this case the learner might eventually tighten or concentrate the subset of items so that it belongs to fewer categories or only one category. Thus concentration is when target words containing a single phoneme are initially dispersed among several phonemes but are then concentrated into a single category.

Since the data in the study that follows uses real lexical items and not nonce items, it is important to distinguish between split, merger and shift on the one hand and dispersion and concentration on the other hand. The term split will be used when there is phonetic evidence of a new phonemic contrast that did not previously exist. The term merger will

be used when there was phonetic evidence of a phonemic contrast but that evidence disappears. The term shift will be used when a subset of lexical items move into a new phonetic space without affecting the number or types of contrasts that exist. The term dispersion will be used when lexical items containing a single English vowel become scattered among numerous preexisting vowel categories. And finally, the term concentration will be used when lexical items that were scattered among several preexisting phoneme categories move into one preexisting phoneme category.

There are two essential points to keep in mind. The first is that differences between movements rest not only on how movement takes place, but the function that movement serves, as well. We have seen that splits function to create phonemic contrasts, mergers function to eliminate phonemic contrasts and shifts preserve phonemic contrasts. We will look at the function of dispersion and concentration subsequently. Second, these definitions are intended only to provide a framework for the direction and types of changes we will see. It is possible that we see combination of changes, incomplete changes or other types of changes altogether.

2.3. Vowel Patterns

In order to understand the nature of change in L2 acquisition it is necessary to understand the structure of the two systems interacting. It is therefore natural at this point to discuss previous studies of vowel inventories and to briefly compare and contrast the inventories

of Spanish and American English. However, any study of vowel systems must be understood within the limitations of the particular study.

The first limitation we should consider is the incompatibility of methodologies and theoretical frameworks. This study exemplifies such an incompatibility. The methodology consisted of collecting acoustic data (F1/F2 and duration measurements) and analyzing them via a multiple linear regression technique called discriminant analysis (described in more detail below). This method of analysis requires each phoneme to be viewed as an atomic unit devoid of internal structure, a requirement that is in direct conflict with virtually all modern phonological theories. Phonological theories view features, not phonemes, as the atomic units. In particular, this study is an attempt to view the evolution of learner's vowel inventories as changes in a system of contrasts, a perspective which directly entails a featural analysis. The reader should understand that this gap is an artifact of the choice of discriminant analysis as a statistical method, not a theoretical claim on the part of the author.

The second limitation we should consider is the variation from one study to the next. Vowel studies vary with respect to the context in which the vowels are couched, the point or points at which the vowels are measured, and the particular dialect of the speakers. An example of the latter case is seen in Hillenbrand et al. (1995), a study that replicated Peterson and Barney (1952). They found significant differences between their results and the Peterson and Barney database that they felt were not due to measurement differences but perhaps dialect differences of the speakers. Hillenbrand et. al. state that "(t)here has

been a tendency to view the PB database as a benchmark of sorts, establishing *the* set of formant frequencies for American English vowels.” (1995:3107). They go on to say that their 1995 study and others like it “serve as a reminder that a study of this kind can only hope to establish a set of formant frequencies that are typical of a specific dialect at a specific time in the history of that dialect.” (1995:3108). We can extend this reminder to vowel context as well. Studies of vowels in open syllables may yield different results than studies of vowels in closed syllables (Bradlow, 1995). Studies of vowels in a classic hVd context may yield different results than those in which vowels are surrounded by a wider variety of consonants (Hillenbrand, Clark and Nearey, 2001). Thus, data from previous research will serve as a point of reference for how English speakers typically use the parameters addressed in this study to contrast vowels, not as absolute values for formant frequencies and duration. Previous studies will also serve to show the similarities and differences between the vowels systems of English and Spanish. The reader should expect reasonable differences in formant and duration means where dialect, context and measuring strategies differ.

2.3.1. Acoustic Properties of Vowels

In the ongoing study of vowels, researchers have identified the primary acoustic features which serve to distinguish vowel contrasts. These include the first three formants (F1, F2 and F3) and duration.

In their replication of the famous Peterson and Barney (1952) study, Hillenbrand et. al. (1995) performed both production and perception tasks on twelve English vowels. Their

findings indicate that the strongest predictors of vowel identification were F1/F2 frequencies at the 20% and 80% point of the vocalic nuclei. F1/F2 frequencies at the steady state *alone* were not strong predictors of identification. These findings coincide with studies of silent center vowels, which show that vowels synthesized without the steady state portion are still identified by listeners and that dynamic information is necessary for accurate identification of vowels (Strange, 1989). Additionally, Hillenbrand et al. found that including duration cues produced “consistent but fairly modest improvements in classification accuracy.” (Hillenbrand et al., 1995:3109)

According to Kent and Read (1992), F1 is roughly correlated with tongue height and F2 is roughly correlated with tongue advancement. Vowels that are considered to be *low* vowels will have high F1 frequencies and vowels that are considered to be *high* will have a low F1 frequency. *Back* vowels will have a low F2 and a smaller distance between the first two formants (a small F2-F1 difference). *Front* vowels will have a higher F2 and a greater F2-F1 difference.

In addition to height and advancement, English vowels are often described using the tense/lax distinction but not without some controversy. Durand (2005) notes that the longstanding tradition in which vowel height allows only three positions (high, mid and low) and the adoption of a binary feature system (as in Chomsky and Halle, 1968) abandons the notion of continuum. Thus any language that appears to have an opposition in more than three degrees of height would need to be handled by some other feature (e.g. tense/lax). This study focuses on acoustic parameters and therefore is phonetic in nature.

Acoustic parameters such as F1 and F2 are in fact scalar and therefore it is not necessary to refer to vowels based on the tense/lax distinction for any other reason than it is convenient to do so when identifying which vowel is being referred to.

Acoustic correlates of tense/lax are also not without controversy. Commonly three acoustic parameters are associated with tenseness or the articulatory correlate advanced tongue root (Walter, 2003, Slifka, 2003). These parameters are 1) lower values for the first formant, 2) longer duration, and 3) breathier voicing. Additionally, higher F2 values may also correlate with tensing. Throughout this study the terms tense and lax are used to help the reader identify which vowels are being referred to (as in traditionally done) but with no intention of ascribing particular acoustic, phonetic or phonological features to a vowel. Differences between pairs of vowels that are traditionally referred to as tense/lax pairs will be discussed in terms of F1 and F2 values. Duration was also included under the assumption that it “helps listeners to distinguish spectrally similar vowels or to place vowels in large categories such as tense versus lax” (Kent and Read, 1992:95).

2.3.2. Acoustic Properties of English Vowels

We now turn to a discussion of how English speakers typically produce vowels with respect to the parameters discussed above. Table 2.1 presents four major studies of vowel production and includes values for F1/F2 and duration measurements when available.

Table 2.1 Results of Four Major Studies of Vowel Production

	Peterson and Barney, 1952 (steady state)			Hillenbrand et al., 1995 (average of measurements)			Bradlow, 1995 (steady state)			Flege et al. 1994 (midpoint measurements) 3 speakers		
	F1	F2	Dur	F1	F2	Dur	F1	F2	Dur	F1	F2	Dur
i												
male	270	2290	Not	342	2322	243	268	2393	Not	317	2299	131
female	310	2790	Incl.	437	2761	306			Incl.	281	2079	130
										300	2180	129
ɪ												
male	390	1990	Not	427	2034	192	463	1995	Not	476	1616	73
female	430	2480	Incl.	483	2365	237			Incl.	373	1618	85
										374	1561	86
e												
male	Not	Not	Not	476	2089	267	430	2200	Not	443	2117	140
female	Incl.	Incl.	Incl.	536	2530	320			Incl.	438	1903	161
										411	2020	195
ɛ												
male	530	1840	Not	580	1799	189	635	1796	Not	629	1653	122
female	610	2330	Incl.	731	2058	254			Incl.	600	1495	104
										552	1575	118
æ												
male	660	1720	Not	588	1952	278	777	1738	Not	777	1788	165
female	860	2050	Incl.	669	2349	332			Incl.	690	1563	170
										732	1468	160
ʌ												
male	640	1190	Not	623	1200	188	640	1354	Not	703	1425	100
female	760	1400	Incl.	753	1426	226			Incl.	599	1200	95
										562	1249	96
ɑ												
male	730	1090	Not	768	1333	267	780	1244	Not	769	1129	155
female	850	1220	Incl.	936	1551	323			Incl.	694	1108	178
										681	1190	172
ɔ												
male	570	840	Not	652	997	283	620	1033	Not	Not	Not	Not
female	590	920	Incl.	781	1136	353			Incl.	Incl.	Incl.	Incl.
o												
male	Not	Not	Not	497	910	265	482	1160	Not	Not	Not	Not
female	Incl.	Incl.	Incl.	555	1035	326			Incl.	Incl.	Incl.	Incl.
u												
male	440	1020	Not	469	1122	192	481	1331	Not	Not	Not	Not
female	470	1160	Incl.	519	1225	249			Incl.	Incl.	Incl.	Incl.
u												
male	300	870	Not	378	997	237	326	1238	Not	Not	Not	Not
female	370	950	Incl.	459	1105	303			Incl.	Incl.	Incl.	Incl.

Keeping in mind that the studies listed in Table 2.1 used speakers of both genders, different dialects, measured formants at different points, and vowels in different contexts, we can tentatively described some patterns that typify AE Vowels.

The vowels /i/ and /ɪ/ in English are typically described as high front tense and high front lax respectively. Although they are both *phonemically* high and front, there is general agreement that they are not *phonetically* identical in height or advancement. In all the studies above we see some degree of difference between F1 and F2 for these vowels. We can expect F1 differences between /i/ and /ɪ/ to fall in the range of 74-195 Hz with lower F1 values for /i/ indicating that it is slightly higher in the vowel space than /ɪ/ (see Figure 2.2 below). We can expect F2 differences between the two vowels to fall in the range of 280-620 Hz with the higher F2 values for /i/ indicating that it is further forward in the vowel space. Duration differences between /i/ and /ɪ/ in the studies above fall in the range of 40-85 msec with /i/ having the longer duration values.

The vowels /e/ and /ɛ/ are typically described as mid front tense and mid front lax respectively. As with the high front vowels of English, the mid front vowels exhibit phonetic differences. We can expect an F1 difference between /e/ and /ɛ/ in the range of 105-205 Hz. Again, the lower F1 values for /e/ indicate a slightly higher position in the vowel space. We can expect an F2 difference between the two vowels in the range of 290-450 Hz. The higher F2 values for /e/ indicate that it is further forward in the vowel space. Duration differences between the two vowels fall in the range of 20-80 msec with /e/ having the longer duration differences.

The low vowels /æ/ and /ɑ/ are typically described by the features front and back. We can expect F2 differences between /æ/ and /ɑ/ that fall in the range of 278-830 Hz. The wide range reflects the variation of /ɑ/ in AE dialects, with some speakers having a low central vowel and some having a low back vowel. We can also expect small differences in F1 values for /æ/ and /ɑ/, with /æ/ having slightly lower F1 values indicating a higher position in the acoustic space. This difference is intensified in some speakers of New York City Dialect (NYCD) who exhibit a raised pronunciation of the vowel /æ/ in certain closed syllables. This raised pronunciation of /æ/ is discussed further in Chapter 4. The duration differences between /æ/ and /ɑ/ range from 8 to 11 msec indicating that duration is *not* a distinguishing feature for these vowels.

The vowels /ɑ/ and /ʌ/ are typically described by both height and advancement. We can expect F1 differences that fall in the range of 66-185 Hz. The lower F1 values for /ʌ/ indicate a higher mid position, while higher F1 values for /ɑ/ indicate a low position. We can also expect F2 differences that fall in the range of 59 to 300 Hz. The high F2 values for /ʌ/ indicate a further forward position but as noted above, there is a great deal of variation for the pronunciation of /ɑ/ in English with respect to degree of advancement. These two vowels have clear duration differences that fall in the range of 55 to 85 msec.

The vowels /o/ and /ɔ/ are difficult to describe phonologically or phonetically. Typically, this pair defies most of what is true of other tense/lax pairs. For example, in terms of the

distribution of these vowels in AE, the tense phonemes appear in stressed final open syllables whereas the lax vowels generally do not (Dubach-Green, 2001). Thus we have we have words such as *see* /si/ but not */sɪ/ and words such a *two* /tu/ but not */tʊ/. With /o/ and /ɔ/, both occur in this environment (as in *sew* /so/ and *saw* /sɔ/). Phonetically, they also behave differently. Tense vowels generally appear to the periphery of the F1/F2 space and closer in height to the corresponding cardinal vowel (Dubach-Green, 2001) while the lax vowels are lower and more centralized. Again, this does not seem to be the case for /ɔ/. Although /ɔ/ is lower than /o/, it is not more centralized than /o/ and arguably as close to the periphery of the F1/F2 space as /o/ (at least in some dialects). Adding to the difficulties is the extraordinary dialect variation we find with these vowels ranging from its merger with /a/ in New England and in the western portion of the United States to its raised pronunciation in New York City. The studies above (from Peterson and Barney, 1952; Hillenbrand et al., 1995; Bradlow, 1995 and Flege, et al., 1994) show little data for this vowel pair because it was excluded from two of the four studies. The two studies that did include /o/ and /ɔ/ showed F1 differences between these vowels that range from 135 to 226 Hz with /o/ having the lower F1 value thus being phonetically higher than /ɔ/. We also saw F2 differences that ranged from 85 to 130 Hz with /o/ having a lower F2 and therefore being further back. Duration differences were only about 25 msec for these vowels with /ɔ/ having the longer duration. Keep in mind, however, that duration values were reported in only one of the four studies. Clearly, more

discussion of these two vowels will be necessary upon examining the results of this study.

The vowels /u/ and /ʊ/ are typically described as high back tense and high back lax respectively. F1 differences between these vowels range from 60 to 155 Hz. The lower F1 values for /u/ indicate a higher position in the acoustic space. F2 differences range from 90 to 210 Hz. The higher F2 values for /ʊ/ indicate that it is slightly further forward. Duration differences for these vowels are approximately 50 msec but as with /o/ and /ɔ/ only two duration means are available for these vowels.

Figure 2.5 shows the vowels plotted in the F1/F2 space based on the means of the values from four studies. The F1/F2 values were determined by taking a mean of the values across the four studies including data from both men and women where available.

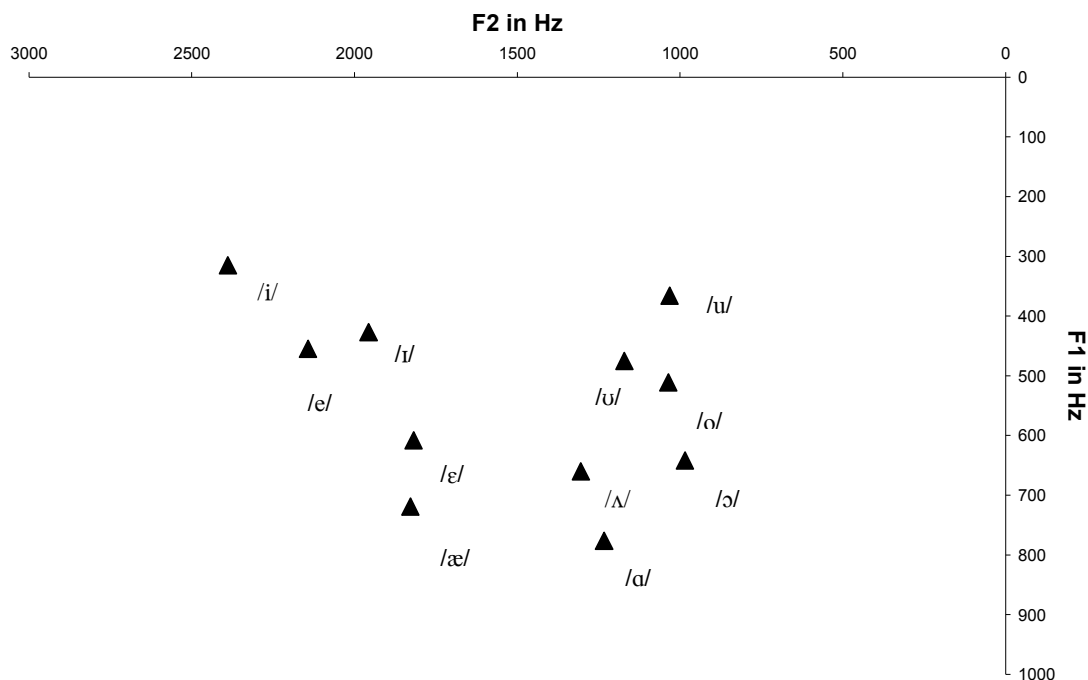


Figure 2.5 F1/F2 means of English vowels across four studies

2.3.3. Acoustic Properties of Spanish Vowels

Spanish is a five vowel system consisting of the phonemic monophthongs /i, e, a, u, o/.

According to Bradlow (1995) the vowel systems of English and Spanish are similar in that neither contrasts vowels by length (alone), nasalization or rounding but they differ with respect to the size of their inventories (i.e. the number of phoneme categories) as well as how the vowels are articulated within those categories. Bradlow (1995) compared English /i/, /e/, /u/, /o/ in both closed syllables (CVC) and open syllables (CVCV) to Spanish /i/, /e/, /u/, /o/ in open syllables. She found that the closed syllable to open syllable comparison yielded an upward shift in F2 for English vowels as compared to

Spanish vowels. Furthermore, English /i/ and /e/ have lower F1 values than Spanish vowels. In the same study, a comparison of English CVCV words to Spanish CVCV words showed that the higher F2 values for all vowels held true regardless of the syllable structure. The F1 differences did not hold in a CVCV context. Simply stated this means that English /i/, /e/, /u/ and /o/ should be further forward in the acoustic space than Spanish vowels. English /i/ and /e/ should also be higher than Spanish /i/ and /e/, in only the CVC context. The results of the CVC comparison in Bradlow's study are, however, relevant to the CVC words in this study in that the Spanish speakers may undershoot English vowels by not reaching the periphery of the vowel space. Below is a chart that compares the means of F1/F2 values from the four studies in Table 2.1 to the F1/F2 values of the Spanish speakers in Bradlow's study.

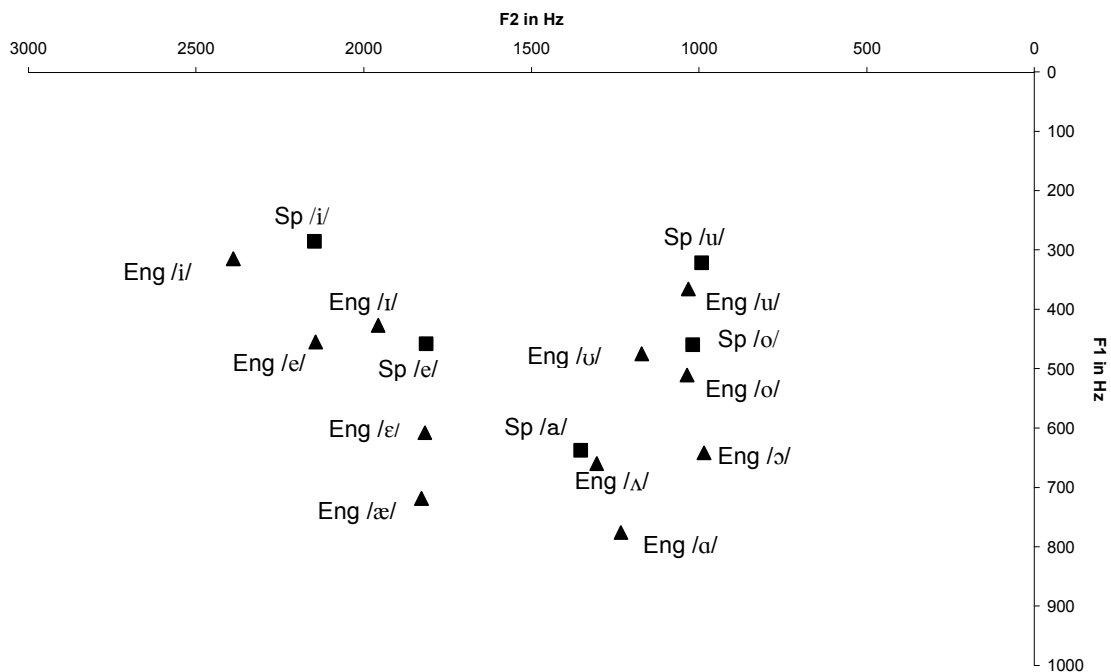


Figure 2.6 A comparison of F1/F2 means of Spanish and English vowels

Figure 2.6 shows the means of English vowels from four studies (Peterson and Barney, 1952; Hillenbrand et al 1995; Bradlow, 1995; Flege et al. 1994) as compared to the means of Spanish speakers in Bradlow's 1995 study. The Spanish vowels /i/ and /e/ are considerably more centralized than English /i/ and /e/, demonstrating the upward shift in F2 for English vowels discussed in Bradlow's study. The English vowels /u/ and /o/ demonstrate the higher F2 values and advancement in the vowels space to a lesser degree. Also note that the Spanish vowel /a/ is somewhat more central than English /a/ and phonetically closer to English /ʌ/. Bradlow's conclusion about the English vowels /i/ and /e/ having lower F1 values and therefore being higher in the vowel space is not indicated by the collective means of the four studies. Keep in mind however that this difference is context sensitive.

One additional note on the mid vowels needs to be addressed at this point. It is often said that Spanish exhibits allophony on the mid vowels with /e/ alternating with /ɛ/ and /o/ alternating with /ɔ/ in closed syllables. It is unclear how widespread this alternation is, but it bears brief discussion, since allophony may potentially assist (or obstruct) pronunciation of the mid tense/lax distinction in English. Additionally, allophony may be relevant since it has been claimed that the task of creating two distinct phonemes from an allophonic pair is actually more difficult than creating distinct phonemes where only one phoneme exists in the L1 (Brière, 1966 and for a current review see Eckman, 2003).

Walter (2003) studied two dialects of Spanish (Argentinean and Puerto Rican) focusing on the mid vowel /e/. She found that Argentinean Spanish speakers demonstrate laxing of /e/ in closed syllables. Recall that tenseness has three acoustic correlates: duration, lower F1 (which results in a higher vowel within the height dimension) and increased breathiness. For Argentinean Spanish, the F1 difference for laxing was about 50Hz, which, as Walter states, is less than F1 differences for English /e/ and /ɛ/ but still significant. Argentinean Spanish also had, to some extent, a lower F2 indicating a more central position for the vowel /e/ in a closed syllable. Puerto Rican Spanish, on the other hand, does not exhibit the F1 difference for the tense/lax distinction. Walters concludes that *...although duration differences did occur in both dialects, conclusions regarding duration cues for tenseness were “hopelessly confounded with syllable weight and its interaction with stress.”* (Walters, 2003:5).

In a study of Madrid Spanish, Morrison (2004) attempted to replicate the findings of Navarro Tomás, to whom Morrison attributes the first reporting of Spanish allophony. According to Morrison, Tomás claimed that Spanish mid vowels have open and close allophones. The acoustic correlate of open would be a higher F1.

Using discriminant analysis (refer to 3.8), Morrison determined that there is no clear allophony of open and close for mid vowels in Madrid Spanish. He did find however, some evidence of front versus retracted allophones of /o/ and close-fronted versus open-retracted allophones of /e/. At this time it is truly unclear what the behavior of /e/ and /o/ will be for the dialects of Spanish in this study.

2.4. Observing Change

Having examined the nature of linguistic change and the nature of the two vowel systems pertinent this study, one important question remains: Can change be observed in real time? Labov (1994) provides a comprehensive discussion of apparent-time observations vs. real-time observations. In sociolinguistic research, apparent-time observations of change are those in which researchers study the distribution of variables across age-levels. That is, they study the linguistic features of younger speakers of a given speech community and older speakers of a given speech community and make assumptions about how the dialect of that community has changed. The analogy to this project would be to study L2 speakers from similar linguistic backgrounds (same native language, amount of linguistic training, etc.) at different stages of acquisition and make assumptions about what changes occur from the early stages of acquisition to the later stages of acquisition. Such apparent-time observations of change have advantages and disadvantages. One advantage would be the practicality of the methodology in comparison to having to track speakers over a long period of time. One disadvantage is knowing whether speakers across age levels truly represent the same linguistic variety or not. Likewise studying nonnative speakers at different stages of acquisition raises the question of whether we are really observing change or simply observing different rates of success at the end state.

Real-time observation, on the other hand requires that the researcher study individuals at one point in time and then those same individuals at another point in time. Real-time studies of linguistic change have an advantage in that one knows for certain that the

individuals or the speech community have truly changed. The important disadvantage rests in the claim that change is so slow it may be imperceptible in real-time observations.

The study presented here is one of real-time observation of change in L2 learners. It was conducted in what amounts to a fraction of the overall process of acquiring a language.

As such, it is possible that change was imperceptible. On the other hand, at least some changes that occur during L2 acquisition may take place at a faster rate than other linguistic change. As we move on to the methodology, the analysis, and the observations of change, we cannot ignore the possibility that change *had* taken place (and we missed it), that change *will* take place (but we studied the individual too early or for too short a period of time), or that changes observed are not yet complete.

Chapter 2: Notes

1. According to Labov (1994) lexical splits display a high degree of conditioning and require speakers to have knowledge of each particular lexeme. Lexical splits are characterized in part by a complex set of conditions that can predict some but not all of the distribution, a variety of grammatical conditions, variable behavior in derived words, unmotivated lexical exceptions and irregular patterns of proper names. The case of the raised pronunciation of /æ/ in NYC dialect is an example of a lexical split. The raised pronunciation of /æ/ generally occurs in closed syllables before voiced stops, nasals and voiceless fricatives. It exhibits many of the properties of lexical split as described by Labov. For example, it shows a variety of grammatical conditions as in the pronunciation of the noun *can* (with a raised pronunciation) and the modal verb *can* (which is often reduced to /kən/ or /kn/ but not generally raised even in stressed position). There is variable pronunciation in certain syllables such as the words *aspirin* and *parent* where some speakers pronounce the raised variation and some do not.
2. It is assumed that the term *split* in some cases would roughly correspond to what Brière (1966) called *divergence* but not all of the instances of split in this study reflect the exact relationship referred to in that paper.
3. It is assumed that the term *merger* would at least in some cases correspond to what Brière (1966) called *convergence* but it is not the case that all instances of merger in this study correlate to allophones becoming a single phoneme.

Chapter 3: Methods and Materials

3.1. Participants

Participants for this study consisted of five non-native speakers and two native speakers of English. The five non-native speakers all spoke Spanish as their native language. Three of them were from Colombia, one was from Guatemala, and one was from Peru. Their ages ranged from 20 to 42 years old, and length of residency at the onset of the study ranged from six months to twelve years. Four of the non-native speakers were male and one was female. All of the non-native speakers were enrolled in at least one English as a Second Language (ESL) class at Nassau Community College at the time their first recordings were taken, but only two were registered in a pronunciation class. The native speakers consisted of one male speaker and one female speaker. At the onset of the study their ages were 34 and 38 years old respectively. They were both born in New York and had lived there all of their lives. They are monolingual English speakers. Both studied Spanish in High School, but neither could converse in any language other than English. The native speakers were used to provide a baseline to evaluate change over time of the non-native speakers.

3.2. Procedures

Participants were solicited for this study via flyers posted in the ESL program office and the Communications Department's Speaking and Listening lab at Nassau Community College. After signing a consent form, participants were asked to fill out a brief questionnaire about their language backgrounds (see Appendix A). Participants then

participated in a recorded interview during which further details about their linguistic backgrounds were obtained. After the interview, participants were asked to read 165 sentences (see Appendix B). The experimenter did not correct any pronunciation during the reading task

The entire session took about 45 minutes for the native speakers and 60-75 minutes for the non-native speakers. Recordings were taken in a quiet room at Nassau Community College with incandescent lighting. A *Sony* DAT recorder, model TCD-D8, BASF DAT tapes, and a *Samson* microphone were used.

This exact procedure was repeated three times over the period of a year for four of the non-native speakers, twice over a period of four years for one of the non-native speakers and two times over the period of a year for the native speakers. Most of the nonnative speakers were recorded at three points in anticipation of possible *backsliding*, the reemergence of non-target forms once targets have been achieved. It was hypothesized that a speaker could have changed early on in the study, but then revert back to former patterns of pronunciation by Time 3. This seemed especially reasonable considering that some ESL students are saturated with input when they first begin the program but then receive qualitatively and/or quantitatively different input after they exit the program. Only one of the nonnative speakers was unavailable for the Time 2 recording. His data are included in this study because he represents the longest time between the first recording to the last (four years as opposed to one year) and may, therefore, provide unique information. Samples from native speakers were collected only twice in the one-

year period because backsliding is not predicted for native speakers of a language who are monolingual.

3.4. Materials

The sentence-reading portion was designed to elicit eleven target vowels: [i, ɪ, e, ɛ, æ, ʌ, u, ʊ, o, ɔ, ɑ]. Each target vowel appeared in three monosyllabic English words and each monosyllabic word was repeated five times. For example, the vowel /i/ appeared in the words *keep*, *peek* and *bead*. Throughout the sentence-reading task each lexical item was repeated five times. Each instance of each word had a different sentential context. Although the position of any lexical item in the five different sentences varied, the sentences were specifically written to increase the likelihood that the target items would receive some degree of prominence.

The entire data set resulted in 15 tokens of each vowel (three words multiplied by five repetitions of each word) and a total of 165 different sentences (15 tokens of each vowel multiplied by eleven 11 vowels). All sentences are listed in Appendix B.

This sentence-reading task included repetition of words in addition to repetition of phonemes to allow for several types of comparisons across time. Given a particular phonemically relevant pair of vowels (e.g./i/- /ɪ/), it was possible to determine if a speaker distinguished the two vowels, if there was any change in that distinction *across* lexical items/phonetic environments, or if there was any change in that distinction *within*

lexical items/phonetic context. It was also possible to determine if there was any change in the entire vowel system over time. For example, if one phonemically relevant pair became more distinct, were others affected in some way? Were new distinctions apparent, did previous distinctions collapse, or did vowels behave autonomously?

Vowels appeared in monosyllabic, CVC words where C was a stop. Stops were selected because they facilitate identification of vocalic duration during spectrographic analysis. Since Spanish speakers often produce *voiced* stops as fricatives, words containing *voiceless* stops were used whenever possible. In some cases voiced stops were intentionally included, either to study lengthening effects or to eliminate extremely low frequency words. In fact, the inclusion of two items, *bad* and *tube*, provided information on how vowel pairs behave with respect to allophonic variation. When voiced stops appeared in a lexical item, the surrounding sentential context was manipulated to avoid intervocalic environments, which generally condition the fricative pronunciation. The target word *boot*, for example, begins with a voiced stop which may be pronounced as a voiced labial fricative by Spanish speaking participants. To prevent this pronunciation it was placed after a consonant-final word.

He was trying to catch a fish, but he caught an old boot instead.

In the sentence above, the /b/ in *boot* is not intervocalic because of the final /d/ in *old*. (In this particular case, even if the /d/ in the word *old* is omitted, the /l/ should prevent /b/ from being pronounced as a fricative).

An attempt was made to choose words that not only fit the CVC pattern but were also likely to be familiar to the participants. Although there is no way to predict whether or not the participants had been exposed to the target words in previous text, high frequency words were used whenever possible as a way of increasing potential familiarity. The number in parentheses next to each word in Table 3.1 below is the frequency count as listed in Francis and Kučera, 1982. Syntactic categories have been handled in the following way; if the different syntactic categories of a word had different spellings (as in *peek* vs. *peak*), only one syntactic category was used and only that frequency was listed. If there was no spelling difference between syntactic categories (as in *cut* as both a verb and noun), then both forms are used in the sentences and the frequency counts have been combined. Additionally, the frequency of the inflected forms of each word has been combined to form the total frequency listed below, provided the inflections are regular. Thus, the frequency of the plural *cups* contributed to the total frequency of the word *cup*. The frequency of the third singular present form *gets* contributed to the frequency of the word *get*. The frequency of the past tense form *kept*, however, was not included in the frequency of the word *keep* because it is irregular. There are several words with seemingly low frequency counts, but it was determined that alternative CVC words had even lower counts or were simply too obscure to include. For example, *coop* has a frequency of (0) but there are only a handful of other CVC words (where C is a stop) containing /u/ and none of these were deemed acceptable choices. Target words are listed in Table 3.1.

Table 3.1 Target Words

[i]- <i>keep</i> (257), <i>peek</i> (3), <i>bead</i> (6)	[ɪ] - <i>pick</i> (143), <i>pit</i> (21), <i>kid</i> (104)
[e] - <i>take</i> (1575) <i>gate</i> (50) <i>paid</i> (144)	[ɛ] - <i>get</i> (968), <i>pet</i> (18), <i>bed</i> (139)
[æ] - <i>cat</i> (42), <i>pat</i> (?), <i>bad</i> (134)	[ʌ] - <i>cut</i> (280), <i>cup</i> (58), <i>but</i> (4621)
[u] - <i>boot</i> (34), <i>coop</i> (0), <i>tube</i> (55)	[ʊ] - <i>put</i> (513), <i>took</i> , (426), <i>could</i> (1782)
[o] - <i>coat</i> (58), <i>boat</i> (123), <i>code</i> (55)	[ɔ] - <i>talk</i> (275) <i>caught</i> (98), <i>taught</i> (50)
[ɑ] - <i>pot</i> (33), <i>cop</i> (32), <i>top</i> (221)	

The 33 words above include minimal pairs representing tense/lax distinctions (*peak/pick*, *gate/get*, *coat/caught*) with the exception of /u-ʊ/, and minimal pairs representing a variety of height distinctions (*pit/pet*, *pet/pat*, *took/talk*, *cup/cop*, *cat/cut*). A minimal pair for the front/back distinction between /æ-ɑ/ (*pat/pot*) was also included. Minimal sentences (sentences that differ only by one word) were included in the set of 165. The sentences were grouped into fifteen blocks of eleven with each target vowel appearing once in a block. Sentences were randomized between speakers by changing the order of the blocks and by changing the order of the sentences within the blocks. Orders were different for each participant, but a single participant received the same order for all three recording sessions.

3.5. Discussion of Materials

There are two important points of discussion regarding the materials used for this study. The first is the use of the sentence-reading task and the second is the nature of the sentences themselves.

The use of written data to elicit target vowels can result in confounds, especially in the form of sound-spelling errors. It is likely that some non-target forms produced during the recordings could be the result of errors in sound-spelling correspondences and not representative of L2 pronunciation. These sound-spelling errors could arise from transfer (i.e. reading a letter as it would be read in Spanish) or from unfamiliarity with the numerous rules and exception to rules of English orthography. In this study, when a speaker made an error that was clearly the result of misreading or a misunderstanding of sound-spelling conventions, the item was discarded at all three times for that speaker. If, for example, the word *pet* was misread in the second sentential context at Time 2, it was excluded in the second sentential context at Times 1 and 3 as well. This may seem excessive, but because every instance of every word was couched in its own sentential context, including a sentence at one time and not another could confound the variables of context and time. That is to say, any changes could be equally attributed to varying contexts as it could be to the passage of time. Therefore, when reading errors did occur, context was maintained across time by discarding instances of the word that were misread across all times.

Determining what constitutes a *reading* error is another matter, with some cases being obvious and some cases being impossible to determine as such. For example, the word *bead* was eliminated from virtually all of the samples because it was most often read as *bed*. This was considered to be a clear case of sound-spelling error because it is unlikely that Spanish speakers are confusing the vowels /i/ and /ε/ and because there are English words that are spelled with “ea” and pronounced as /ε/ (as in *head*). Another clear

example of a sound-spelling error would be the pronunciation of the word *cut* as [kut]. There is no evidence of [u] and [ʌ] alternating in Spanish accented English and there is an obvious correlation between the error and the pronunciation of the letter “u” in Spanish as /u/.

Other cases were not so obvious. For example, the pronunciation of the word *kid* with the vowel /i/ is common for native Spanish speakers but could also be a sound spelling error in that the letter “i” in Spanish is pronounced as /i/. Within the limits of a sentence reading task, in which all words are monosyllabic and CVC, this confounding variable is unavoidable. The lax vowel /ɪ/ is spelled as “i” in these circumstances.

The question arises as to why the sentence production task was used to elicit samples if there is such a potential for confounding errors of the type discussed above. The answer is simply lack of a better method to collect such an extensive number of vowels, in CVC words, in sentences, such that all would be the same at three different times over a period of a year. Spontaneous speech, for example, leaves many gaps in the data, and one has very limited control over what a speaker will say. Imitation tasks could confound a speaker’s ability to perceive a vowel with the speaker’s ability to produce a vowel.

Picture description tasks also have their limitations in that it is hard to control what will be said about a picture as well as if the picture will be described using the same words at all three times over the one-year period. If, for example, we were to think of common monosyllabic CVC words containing /ʊ/ (where both Cs are stops) we would come up

with words such as *took*, *good*, *book*, *cook*, *could*, *put*. One could imagine a picture description task that could easily elicit the word *book* but finding a picture that forces someone to say the word *could*, or a specific tense/aspect of a verb (as in *took* vs. *is taking*) is challenging to say the least.

The second point of discussion is the nature of the sentences themselves. In other studies that measure acoustic parameters of vowels, the materials are generally word lists or words couched in carrier sentences. The sentence-reading task in this study used five different words for each target vowel and 165 different sentences of varying syntactic structure and varying semantic content. This design incorporated the contextual richness of speech while ensuring that enough data were collected and that the same data were collected at all three times.

3.6. Acoustic Analysis

In this study, recorded samples were digitized using *Soundforge 4.5*, with a sampling rate of 22,050 and a 16-bit quantization. The acoustic analysis was performed on *Multispeech* (Model 3700). Formants were measured from spectrograms as well as FFT (Fast Fourier Transform) power spectra and LPC (Linear Predictive Coding) spectral envelopes. The spectrogram was measured using a Hamming window with an analysis size of 125 points and a pre-emphasis filter of .80. The FFT power spectrum used a Hamming window with an analysis size of 1024 points (or 25 ms) and the pre-emphasis filter was .90. The LPC frequency response used a Hamming window, the frame length was 25 ms, the filter order was 24, and the pre-emphasis filter was .90.

Duration measures were taken with the cursors linked on the waveform and the spectrogram. They were based on the syllabic gesture, defined for the CVC target words as the period from the release of the first stop to the beginning of the closure for the second stop. The release of the first stop was measured from the first significant pitch period after the initial stop-gap. The closure for the final stop was taken at the last pitch period with significant energy in the upper formants. Where there was contextual variation, consonant weakening, and so forth, separate criteria were established for each word and were kept constant across all instances of that word.

Formant frequencies were measured at the 25%, 50% and 75% points. The 50% point was considered the 'target' and the change from 25% to 75% was used to examine diphthongization. The 25%, 50%, and 75% points were calculated from the beginning point and the end point of the vowel via a spreadsheet formula. Once the location of the three points was determined, the cursor was placed at each location and measurements for F1, F2, and F3 were taken using information from the spectrogram, the FFT power spectrum and the LPC spectral envelope. Generally the LPC results were used, except in cases where the LPC response failed (i.e. clearly did not match manual measurement on the spectrogram). It should be noted that, although vowels were measured at three points and for all three formants, observations of change in the following chapters are based on F1/F2 and Duration at the 50% point. These were simply the clearest and least ambiguous of the measurements.

3.7. Reliability of Measurements

In order to ensure that the vowels were being measured consistently from one time to the next, each sample was checked several weeks to several months after the initial measurements were taken. The investigator randomly selected 10% of the sample (17 items) and re-measured. Margins of error for individual speakers are discussed separately in the subsequent chapters. In addition to re-measuring randomly selected items, extreme outliers on the F1/F2 plots were re-measured for verification in all participants' data.

3.8. Discriminant Analysis

Acoustic measurements were analyzed via discriminant analysis; This is a multiple regression technique that examines a set of variables or predictors that serve to distinguish a set of categories. Independent parameter values are weighted to maximally distinguish separate categories. For this investigation, individual speakers were treated as separate case studies. The 11 *intended* vowels (AE vowels designated for the lexical items) served as the categories; parameter values (F1/F2 and duration) of the vowels *actually uttered* served as input to the model. The discriminant analysis essentially took the acoustic parameters of all vowels entered for an intended group and found a centroid for that group. It then determined how near or far the acoustic parameters for each uttered vowel were from that centroid. If the acoustic parameters of a spoken vowel were close to the centroid of the intended category, the discriminant analysis characterized them as *correct* matches. If the acoustic parameters of a spoken vowel were far from the centroid of the intended category (or closer to the centroid of an unintended category), they were

characterized as being mismatched. In this respect, *intended* simply means the vowel phoneme that linguists consider to be in the particular word being spoken. For example, in the word *keep* linguists consider the vowel phoneme to be /i/. Therefore /i/ is the intended category. It does not imply any knowledge on the part of the speaker as to what should be produced in a given English word.

Discriminant classifications were used in two types of analyses. The first analysis considered the vowel system of a speaker as a separate system and did not compare it to any external criteria. The second type of analysis used the centroids of one speaker as the criteria for evaluating the vowels of another speaker. This made it possible to evaluate a system in direct comparison to another system (i.e. nonnative in comparison to native).

The output of discriminant analyses was classification matrices that showed the extent to which the actual utterances fell into intended categories based on the acoustic parameters. In the following chapters, the data from the classification matrices are presented in tables (such as Table 3.2) that indicate what the intended vowels were (categories), which acoustic parameters were used (predictors), how many vowels were actually uttered (N), and how the analysis grouped the uttered vowels according to the predictors. Take as an example Table 3.2 of a native speaker producing tokens of the intended vowel /i/ in the words *keep*, *peek* and *bead*.

Table 3.2 Sample Table of the Results of a Classification Matrix

Target Vowel	Time 1		Time 2	
	Match / #of tokens F1/F2	Match / #of tokens F1/F2 Duration	Match / #of tokens F1/F2	Match / #of tokens F1/F2 Duration
i	i (14)	i (14)	i (15)	i (15)
N=15	e (1)	e (1)		
% correct	93.3	93.3	100	100

The first row of the chart makes the time distinction: data to the left are from the first point in time and data to the right are from the second point in time. The second row divides each time period into two conditions based on acoustic parameters. That means that at Time 1 two separate analyses were conducted based on different parameters or predictors: *F1/F2 Only* and *F1/F2 plus Duration*. The same two analyses were conducted at Time 2.

The left-most column indicates which vowels were intended and how many vowels were actually uttered. As an example, the sample table shows that the speaker uttered 15 vowels that were *intended* to be /i/.

Looking to the second column we can now see how the discriminant analysis grouped the 15 utterances of the vowels intended to be /i/. Note that the heading for the second column reads *Match/# of tokens F1/F2*. This means that the column shows how the intended vowels were matched according to the predictors F1/F2. It also shows how many of the total number of vowels were grouped into the intended category and how many were grouped into other categories. The sample table shows that of the 15 vowels

uttered in the words *keep*, *peek* and *bead*, 14 of them had F1/F2 measurements that were similar to the centroid of /i/ and one had F1/F2 measurements that were closer to the centroid of /e/. The total correct classification is listed as 93.3%. That means that 93.3% of the vowels actually uttered were matched to their intended category. Looking at the third column, which is still Time 1 but has the added input parameter of duration, we can see that there is no change in category match for the 15 vowels. The additional parameter did not make a difference in classification rates for /i/. We could be tempted to say that duration does not help distinguish the vowel /i/ from other vowels, but such an interpretation is premature at this point. Vowels in this study are considered not only in isolation but as part of phonemically relevant pairs. A more pertinent question would be *does duration help distinguish /i/ from /ɪ/?* This can only be answered by looking at the category matches for both vowels with duration included and then excluded. In this study, a feature is said to *distinguish* vowel pairs only when two vowels are compared with respect to the category matches with and without the parameter and there is a difference in how well the vowels matched their intended targets between the two conditions. Of course, we will return to the comparison of /i/ and /ɪ/ in this speaker in the next chapter.

One additional note on the output charts should be made. Since this is a longitudinal study, the focus is on how contrasts change over time in the speech of nonnative speakers. The charts allow for comparison across time by presenting the category matches in each condition at all times. So looking again at the sample chart we can see

that at Time 2, all instances of /i/ for this speaker are now considered to belong to the intended category and that the total correct classification is 100% both on the two-parameter and three-parameter conditions. The native speakers in this study are intended to serve as a baseline for what should be considered actual change in the nonnative speakers and what could be normal variation in speech. Thus, we see that it is reasonable to expect some variation across time in the native speakers (in the case above, a difference of one vowel). Evaluating change in the nonnative speakers, either in the direction of improvement (learning) or backsliding, should be greater than the normal variation we see in the native speakers.

Initially, four separate discriminant analyses were performed for each speaker: *Time 1 F1/F2 Only*, *Time 1 F1/F2 plus Duration*, *Time 2 F1 /F2 Only*, and *Time 2 F1/ F2 plus Duration*. This allowed for a cross-sectional examination of how vowels were grouped in the F1/ F2 space and how duration affected those groupings. The four initial discriminant analyses also allowed for a longitudinal examination of these same contrasts.

After analyzing the results, additional discriminant analyses were conducted on what will be referred to as *reduced item sets*. The reduced item sets eliminated certain lexical items in order to answer additional questions. For example, some reduced item sets examined vowels in individual lexical items (one of three words) as opposed to multiple lexical items (all three words). This allowed an investigation of whether the rate at which L2 learners could match their utterances to the targets was tied to individual lexical items. Other reduced item sets grouped items according to initial and final consonants (e.g.

whether the final consonant was voiced or voiceless, whether the initial consonant was alveolar). This allowed an investigation of whether allophonic variation affected category groupings. Additionally, the words *bad* and *tube* presented unique characteristics and discriminant analyses were conducted with these items included and with these items treated separately.

3.9. Vowel Comparisons

The goals of this study were to determine if speakers distinguish phonemically relevant pairs of vowels, which features are used to distinguish those pairs and whether distinctions change over time. Towards this end native speakers were analyzed first to determine how English categories patterned with respect to the data in this particular study and whether English speakers were in fact stable over time. It will be shown in subsequent chapters that the native speakers in this study generally distinguished vowels on the three acoustic parameters (F1/F2 and duration) but not always. In fact there was a great deal of overlap in the F1/F2 space and a great deal of dialectal, allophonic and individual variation in how native speakers distinguished vowels. Furthermore, the native speakers were generally stable over time but not completely so. The results from the native speakers indicate that we cannot compare nonnative speakers to an idealized native system of contrast and stability, but rather we must consider the input that nonnative speakers receive with all its complexities.

Once the native speakers' vowels were analyzed, the nonnative speakers' vowels were examined using virtually the same methodology. The major difference was that the vowel

systems of the nonnative speaker's producing English target words were considered both as entities unto themselves and in direct comparison to the native speaker's vowels. Male nonnative speakers were compared to the male native speaker and the female nonnative speaker was compared to the female speaker. Recall in the previous section we said that the discriminant analysis takes parameters entered and creates a centroid. It then determines whether individual tokens are closer to that centroid or closer to the centroid of another category. For the first analysis of the nonnative speakers, "correct" category matches were simply determined by whether the vowels produced were distinct from each other. For example, did a particular nonnative speaker produce the vowel in the lexical items *keep*, *peek* and *bead* the same as the vowel in the lexical items *kid*, *pick* and *pit*, or did they make some distinction between the two? The second series of analysis used one of the native speaker's values as the criteria for the categories and "correct" matches were determined by how well the individual tokens matched the centroids of the native speaker's categories. For example, did a particular nonnative speaker have the same distinction in *keep-peek-bead* vs. *kid-pick-pit* as did the native speaker?

Why are both analyses necessary? Researchers have found that L2 learners show intermediate stages in which they exhibit differences from both the native language and the target language. An example from speech production comes from Flege (1987) in which he tested VOT times of the phone /t/ on French monolinguals and English speakers learning French. Flege found that the intermediate groups of learners produced VOT times that came closer to the French phonetic norm than the English norm but still differed significantly from French monolinguals. This and other findings indicate that the

speech of L2 learners cannot be considered with respect to the end state alone, but rather must be considered with respect to approximations along the way. The analogous scenario in this study would be the case of two vowels that were initially merged by the nonnative speaker but over time became distinct even though they still did not match the native speakers' categories for those vowels. It is true, however, that when we study second language acquisition we are also concerned with how close a speaker's vowels are to the target language. Therefore, the second type of analysis, in which the nonnative speakers are compared directly to the categories of the native speakers, is also necessary.

The subsequent chapters present the results of the discriminant analyses on both the native and nonnative speakers.

Chapter 4: Analysis of the Native Speakers

4.1. Introduction

This chapter addresses the results of the two native speakers in the study, one male and one female. These speakers provided a baseline for cross-sectional category matches of the eleven vowel phonemes as well as a baseline for how category matches behave longitudinally. The results of two conditions from samples collected twice over the period of one year are described here. The two conditions were *F1/ F2 Only* and *F1/F2 plus Duration*. The results raise several issues relevant to the acquisition of an L2 vowel system. First, native speakers do not have perfect category matches for these eleven vowels; rather distributions of vowels encroach on the F1/F2 space of the distributions of other vowels. The overlap in the F1/F2 space increases with contextual variation (i.e. when vowels are analyzed in multiple lexical items as opposed to a single lexical item). Second, individual speakers exhibit differences as to which vowels are more likely to overlap and which vowels are more separated in the acoustic space. These differences are based on context, dialect, and phonological and phonetic features. Finally, the nonnative speakers are generally stable across time, but not completely so. Longitudinal differences were seen in category matches as well as in distinguishing parameters, although some were greater than others. The following sections address these results and their potential effect on L2 acquisition.

4.2. Native Speaker 1 (NS1)

Native Speaker 1 (henceforth NS1) is a male monolingual speaker of AE who was 34 years old at the time of the first recording. He was born and raised in New York City and exhibits some features of a New York City dialect (henceforth NYCD). These features will be addressed subsequently.

4.2.1 Sample Collection

As expected, NS1 had little difficulty with the sentence-reading task, but four items were misread and thus discarded. These items included one instance each of the words *paid* and *bed* and two instances of the word *pot* leaving a total of 161 items.

In order to determine intra-rater reliability, 17 items from the Time 1 sample and 17 different items from Time 2 items were randomly selected and re-measured. As indicated in Table 4.1, mean differences between the re-measure and the original measure were less than 10 msec for duration and less than .20 Bark for F1 and F2 at the 50% point.

Table 4.1 Margin of Error for NS1

	Mean Difference Between Time 1 Measure and Re-measure	Mean Difference Between Time 2 Measure and Re-Measure
Duration	9.58 msec	3.98 msec
F1 at 50% Point	0.14 Bark	0.18 Bark
F2 at 50% Point	0.18 Bark	0.17 Bark

4.2.2. Category Matches within Lexical Items

Before describing the distribution of the individual vowels in the system, it is necessary to discuss findings that relate to how vowels were classified with respect to the intended target and the general nature of the data in this particular study. We will soon see that the total correct classification for the 161 vowels uttered by NS1 was about 70% (at Time 1). Stated another way, about 70% of his vowels were close enough to their respective centroids that they were judged to belong to the correct category. The remaining 30% were judged to fall into unintended vowel categories. These results are somewhat surprising given the assumption that speakers produce the vowels of their native language correctly. One might expect a higher overall percentage of correct category matches. In fact, the percentage of correct category matches increased as the number of lexical items decreased. That is to say, notable differences occurred on phoneme category matches *within* lexical items as opposed to *across* lexical items. It will be argued that these differences are important to understanding vowel systems and their acquisition.

Much of the data that we have on the distinctions between English vowels comes from single context studies. An example of this is the famous Peterson and Barney (1952) study in which all vowels were in the context /h/- vowel -/d/ (hVd). Although current research is moving towards vowels in varied contexts, the nature of vowels in the entire context of the language is still unclear. The results of this study show that AE vowels vary widely across lexical items with even small contextual differences. For native speakers, category matches *within* a single lexical item were high with few exceptions.

Category matches *across* lexical items show a different picture of this speaker's vowels system.

To see the differences, consider the results of the discriminant analyses performed a subset of randomly selected lexical items including *keep*, *kid*, *gate*, *get*, *cat*, *cup*, *boat*, *put*, *coat*, *taught*, and *top* (henceforth the *keep sequence*). For this subset, each of the 11 lexical items was repeated five times yielding 55 tokens, but each vowel occurred in only one lexical item (as opposed to three) and in one immediate phonetic context. With F1/F2 as the only parameters, the total correct classification was 89% compared to 65% (when these vowels were considered across three lexical items). When duration was added as a parameter in the discriminant analysis of the *keep sequence*, the total correct classification was a striking 96% as compared to 70% when these vowels were compared across lexical items. Table 4.2 shows the classification results of the discriminant analysis of the single-item subset (*keep sequence*) as compared to the multiple-item set.

Table 4.2 Single-Item vs. Multiple-Item Comparison of NS1 at Time 1

Target Vowel	Single-Item Subset		Multiple-Item Set	
	Percent/Number Correctly Matched: F1/F2	Percent/Number Correctly Matched F1/F2 and Duration	Percent/Number Correctly Matched: F1/F2	Percent/Number Correctly Matched: F1/F2 and Duration
i	100 (5/5)	100 (5/5)	93.3 (14/15)	93.3 (14/15)
ɪ	60 (3/5)	100 (3/5)	46.6 (7/15)	33.3 (5/15)
e	100 (5/5)	100 (5/5)	85.7 (12/14)	92.8 (13/14)
ɛ	100 (5/5)	100 (5/5)	71.4 (10/14)	85.7 (12/14)
æ	100 (5/5)	100 (5/5)	100 (10/10)	100 (10/10)
ʌ	100 (5/5)	100 (5/5)	53.3 (8/15)	53 (8/15)
u	100 (5/5)	100 (5/5)	90 (9/10)	90 (9/10)
ʊ	100 (5/5)	100 (5/5)	60 (9/15)	66.6 (10/15)
o	80 (4/5)	80 (4/5)	73.3 (11/15)	60 (9/15)
ɔ	40 (2/5)	80 (4/5)	46.6 (7/15)	66.6 (10/15)
ɑ	100 (5/5)	100 (5/5)	100 (13/13)	100 (13/13)
Total %	89	96.3	65.2	70.8

It should also be noted that various lexical items and the phonetic contexts that they create make a difference in the number of vowels that matched the intended target. While the *keep* sequence above showed perfect matches in most vowels, the *peek* sequence (*peek, pick, paid, bed, bad, but, tube, could, boat caught* and *cop*) and the *bead* sequence (*bead, pit, take, pet, pat, cut, coop, took, code, talk* and *pot*) had different overall category matches at 90% and 85% correct respectively. Both of these were lower than the *keep* sequence but still considerably higher than the across lexical item comparison (70% correct).

The contextual variation of lexical items in this study was relatively small compared to the variation we would expect to find in all of English. All words were monosyllabic, not containing an unstressed vowel, all were CVC, and all were stop-vowel-stop sequences. One can only speculate what the category mismatches would be if the vowels occurred in all possible contexts including unstressed syllables, surrounded by nasals, approximants, other vowels, and so forth. We therefore cannot think of the native system as a group of near perfect category matches and the nonnative system as a group of mismatches. In order to understand native/nonnative contrast we must examine the *extent* to which vowels overlap and encroach on each other's acoustic space in both systems, as well as the *way* in which they do so.

As noted earlier, additional reduced items sets were analyzed, including lexical items ending with voiced consonants and those beginning with alveolar consonants. The former set addresses the role of duration in distinguishing vowel categories, the latter addresses the role of allophonic variation known to occur with initial alveolars (Hillenbrand and Clark, 2000). These additional reduced item sets will be discussed throughout the subsequent sections as they are relevant to specific data.

Thus we proceed, with a greater understanding of native speaker performance on the data and the complexities that face nonnative speakers when they attempt to learn an L2 phonology.

4.2.3 Category Matches across Lexical Items: The Front Vowels

We now turn to the front vowels of AE as spoken by NS1. Figures 4.1 and 4.2 show the F1/F2 plots of the vowels /i, ɪ, e, ε, æ/ recorded two times over the period of one year.

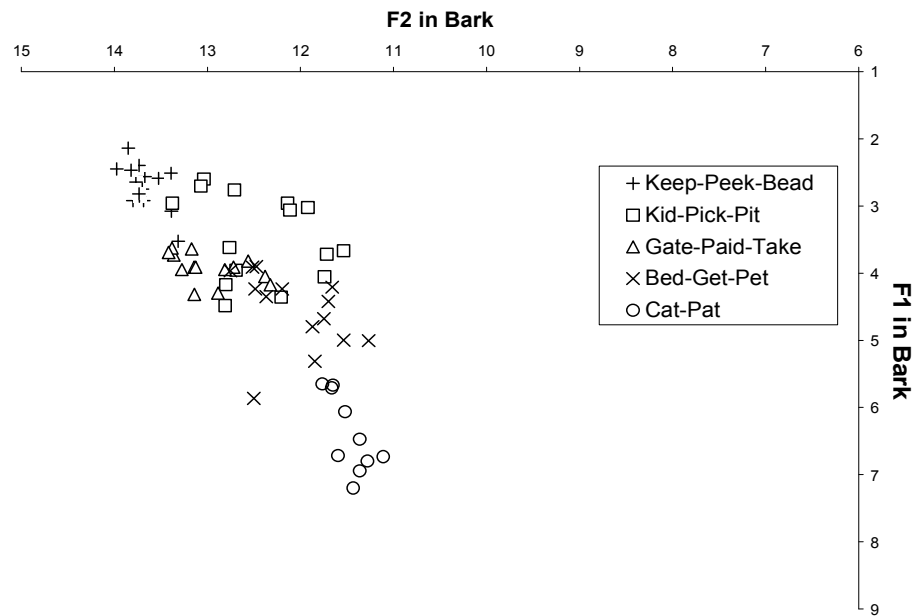


Figure 4.1 F1/F2 plot of the front vowels at Time 1 pronounced by NS1

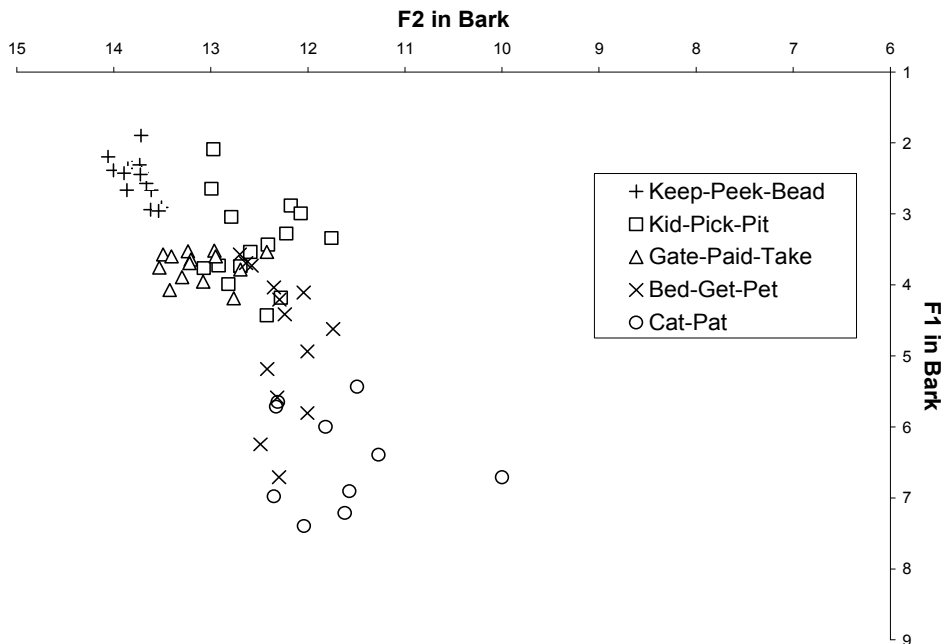


Figure 4.2 F1/F2 plot of the front vowels at Time 2 pronounced by NS1

Note that although it is possible to identify five groups, these vowels were not completely differentiated in the F1/F2 space. Each vowel grouping showed some overlap into the F1/F2 space of other vowel groupings and some did so to a greater extent than others. In order to understand the distribution of these vowels, we turn to the results of the discriminant analyses. Table 4.3 shows the results of the discriminant analyses on two separate conditions (*F1/F2 Only* and *F1/F2 plus Duration*) at Time 1 and Time 2.

Table 4.3 Results of the Discriminant Analyses of the Front Vowels as Pronounced by NS1 across Two Times

Target Vowel	Time 1		Time 2	
	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration
i	i (14)	i (14)	i (15)	i (15)
N=15	e (1)	e (1)	-----	-----
% correct	93.3	93.3	100	100
ɪ	ɪ (7)	ɪ (5)	ɪ (8)	ɪ (8)
N=15	i (3)	i (4)	i (2)	i (2)
	e (3)	e (4)	e (3)	e (4)
	ɛ (2)	ɛ (2)	ɛ (2)	ɛ (1)
% correct	46.6	33.3	53.3	53.3
e	e (12)	e (13)	e (14)	e (13)
N=14	ɪ (1)	ɪ (1)	-----	-----
	ɛ (1)	-----	-----	ɛ (1)
% correct	85.7	92.8	100	92.8
ɛ	ɛ (10)	ɛ (12)	ɛ (7)	ɛ (8)
N=14	-----	ɪ (1)	ɪ (4)	ɪ (4)
	æ (1)	æ (1)	æ (3)	æ (2)
	e (3)	-----	-----	-----
% correct	71.4	85.7	50	57.1
æ	æ (10)	æ (10)	æ (7)	æ (10)
N=10	-----	-----	ɛ (3)	-----
	% correct	100	100	70

To begin, consider the vowels /i/ and /ɪ/ uttered in the target words *keep*, *peek*, *bead* vs. *pick*, *pit*, and *kid*). Table 4.3 shows that the vowels /i/ and /ɪ/ were distinguished by NS 1, but /i/ had a higher classification rates (93% or 14/15) as compared to /ɪ/ (46.6% or 7/14) and was less likely to fall into the F1/F2 range of other vowels.

The vowel /i/ had longer duration means than the vowel /ɪ/ but by only about 20 msec.

When duration was included as an additional input parameter it had little effect on the distinction between these two vowels. At Time 1 the inclusion of duration as a parameter in the discriminant analysis actually decreased the number of instances of /ɪ/ that fell into the category of /i/ by two.

With respect to change over time, there was a slight difference between Time 1 and Time 2 during which the category matches improved.

With respect to the reduced item condition where words were separated based on final consonants, the effect of duration was not any more apparent. When considering words that ended only in *voiceless* consonants, duration had no effect on the number of vowels that matched the intended target. When considering words that ended in only voiced consonants, duration made a difference of one vowel or a 10% improvement in how well the uttered vowels matched the intended target. Keep in mind, however, that there was only one lexical item that ended in a voiced stop and it has already been shown that reducing the number of lexical items can have an impact on classification rates.

The vowels /e/ and /ɛ/ (uttered in the target words *take, gate, paid* vs. *get, pet and bed*) were also distinguished by NS1. The vowel /e/ had higher classification rates and was less likely to overlap with other vowels. This was seen most clearly at Time 2 in the *F1/F2 Only* condition but held true across the board. The vowel /e/ also had higher

duration means than the vowel /ε/ by about 30 msec. When duration was added as an additional input parameter it played a small role in distinguishing the vowel /ε/ from /e/ but mainly improved the classification rates for the vowel /ε/. There also seemed to be a difference from Time 1 to Time 2 during which the percentage of category matches for /ε/ was lower at the second recording. At Time 1, 10 out of 14 or 71% were correct matches for the *F1/F2 Only* condition and 12 out of 14 or 85% were correct for the *F1/F2 plus duration* condition. At Time 2, only 7 out of 14 or 50% were correct matches for the *F1/F2 Only* condition and 8 out of 14 or 57% were correct matches for the *F1/F2 plus Duration* condition. In the reduced item condition where words were separated based on final consonants, the effect of duration was not any more apparent.

The vowel /æ/ (uttered in the words *cat* and *pat*) was clearly differentiated from other vowels with perfect category matches in three of the four conditions (namely Time 1 *F1/F2 Only*, Time 1 *F1/F2 plus Duration*, and Time 2 *F1/F2 plus Duration*) as shown previously in Table 4.3. This vowel had longer duration means than any of the front vowels discussed thus far. When duration was included as an input parameter it had no effect at Time 1 but at Time 2 it increased the number of correct category matches by 3 and helped distinguish /æ/ from /ε/.

At this point it is necessary to address a feature of NYCD relevant to this study. It has been shown that the vowel /æ/ in NYCD exhibits a raised pronunciation in certain phonetic environments (Setzer, 1998). For the purposes of this discussion, the raised

allophone will be referred to as [Æ]. Among the environments that condition this allophone is a within syllable postvocalic voiced stop. This directly affected the lexical item *bad* which was excluded from the initial discriminant analysis represented in the Table 4.3. With the item *bad* included in the discriminant analysis, the category matches for /æ/ decreased from 7-10 out of 10 or 70-100% to 6-8 out of 10 or 40-60% as shown in Table 4.4.

Table 4.4 Results of the Discriminant Analyses of the Vowel /æ/ with the Item *Bad* Included for NS1

Target Vowel	Time 1		Time 2	
	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration
æ	æ (6)	æ (8)	æ (9)	æ (8)
N=15	ε (5)	ε (4)	ε (5)	ε (4)
	ɑ (4)	ɑ (2)	ɑ (1)	ɑ (2)
	-----	e (1)	-----	e (1)
% correct	40	53.3	60	53.3

Clearly allophonic variations of this sort significantly affect the way in which vowels match the intended target. In this case, the instances that fell into the /æ/ range dropped by as much as 60% in some conditions. While many studies seek to control for such variations, they are important for this investigation. These variations further demonstrate that when nonnative speakers are learning a language they are faced with imperfect category matches as input.

4.2.4. Category Matches across Lexical Items: The Back Vowels

The back vowels are known to be difficult to measure. In fact many studies of AE vowels focus on the front vowels which yield clearer spectra and F1/F2 measurements. It is the intent of this study to look at the entire vowel system being acquired by nonnative speakers. Thus we proceed to a description of the back vowels with special attention paid to the vowel /u/, which exhibits allophonic variation in most varieties of AE. The F1/F2 plots of the central and back vowels across two points in time are shown Figures 4.3 and 4.4.

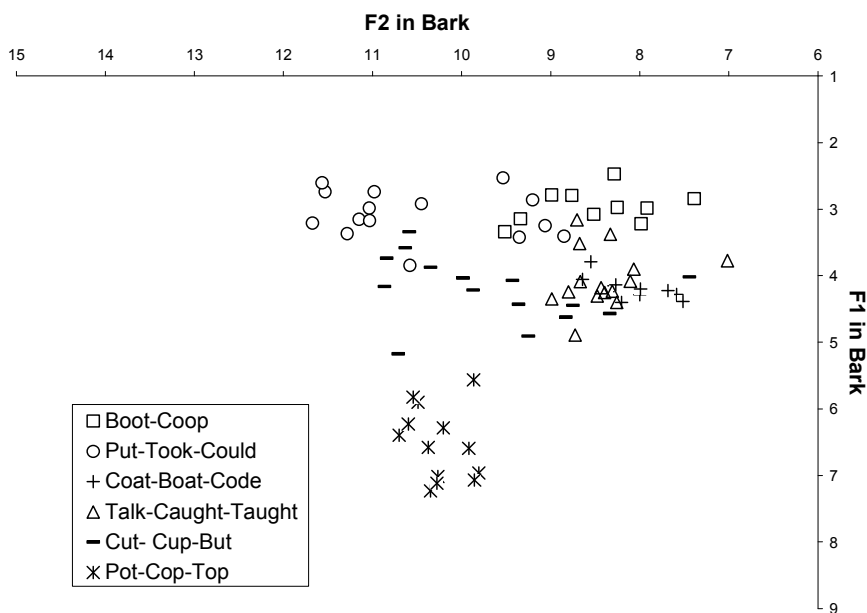


Figure 4.3 F1/F2 plot of the central and back vowels at Time 1 pronounced by NS1

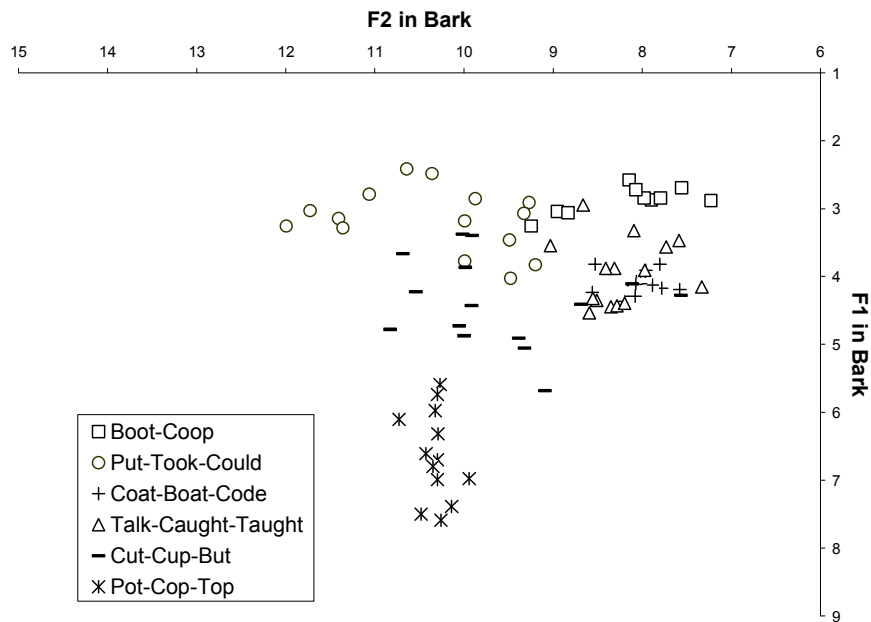


Figure 4.4 F1/F2 plot of the central and back vowels at Time 2 pronounced by NS1

Once again, the F1/F2 plots show how this speaker's vowels overlap into the F1/F2 space of other vowels. As was the case with the front vowels, some do so to a greater extent than others. In order to clearly understand the distribution of the central and back vowels, we turn to the discriminant analyses. Table 4.5 shows the results of discriminant analysis performed on two separate conditions (*F1/F2 Only*, *F1/F2 plus Duration*).

Table 4.5 Results of the Discriminant Analyses of the Central and Back Vowels Pronounced by NS1 across Two Times

Target Vowel	Time 1		Time 2	
	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration
u N=10	u (9) ɔ (1)	u (9) ɔ (1)	u (9) ɔ (1)	u (9) ɔ (1)
% correct	90	90	90	90
ʊ N=15	ʊ (9) u (3) ʌ (1) ɪ (1) ɔ (1)	ʊ (10) u (3) ʌ (1) ɪ (1) -----	ʊ (11) ----- ʌ (2) ɪ (2) -----	ʊ (10) ----- ʌ (3) ɪ (2) -----
% correct	60	66.6	73.3	66.6
o N=15	o (11) ɔ (4)	o (9) ɔ (6)	o (13) ɔ (2)	o (7) ɔ (8)
% correct	73.3	60	86.6	46.6
ɔ N=15	ɔ (7) o (4) u (2) ʌ (2)	ɔ (10) o (2) u (3) -----	ɔ (6) o (7) u (2) -----	ɔ (11) o (3) u (1) -----
% correct	46.6	66.6	40	73.3
ʌ N=15	ʌ (8) ʊ (3) o (2) ɔ (1) ɛ (1)	ʌ (8) ʊ (3) o (1) ɔ (2) ɛ (1)	ʌ (9) ʊ (3) o (2) ɔ (1) -----	ʌ (10) ʊ (3) o (2) ----- -----
% correct	53.3	53	60	66
a N=13	a (13)	a (13)	a (13)	a (13)
% correct	100	100	100	100

The vowels /u/ and /ʊ/ (as uttered in the words *boot*, *coop* vs. *put*, *took* and *could*) were

distinguished by NS1. As with the tense-lax pairs /i/-/ɪ/ and /e/-/ɛ/, the tense vowel /u/

had a higher percentage of category matches (90%) as compared to the lax vowel /ʊ/ (60%-73%).

The inclusion of duration eliminated the confusion of /ʊ/ with /ɔ/ at Time 1. The vowel /ʊ/ had shorter duration means than /ɔ/ by at least 80 msec. At Time 2 when duration was included as a parameter the instances of confusion of /ʊ/ with /ʌ/ increased. These two vowels had mean duration differences of about 20 msec. Duration had absolutely no effect on the vowel /u/ or on the distinction between the vowels /u/ and /ʊ/. Although duration means between the two differed by over 50 msec, the classification rates for /u/ stayed constant across the board and the instances of confusion between /u/ and /ʊ/ remained the same with or without duration.

Across time, the vowel /u/ remained stable, but there were slight differences in the vowel /ʊ/ from Time 1 to Time 2. At Time 1, three of the attempts at /ʊ/ fell into the range of /u/ (on the *F1/F2 plus Duration* condition) whereas none did at Time 2.

The vowel /u/ warrants a special discussion due to the lexical item *tube* and the allophonic variation conditioned by the initial alveolar stop. Hillenbrand and Clark (2001) showed that initial alveolars tend to front the back vowels with the most dramatic effects seen for the vowel /u/ (p. 760). As previously shown in Table 4.5, there are only

ten instances of /u/ in the discriminant analysis because *tube* was initially excluded as an item. In those ten lexical items, /u/ exhibited a clear distinction from other vowels, was highly stable, and the percentage of category matches was not affected by duration. With the item *tube* included in the data set the results were somewhat different. Table 4.6 shows the results of the discriminant analysis with the lexical item *tube* included.

Table 4.6 Results of the Discriminant Analyses of the Vowel /u/ with the Item *Tube* Included for NS1

Target Vowel	Time 1		Time 2	
	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration
u N=15	u (9)	u (14)	u (9)	u (11)
	ʊ (5)	ʊ (1)	ʊ (5)	ʊ (3)
	ɔ (1)	-----	ɔ (1)	-----
	-----	-----	-----	o (1)
% correct	60	93.3	60	73.3
ʊ N=15	ʊ (8)	ʊ (10)	ʊ (8)	ʊ (8)
	u (5)	u (3)	u (3)	u (2)
	ʌ (1)	ʌ (1)	ʌ (2)	ʌ (3)
	ɪ (1)	ɪ (1)	ɪ (2)	ɪ (2)
% correct	60	66.6	73.3	53.3

Note that at Time 1 in the *F1/F2 Only* condition, nine of the instances of /u/ were still correct category matches but six attempts now fell into the F1, F2 range of neighboring vowels. Additionally, with the item *tube* included, duration played a far greater role in distinguishing this vowel from others. In fact, at Time 1 duration improved the number of correct category matches from 9 out of 15 (60%) correct to 14 out of 15 (93%) correct. A

similar pattern was seen at Time 2, although the improvement with duration was not so dramatic.

The vowels /o/ and /ɔ/ (uttered in the words *coat, boat, code* vs. *talk, caught and taught*) were slightly less differentiated than other vowels discussed thus far. Notice that at Time 1, 4 out of 15 instances of /o/ fell into the F1/F2 range of /ɔ/ and vice versa. It may be the case that additional parameters help to distinguish these vowels for English speakers (including F3, formant transitions and/or lip rounding). These distinctions were also confounded by the inclusion of duration, meaning that the vowels became less distinct and showed more category confusion when duration was a parameter than with F1/F2 as the only parameters. These vowels had duration means that differed by about 20 msec with the vowel /ɔ/ being slightly longer. Finally, /o/ and /ɔ/ also showed more variation across time than the vowels discussed above.

It should be noted that the lexical items containing the vowels /o/ and /ɔ/ ended mostly in voiceless stops (with the word *code* as the only exception). Furthermore, none of the words containing /o/ began with an alveolar consonant while two of the words containing /ɔ/ (*taught, talk*) began with an alveolar consonant. It is difficult to assess whether allophonic variation affected the classification rates of these vowels but the reduced item conditions (both initial and final consonant) yielded an increase in the accuracy of /o/ and a decrease in the accuracy of /ɔ/.

The vowel /ʌ/ showed the greatest variation and the poorest classification rates of all vowels. At Time 1 only 8 out of the 15 instances of /ʌ/ were considered to be /ʌ/ regardless of whether duration was included as a parameter or not. Time 2 showed slightly better category matches and a slight difference when duration was included. It was first thought that the lexical item *but* might be affecting the results. Although an attempt was made to force this word into a position of stress, the strong tendency for English speakers is to reduce function words. A separate discriminant analysis was run with the word *but* excluded. This seemed to make only a very small difference in the number of correct category matches. It was therefore concluded that this vowel is somewhat variable regardless of whether the lexical item is a function word such as *but* or a content word such as *cut* or *cup*. The vowel /ʌ/ did not appear in any words that ended in voiced stops or that began with alveolar consonants so the reduced item conditions did not apply. This vowel had the second lowest duration means of all vowels (with only /ʊ/ being shorter).

The vowel /ɑ/ showed the greatest differentiation of the back vowels with all instances at each time and in both conditions being correctly matched to their intended category. It was completely stable over time for this speaker, with no changes in category match across times or across conditions. The vowel /ɑ/ did not occur in any words that ended in voiced stops or that began with alveolar consonants so the reduced item conditions did not apply. The vowel /ɑ/ had the highest duration means of all vowels with the exception of /ɔ/.

4.2.5. Summary of the Vowel System of NS1

NS1 distinguished most of the eleven vowels of this study on the F1/F2 parameters, although some were more clearly differentiated than others. When the lexical items *bad* and *tube* were excluded, the vowels /i/, /e/, /æ/, /u/ and /ɑ/ were the most clearly differentiated in the F1/F2 space and the most stable over time. The vowels /ɪ/, /ɛ/, /ʌ/ and /ʊ/ exhibited far more category confusion than /i, e, æ, u, ɑ/. They were also affected by duration to a greater degree than the tense vowels but the overall effect of duration was minimal and did not always create greater distinctions between phonemic pairs. This does not mean that duration has no role in the pronunciation of AE vowels. (We cannot ignore the general tendency of longer vowels being better differentiated than shorter vowels.) It may simply mean that the spectral distinctions were sufficient.

The vowels /æ/ and /u/ were most likely to be affected by allophonic variation in this data set but that is not to say that the other vowels would not have shown allophonic variation had different lexical items been selected. The vowel /ʌ/ showed the poorest category match of all vowels.

NS1 exhibited strong category matches, but not perfect category matches. These generally improved when the number of lexical items was reduced as discussed in section 4.3 indicating that phonemes were affected either by phonetic context or by some other factor specific to the lexical item (such as frequency, familiarity, idiosyncrasies, etc.). Category matches improved for this speaker when items containing strong allophonic or

dialectal variation were excluded. NS1 is generally stable across the two times but not completely so. This particular speaker shows changes no greater than four instances in any individual phoneme or contrast and thus we will take this as a starting point for the baseline of change when we examine the nonnative speakers.

4.3. Native Speaker 2 (NS2)

Native Speaker 2 (henceforth NS2) is a female monolingual speaker of English who was 38 years old at the time of the first recording. She was born and raised in New York City and areas of Long Island. As with NS1, this speaker also exhibits some features of NYCD.

4.3.1. Sample Collection

As expected, NS2 had little difficulty with the sentence-reading task, but eight items were discarded. All five instances of the word *could* were discarded because they were so significantly reduced in the sample that they no longer represented to the vowel /ʊ/. One instance of the word *pet*, one instance of the word *put* and one instance of the word *boot* were discarded because they were misread. Thus, 157 items remained in the sample.

In order to determine intra-rater reliability, 17 items from the Time 1 sample and 17 items from Time 2 items were randomly selected and re-measured. As indicated in Table 4.7, mean differences between the re-measure and the original measure were less than 4 msec for length and less than .13 Bark for F1 and F2 at the 50% point.

Table 4.7 **Margin of Error for NS2**

	Mean Difference Between Time 1 Measure and Re- measure	Mean Difference Between Time 2 Measure and Re- Measure
Duration	3.67 msec	3.18 msec
F1 at 50% Point	0.05 Bark	0.08 Bark
F2 at 50% Point	0.08 Bark	0.12 Bark

4.3.2. **Category Matches within Lexical Items**

As with NS1, this speaker also had differences in category matches within lexical items as compared to across lexical items. Consider again the single-item subset we referred to as the *keep sequence* in which vowels appeared in the words *keep, kid, gate, get, cat cup, boat, put, coat, taught, and top* (a subset of the whole data set). Recall that each of the eleven vowels was repeated five times (with the exception of *boot* and *put*) but in only one lexical item and one immediate phonetic context. As with the first native speaker, there were differences in the way vowels matched their intended targets when they were considered in the single-item subset as opposed to the multiple-item set. As an example, the total correct classification for the *keep sequence* was 90% (at Time 1 with F1/F2 as the parameters) as compared to 75% on the multiple-item data. With duration added, the total correct classification was roughly the same. These results are presented in Table 4.8.

Table 4.8 Single-Item vs. Multiple-Item Comparison of NS2 at Time 1

Target Vowel	Single-Item Subset		Multiple-Item Set	
	Percent/Number Correctly Matched: F1/F2	Percent/Number Correctly Matched F1/F2 and Duration	Percent/Number Correctly Matched: F1/F2	Percent/Number Correctly Matched: F1/F2 and Duration
i	100 (5/5)	100 (5/5)	100(15/15)	100 (15/15)
ɪ	80 (4/5)	60 (3/5)	80 (12/15)	80 (12/15)
e	60 (3/5)	80 (4/5)	86.6 (13/14)	86.6 (13/14)
ɛ	100 (5/5)	100 (5/5)	78.5 (11/14)	85.7 (12/14)
æ	100 (5/5)	100 (5/5)	100 (10/10)	100 (10/10)
ʌ	100 (5/5)	100 (5/5)	33.3 (5/15)	46.6 (7/15)
u	100 (4/4)	100 (4/4)	100 (9/9)	100 (9/9)
ʊ	100 (4/4)	100 (4/4)	88.8 (8/9)	88.8 (8/9)
o	60 (3/5)	60 (3/5)	80 (12/15)	73.3 (11/15)
ɔ	100 (5/5)	100 (5/5)	73.3 (11/15)	66.6 (10/15)
ɑ	100 (5/5)	100 (5/5)	86.6 (13/15)	86.6 (13/150)
Total %	90.5	90.5	75.1	76.4

There were some differences, however, between the two native speakers. Although all single-item subsets had generally better category matches than the multiple-item sets, NS2 had a higher overall percentage of correct category matches on the *peek* sequence than the *keep* sequence. The reverse was true for NS1. This may indicate that phoneme accuracy is not only a function of phonetic environment but may be a function of individual lexical items. That is to say, native speakers may have particular idiosyncratic pronunciations of some lexical items that are closer to the intended phoneme category or farther away.

Additional evidence that phoneme accuracy may be a function of individual lexical items comes from a closer examination of the *keep* sequence in NS2. Consider again Table 4.8.

Although the total correct classification for the *keep* sequence is higher than for the multiple-item context, this is not the case for three specific vowels. Note that the vowels /i, e, o/ actually increase in accuracy in the multiple item condition.

Thus we examined reduced lexical item sequences because much of our knowledge of the acoustic properties of vowels comes from seminal studies that used only a single lexical item or a single context. It was necessary to determine how the data of this study compared to our general knowledge of vowels. Furthermore, if native speakers were to serve as a baseline, it was necessary to see how they produced the vowels in the lexical items of this study. In this study, it first appeared that differences in single-item subsets vs. multiple-item sets were solely due to limited context. Two additional facts make it apparent that this is only part of the story. First, some speakers show greater accuracy depending on the lexical items in the sequence. If increased phoneme accuracy were only a factor of single-item subset vs. multiple-item sets, it shouldn't matter which words served as the single-item subset. Second, some vowels are actually less accurate in single lexical items than they are in multiple lexical items indicating that these may reflect idiosyncratic pronunciations.

4.3.3. Category Matches across Lexical Items: The Front Vowels

We now turn to the front vowels of English as spoken by NS2. Figures 4.5 and 4.6 show the F1/F2 plots of the vowels /i, ɪ, e, ε, æ/ recorded two times over the period of one year.

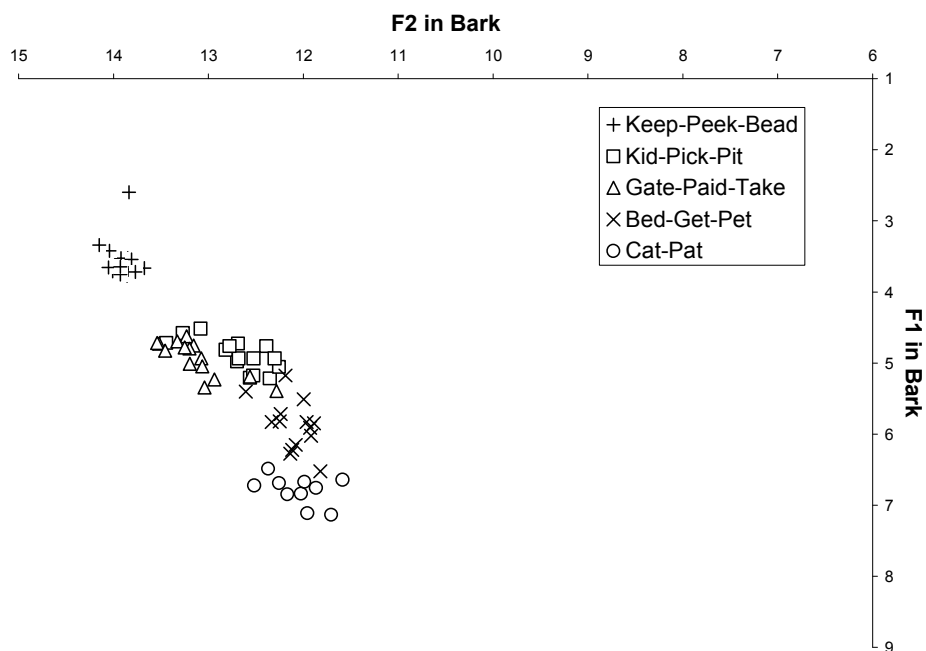


Figure 4.5 F1/F2 plot of the front vowels at Time 1 pronounced by NS2

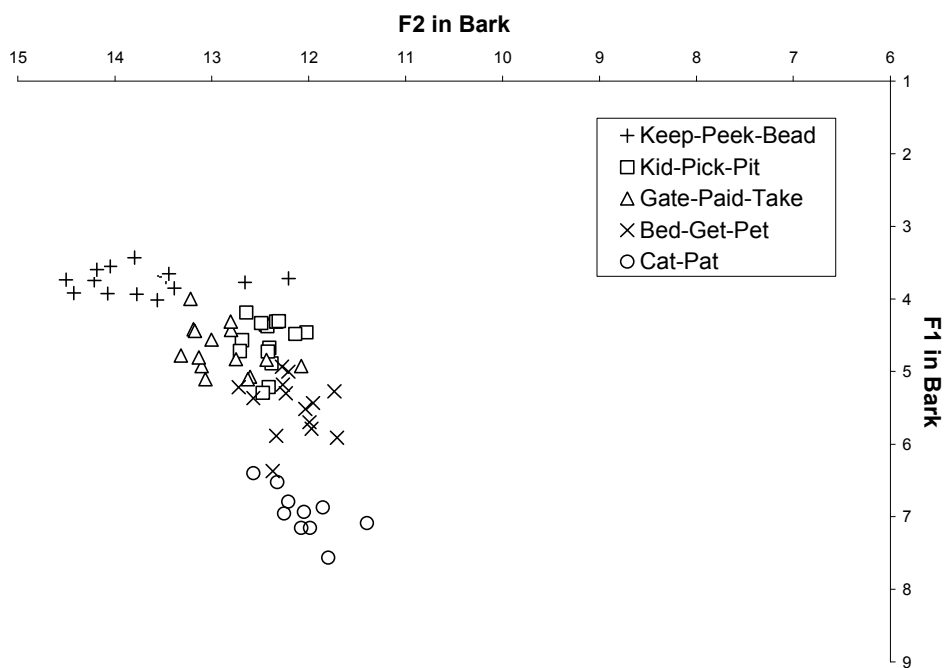


Figure 4.6 F1/F2 plot of the front vowels at Time 2 pronounced by NS2

As with the first native speaker, it is possible to identify five vowel categories for the front vowels, but these vowels do overlap in the F1/F2 space and some to a greater extent than others. In order to understand the distribution we look at the results of the discriminant analysis as presented in Table 4.9.

Table 4.9 Results of the Discriminant Analyses of the Front Vowels Pronounced by NS 2 across Two Times

Target Vowel	Time 1		Time 2	
	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration
i N=15	i (15) -----	i (15) -----	i (13) I (2)	i (13) I (2)
% correct	100	100	86.6	86.6
I N=15	I (12) e (3) -----	I (12) e (3) -----	I (11) e (2) ε (2)	I (9) e (4) ε (2)
% correct	80	80	73.3	60
e N=14	e (13) ε (1) I (1) -----	e (13) ε (1) I (1) -----	e (11) ----- I (3) i (1)	e (11) ----- I (3) i (1)
% correct	86.6	86.6	73.3	73.3
ε N=14	ε (11) I (2) æ (1) ----- -----	ε (12) ----- æ (1) υ (1) -----	ε (10) I (2) æ (1) ----- e (1)	ε (11) I (2) æ (1) ----- -----
% correct	78.5	85.7	71.4	78.5
æ N=10	æ (10) -----	æ (10) -----	æ (9) ɑ (1)	æ (9) ɑ (1)
% correct	100	100	90	90

Looking at Table 4.9 we see that the vowels /i/ and /ɪ/ (uttered in the words *keep, peek, bead* vs. *pick, bit* and *kid*) were clearly distinguished by NS2. As we saw with the first native speaker, /i/ had a higher percentage of category matches (86-100%) as compared to /ɪ/ (60-80%) and /i/ was less likely to fall into the F1/F2 range of other vowels. The vowel /i/ had longer duration means than the vowel /ɪ/ by about 20 msec. When duration was included as an additional input parameter it had no effect on the classification of the vowel /i/ and did not make the vowels /i/ and /ɪ/ any more or less distinct from *each other*. At Time 2, duration made the vowel /ɪ/ more distinct from the vowel /e/ (with /ɪ/ having lower duration means than /e/ by about 30 msec.). There was a decrease in percentage of category matches for both vowels across time.

In the reduced item condition, the percentage of correct category matches was affected by the elimination of final voiced consonants but not in the expected way. When the words *bead* and *kid* were eliminated from the analysis, the classification rate was 100% for both vowels at Time 1. It should be noted however that the percentage was the same regardless of whether duration was included as a parameter or excluded as a parameter. At Time 2, the classification rate was 90% correct for /i/ and 80% for /ɪ/, regardless of whether duration was included or not. The elimination of the word initial alveolar items did not affect the percentage of correct category matches of these vowels.

The vowels /e/ and /ɛ/ (uttered in the words *take, gate, paid* vs. *get, pet, and bed*) were also distinguished by NS2. This speaker had only a slightly higher number of correct category matches for /e/ than for /ɛ/. Although /e/ had higher duration means (by about 30 msec) than /ɛ/, adding duration as an input parameter had little effect on how well these vowels were differentiated from each other or from other vowels. As with the vowels /i/ and /ɪ/, there was a small decrease in the percentage of correct matches across time.

In the reduced item conditions, where items with final voiced and voiceless stops were treated separately, this speaker showed a slight decrease in accuracy on both vowels across times. The difference was the same, however, regardless of whether duration was included as a parameter. In the reduced item condition where initial alveolars were treated separately, there was no effect on the accuracy of /ɛ/, but the accuracy of /e/ decreased slightly with more instances being confused with /ɪ/.

The vowel /æ/ for NS2 patterned much like it did for NS1. That is to say, with the lexical item *bad* excluded, /æ/ exhibited strong category matches (9 -10 out of 10 or 90-100%) and was relatively stable over time. Although this vowel had the highest duration means of all vowels for NS2, adding duration as an input parameter did not have an effect of how well it was differentiated. Again, this could simply mean that spectral cues were sufficient to differentiate this vowel from others.

As with NS1, the vowel /æ/ behaved differently when the item *bad* was included as shown in Table 4.10. With the lexical item *bad* included in the discriminant analysis, the number of correct category matches decreased significantly (9 -11 out of 15 or 60-73%) and duration had a greater impact on distinguishing the vowel /æ/ from /ε/ (at least at Time 1).

Table 4.10 Results of the Discriminant Analyses of the Vowel /æ/ with the Item *Bad* Included for NS2

Target Vowel	Time 1		Time 2	
	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration
æ	æ (9)	æ (11)	æ (9)	æ (9)
	ε (4)	ε (2)	ε (5)	ε (5)
	α (2)	α (2)	α (1)	α (1)
N=15				
% correct	60	73.3	60	60

4.3.4. Category Matches across Lexical Items: The Back Vowels

Having discussed the front vowels we now turn to the central and back vowels. Figures 4.7 and 4.8 show the F1/F2 plots of the vowels /u, ʊ, o, ɔ, ɑ, ʌ/ as produced by NS2 twice in the period of a year.

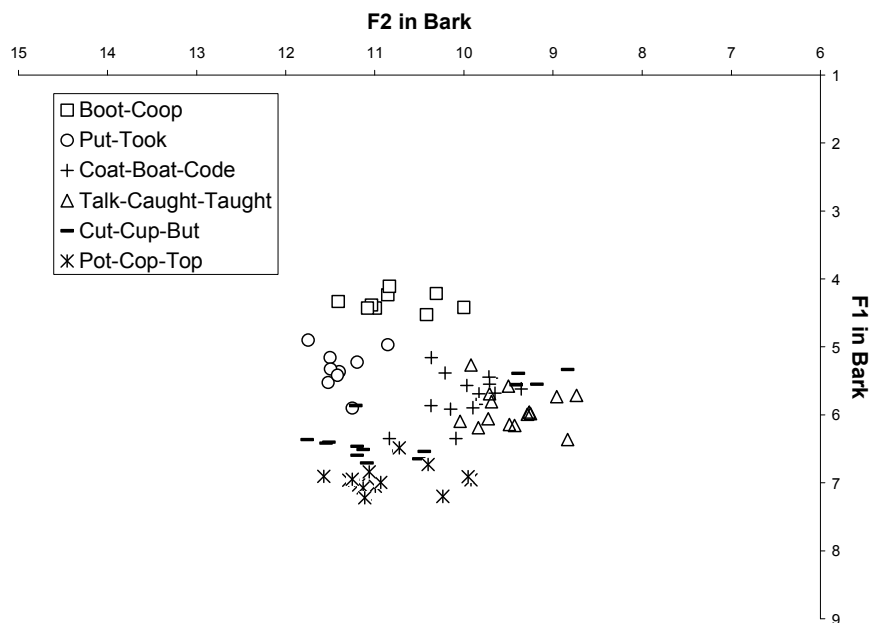


Figure 4.7 F1/F2 plots of the central and back vowels at Time 1 pronounced by NS2

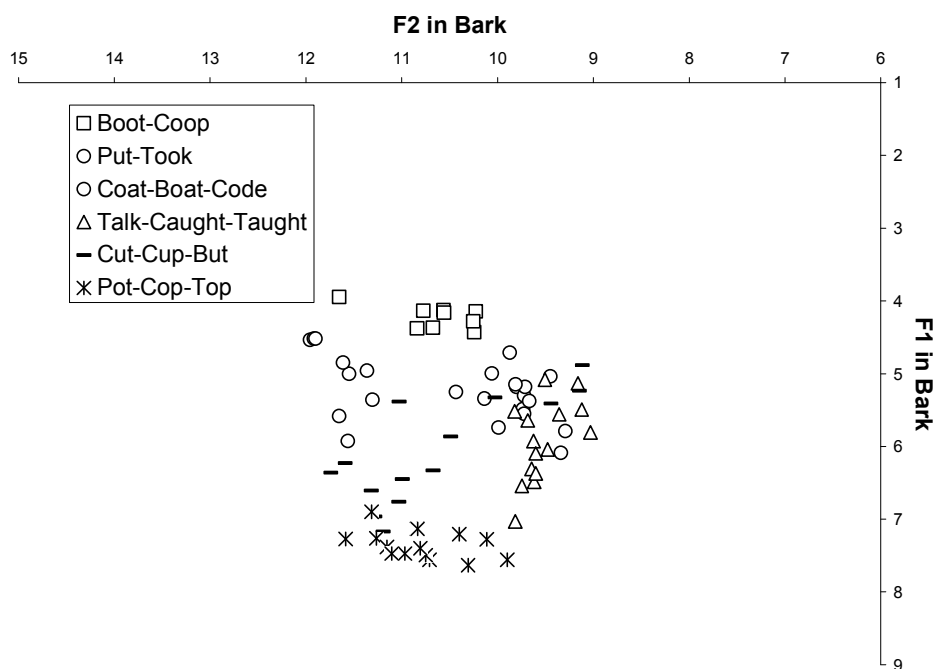


Figure 4.8 F1/F2 plot of the central and back vowels at Time 2 pronounced by NS2

Each of the vowel groupings overlap to some degree with the surrounding phonemes, but some are more differentiated in the vowel space and some are less differentiated in the vowels space. Examples of both cases would be /u/ which does not overlap and /ʌ/ which is dispersed throughout the central and back area. The results of the discriminant analyses will clarify the distribution. Table 4.11 shows the results of discriminant analysis performed on two separate conditions (*F1/F2 Only*, *F1/F2 plus Duration*) at two points in time.

Table 4.11 Results of the Discriminant Analyses of the Central and Back Vowels Pronounced by NS2 across Two Times

Target Vowel	Time 1		Time 2	
	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration
u	u (9)	u (9)	u (8)	u (8)
N=9	-----	-----	ɪ (1)	ɪ (1)
% correct	100	100	88.8	88.8
ʊ	ʊ (8)	ʊ (8)	ʊ (4)	ʊ (4)
N=9	ε (1)	ε (1)	ε (2)	ε (2)
	-----	-----	ɪ (3)	ɪ (3)
% correct	88.8	88.8	44.4	44.4
o	o (12)	o (11)	o (13)	o (12)
N=15	ɔ (1)	ɔ (3)	ɔ (2)	ɔ (2)
	ʌ (2)	ʌ (1)	-----	ʌ (1)
% correct	80	73.3	86.6	80
ɔ	ɔ (11)	ɔ (10)	ɔ (10)	ɔ (10)
N=15	o (4)	o (5)	o (4)	o (4)
	-----	-----	ɑ (1)	ɑ (1)
% correct	73.3	66.6	66.6	66.6
ʌ	ʌ (5)	ʌ (7)	ʌ (6)	ʌ (8)
N=15	ɑ (3)	ɑ (2)	ɑ (3)	ɑ (3)
	o (1)	o (2)	o (4)	o (3)
	-----	-----	ʊ (1)	ʊ (1)
	-----	ε (2)	-----	-----
	ɔ (3)	ɔ (1)	-----	-----
	æ (3)	æ (1)	æ (1)	-----
% correct	33.3	46.6	40	53.3
ɑ	ɑ (13)	ɑ (13)	ɑ (14)	ɑ (14)
N=15	æ (1)	æ (1)	æ (1)	æ (1)
	ʌ (1)	ʌ (1)	-----	-----
% correct	86.6	86.6	93.3	93.3

Consider first the high back vowels /u/ and /ʊ/ (uttered in the words *boot*, *coop* vs. *put*, *took*, and *could*). When the lexical item *tube* was excluded from the discriminant

analysis, the vowels /u/ and /ʊ/ were clearly distinguished by NS2. As with NS1, the vowel /u/ had higher classification rates (8 to 9 out of 9 or 88-100%) compared to the vowel /ʊ/ (4-8 out of 9 or 44-88%) but this difference was more dramatic at Time 2. The vowel /u/ had longer duration means than the vowel /ʊ/ by about 60 msec. Yet, duration as an additional input parameter had no effect on either of these two vowels nor did it seem to affect how these vowels were distinguished from other vowels.

When the item *tube* was included in the discriminant analysis (in Table 4.12), the percentage of category matches for /u/ decreased (9-11 out of 14 or 64-78%) with more instances of /u/ being confused with front vowels. This clearly indicates the fronted position of the lexical item *tube*.

Table 4.12 Results of the Discriminant Analyses of the Vowel /u/ with the Item Tube Included for NS2

Target Vowel	Time 1		Time 2	
	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration
u N=14	u (11)	u (11)	u (10)	u (9)
	i (3)	i (3)	i (4)	-----
	-----	-----	-----	e (4)
	-----	-----	-----	o (1)
% correct	78.5	78.5	71.4	64.2
u N=9	u (8)	u (8)	u (4)	u (4)
	Λ (1)	Λ (1)	i (3)	i (3)
	-----	-----	ε (2)	ε (2)
% correct	88.8	88.8	44.4	44.4

The vowels /o/ and /ɔ/ (uttered in the words *coat*, *boat*, *code* vs. *talk*, *caught* and *taught*) exhibited a similar pattern to the first native speaker in that they were not as clearly differentiated in F1/F2 and duration parameters as the other pairs in this study. The speakers diverge in that there was an asymmetry of category confusion for NS2. Recall that with the male native speaker, roughly an equal number of instances of /o/ were judged to be /ɔ/ and vice versa. With NS2, however, it was more likely for an instance of /ɔ/ to fall into the F1/F2 range of /o/.

The vowel /ɔ/ was slightly longer than the vowel /o/ but by less than 10 msec. At Time 1 duration affected these vowels by making them less distinct from each other (i.e. increasing the number of instances of /ɔ/ being categorized as /o/ and the number of

instances of /o/ being categorized as /ɔ/). At Time 2, duration had less of an effect.

Finally, /o/ and /ɔ/ showed greater variation across time than the vowels discussed above.

The vowel /ʌ/ (uttered in the words *but*, *cup* and *cut*) showed the lowest classification rates, was most likely to overlap into the F1/F2 space of other vowels and showed the greatest variability cross-sectionally and longitudinally. Note that the discriminant analysis identified instances of the vowel /ʌ/ as belonging to as many as six different categories. This variability was similar to that of NS1. This vowel also differed with respect to which vowels it was confused with across time. As with NS1, this vowel had the second shortest duration means of all vowels (being longer than only the vowel /ʊ/). When duration was included as an input parameter, the classification rate improved somewhat.

Since the items containing the vowel /ʌ/ had neither initial alveolar consonants nor final voiced consonants, the reduced item sets were not applicable.

The vowel /ɑ/ (uttered in the words *pot*, *top* and *cop*) was clearly distinct from other vowels in this study. Although one or two instances were determined to fall into the acoustic space of /æ/ and /ʌ/, the majority of the instances were correct category matches for their intended centroid (13-14 of the 15 attempts). This vowel had among the longest duration means of all vowels for this speaker (with only /ɔ/ and /æ/ being longer). When

duration was added as an input parameter there was no effect on how well this vowel was differentiated from others. The classification of this vowel showed a slight improvement over time (one instance). The vowel /ɑ/ did not occur in any words that ended in voiced stops or began with alveolar consonants so the reduced item conditions did not apply.

4.3.5. Summary of the Vowel System NS2

The NS2 exhibited many similarities to NS1. She distinguished most of the eleven vowels of this study on the *F1/F2 plus Duration* parameters. The vowels /æ/ and /u/ showed similar patterns of allophonic variation as those shown by NS1. This speaker also a high percentage of correct category matches, but not perfect category matches which improved when the number of lexical items was reduced. Like NS1, this speaker was relatively stable but not completely so. Again, we see changes but by no more than four instances for any individual phoneme or contrast.

Adding duration as a parameter did not increase classification rates as much on these vowels for NS2. In the twenty-two groups (eleven vowels each at two times) only eight showed any effect of duration at all for NS2. For NS1, on the other hand, 15 of 22 groups showed some improvement in classification when duration was included as a parameter, even if these were small. Only five vowel categories were affected by duration for NS2 (/ɪ, ε, o, ʌ, ɔ/) whereas eight categories were affected by duration for NS1 (/ɪ, e, ε, æ, u, o, ɔ, ʌ/).

In conditions where *bad* and *tube* were excluded, the vowels /i/, /u/ /æ/ and /ɑ/ were the most differentiated in the F1/F2 space and the most stable over time. The vowel /ʌ/ showed the most overlap and the poorest category matches.

Chapter 5: Analysis of Nonnative Speaker 01

5.1. Overview

We now turn to the analysis of the nonnative speakers. Vowels of the nonnative speakers were compared using the same input variables as were the native speakers (*F1/F2 Only* and *F1/F2 plus Duration*) but most of the nonnative speakers were considered at three points in time (yielding six conditions) as opposed to two points in time. An additional difference between the analyses is that the vowel systems of the nonnative speakers were considered both separately and in comparison to the native speakers. For each nonnative speaker discriminant analyses were performed on the six conditions and the results were discussed with respect to which vowels were differentiated, which parameters were used to differentiate them, and whether or not those contrasts changed across times. After the nonnative speaker's vowel system was examined as an entity unto itself, additional discriminant analyses were conducted on the same six conditions using a native speaker's data as the criteria for vowel categories. The male nonnative speakers were compared to the male native speaker and the female nonnative speaker was compared to the female native speaker.

5.2. Background of Nonnative Speaker 01 (NNS01)

We begin by examining the vowel system of Nonnative Speaker 01 (henceforth NNS01) who is a male native Spanish speaker, born in Medellin, Colombia. At the time of the first recording he was forty years old and had lived in the United States for twelve years. He began studying English in Colombia as part of a high school requirement and took

some English classes when he first came to the United States at the age of twenty-eight. At the onset of the study he was enrolled in one advanced writing course for ESL students at Nassau Community College as well as courses required for an Associates degree. He reported watching several hours of American television per day, spending about a half hour reading American newspapers each morning, and reading approximately seven or eight books in English each month (including novels and required text readings for his college courses). He speaks English at work and with the majority of his friends; he uses both English and Spanish with his wife and school-aged children.

5.3. Sample Collection

It should be noted that NNS01 had little difficulty with the sentence-reading task. As with most of the nonnative speakers, all five instances of the word *bead* had to be excluded¹. Additionally, one instance each of the words *get*, *coop*, *could* and *pot* was excluded from this speaker's sample, leaving a total of 156 target vowels in the sentence-reading task.

In order to determine intra-rater reliability, seventeen items from each of the three samples were randomly selected and re-measured. As indicated in Table 5.1, mean differences between the re-measure and the original measure were less than 6 msec for duration and less than .13 Bark for F1 and F2 at the 50% point.

Table 5.1 **Margin of Error for NNS01**

	Mean Difference Between Time 1 Measure and Re-measure	Mean Difference Between Time 2 Measure and Re- Measure	Mean Difference Between Time 3 Measure and Re- Measure
Duration	5.08 msec	5.7 msec	4.8 msec
F1 at 50% Point	0.11 Bark	0.05 Bark	0.03 Bark
F2 at 50% Point	0.12 Bark	0.10 Bark	0.07 Bark

5.4. **Category Matches within Lexical Items**

As with the native speakers, discriminant analyses were conducted on the single-item subsets as well as the multiple-item sets. Recall the earlier findings regarding category matches for phonemes in a single-item subset as opposed to category matches for phonemes produced in the multiple-item sets. For both native speakers, the eleven vowel system showed better overall category matches in the single-item subset than in the multiple-item set. There were, however, a few vowels for which it did not matter or which had better category matches in the multiple-item set. These were idiosyncratic to the individual speaker. Similar findings occurred when the vowel productions of NNS01 were considered separately from the native speaker's productions. That is, the eleven vowels showed a higher overall classification rates in the single-item subset than in the multiple-item set.

Table 5.2 shows the classification rates of phonemes on the *keep sequence* at Time 1 under two conditions (*F1/ F2 Only*, and *F1/ F2 plus Duration*) as compared to these same conditions across multiple lexical items. This first comparison considers the vowel

system of the nonnative speaker without the native speaker's values entered into the analysis.

Table 5.2 Single Item vs. Multiple Item Comparison of NNS01 at Time 1

Target Vowel	Single-Item Subset		Multiple-Item Subset	
	Percent/Number Correctly Matched: F1/F2	Percent/Number Correctly Matched F1/F2 and Duration	Percent/Number Correctly Matched: F1/F2	Percent/Number Correctly Matched: F1/F2 and Duration
i	60 (3/5)	60 (3/5)	0 (0/15)	0 (0/15)
ɪ	60 (3/5)	20 (3/5)	93.3 (14/15)	100 (15/15)
e	80 (4/5)	100 (5/5)	86.6 (13/15)	73.3 (11/15)
ɛ	50 (2/4)	100 (4/4)	35.7 (5/14)	64.2 (9/14)
æ	100 (5/5)	80 (4/5)	90 (9/10)	90 (9/10)
ʌ	80 (4/5)	60 (3/5)	40 (6/15)	46.6 (7/15)
u	60 (3/5)	60 (3/5)	77.7 (7/9)	77.7 (7/9)
ʊ	60 (3/5)	60 (3/5)	57.1 (8/14)	64.2 (9/14)
o	60 (3/5)	80 (3/5)	86.6 (13/15)	86.6 (13/15)
ɔ	20(1/5)	60 (3/5)	40 (6/15)	33.3 (5/15)
ɑ	100 (5/5)	100 (5/5)	21.4 (3/14)	21.4 (3/14)
Total	66.6	70.3	57.5	60.2

With F1/F2 as the only parameters, the overall correct classification was 66.6% for the single-item subset as compared to 57.5% (when these vowels were considered across three lexical items). When duration was added as a parameter in the discriminant analysis of the *keep sequence*, the overall correct category match was 70.3% correct as compared to 60% correct when these vowels were compared across lexical items. This general pattern was similar to that of both native speakers in that category matches were better when vowels were considered in one lexical item and one immediate phonetic context. It should be noted that some vowels dramatically increased in accuracy in the single-item

subset. All five instances of the vowel /a/, for example, were correct category matches in the word *top*. Yet only three instances of the vowel /a/ were correct category matches across the items *top*, *cop* and *pot*. Similarly, the vowel /i/ in the single-item subset was more accurate than in the multiple-item set. It was also the case, however, that some vowels showed were *less* frequently matched to the intended centroid in the single-item subset than in the multiple-item set (e.g. /ɪ, o, u/)

Now consider the *keep sequence* when the native speaker's data were used as the criteria for vowel categories. That is to say, using the native speaker as the input data for the intended vowels, the discriminant analysis established the centroids based on the native speaker's parameters. Then the nonnative speaker's actual data were tested against this model (results in Table 5.3).

Table 5.3 Single Item vs. Multiple Item Comparison of NNS01 Using the Native Speaker's Data as Criteria (Time 1)

Target Vowel	Single-Item Subset		Multiple-Item Set	
	Percent/Number Correctly Matched: F1/F2	Percent/Number Correctly Matched F1/F2 and Duration	Percent/Number Correctly Matched: F1/ F2	Percent/Number Correctly Matched: F1/F2 and Duration
i	80 (4/5)	80 (4/5)	70 (7/10)	60 (6/10)
ɪ	20 (1/5)	20 (1/5)	13.3 (2/15)	20 (3/15)
e	40 (2/5)	100 (5/5)	60 (9/15)	80 (12/15)
ɛ	75 (3/4)	100 (4/4)	35.7 (5/14)	35.7 (5/14)
æ	0 (0/5)	40 (2/5)	30 (3/10)	40 (4/10)
ʌ	40 (2/5)	40 (2/5)	73.3 (11/15)	66.6 (10/15)
u	60 (3/5)	60 (3/5)	77.7 (7/9)	55.5 (5/9)
ʊ	60 (3/5)	80 (4/5)	35.7 (5/14)	35.7 (5/14)
o	40 (2/5)	40 (2/5)	33.3 (5/15)	13.3 (2/15)
ɔ	0 (0/5)	0 (0/5)	6.6 (1/15)	26.6 (4/15)
ɑ	0 (0/5)	0 (0/5)	21.4 (3/14)	21.4 (3/14)
Total	37	50	39	40

With F1/F2 as the only parameters, the overall correct classification was 37% on the single-item subset and 39% when vowels were considered in the multiple-item set. When duration was added as a parameter in the discriminant analysis of the *keep sequence*, the overall correct category match was 50% correct as compared to 40% correct when these vowels were compared across lexical items.

We can tentatively conclude that whether a vowel was uttered several times within a single lexical item as opposed to several times across three lexical items had an effect on how well various instances of a vowel matched each other on the discriminant analysis. These variables however, had less of an effect on the way this nonnative speaker's vowels matched the native speaker's vowels.

5.5. The High and Mid Front Vowels

Let us now consider phonemically relevant vowel pairs in the entire data set across all lexical items. We begin with the high front vowels /i/ and /ɪ/ as uttered in the words *keep*, *peek*, *pick*, *kid* and *pit* and the mid front vowels /e/ and /ɛ/ as uttered in the words *take*, *gate*, *paid*, *get*, *pet* and *bed*.

5.5.1. Distribution of /i/, /ɪ/, /e/ and /ɛ/ by NNS01

The first matter to address is how the vowels in these target words were distributed independently of the native speaker's values and as a separate system. Figures 5.1, 5.2 and 5.3 show the F1/F2 plots of the vowels /i/, /ɪ/, /e/ and /ɛ/ recorded at three points in time over a period of one year. A preliminary examination of the F1/F2 plots indicates that the speaker had two major groups for these four English vowels: one in the high front region and one in the mid front region. Not unexpectedly, lexical items containing the four AE target phonemes were grouped into two categories corresponding more to the vowels of the Spanish.

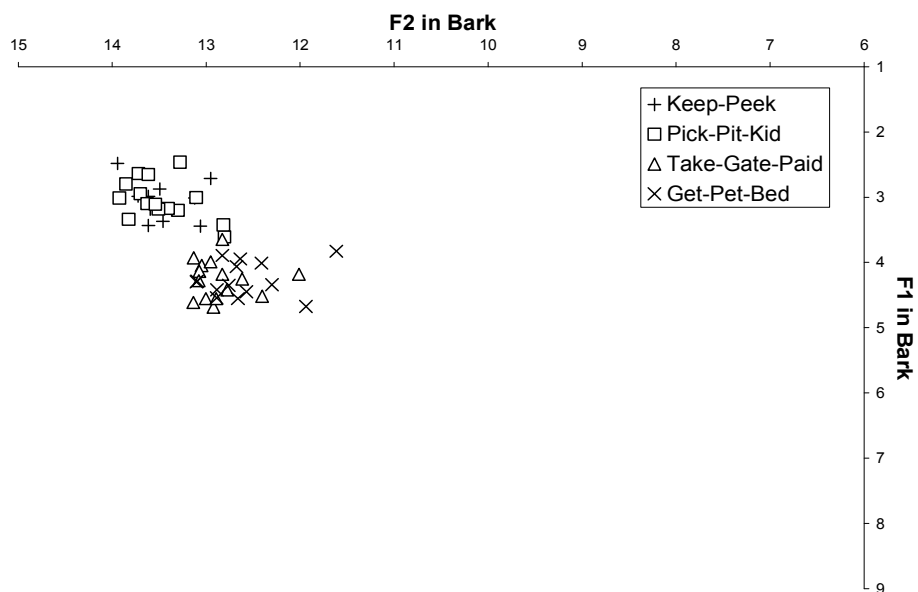


Figure 5.1 F1/F2 plot of the high and mid front vowels at Time 1 pronounced by NNS01

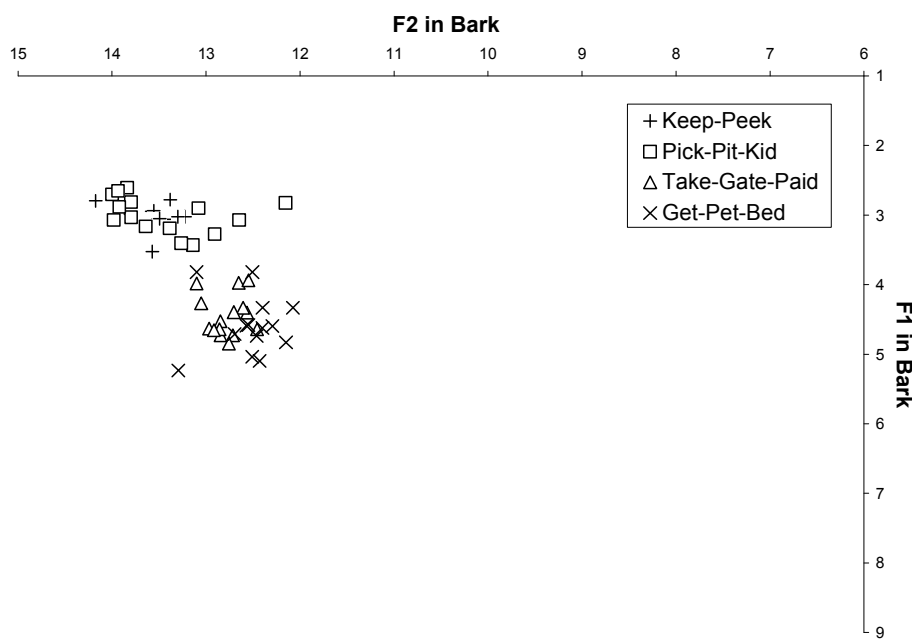


Figure 5.2 F1/F2 plot of the high and mid front vowels at Time 2 pronounced by NNS01

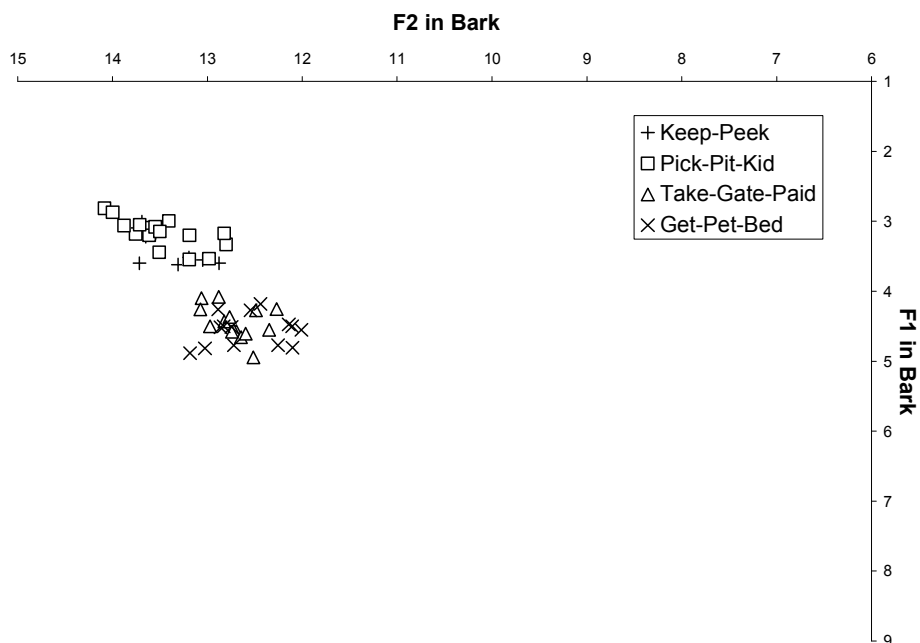


Figure 5.3 F1/F2 plot of the high and mid front vowels at Time 3 pronounced by NNS01

In order to understand the nature of the distribution more clearly and whether it changed across time we look to the results of the discriminant analyses, first of the high front vowels then of the mid front vowels. This particular set of analyses was conducted on this nonnative speaker's data alone without using the native speaker's values for comparison. The terms *match* and *correct* simply refer to how close the individual vowel utterances were to the centroid of the intended group. *Intended group* simply refers to which phoneme the word contained without implying knowledge on the part of the speaker. Table 5.4 shows the results of the discriminant analyses on two conditions (*F1/F2 Only*, and *F1/F2 plus Duration*) across three times for the vowels /i/ and /ɪ/.

Table 5.4 Results of the Discriminant Analyses of the Vowels /i/ and /ɪ/ Pronounced by NNS01 across Three Times.

Target Vowel	Time 1		Time 2		Time 3	
	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration
i	-----	-----	-----	-----	i (2)	i (4)
N=10	ɪ (10)	ɪ (10)	ɪ (10)	ɪ (10)	ɪ (8)	ɪ (6)
% correct	0	0	0	0	20	40
ɪ	ɪ (14)	ɪ (15)	ɪ (15)	ɪ (14)	ɪ (15)	ɪ (12)
N=15	----- e (1)	-----	-----	i (1) -----	-----	i (3) -----
% correct	93	100	100	93	100	80

At Time 1, NNS01 did not clearly distinguish the vowels /i/ and /ɪ/. In total, this speaker produced ten attempts at /i/ and fifteen attempts at /ɪ/. A discriminant analysis of the F1/F2 values at Time 1 showed that 10 out of 10 attempts at /i/ and 14 out of 15 attempts at /ɪ/ fell into the same F1/F2 range, indicating that the speaker had a single vowel category for the target words *keep*, *peek*, *pick*, *kid* and *pit*.

Initially the duration means of these vowels differed by less than 5 msec. When duration was added as an additional input parameter it minimally affected the output by *eliminating* the one attempt that was confused with /e/ causing all target words to contain a single vowel.

There was some change in these vowels over time. By the final recording, four instances of the vowel /i/ were distinct (when all three parameters were considered). Interestingly,

the number of correct matches of /ɪ/ decreased as this happened. Although one cannot say that the speaker improved his accuracy in pronouncing target lexical items, it appeared that a new vowel category was being formed by Time 3. Although the speaker was still producing instances of the words *keep*, *pick*, *kid*, *pit* and *pick* with non-target vowels, there was some evidence of an /i/ category by Time 3, where at Time 1 there was no evidence of any other category but /ɪ/. This can be seen clearly if one compares the results of the discriminant analysis at Time 1 (with all parameters included) to the results of the discriminant analysis at Time 3 (with all parameters included). Note that all 25 attempts at these two vowels all fell into a single category at Time 1. By Time 3, seven of the attempts (four for /i/ and three for /ɪ/) were considered distinct (even if they were not accurately associated with the target words). It should be noted that the new category is based more on a durational distinction than a formant distinction. This should not be surprising since researchers have found that L2 learners to use duration to differentiate this vowel pair perceptually (Bohn, 1995; Escudero, 2000; Morrison, 2008)². What is surprising is that at Time 3 /ɪ/ was the longer of the two for this native speaker.

We will tentatively characterize this change as split. Recall, that split is the process whereby a single phoneme is separated into two distinct phonemes. It is by no means the typical split described in Chapter 2. First, splits are technically defined as movement in the acoustic space which generally refers to the formants. Second, this is not a complete split in that there is still confusion between the two vowels. But we must recognize the brief window of time in which this study was conducted and the possibility that complete

splits (if they happen at all in L2 acquisition) might take a longer period of time. We identify this as change because the number of instances that were categorized differently across time exceeded what we saw in the native speakers. We can refer to this change as split because a new phoneme category, that previously did not exist, was formed. The split can be illustrated in Figure 5.4, which shows that 25 lexical items with vowels categorized as /ɪ/ have separated into eighteen instances of /ɪ/ and seven instances of /i/.

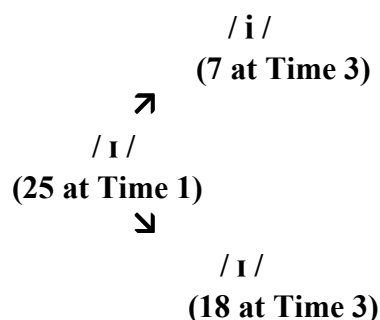


Figure 5.4 The partial split of /ɪ/ into /i/ and /ɪ/

It is unlikely that this split will bring the nonnative speaker closer to the native speaker's vowels because for both native speakers in this study the differentiation of /i/ and /ɪ/ was mainly based on spectral differences not duration.

We now turn to the vowels /e/ and /ɛ/ as uttered in the words *take*, *gate*, *paid*, *get*, *pet* and *bed*. Table 5.5 shows the results of the discriminant analyses across three times on both conditions (*F1/F2 Only* and *F1/F2 plus Duration*) with this nonnative speaker's vowel system considered separately from the native speaker's.

Table 5.5 Results of the Discriminant Analyses of the Vowels /e/ and /ɛ/ Pronounced by NNS01 across Three Times

Target Vowel	Time 1		Time 2		Time 3	
	Match /# of Tokens F1/ F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/ F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/ F2	Match /# of Tokens F1/F2 Duration
e N= 15	e (13)	e (11)	e (12)	e (13)	e (11)	e (9)
	ɛ (2)	ɛ (4)	ɛ (3)	ɛ (2)	ɛ (4)	ɛ (6)
% correct	86.6	73.3	80	86.6	73.3	60
ɛ N=14	ɛ (5)	ɛ (9)	ɛ (11)	ɛ (10)	ɛ (6)	ɛ (9)
	e (9)	e (5)	e (3)	e (4)	e (8)	e (5)
% correct	35.7	64.2	78.5	71.4	42.8	64.2

NNS01 made some distinction between the vowels /e/ and /ɛ/ at Time 1. In total, this speaker produced fifteen attempts at /e/ and fourteen attempts at /ɛ/. A discriminant analysis of the F1/F2 values at Time 1 showed that 13 out of the 15 attempts at /e/ were distinct from /ɛ/ as well as from the other vowels in this study. Two of the fifteen attempts at /e/ fell into the F1/F2 range of /ɛ/. Of the fourteen attempts at the vowel /ɛ/, five were distinct from all other vowels whereas nine fell into the F1/F2 range of the /e/.

Duration differences between /e/ and /ɛ/ were about 40 msec (with /e/ being the longer of the two) and remained stable across the three times. Duration had a small effect on the accuracy of these vowels in that target words containing /ɛ/ became more differentiated from target words containing /e/, but the opposite also occurred; Target words containing

/e/ became less differentiated from target words containing /ɛ/ when duration was included as an additional input parameter.

We do see change over time in the accuracy of these vowels. Certainly with respect to the F1/F2 parameters, the accuracy of the vowel /e/ improved from Time 1 to Time 2. Only 5 instances of /e/ were differentiated in the F1/F2 space, whereas eleven instances of /ɛ/ were differentiated by Time 2. Additionally, there were fewer confusions with /e/ at Time 2. Time 3, however, revealed a collapse in the contrast. Although nine instances of each vowel were distinct, a roughly equal number of instances were being confused with /e/. This pattern is one of split-merge or perhaps backsliding. The mid front category, which was dominated by instances of /e/ at Time 1 moved towards a greater distinction between /e/ and /ɛ/ at Time 2, then merged back to less distinction at Time 3. The change is illustrated in Figure 5.5. In the target words *take, gate, paid, get, pet* and *bed*, /e/ is the primary categorization at Time 1. At Time 2 there was an increase of instances categorized as /e/. By Time 3, these instances of /ɛ/ decreased again.

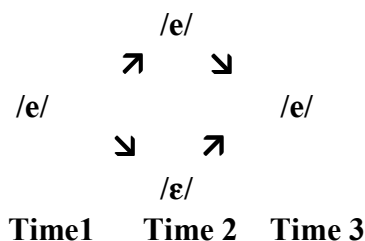


Figure 5.5 Split-merge of the vowels /e/ and /ɛ/

At no point were any of the changes complete. We did not see a complete collapse of /e/ and /ɛ/ nor did we see a complete split of /e/ and /ɛ/. The diagram merely indicates the direction of the changes.

5.5.2 Comparison of /i/, /ɪ/, /e/ and /ɛ/ to the Native Speaker

We now consider these same vowels in comparison to the native speaker's vowel categories. In this set of analyses the terms *match* and *correct* refer to how close the individual vowels uttered by NNS01 were to the male native speaker's categories for these vowels. Beginning with the high front pair, Table 5.6 shows how the vowels /i/ and /ɪ/, as produced by NNS01, were distributed in direct comparison to the F1/F2 and duration values of the male native speaker.

Table 5.6 Results of the Discrimant Analyses of the Vowels /i/ and /ɪ/ Pronounced by NNS01 Compared to the Native Speaker

Target Vowel	Time 1		Time 2		Time 3	
	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration
i	i (7)	i (6)	i (9)	i (9)	i (5)	i (5)
N=10	e (3)	e (2)	e (1)	e (1)	e (5)	e (1)
	-----	ɪ (2)	-----	-----	-----	ɪ (4)
% correct	70	60	90	90	50	50
ɪ	ɪ (2)	ɪ (3)	ɪ (3)	ɪ (5)	ɪ (3)	ɪ (4)
N=15	i (13)	i (11)	i (10)	i (9)	i (9)	i (9)
	-----	e (1)	e (2)	e (1)	e (3)	e (2)
% correct	13.3	20	20	33.3	20	26.6

When compared to the native speaker data, the majority of this participants' vowels fell into the F1/F2 range of /i/. At Time 1, 7 out of 10 attempts at /i/ were matched to the native speaker F1/F2 values of /i/ (with the remaining three being matched to /e/). Only 2 of 15 attempts at /ɪ/ were matched to the native speaker values for /ɪ/ with most of the attempts at /ɪ/ (13 out of 15) matched to the native speaker's /i/.

Duration had a very small impact on the accuracy of these vowels. When duration was included as a parameter in the discriminant analyses, the classification of the vowel /i/ decreased slightly from 70% correct to 60% correct, with 6 out of 10 attempts matching the native speaker's /i/, two matching /ɪ/ and two matching /e/. Duration barely improved the number of correct attempts of the vowel /ɪ/ from 2 out of 15 correct to 3 out of 15 (20% correct).

With respect to change across time, the classification of the vowel /i/ improved slightly by Time 2 but decreased by Time 3 to only 50% correct. This pattern held true regardless of whether duration was included or excluded from the discriminant analyses. The vowel /ɪ/ showed slight improvement from Time 1 to Time 2 and was maintained (but not improved) from Time 2 to Time 3. Again we see a pattern of split-merge as the category of /i/ moved towards distinction from Time 1 to Time 2 but then merged again with its previous confusion categories. This change, however, was not greater than the normal variation we saw in the native speakers.

Turning to the mid front vowels, Table 5.7 shows the results of the vowels /e/ and /ɛ/ as directly compared to the native speaker's F1/F2 and duration values.

Table 5.7 Results of the Discriminant Analyses of the Vowels /e/ and /ɛ/ Pronounced by NNS01 Compared to the Native Speaker

Target Vowel	Time 1		Time 2		Time 3	
	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration
e N=15	e (9)	e (12)	e (4)	e (11)	e (5)	e (7)
	ɛ (6)	ɛ (2)	ɛ (11)	ɛ (3)	ɛ (10)	ɛ (8)
	-----	ɪ (1)	-----	ɪ (1)	-----	-----
% correct	60	80	26.6	73.3	33.3	46.6
ɛ N=14	ɛ (5)	ɛ (5)	ɛ (12)	ɛ (11)	ɛ (13)	ɛ (10)
	e (7)	e (6)	e (1)	e (2)	e (1)	e (4)
	ɪ (2)	ɪ (3)	ɪ (1)	ɪ (1)	-----	-----
% correct	36.7	35.7	85.7	78.5	92.8	71.4

Note that 9 out of 15 attempts at /e/ matched the F1/F2 values of the native speaker's /e/ (60% correct). The remaining six attempts at /e/ fell into the F1/F2 range of the native speaker's /ɛ/. Of the fourteen attempts at the vowel /ɛ/, five fell into the F1/F2 range of /ɛ/ (35% correct), while seven of the attempts were more like /e/ and two of the attempts were more like /ɪ/. When duration was included, the classification rates for /e/ increased from 60% to 80% correct (9/15 to 12/15). Duration had less of an effect on the accuracy of the vowel /ɛ/ and in fact classification decreased at some points in time when it was included as an input parameter.

With respect to change across time, the accuracy of the vowel /e/ decreased over time while the accuracy of the vowel /ɛ/ increased over time. Table 5.7 shows that the number of correct attempts at /e/ (with all parameters included) decreased from twelve correct to eleven correct then to seven correct by Time 3. This was a change in accuracy from 80% correct to 46% correct. The vowel /ɛ/ however increased from six correct to eleven correct at Time 2 (with a slight drop to ten correct attempts at Time 3). We will recognize this pattern as change because the number of instances involved was greater than what we saw for normal variation in the native speaker. Clearly these vowels were not becoming more distinct. Rather, what was initially a poorly distinguished pair pronounced mainly in the range of the native speaker's /e/, remained a poorly distinguished pair but in the range of /ɛ/. We can refer to this change as a shift in which /e/ lowered to /ɛ/. NNS01 was not differentiating the vowels in the target words *gate*, *take*, and *pet* from the vowels in the target words *get*, *pet* and *bed* at Time 1, but the majority of attempts fell into the range of the native speaker's /e/. Over time, the speaker was still having difficulty differentiating these vowels but the majority of the attempts shifted to the range of native speaker's /ɛ/.

5.6. The Low Vowels and the Mid Central Vowel

Having examined the high and mid front vowels of NNS01 separately and in comparison to the native speaker, we can move to the low and central vowels. In discussing the native speakers, the five front vowels (including /æ/) were discussed together. For this nonnative speaker, the vowel /æ/ was produced considerably more central than front, and

was confused most often with the native speaker's /ɑ/. It therefore seemed appropriate to discuss the /æ/ and /ɑ/ together. Likewise, the vowel /ʌ/ showed confusion with the vowel /ɑ/ and so it too will be included in this section.

5.6.1. Distribution of /æ/, /ɑ/ and /ʌ/ by NNS01

Consider Figures 5.6, 5.7 and 5.8 which show the F1/F2 plots for the vowels /æ/, /ɑ/, /ʌ/ recorded at three points in time over the period of one year. It is clear that there is a great deal of overlap among these vowels. The vowel /æ/, as uttered in the words *cat* and *pat*, had the major concentration in the low central area of the figure. Note that the vowel /ɑ/ (as uttered in the words *pot*, *cop*, and *top*) overlapped into F1/F2 the space of /æ/ as well as into the F1/F2 space of /ʌ/ (in the target words *cup*, *cut* and *but*), which was slightly higher in vowel space.

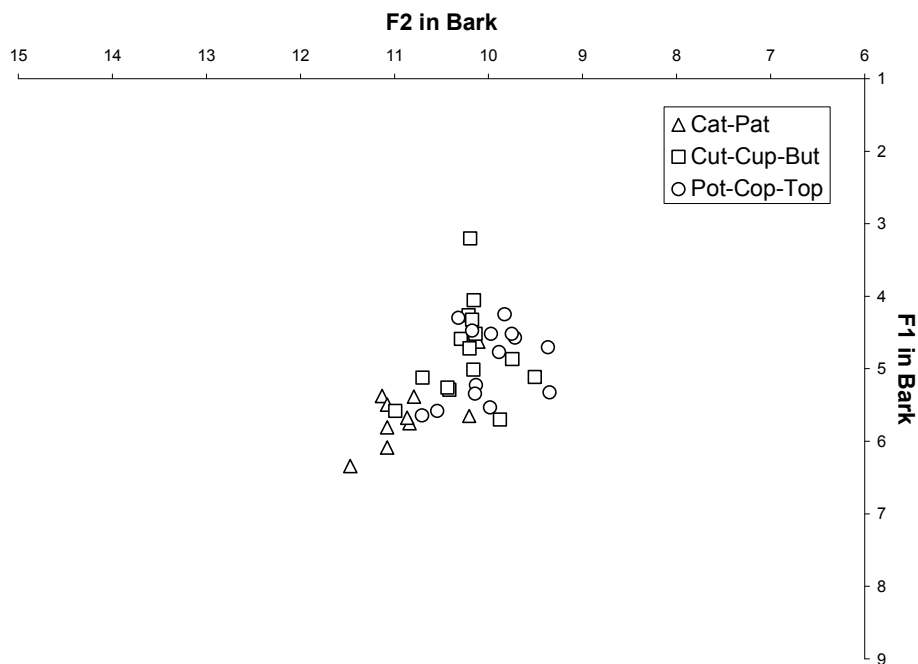


Figure 5.6 F1/F2 plot of the low and central vowels at Time 1 pronounced by NNS01

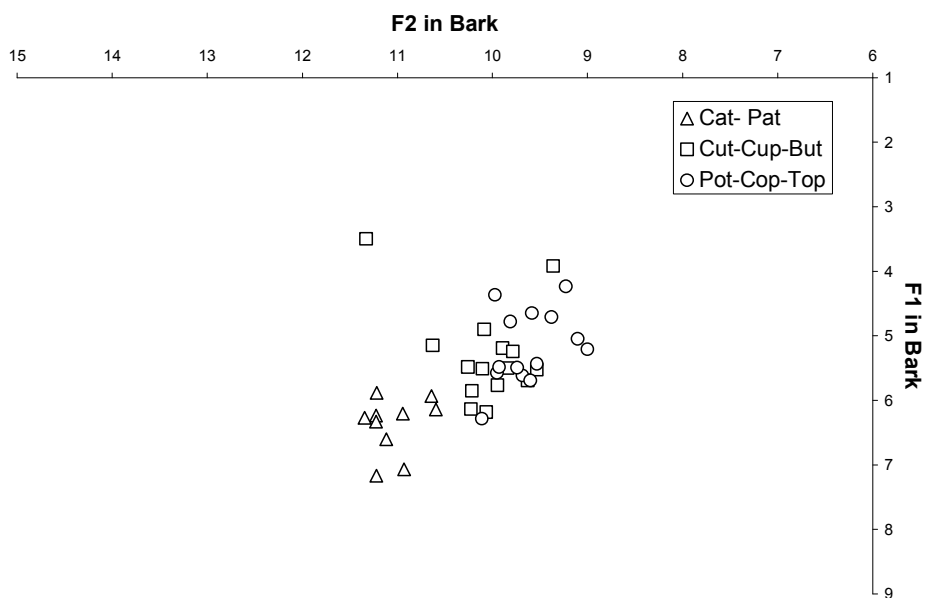


Figure 5.7 F1/F2 plot of the low and central vowels at Time 2 pronounced by NNS01

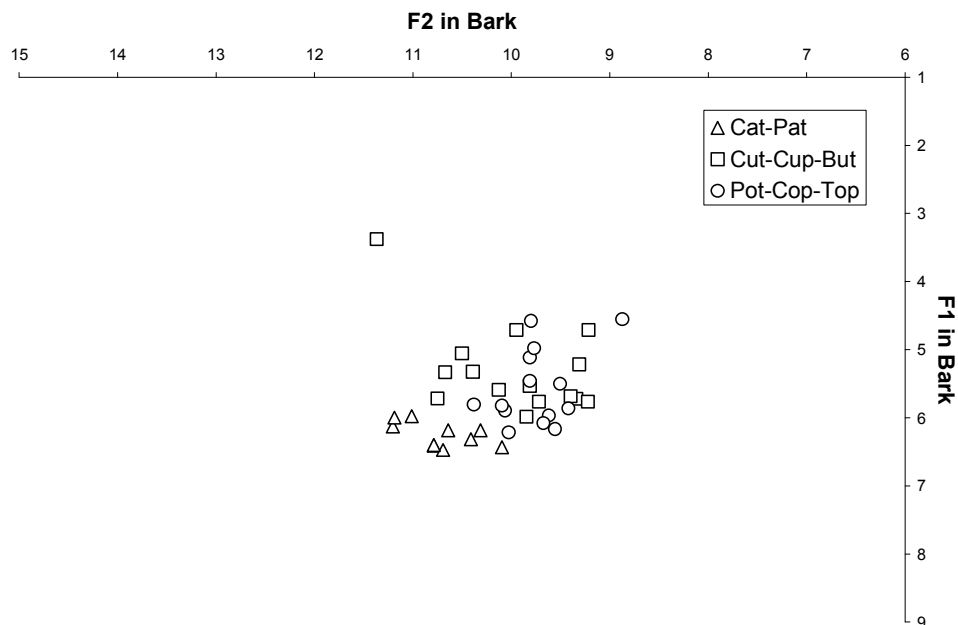


Figure 5.8 F1/F2 plot of the low and central vowels at Time 3 pronounced by NNS01

In order to understand the distribution more clearly, we turn to the discriminant analyses of these vowels. Table 5.8 shows the results of the discriminant analyses of these vowels across three times on both conditions (*F1 /F2 Only* and *F1/F2 plus Duration*) with this nonnative speaker's vowel system considered independently of the native speaker's.

Table 5.8 Results of the Discriminant Analyses of the Vowels /æ/, /ɑ/ and /ʌ/ Pronounced by NNS01 across Three Times

Target Vowel	Time 1		Time 2		Time 3	
	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration
æ N=10	æ (9)	æ (9)	æ (10)	æ (10)	æ (10)	æ (10)
	ʌ (1)	ʌ (1)	-----	-----	-----	-----
	% correct	90	90	100	100	100
ʌ N=15	ʌ (6)	ʌ (7)	ʌ (9)	ʌ (8)	ʌ (3)	ʌ (5)
	ɑ (4)	ɑ (3)	ɑ (2)	ɑ (3)	ɑ (7)	ɑ (6)
	ɔ (2)	ɔ (2)	ɔ (1)	-----	ɔ (3)	ɔ (2)
	æ (2)	æ (2)	æ (2)	æ (2)	æ (1)	æ (1)
	ʊ (1)	ʊ (1)	-----	ʊ (1)	-----	-----
	-----	-----	ε (1)	ε (1)	-----	-----
% correct	40	46.6	60	53.3	20	33.3
ɑ N=14	ɑ (3)	ɑ (3)	ɑ (2)	ɑ (3)	ɑ (9)	ɑ (8)
	ɔ (6)	ɔ (5)	ɔ (6)	ɔ (7)	ɔ (2)	ɔ (2)
	ʌ (2)	ʌ (3)	ʌ (5)	ʌ (3)	ʌ (2)	ʌ (3)
	æ (3)	æ (3)	æ (1)	æ (1)	æ (1)	æ (1)
% correct	21.4	21.4	14.2	21.4	64.2	57.1

With F1/F2 as the only parameters, 9 out of 10 attempts at /æ/ were distinct at Time 1, with one attempt falling into the F1/F2 range of /ʌ/. Of the fifteen attempts at /ʌ/, six matched the intended centroid, four fell into the range of /ɑ/, two into the range of /ɔ/ and two into the range of /æ/. The vowel /ɑ/ was the least differentiated with only three attempts matching the intended centroid, six attempts matching /ɔ/, three attempts matching /æ/ and two attempts matching /ʌ/.

Initially, the vowels /æ/ and /ɑ/ had duration means that differed by less than 5 msec.

Although the duration means were somewhat lower than /æ/ and /ɑ/ for the native speaker, the relationship between the two vowels were similar. That is to say, the vowels /ɑ/ and /æ/ were long and roughly equal in duration to each other. The native/nonnative duration difference that is most noteworthy is with the vowel /ʌ/. For the native speaker this vowel was short and showed duration means that differed from both /æ/ and /ɑ/ by more than 50 msec. Duration means for the vowel /ʌ/ as uttered by the nonnative speaker differed from /æ/ and /ɑ/ by only about 20 msec. Duration had little effect on the categorization of these vowels when included as an input parameter. When duration was included, the number of attempts that matched the target did not change for /æ/. For the vowels /ɑ/ and /ʌ/ the number of attempts that matched the target differed by one or two, but not always in the direction of improved accuracy.

We can now examine these vowels with respect to change over time. The vowel /æ/ had a high rate of classification and was relatively stable. The vowel /ʌ/ showed change but most notably from Time 2 to Time 3. At Time 2, eight to nine instances of /ʌ/ were differentiated but by Time 3 only three to five instances were differentiated. This was a decrease in rate of classification by four or five instances which was just above what we saw for normal variation in the native speakers. We can tentatively refer to this change as merger. We can also tentatively say that /ʌ/ was the merging element and /ɑ/ was the

absorbing element because as the confusions with /ɑ/ increased, the number of distinct productions of /ʌ/ decreased. It would be useful, however, to consider changes in /ɑ/ that occurred before we draw this conclusion.

The vowel /ɑ/ also changed in that it increased from 3 out of 14 correct to 9 out of 14 correct (at Times 1 and 3, *F1/F2 Only*). The vowel /ɑ/ became more distinct from /ɔ/, which was its primary confusion category at Time 1. As this happened /ʌ/ became less distinct from /ɑ/. The question arises as to which is moving? An examination of the F1/F2 means shows greater changes in the vowel /ɑ/ and smaller changes in /ʌ/. By definition /ɑ/ splits from /ɔ/ and becomes a more differentiated category in the discriminant analyses. But this movement seems to result in the merger of /ɑ/ and /ʌ/.

One additional point needs to be discussed before moving to the native speaker comparison. Recall that both native speakers produced significant allophonic variation on the vowel /æ/ in the word *bad*. The results reported for NNS01 thus far have excluded the word *bad* from the discriminant analysis. With the word *bad* included, the accuracy of /æ/ was slightly lower (73.3% or 11 out 15) as compared to when *bad* was excluded (90% correct or 9/10). Most of the incorrect attempts were towards /ɛ/ and /ʌ/. Interestingly, by Time 3 all 15 attempts at /æ/ were distinct from all other vowels in the system (100% category match) on F1/F2 values.

5.6.2. Comparison of /æ/, /ɑ/ and /ʌ/ to the Native Speaker

When the vowels /æ/, /ɑ/ and /ʌ/ are considered in direct comparison to the native speaker values we see somewhat different patterns. Table 5.9 shows the results of the discriminant analyses of these vowels evaluated against the centroids established for the male native speaker's data.

Table 5.9 Results of the Discriminant Analyses of the Vowels /æ/, /ɑ/ and /ʌ/ Pronounced by NNS01 Compared to the Native Speaker

Target Vowel	Time 1		Time 2		Time 3	
	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2	NS Match /# of Tokens F1/F2 Duration
æ N=10	æ (3)	æ (4)	æ (6)	æ (6)	æ (2)	æ (2)
	ɑ (4)	ɑ (4)	ɑ (4)	ɑ (4)	ɑ (8)	ɑ (8)
	ʌ (1)	ʌ (1)	-----	-----	-----	-----
	ε (2)	ε (1)	-----	-----	-----	-----
% correct	30	40	60	60	20	20
ʌ N=15	ʌ (11)	ʌ (10)	ʌ (6)	ʌ (7)	ʌ (4)	ʌ (4)
	ɑ (2)	ɑ (2)	ɑ (8)	ɑ (7)	ɑ (10)	ɑ (8)
	ʊ (1)	ʊ (1)	ʊ (1)	ʊ (1)	ʊ (1)	ʊ (1)
	ε (1)	ε (1)	-----	-----	-----	ε (1)
	-----	ɔ (1)	-----	-----	-----	-----
% correct	73.3	66.6	40	46.6	76.6	26.6
ɑ N=14	ɑ (3)	ɑ (3)	ɑ (5)	ɑ (6)	ɑ (8)	ɑ (5)
	ʌ (11)	ʌ (11)	ʌ (9)	ʌ (7)	ʌ (6)	ʌ (9)
	-----	-----	-----	ɔ (1)	-----	-----
% correct	21.4	21.4	35.7	42.8	57.1	64.2

When compared to the F1/F2 values of the native speaker, the vowel /ʌ/ was produced most accurately at Time 1. Eleven of fifteen attempts fell into the range of the native

speaker's /ʌ/ while other attempts matched a variety of vowel centroids. Of the ten attempts at /æ/, only three fell into the range of the native speaker's /æ/ with other attempts most frequently matching /ɑ/. Of the fourteen attempts at the vowel /ɑ/, only three were considered to match the native speaker's /ɑ/ but eleven matched /ʌ/.

When duration was included as an input parameter, it had no effect on the vowel /ɑ/ but changed the number of correct attempts of /æ/ and /ʌ/ each by one.

With respect to change across time, the vowel /æ/ showed a pattern of increase in accuracy followed by a decrease but only by a few instances each time (from 40% correct to 60% correct to 20% correct across times when all parameters were included). The vowels /ɑ/ and /ʌ/ showed a pattern similar to the changes that occurred when NNS01 was evaluated independently of the native speaker. When one vowel increased in accuracy, the other vowel decreased in accuracy. In this case the vowel /ʌ/ decreased from ten correct attempts to four correct attempts with a steady increase in the number of times /ʌ/ fell into the range of /ɑ/. While /ʌ/ became less like the native speaker's /ʌ/ and more like /ɑ/, the number of correct attempts at /ɑ/ increased slightly. The difference between this change and the change discussed above is that when the native speaker's system was considered independently, the primary confusion category for /ɑ/ had been /ɔ/. When compared to the native speaker, the primary confusion category for /ɑ/ was /ʌ/. Thus when the classification of one increased and the classification of the other

decreased, we saw the same type of shift that we did for /e/ and /ɛ/. Essentially two vowels that were poorly distinguished and fell mainly into the range of the native speaker's /ʌ/, remained poorly distinguished but shifted together into the range of the native speaker's /ɑ/. So /ʌ/ had the better classification rates of the two categories at Time 1. By Time 3, /ɑ/ had the better classification rates of the two categories.

One other interesting change took place involving the vowel /æ/ when the item *bad* was included in the analysis. Initially, the number of correct matches to the native speaker's F1/F2 values of /æ/ was 10 out of 15 attempts or 66.6% or. By Time 3, this number dropped dramatically to 4 out of 15 or 26.6% correct. This is the exact opposite of what we saw when the nonnative speaker's system was considered independently. In that case, when *bad* was included in the analysis there was a steady increase in classification and by Time 3 the classification rate was 100% correct (all 15 attempts matched the intended centroid). Clearly, we saw that the vowel /æ/ never quite matched the native speaker's category for /æ/. Rather it was produced more centralized in the vowel space and, therefore, was matched to native speaker's /ɑ/. Why the decrease over time in classification over time? It simply may be that as the nonnative speaker's attempts at /æ/ were produced closer to his own centroid they became less like the native speaker whose attempts at /æ/ ranged from low to mid in the F1/F2 space. This is a small but important point. The nonnative speaker has achieved a well differentiated vowel /æ/ that does not necessarily match /æ/ in the vowel system that is a likely model.

5.7. The High Back Vowels

Now consider the high back vowels /u/ and /ʊ/ as uttered in the words *boot*, *coop*, *put*, *took* and *could*. Figures 5.9, 5.10 and 5.11 show the F1/F2 plots of these vowels at three points in time over the period of one year. Although there is a great deal of overlap, one can distinguish two categories for these vowels in the nonnative speaker's system.

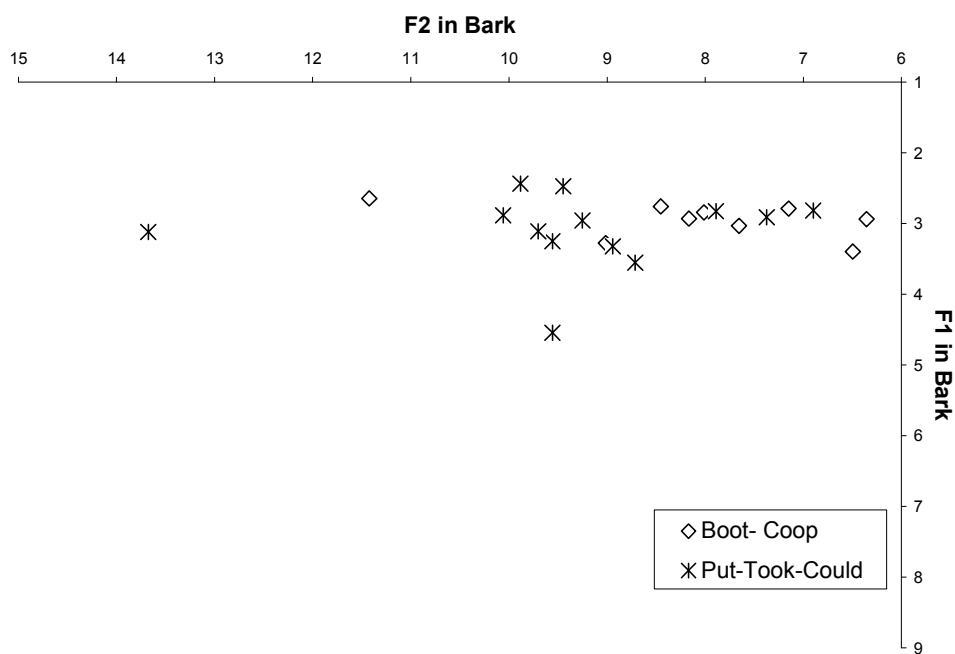


Figure 5.9 F1/F2 plot of the high back vowels at Time 1 pronounced by NNS01

5.7.1. Distribution of /u/ and /ʊ/ by NNS01

Table 5.10 shows the results of the discriminant analysis of these vowels across three times on both conditions (*F1/F2 Only* and *F1, F2 plus Duration*) with this nonnative speaker's vowel system considered separately from the native speaker's.

Table 5.10 Results of the Discriminant Analyses of the Vowels /u/ and /ʊ/ Pronounced by NNS01 across Three Times

Target Vowel	Time 1		Time 2		Time 3	
	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration
u N=9	u (7)	u (7)	u (6)	u (6)	u (6)	u (8)
	ʊ (1)	ʊ (1)	ʊ (2)	ʊ (2)	ʊ (3)	ʊ (1)
	-----	-----	o (1)	o (1)	-----	-----
	i (1)	i (1)	-----	-----	-----	-----
% correct	77.7	77.7	66.6	66.6	66.6	88.8
ʊ N=14	ʊ (8)	ʊ (9)	ʊ (8)	ʊ (8)	ʊ (9)	ʊ (10)
	u (3)	u (3)	u (5)	u (5)	u (4)	u (4)
	o (1)	-----	o (1)	o (1)	o (1)	-----
	ɔ (1)	ɔ (1)	-----	-----	-----	-----
	i (1)	i (1)	-----	-----	-----	-----
% correct	57.1	64.2	57.1	57.1	64.2	71.4

NNS01 distinguished the vowels /u/ and /ʊ/ to some extent. A discriminant analysis of F1/F2 values indicated that 7 out of 9 attempts at the vowel /u/ were classified as distinct from /ʊ/ as well as other vowels in this study. Eight of thirteen attempts at the vowel /ʊ/ were differentiated, with only three attempts falling into the F1/F2 range of /u/.

Initially, the duration means of the two vowels differed by about 35 msec with /u/ being the longer of the two. When duration was included as an input parameter it had little effect, increasing the number of correct attempts at /u/ by one but not decreasing the number of instances that fell into the F1/F2 range of /u/.

With respect to change across time, these vowels change by one or two attempts at the various recording points but otherwise remained relatively stable.

One additional point must be addressed before turning to the native speaker comparison.

Recall that the native speaker's in the study exhibited allophonic variation with the lexical item *tube* in that the /u/ was fronted after the alveolar consonant. The data reported thus far for NNS01 was analyzed with the word *tube* excluded. With *tube* included in the analysis, 6 out of 14 instances of /u/ were distinct (42.8%) and 8 out of 15 instances of /u/ were distinct. These were both lower than when *tube* was excluded.

Duration improved the number of correct category matches to 9 out 14 for /u/ and 9 out of 15 for /u/.

5.7.2. Comparison of /u/ and /u/ to the Native Speaker

The above discussion of /u/ and /u/ showed how these vowels were distributed without direct reference the native speaker's values. What follows are the results of the discriminant

analyses of these vowels when this nonnative speaker's values are evaluated against the established categories of the male native speaker. Consider Table 5.11.

Table 5.11 Results of the Discriminant Analyses of the Vowels /u/ and /ʊ/ Pronounced by NNS01 Compared to the Native Speaker

Target Vowel	Time 1		Time 2		Time 3	
	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration
u N=9	u (7)	u (5)	u (8)	u (7)	u (6)	u (4)
	o (1)	o (1)	o (1)	o (2)	o (1)	o (1)
	-----	ɔ (2)	-----	-----	ɔ (2)	ɔ (4)
	u (1)	ʊ (1)	-----	-----	-----	-----
% correct	77.7	55.5	88.8	77.7	66.6	44.5
ʊ N=14	ʊ (5)	ʊ (5)	ʊ (6)	ʊ (6)	ʊ (2)	ʊ (2)
	u (5)	u (6)	u (7)	u (6)	u (7)	u (7)
	ɔ (2)	ɔ (2)	ɔ (1)	ɔ (1)	ɔ (3)	ɔ (2)
	ʌ (1)	-----	-----	-----	ʌ (1)	ʌ (2)
	-----	-----	-----	o (1)	o (1)	o (1)-
i (1)	i (1)	-----	-----	-----	-----	
% correct	35.7	35.7	42.8	42.8	14.2	14.2

When compared to the F1/F2 values of the native speaker, 7 out of 9 attempts at /u/ fell into the range of the native speaker's /u/ at Time 1. For the vowel /ʊ/, 5 out of 13 attempts fell into the F1/F2 range of the native speaker's /ʊ/ at Time 1. The vowel /ʊ/ was more likely to be confused with /u/ than vice versa. When duration was added as a variable in the discriminant analysis, the accuracy of /u/ with respect to the native speaker's values decreased. The accuracy of the vowel /ʊ/ did not change with duration included.

With respect to change over time both vowels showed a pattern of slight increase from Time 1 to Time 2 with a subsequent decrease at Time 3. The Time 3 decrease was greater for /ʊ/ than for /u/. Each vowel group, however, changed by only a few instances.

A final note before considering the next pair of vowels, when the word *tube* is introduced into the analyses, the accuracy of these vowels as compared to the native speaker is worse. With the item *tube* included the accuracy of /u/ is 50% (7/14) and the accuracy of /ʊ/ is 7.14% or (1/15). When duration was included as an input parameter, it had little effect on the results. By Time 2, the accuracy of /u/ remained the same but the accuracy of /ʊ/ improved from 7.14% to 42.8%.

5.8. The Mid Back Vowels

The final pair to be discussed for this nonnative speaker is the mid back pair /o/ and /ɔ/ as uttered in the words *coat*, *boat*, *code*, *talk*, *caught*, *taught*. It should be noted that the vowel /ʌ/ is included in the F1/F2 plots because there was frequent confusion between the vowels /ɔ/ and /ʌ/. In fact, in considering this nonnative speaker's system independently of the native speaker's vowels, the distinction between /o/ and /ɔ/ is quite strong; It is the distinction between /ɔ/ and /ʌ/ that is poor. For an additional perspective of these vowels, the F1/ F2 plots also include the vowel /a/. Figures 5.12, 5.13 and 5.14 show the F1/ F2 plots of these vowels at three points in time over the period of one year.

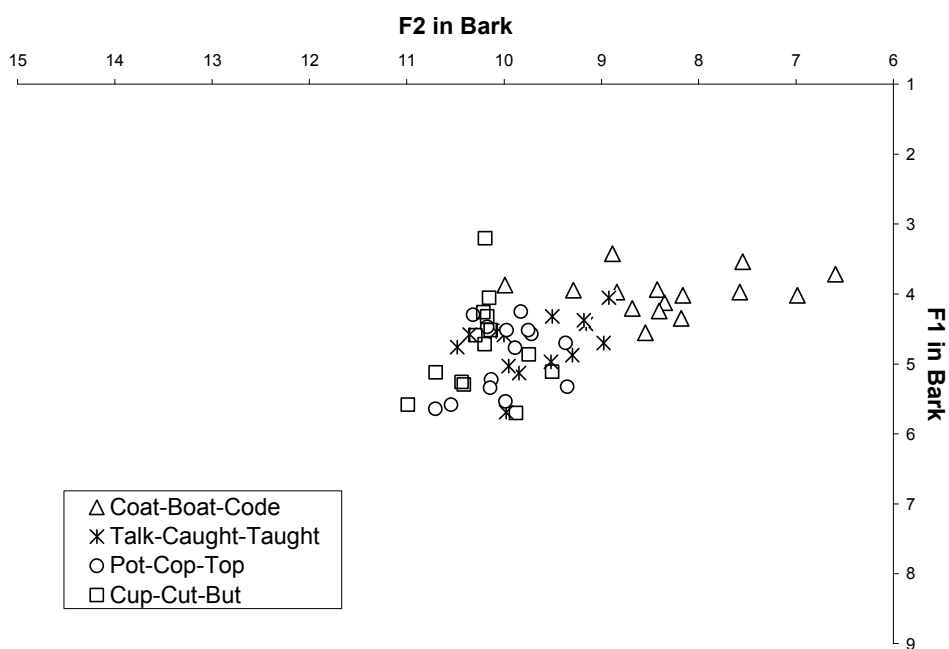


Figure 5.12 F1/F2 plot of the mid back vowels at Time 1 pronounced by NNS01

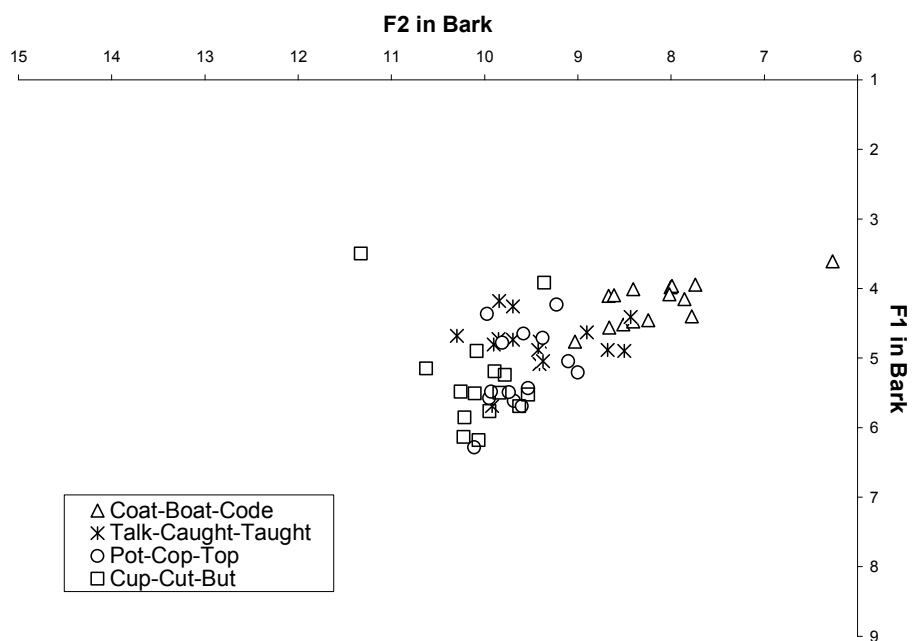


Figure 5.13 F1/F2 plot of the mid back vowels at Time 2 pronounced by NNS01

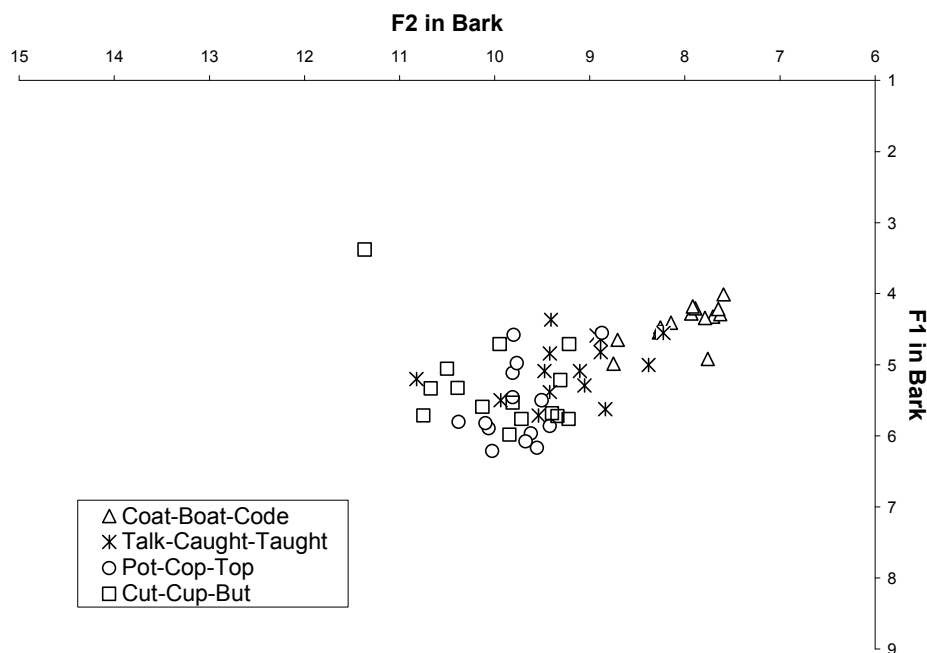


Figure 5.14 F1/F2 plot of the mid back vowels at Time 3 pronounced by NNS01

5.8.1. The Distribution of /o/ and /ɔ/ by NNS01

In order to understand the distribution of these vowels, consider Table 5.12, which shows the results of the discriminant analyses of these vowels across three times on both conditions (*F1/F2 Only* and *F1/F2 plus Duration*) with the nonnative speaker's vowel system considered separately from the native speaker's.

Table 5.12 Results of the Discriminant Analyses of the Vowels /o/ and /ɔ/ Pronounced by NNS01 across Three Times

Target Vowel	Time 1		Time 2		Time 3	
	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration
o N=15	o (13)	o (13)	o (13)	o (13)	o (14)	o (13)
	ɔ (1)	ɔ (1)	ɔ (1)	ɔ (1)	ɔ (1)	ɔ (2)
	ʊ (1)	ʊ (1)	u (1)	u (1)	-----	-----
	% correct	86.6	86.6	86.6	86.6	93.3
ɔ N=15	ɔ (6)	ɔ (5)	ɔ (10)	ɔ (8)	ɔ (10)	ɔ (9)
	ʌ (5)	ʌ (6)	ʌ (2)	ʌ (2)	ʌ (2)	ʌ (2)
	ɑ (2)	ɑ (2)	ɑ (2)	ɑ (2)	ɑ (2)	ɑ (2)
	o (1)	o (1)	o (1)	o (3)	o (1)	o (2)
	æ (1)	æ (1)	-----	-----	-----	-----
% correct	40	33.3	66.6	53.3	66.6	60

At Time 1, NNS01 distinguished the vowels /o/ and /ɔ/ from each other, but attempts at /ɔ/ were frequently matched to /ʌ/. A discriminant analysis of the F1/F2 values indicated that of fifteen attempts at the vowel /o/, thirteen were considered to be distinct from /ɔ/ and the other vowels in this study. Of the fifteen attempts at /ɔ/, six were considered to have F1/F2 values that were distinct from other vowels, but five fell into the F1/F2 range of /ʌ/, two in the range of /ɑ/, one in the range of /o/ and one on the range /æ/

Initially duration means for /o/ and /ɔ/ differed by about 80 msec with /o/ being the longer of the two. This differed from both native speakers for whom duration means for /o/ and /ɔ/ were closer with /ɔ/ being the longer of the two. When duration was included

as an input parameter, it had virtually no impact on the classification rate of the vowel /o/ and changed the classification rate of /ɔ/ by one or two instances.

With respect to change over time, these vowels improved in an interesting way. Note that /o/ remains relatively stable and therefore is not part of the change. The F1/F2 values of /ɔ/ increased in accuracy from 6 correct to 10 correct by Time 3. This increase in accuracy occurred by concentration in that lexical items containing the target vowel /ɔ/, that were originally (and incorrectly) produced with /ʌ/, /æ/ and /ɑ/, were slowly concentrated into the category of /ɔ/. Recall that concentration refers to the reorganization of lexical items into preexisting phoneme categories and specifically from more dispersed to less dispersed. This particular case is concentration because the phoneme /ɔ/ initially existed for this speaker but over time lexical items produced with other vowels moved into its range. This in essence strengthens a phoneme category.

5.8.2. Comparison of /o/ and /ɔ/ to the Native Speaker

The above discussion of /o/ and /ɔ/ showed how these vowels were distributed without direct reference to the native speaker's values. What follows are the results of the discriminant analyses of these vowels evaluated against centroids established on the male native speaker's data. Consider Table 5.13.

Table 5.13 Results of the Discriminant Analyses of the Vowels /o/ and /ɔ/ Pronounced by NNS01 Compared to the Native Speaker

Target Vowel	Time 1		Time 2		Time 3	
	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration
o N=15	o (5)	o (2)	o (9)	o (3)	o (13)	o (4)
	ɔ (8)	ɔ (13)	ɔ (5)	ɔ (12)	ɔ (1)	ɔ (10)
	ʌ (2)	-----	ʌ (1)	-----	ʌ (1)	ʌ (1)
	% correct	33.3	13.3	60	20	86.6
ɔ N=15	ɔ (1)	ɔ (4)	ɔ (1)	ɔ (4)	ʌ (10)	ɔ (3)
	ʌ (13)	ʌ (10)	ʌ (12)	ʌ (9)	-----	ʌ (7)
	ɑ (1)	-----	ɑ (1)	ɑ (1)	ɑ (2)	ɑ (1)
	-----	-----	o (1)	o (1)	o (2)	o (3)
	-----	-----	-----	-----	ε (1)	ε (1)
% correct	6.6	26.6	6.6	26.6	0	20

When compared to the F1/F2 values of the native speaker, only five of the fifteen attempts at /o/ matched the values of the native speaker with most falling into the range of the native speaker's values for /ɔ/. Only one attempt at the vowel /ɔ/ fell into the F1/F2 range of the native speaker's /ɔ/, with thirteen instances falling into the range of /ʌ/ and one falling into the F1/F2 range of /ɑ/.

Duration had a minimal effect on how these vowels compared to the native speaker's. When duration was included as a parameter in the discriminant analysis, the number of correct attempts at /o/ decreased from five to one and the number of correct attempts at /ɔ/ increased from one to four. It can be concluded that duration did not help the speaker

differentiate /o/ from /ɔ/ (nor did it for the native speakers). It did however, help to distinguish the vowels /ɔ/ and /ʌ/. NNS01 produces /ɔ/ with duration means that are 40 msec longer than the native speaker's duration means for /ʌ/. So if spectral differences are not great enough to distinguish nonnative /ɔ/ from native /ʌ/ then duration might assist in making them different.

With respect to change over time, the F1/F2 values of /o/ improved toward the native speaker's values. At Time 1, only five attempts matched the native speaker's centroid for /o/ but by Time 3, thirteen attempts matched. This is another case of concentration in which dispersed lexical items become less dispersed and strengthen a category distinction.

5.9. Summary of the Vowel System of NNS01

The examination of the vowels of NNS01 included discussions of the how the system behaved as an entity unto itself as well as how the system was distributed with respect to the native speaker's categories. Each of these included cross-sectional information, longitudinal information, F1/F2 as parameters, duration as an added parameter, and reduced data sets related to single-item subsets and subsets that condition allophonic variation in English.

We saw that for NNS01 (as for the native speaker's as well) classification rates were better when vowels were couched within a lexical item as opposed to across lexical items, but this did not hold true in direct comparison to the native speaker's vowels.

In examining the entire data set independently of the native speaker's values, it was shown that the pair /i/ and /ɪ/ were not initially differentiated at all by the speaker. The vowels /e/ and /ɛ/ and /u/ and /ʊ/ were only slightly more differentiated. The vowels /o/ and /ɔ/ were differentiated from each other but /ɔ/ overlapped with /ʌ/. The vowel /æ/ was distinct (but was uttered as low central as opposed to low front). The vowel /ʌ/ essentially formed a category that included both /ɔ/ and /ɑ/. Thus, at the initial recording the speaker had roughly the equivalent of a five vowel system when producing the eleven target vowels of English.

In comparison to the native speaker values at the initial recording, the vowels /i/ and /ɪ/ most frequently matched the native speaker's /i/. The vowel /e/ was a relatively accurate match to the native speaker's /e/, but the vowel /ɛ/ was less accurate and more frequently matched the native speaker's /e/ as opposed to /ɛ/. Initially, the vowel /ʌ/ was accurately matched to the native speaker's category for this vowel but classification rates decreased over time. Initially /ɑ/ was the poorest match to native speaker's values for /ɑ/ but classification rates improved slightly over time. The vowel /u/ was a relatively accurate match to the native speaker's category for /u/. The vowel /ʊ/ was less accurately matched.

Finally, the vowels /o/ and /ɔ/ were both relatively poor matches for the native speaker's corresponding categories, but /ɔ/ was considerably worse.

Several interesting patterns of change were revealed in this speaker, some of which confirmed the possible types set forth in Chapter 2 and others that need reconsideration.

First, we see that examining this nonnative vowels system independently (as opposed to only comparing nonnative to native) is useful. There were several instances of change that occurred in the nonnative speaker's vowels, even though those changes did not yield the correct target. Among these were a split in the category of /ɪ/, a split-merger pattern between /e/ and /ɛ/, and a split of /ɑ/ from /ɔ/ which seemed to be related to a merger between /ʌ/ and /ɑ/. These changes were evidenced when the nonnative speaker's system was considered independently of the native speaker's system.

Second, we see that it is also useful and important to study changes when the nonnative speaker's system is compared to the native speaker's. Several changes occurred; among these were cases of shift with /e/ and /ɛ/ and /ʌ/ and /ɑ/ in which the more frequently classified of the two becomes the less frequently classified of the two. We also saw concentration in both /ɔ/ and /o/ during which dispersed pronunciations were concentrated and thereby strengthened these preexisting categories.

Two additional findings are worth noting. First, in at least some cases where spectral distinctions were not enough to differentiate vowels, duration was sometimes used to facilitate the differentiation. We saw this specifically in the split between /i/ and /ɪ/ and in the differentiation of /ɔ/ and /ʌ/ (when vowels were evaluated against the native speaker's centroids). Second, we saw that a vowel could be differentiated (match its intended centroid 100% of the times) but still not match the F1/F2 or duration values of the native speaker. We can speculate that this might make a nonnative speaker fluent and easily understood but still accented. It would be interesting to examine what would motivate the learner to move from differentiated vowels to native-like vowels.

Chapter 5: Notes

1. The word *bead* was most often pronounced as *bed* by this speaker as well as most of the other nonnative speakers. Using the criteria established in Chapter 3, all five instances of this item were excluded from the analysis.
2. Escudero (2000) proposed stages of acquisition for L2 learners on the /i-/ɪ/ continuum. The first stage was a duration-based perceptual identification, the second combined duration and spectral identification and the third was spectrally based identification. Morrison (2008) suggests that Spanish speaker's tendency to use duration cues is not an initial strategy but rather a secondary developmental stage.
3. At Time 1, nine instances of the words *gate*, *take* and *paid* and six instances of the words *get*, *pet* and *bed* were produced with /e/. We can see that the majority of vowels (16 instances for *F1/F2 Only* and 18 instances for *F1/F2 plus Duration*) were produced in the target words were initially categorized as /e/. At Time 3, however, the majority of vowels (23 in *F1/F2 Only* and 18 in *F1/F2 plus Duration*) were produced in the target words were produced as /ɛ/.

Chapter 6: Analysis of Nonnative Speaker 02

6.1. Background of Nonnative Speaker 02 (NNS02)

Nonnative Speaker 02 (henceforth NNS02) is a male native Spanish speaker, born in Lima, Peru. At the time of the first recording he was 26 years old and had lived in the United States for twelve years. He began studying English in Peru as part of a high school requirement and also took ESL classes on and off in the United States for five years. At the onset of this study he had just completed his last semester of ESL requirements at Nassau Community College, including one course devoted to pronunciation. He reported speaking both English and Spanish at work and with his friends. He speaks only Spanish with his family.

6.2. Sample Collection

The sample collection for NNS02 differs from the other nonnative speakers in two significant ways. First, this speaker provided only two samples (as opposed to three). Second, and most important, is that the two samples were four years apart.

The group of excluded items from this speaker consisted of two instances of the word *bead*, three instances of the word *could*, all five instances of the word *coop*, and one instance of each of the following words: *kid*, *pit*, *pat*, *put*, *boat*, *taught*, and *talk*. This left a total of 148 target words.

In order to determine intra-rater reliability, 17 items from each of the samples were randomly selected and re-measured. As indicated in Table 6.1, mean differences between

the re-measure and the original measure were less than 6 msec for duration and less than .16 Bark for F1 and F2 at the 50% point.

Table 6.1 **Margin of Error for NNS02**

	Mean Difference Between Time 1 Measure and Re- measure	Mean Difference Between Time 2 Measure and Re- Measure
Duration	5.95 msec	3.57 msec
F1 at 50% Point	0.03 Bark	0.15 Bark
F2 at 50% Point	0.13 Bark	0.12 Bark

6.3. Category Matches within Lexical Items

As with the other speakers in this study, discriminant analyses were conducted on the vowels in single-item subsets as compared to the multiple-item set. The results of this comparison are of particular interest for this speaker due to the number of items that were discarded at the onset. For example, NNS02 had considerable difficulty with the word *coop*. The errors were consistent across the five instances of *coop* and were judged to be errors in sound-spelling correspondence. Since for part of the analysis, the word *tube* was treated separately, only five instances of the vowel /u/ were left to represent this vowel.

All five instances occurred in a single lexical item *boot*. It is therefore important to understand if vowels behaved differently when the number of lexical items was reduced. Table 6.2 below shows the comparison of the single-item subset and the multiple-item set when the nonnative speaker is considered separately from the native speaker at Time 1.

Table 6.2 Single-Item vs. Multiple-Item Comparison of NNS02 at Time 1

Vowel	Single-Item Subset		Multiple-Item Set	
	Percent/Number Correctly Matched: F1/F2	Percent/Number Correctly Matched: F1/ F2 and Duration	Percent/Number Correctly Matched: F1/F2	Percent/Number Correctly Matched: F1/F2 and Duration
i	80 (4/5)	80 (4/5)	46.1 (6/13)	38.4 (5/13)
ɪ	0 (0/4)	50 (2/4)	53.8 (7/14)	53.8 (7/14)
e	80 (4/5)	100 (5/5)	60 (9/15)	73.3 (11/15)
ɛ	80 (4/5)	100 (5/5)	53.3 (8/15)	73.3 (11/15)
æ	40 (2/5)	80 (4/5)	22.2 (2/9)	44.4 (4/9)
ʌ	40 (2/5)	40 (2/5)	20 (3/15)	33.3 (5/15)
u	80 (4/5)	60 (3/5)	60 (3/5)	60 (3/5)
ʊ	0 (0/4)	50 (2/4)	72.7 (8/11)	72.7 (8/11)
o	80 (4/5)	100 (5/5)	92.8 (13/14)	92.8 (13/14)
ɔ	75 (3/4)	75 (3/4)	30.7 (4/13)	30.7 (4/13)
ɑ	80 (4/5)	80 (4/5)	66.6 (10/15)	60 (9/15)
Total	59.6	75	52.8	57.9

Note that the total correct classification was very similar in all conditions with one exception; in the single-item subset with duration included as an additional parameter, the total correct classification was 75% as compared to the other the conditions which were all in the fifties. This is different from the other speakers we have seen in which the overall classification rates for the vowels couched in a single-item subsets as opposed to multiple-item sets were higher in *both* the *F1/F2 Only* and *F1/F2 plus Duration* conditions. Individual comparisons of this speaker's vowels, however, indicate that virtually all had a slightly higher classification rate in the single-item subset than in the multiple-item set with two notable exceptions: the vowel /ɪ/ in the word *kid* and the vowel /ʊ/ in the word *put*.

We now compare the single-item subset to multiple-item set when the nonnative speaker's data were evaluated in terms of their acoustic similarity to the native speaker's centroids. In this case we find that when matched word to word to the native speaker's values, the nonnative speaker had a lower overall percentage of correct category matches than when the vowels were considered across lexical items as shown in Table 6.3.

Table 6.3 Single-Item vs. Multiple-Item Comparison of NNS02 Using the Native Speaker's Data as Criteria (Time 1)

Vowel	Single-Item Subset		Multiple Item Set	
	Percent/Number Correctly Matched: F1/F2	Percent/Number Correctly Matched: F1/ F2 and Duration	Percent/Number Correctly Matched: F1/F2	Percent/Number Correctly Matched: F1/F2 and Duration
i	40 (2/5)	40 (2/5)	61.5 (8/13)	61.5 (8/13)
ɪ	0 (0/4)	0 (0/4)	7.69 (1/14)	30.7 (4/14)
e	0 (0/5)	0 (0/5)	26.6 (4/15)	66.6 (10/115)
ɛ	80 (4/5)	60 (3/5)	73.3 (11/15)	60 (9/15)
æ	20 (1/5)	40 (2/5)	0 (0/9)	11.1 (1/9)
ʌ	40 (2/5)	40 (2/5)	53.3 (9/15)	60 (9/15)
u	80 (4/5)	60 (3/5)	80 (4/5)	40 (2/5)
ʊ	0 (0/4)	0 (0/4)	9.09 (1/11)	9.09 (1/11)
o	40 (2/5)	40 (2/5)	85.7 (12/14)	28.5 (4/14)
ɔ	0 (0/4)	0 (0/4)	23 (3/13)	38.4 (5/13)
ɑ	20 (1/5)	20 (1/5)	40 (6/15)	46.6 (7/15)
Total	30.7	28.8	42	43.4

As with saw with the previous nonnative speaker, whether a vowel was repeated several times within a single-item subset as opposed to across the multiple-item set had an effect on how well various instances of a vowel matched each other on the discriminant analysis; the former clearly showed higher classification rates than the latter. These variables

however, had less of an effect on the way this nonnative speaker's vowels matched the native speaker's vowels.

6.4. The High and Mid Front Vowels

Let us now consider phonemically relevant vowel pairs in the entire data set across all lexical items. We begin with the high front vowels /i/ and /ɪ/ as uttered in the words *keep*, *peek*, *pick*, *kid* and *pit* and the mid front vowels /e/ and /ɛ/ as uttered in the words *take*, *gate*, *paid*, *get*, *pet* and *bed*. Figures 6.1 and 6.2 show the F1/F2 plots of the high and mid front vowels. As with the first nonnative speaker in this study, the four vowels were not completely distinct. The height distinction was clear in that the high vowels were distinguished from the mid vowels. There was less distinction between what are traditionally referred to as the tense-lax pairs in each height.

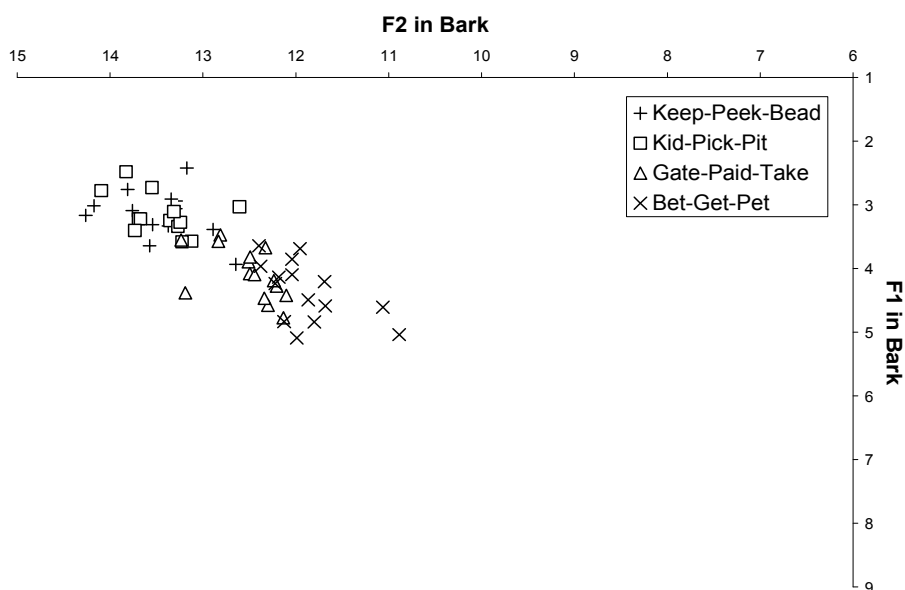


Figure 6.1 F1/F2 plot of the high and mid front vowels at Time 1 pronounced by NNS02

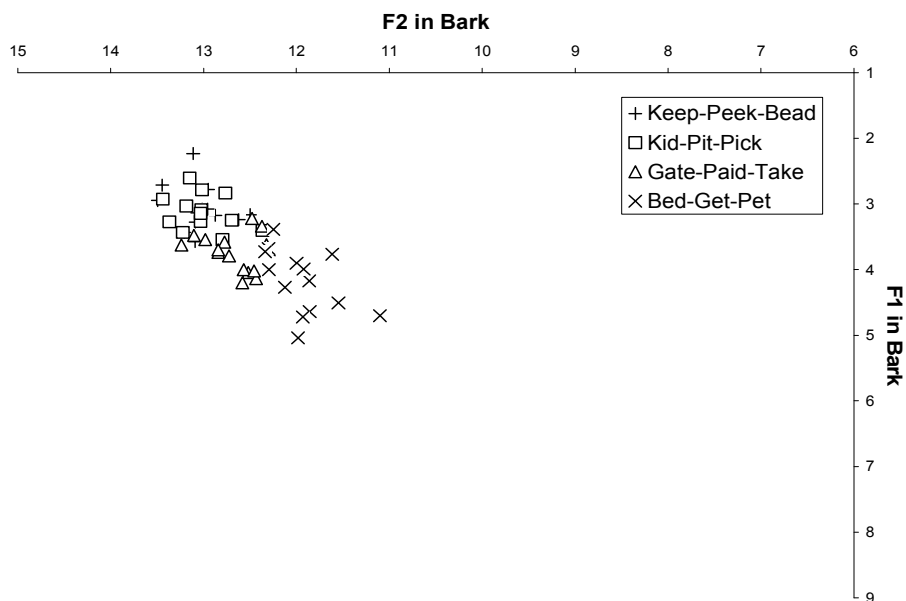


Figure 6.2 F1/F2 plot of the high and mid front vowels at Time 2 pronounced by NNS02

6.4.1. Distribution of /i/, /ɪ/, /e/ and /ɛ/ by NNS02

In order to fully understand the distribution of these vowels we can turn to the discriminant analyses beginning with the high front pair and then the mid front pair.

Table 6.4 shows the results of the discriminant analyses of /i/ and /ɪ/ on both conditions (*F1/ F2 Only* and *F1/F2 plus Duration*) at two points in time over the period of four years

Table 6.4 Results of the Discriminant Analyses of the Vowels /i/ and /ɪ/ Pronounced by NNS02 across Two Times

Target Vowel	Time 1		Time 2	
	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2 Duration
i N= 13	i (6)	i (5)	i (5)	i (5)
	ɪ (6)	ɪ (7)	ɪ (7)	ɪ (8)
	e (1)	e (1)	e (1)	-----
% correct	46.1	38.4	38.4	38.4
ɪ N=13	ɪ (7)	ɪ (7)	ɪ (4)	ɪ (7)
	i (6)	i (6)	i (7)	i (6)
	-----	-----	e (2)	-----
% correct	53.8	53.8	30.7	53.8

As we can see from the table the vowels /i/ and /ɪ/ were primarily confused with each other when the system was considered independently of the native speaker. At Time 1, 6 out of 13 attempts at the vowel /i/ fell into the F1/F2 range of /i/ (or 46.1%) while six fell into the F1/F2 range of /ɪ/. Seven of the thirteen attempts at the vowel /ɪ/ fell into the F1/F2 range of /ɪ/ (53.6%) while 6 attempts fell into the range of /i/. Note that overlap was apparent, but not to the extent of what we saw with speaker NNS01. Recall that NNS01 produced virtually all attempts at these two target vowels as a single vowel category. NNS02, however, has evidence of two categories, although he has not completely distinguished the vowels in the target words.

Duration means between these vowels initially differed by only 1 msec. When duration was included as an input parameter it had little impact on classification of the vowel /i/

but improved classification rates of /ɪ/ by three attempts (at Time 2 only). This improvement is the only notable longitudinal change in these vowels which were otherwise quite stable over time.

The mid vowels behaved similarly to the high vowels in that roughly an equal number of instances of each target vowel was confused with their mid counterparts. Table 6.5 shows the results of the discriminant analyses of /e/ and /ɛ/ on both conditions (*F1/F2 Only* and *F1/F2 plus Duration*) at two points in time over the period of four years.

Table 6.5 Results of the Discriminant Analyses of the Vowels /e/ and /ɛ/ Pronounced by NNS02 across Two Times

Target Vowel	Time 1		Time 2	
	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration
e N= 15	e (9)	e (11)	e (12)	e (10)
	ɛ (5)	ɛ (3)	ɛ (2)	ɛ (3)
	ɪ (1)	ɪ (1)	ɪ (1)	ɪ (2)
% correct	60	73.3	80	66.6
ɛ N=15	ɛ (8)	ɛ (11)	ɛ (11)	ɛ (14)
	e (6)	e (3)	e (4)	e (1)
	ʌ(1)	ʌ (1)	-----	-----
% correct	53.3	73.3	73.3	93.3

Again, when the system is considered independently of the native speaker, the primary confusion between these vowels is with each other. At Time 1, 9 out of 15 instances of /e/ (60%) matched the correct category while five instances were confused with /ɛ/.

Likewise, 8 out of 15 instances of /ɛ/ (53.3%) matched the correct category, while six instances were confused with /e/. Initially, the duration means of these vowels differed by about 40 msec with /e/ being the longer of the two. The inclusion of duration as a parameter at Time 1 increased the number of correct category matches of /e/ by two instances (or from 60% to 73.3% correct). Duration also improved the number of correct matches of /ɛ/ by three instances (from 53.3 to 73.3% correct).

With respect to change across time, these vowels became somewhat more differentiated at Time 2 on the F1/F2 condition. Looking at the *F1/F2 Only* condition, we see that the number of correct category matches of the vowel /e/ improved from nine to twelve.

Likewise the number of correct category matches for the vowel /ɛ/ improved from eight to eleven. The difference between duration means increased at Time 2 to about 80 msec (with /e/ still be the longer of the two). This increase did not improve the classification rate for /e/ but it did improve the classification rate for /ɛ/. With duration included as an input parameter, 14/15 instances of /ɛ/ matched the correct centroid at Time 2. If the pattern for /e/ and /ɛ/ continued in the direction described here, we would most likely see a complete split between these two vowels with each one increasing in the number of correct instances and decreasing in the number of confusions with its mid counterpart. However, these changes were not greater than those we saw in the native speaker's data and they took four years to occur.

6.4.2. Comparison of /i/, /ɪ/, /e/ and /ɛ/ to the Native Speaker

We now consider these vowels in comparison to the native speaker's F1/F2 and duration values. Table 6.6 shows the results of the discriminant analyses for the vowels /i/, /ɪ/, /e/ and /ɛ/ when the native speaker's values were used as the criteria for categorization. The vowels are presented in one table because when the vowels of NNS02 were compared to the native speaker, the primary confusion categories of the high vowels included the mid vowels and vice versa.

Table 6.6 Results of the Discriminant Analyses of the Vowels /i/, /ɪ/, /e/ and /ɛ/ Pronounced by NNS02 Compared to the Native Speaker

Target Vowel	Time 1		Time 2	
	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2	NS Match /# of Tokens F1/F2 Duration
i	i (8)	i (8)	i (4)	i (4)
N=13	i (1)	ɪ (2)	ɪ (7)	ɪ (7)
	e (4)	e (3)	e (2)	e (2)
% correct	61.5	61.5	30.7	30.7
ɪ	ɪ (1)	ɪ (4)	ɪ (7)	ɪ (7)
N=13	i (6)	i (6)	i (4)	i (4)
	e(6)	e (3)	e (2)	e (2)
% correct	7.6	30.7	53.8	53.8
e	e (4)	e (10)	e (9)	e (12)
N=15	ɪ (5)	ɪ (3)	ɪ (5)	ɪ (2)
	ɛ (6)	ɛ (2)	ɛ (1)	ɛ (1)
% correct	26.6	66.6	60	80
ɛ	ɛ (11)	ɛ (9)	ɛ (7)	ɛ (7)
N=15	ɪ (4)	ɪ (2)	ɪ (8)	ɪ (6)
	-----	e (4)	-----	e (2)
% correct	73.3	60	46.6	46.6

Although NNS02 had some distinction between the high front vowels when his vowels were analyzed independently of the native speaker, the analysis using the native speaker's centroids shows that the majority of both /i/ and /ɪ/ were produced in the F1/F2 range of native speaker's /i/. In fact, at Time 1, of the 26 total attempts at these two vowels, fourteen were considered to be /i/, only two instances from the total number matched /ɪ/, and ten actually fell into the F1/F2 range of /e/.

Including duration as a parameter improved the number of correct category matches of /ɪ/ by three instances (from 7.6% to 30.7%) and reduced the number of times /ɪ/ was confused with /e/. Duration had no effect on the classification of /i/.

With respect to change across time, we see that /i/ decreased and /ɪ/ increased in the percentage of correct category matches. The number of instances that changed for /i/ were on the borderline for normal variation but the number of instances that changes for /ɪ/ was greater than what we saw in the native speakers, at least in the *F1/F2 only* condition. At first it seems as though /i/ has merged into /ɪ/, but a more likely explanation is that two poorly differentiated have shifted together into a space that is a better match for the native speaker /ɪ/. We will refer to this as a shift because it has not eliminated or created a phonemic distinction but has maintained a single category for high front. That single category has moved into a different F1/F2 space.

Next, consider the mid front vowels as compared to the native speaker also shown in Table 6.6. At Time 1, the vowel /e/ barely existed as an F1/F2 category for the target words *gate*, *paid* and *take*. Most of the vowels uttered in these words fell into the F1/F2 range of the native speaker's /ɛ/ or /ɪ/. The vowels uttered in the words *pet*, *get* and *bed* had a high percentage of category matches to the intended vowel category with 11 out of 15 matched to the native speaker's F1/F2 values for /ɛ/ and only four instances being confused with /ɪ/.

When duration was included as an input parameter, it improved the percentage of correct category matches and changed the primary confusion category of the vowel /e/. The categorization vowel /e/ improved by six instances (from 26.6% correct to 66.6% correct) at Time 1 and by 3 instances (60% correct to 80% correct) at Time 2. With duration included, the vowel /e/ was more likely to be confused with the native speaker's /ɪ/ than with /ɛ/. Duration slightly lowered the classification rates of /ɛ/ at Time 1 but had no effect at all on this vowel at Time 2.

With respect to change over time, target words containing the vowel /e/ became more distinct from /ɛ/. Words containing /ɛ/ decreased in the percentage of correct category matches and increased in the number of confusions with the vowel /ɪ/. To understand this more clearly consider the vowel /e/ with F1/F2 as the only parameters. Recall that /e/ was confused with /ɛ/ six times at Time 1 but only once at Time 2. At the same time there was

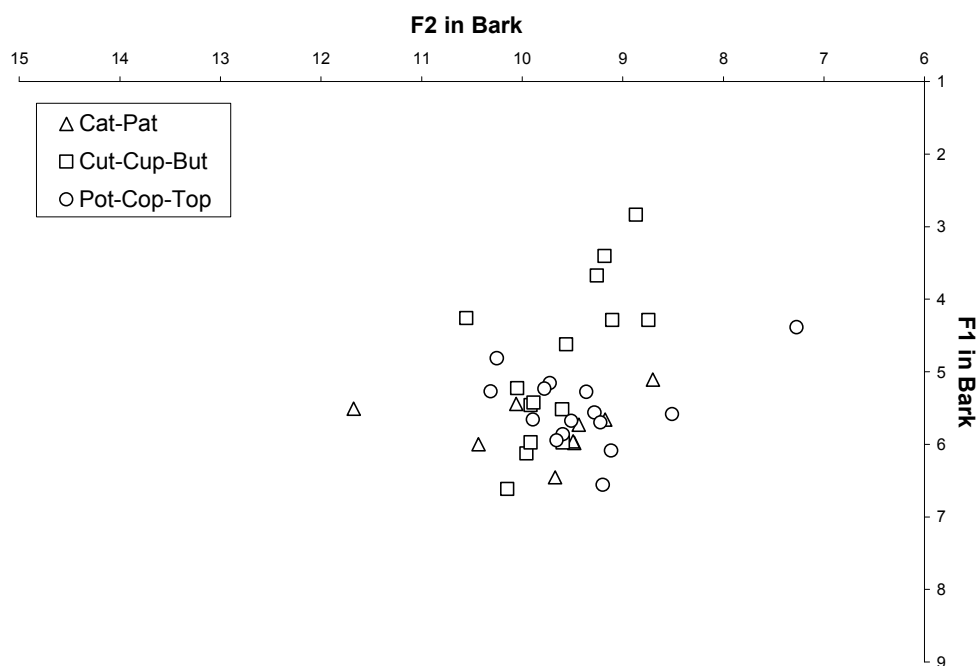
an increase in the number of times /ɛ/ was confused with /ɪ/. So, as /ɛ/ and /e/ moved apart in the F1/F2 space, the vowel /ɛ/ encroached on the F1/F2 space of /ɪ/. The split between /e/ and /ɛ/ occurred with a merge of /ɛ/ into /ɪ/.

It should be noted that there is a general shift of the high and mid front vowels towards the native speaker's category for /ɪ/. One can see this by simply comparing the total number of times a vowel uttered in one of the target words was categorized as /ɪ/ across the two times. If we look at all of the words containing the target vowels /i/, /ɪ/, /e/, and /ɛ/ at Time 1, we see that 11 instances matched the native speaker's category of /ɪ/. At Time 2, 27 instances matches the native speaker's category of /ɪ/ across words containing the targets /i/, /ɪ/, /e/, and /ɛ/ (or 22 instances in the *F1/F2 plus Duration* condition). This movement towards /ɪ/ can be described as split between some vowels, merger between others and shifts for others. Specifically, /i/ and /ɪ/ seem to be undergoing split in that the two vowels were grouped together at Time 1 but at Time 3, /ɪ/ has a higher percentage of category matches. The vowel /ɛ/ seems to be shifting away from /e/ but only because it is merging with /ɪ/.

6.5. The Low Vowels and the Mid Central Vowel

Having examined the high and mid front vowels of NNS02 separately and in comparison to the native speaker, we can move to the low vowels and the central vowel. As

previously seen with the nonnative speakers, the vowel /æ/ (uttered in the words *pat* and *cat*) was more likely to be confused with /ɑ/ (uttered in the words *pot*, *cop* and *top*) than with the mid front vowels /e/ and /ɛ/. It therefore seemed appropriate to discuss the /æ/ and /ɑ/ together. Likewise, the vowel /ʌ/ (uttered in the words *cut*, *cup* and *but*) showed confusion with the vowel /ɑ/, and so it too will be included in this section. Figures 6.3 and 6.4 below show the F1/F2 plots of the vowels /æ/, /ɑ/ and /ʌ/ at two points in time over the period of four years.



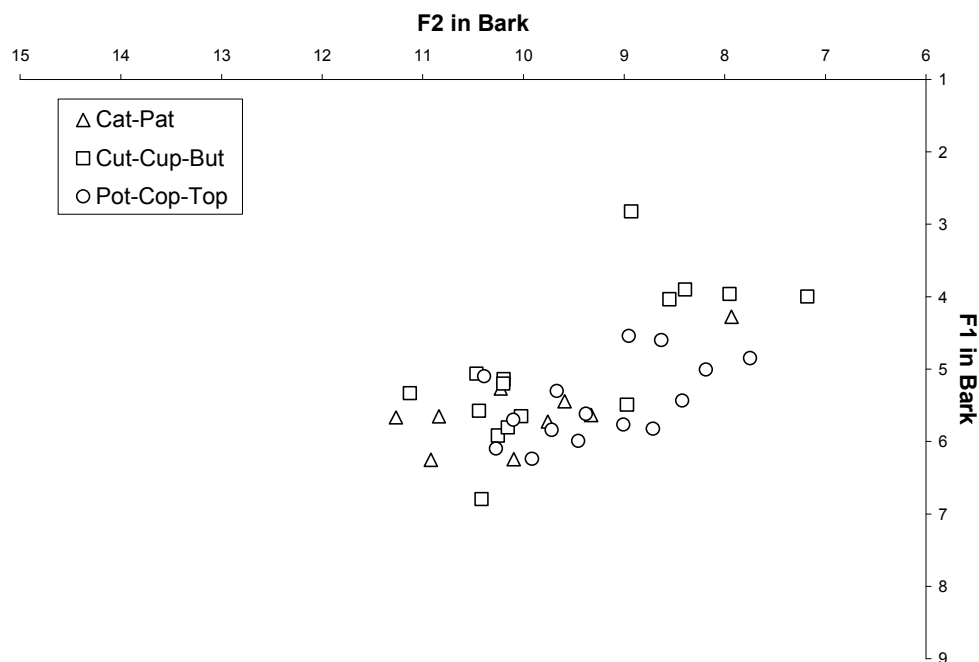


Figure 6.4 F1/F2 plot of the low and central vowels at Time 2 pronounced by NNS02

A preliminary examination of the F1/F2 plots indicates that the vowel /ʌ/ fell considerably high and back in the F1/F2 space. This might be due to a sound spelling error in which the letter “u” was interpreted as /u/. Even so there was a good deal of overlap in the space among all of these vowels.

6.5.1 Distribution of /æ/, /ɑ/ and /ʌ/ by NNS02

In order to understand the distribution more clearly we turn to the discriminant analyses of these vowels. Table 6.7 below shows the results of the discriminant analyses of /æ/, /ɑ/

and /ʌ/ across two times on both conditions (*F1/F2 Only* and *F1/F2 plus Duration*) with this nonnative speaker's vowel system considered separately from the native speaker's.

Table 6.7 Results of the Discriminant Analyses of the Vowels /æ/, /ɑ/ and /ʌ/ Pronounced by NNS02 across Three Times

Target Vowel	Time 1		Time 2	
	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration
æ N=9	æ (2)	æ (4)	æ (3)	æ (5)
	ɑ (4)	ɑ (3)	ɑ (4)	ɑ (3)
	ɔ (1)	ɔ (1)	ɔ (1)	ɔ (1)
	ε (1)	ε (1)	-----	-----
	ʌ (1)	-----	ʌ (1)	-----
% correct	22.2	44.4	33.3	55.5
ʌ N=15	ʌ (3)	ʌ (5)	ʌ (4)	ʌ (4)
	æ (3)	æ (3)	æ (5)	æ (5)
	ɔ (2)	ɔ (1)	ɔ (3)	ɔ (3)
	ɑ (4)	ɑ (3)	ɑ (1)	ɑ (1)
	ʊ (3)	ʊ (3)	ʊ (1)	ʊ (1)
	-----	-----	o (1)	o (1)
% correct	20	33.3	26.6	26.6
ɑ N=15	ɑ (10)	ɑ (9)	ɑ (8)	ɑ (10)
	ʌ (4)	ʌ (4)	ʌ (3)	ʌ (1)
	-----	æ (1)	æ (2)	æ (2)
	-----	-----	ɔ (1)	ɔ (2)
	o (1)	o (1)	o (1)	-----
% correct	66.6	60	53.3	66.6

With F1/F2 as the only parameters, only 2 out of 9 attempts at /æ/ and only 3 out of 15 attempts at /ʌ/ were considered to be distinct from other vowel categories in this speaker's system. It should be noted as well that these vowels had a wider range of

category confusion than did the high and mid front vowels, with as many as six categories for some. The vowel /ɑ/ was the most differentiated in the F1/F2 space with 10 out of 15 instances being correct category matches.

Duration means of these vowels at Time 1 indicate that /æ/ and /ɑ/ are virtually identical in duration and that /ʌ/ is shorter than both /æ/ and /ɑ/ by about 35 msec. When duration was included as an input parameter there was a small effect each on the vowels in that it improved the classification of /æ/ and /ʌ/ by two instances each. The number of correct category matches for /ɑ/ actually decreased by one when duration was included.

With respect to change over time, these vowels remained relatively stable, each changing no more than one instance in either direction.

Recall that the item *bad* had been excluded up to this point. With *bad* included, the vowel /æ/ was slightly more distinct at Time 1, with 4 out of 14 (as opposed to 2 out of 9 without the word *bad* in the data set). At Time 2, it was more distinct with 7 out of 14 instances (50%) of the vowel /æ/ being distinct from the other vowels in the system.

6.5.2. Comparison of /æ/, /ɑ/, /ʌ/ to the Native Speaker

Now consider the vowels /æ/, /ɑ/, /ʌ/ in direct comparison to the native speaker's values.

Table 6.8 shows the results of the discriminant analyses of these vowels evaluated against centroids established on the male native speaker's data.

Table 6.8 Results of the Discriminant Analyses of the Vowels /æ/, /ɑ/ and /ʌ/ Pronounced by NNS02 Compared to the Native Speaker

Target Vowel	Time 1		Time 2	
	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration
æ N=9	-----	æ (1)	æ (1)	æ (1)
	ɑ (6)	ɑ (7)	ɑ (4)	ɑ (4)
	ʌ (2)	ʌ (1)	ʌ (3)	ʌ (2)
	-----	-----	-----	ɔ (2)
	-----	-----	o (1)	-----
ε (1)	-----	-----	-----	
% correct	0	11.1	11.1	11.1
ʌ N=15	ʌ (8)	ʌ (9)	ʌ (4)	ʌ (3)
	ɑ (4)	ɑ (5)	ɑ (5)	ɑ (5)
	-----	-----	o (2)	o (4)
	ɔ (2)	-----	ɔ (2)	ɔ (1)
	u (1)	u (1)	u (1)	u (1)
-----	-----	ε (1)	ε (1)	
% correct	53.3	60	26.6	20
ɑ N=15	ɑ (6)	ɑ (7)	ɑ (5)	ɑ (6)
	ʌ (8)	ʌ (4)	ʌ (6)	ʌ (2)
	-----	ɔ (4)	ɔ (1)	ɔ (6)
	o (1)	-----	o (3)	o (1)
% correct	40	46.6	33.3	40

Looking at the *F1/ F2 Only* condition at Time 1, we can see that the vowel /æ/ was produced most frequently in the range of the native speaker's /a/. Duration barely improved the number of correct category matches of this vowel by one. The number of correct attempts at /æ/ was stable across time with the only notable difference being the categories that the vowel was confused with.

A final note about /æ/ before moving on to the vowels /ʌ/ and /ɑ/. Inclusion of the lexical item *bad* improved the classification rates of this nonnative speaker's production of /æ/, but just barely. At Time 1, with the lexical item *bad* included and all parameters included, the number of correct matches for /æ/ was 2 out of 14 (or 21.4%). At Time 2 it was 3 out of 14 (28.5%).

The vowel /ʌ/ was initially produced with 8 out of 15 attempts matching the native speaker's category for /ʌ/ at Time 1. This accuracy clearly decreased at Time 2 with fewer instances of the vowel matching the native speaker's category for /ʌ/ and a longer list of categories that /ʌ/ was confused with. We have referred to this type of change as dispersion in which a category that was relatively distinct at one time is subsequently distributed into several preexisting categories.

The vowel /ɑ/ also initially showed some distinction from the other vowels in the system. At Time 1, 6 out of 15 attempts at /ɑ/ (40%) matched the native speaker's category for

/ɑ/. Duration affected this vowel by improving the number of correct category matches by one instance but also by changing the primary confusion category from /ʌ/ to /ɔ/. The vowel was relatively stable over time but not completely so. At the second recording fewer instances of /ɑ/ matched the native speaker's category and there were more categories with which /ɑ/ was confused. This change, however, was relatively small.

6.6. The High Back Vowels

Now consider the high back vowels /u/ and /ʊ/ as uttered in the words *boot*, *put*, *took* and *could*. Recall that due to difficulties in sound-spelling correspondences, the word *coop* was completely eliminated from this speaker's analysis. Furthermore, due to allophonic variation, the word *tube* was treated in a separate analysis. This leaves only five attempts at the vowel /u/ in the preliminary analysis, although five additional instances of the vowel in the lexical item *tube* will be considered subsequently as part of the overall data set. Figures 6.5 and 6.6 show the F1/F2 plots of the vowels /u/ and /ʊ/ at two points in time over the period of four years.

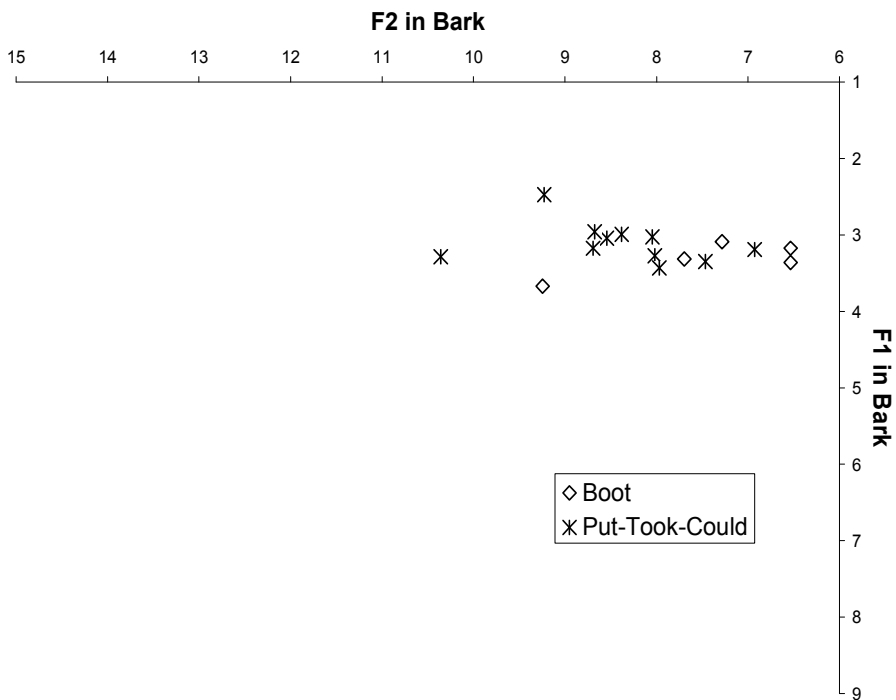


Figure 6.5 F1/F2 plot of the high back vowels at Time 1 pronounced by NNS02

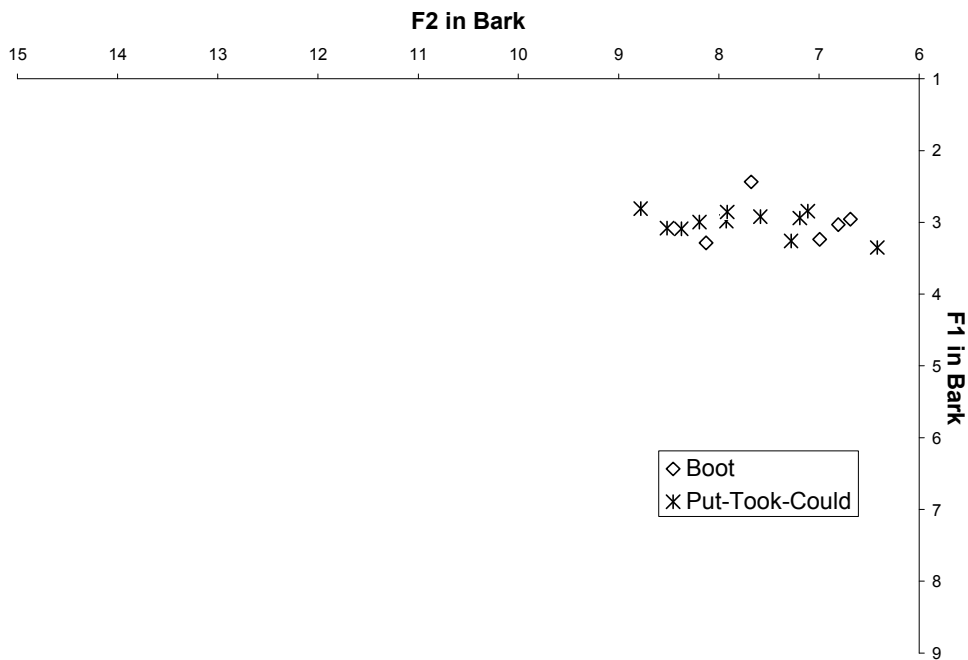


Figure 6.6 F1/F2 plot of the high back vowels at Time 2 pronounced by NNS02

6.6.1. Distribution of /u/ and /ʊ/ by NNS02

To understand the nature of this distribution we turn to the discriminant analysis. Table 6.9 shows the results of the discriminant analyses of /u/ and /ʊ/ across two times on both conditions (*F1/F2 Only* and *F1/F2 plus Duration*) with the nonnative speaker's vowel system considered separately from the native speaker's.

Table 6.9 Results of the Discriminant Analyses of the Vowels /u/ and /ʊ/ Pronounced by NNS02 across Three Times

Target Vowel	Time 1		Time 2	
	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration
u	u (3)	u (3)	----	-----
N= 5	-----	o (1)	o (3)	o (2)
	ʊ (2)	ʊ (1)	ʊ (2)	ʊ (2)
	-----	-----	-----	o (1)
% correct	60	60	0	0
ʊ	ʊ (8)	ʊ (8)	ʊ (9)	ʊ (10)
N=11	u (2)	u (2)	-----	-----
	-----	-----	o (2)	o (1)
	ε (1)	ε (1)	-----	-----
% correct	72.7	72.7	81.8	90.9

Note that at Time 1, 3 of 5 attempts (60%) at the vowel /u/ are distinct from /ʊ/ and from other vowels in the system. The difference between duration means indicated that the vowel /u/ was the longer of the two. When duration was included in the analysis it did not affect the number of correct instances but did change the confusion categories slightly.

At Time 2, the three instances of /u/ that were distinct have been distributed among the categories /u/ and /o/ and /ɔ/. We can consider this an instance of dispersion in that a distinct group is being distributed among several preexisting groups over time.

Admittedly, it is premature to draw conclusions given the small number of tokens of /u/.

It would be helpful to consider the vowel /u/ with additional tokens from the lexical item *tube* added to the data set, as shown in Table 6.10.

Table 6.10 Results of the Discriminant Analyses of the Vowel /u/ with the Item *Tube* Included for NNS02

Target Vowel	Time 1		Time 2	
	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration
u	u (4)	u (6)	u (1)	u (3)
N= 10	ɯ (5)	ɯ (4)	ɯ (5)	ɯ (5)
	-----	-----	o (4)	o (2)
	ε (1)	-----	-----	-----
% correct	40	60	10	30
u	ɯ (6)	ɯ (8)	ɯ (7)	ɯ (7)
N=11	u (4)	u (3)	u (2)	u (3)
	-----	-----	o (2)	o (1)
	ε (1)	-----	-----	-----
% correct	54.5	72.7	63.6	63.6

Note that the inclusion of additional tokens of /u/ increased percentage of correct category matches. At Time 1, with all parameters included, 6 out of 10 attempts at the vowel /u/ (60%) were distinct from other vowels in the system, five fell into the range of /u/ and one fell into the range of /ε/. By Time 2, the classification rate was reduced by

half with seven tokens being distributed into the categories for /ʊ/ and /o/. The vowel /u/ became less differentiated over time.

The vowel /ʊ/ was affected by the inclusion of the lexical item *tube* in that the number of correct instances was lower with *tube* included. Duration improved the distinction between /ʊ/ and /u/ at least at Time 1. The vowel was relatively stable with respect to how many instances were classified as distinct but there was a change with respect to which categories the vowel /ʊ/ was confused with. Note that at Time 2, one or two instances of /ʊ/ had been confused with /o/ where at Time 1, none had. This may indicate a fronted pronunciation of the vowel /u/ in *tube*, because as the number of confusions with /o/ decreased the number of confusions with /u/ increase.

6.6.2. Comparison of /u/ and /ʊ/ to the Native Speaker

When compared to the F1/F2 values of the native speaker, the vowels /u/ and /ʊ/ are distributed quite differently. Table 6.11 shows the results of the discriminant analyses on both conditions across time with the native speaker's values used as the category standard.

Table 6.11 Results of the Discriminant Analyses of the Vowels /u/ and /ʊ/ Pronounced by NNS02 Compared to the Native Speaker

Target Vowel	Time 1		Time 2	
	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2	NS Match /# of Tokens F1/F2 Duration
u	u (4)	u (2)	u (5)	u (3)
N= 5	-----	ɔ (1)	-----	ɔ (2)
	----- ʌ (1)	o (1) ʌ (1)	-----	-----
% correct	80	40	100	60
ʊ	ʊ (1)	ʊ (1)	-----	-----
N= 11	u (9)	u (7)	u (11)	u (8)
	ɔ (1)	ɔ (3)	-----	ɔ (3)
% correct	9	9	0	0

Clearly, the vowel /u/ is matched better to the native speaker's category for /u/ than /ʊ/ is to its intended category. Four out of the five attempts at /u/ at Time 1 fell into the F1/F2 range of the native speaker's /u/ whereas only 1 out of 11 attempts at /ʊ/ fell into the range of the native speaker's /ʊ/. Duration actually decreased the number of correct instances of /u/, indicating that the nonnative speaker did not use duration in the same way that the native speaker did. Duration had no effect on the classification of the vowel /ʊ/.

By Time 2, all but 5 of the 16 total attempts at these two vowels fell into the range of the native speaker's /u/. The change in the actual number of correct matches is not large but it seems to be in the direction of merger. That is, these two vowels that were poorly

distinguished at Time 1 all seem to be moving into the range of /u/. Any evidence of the vowel /u/ is gone by Time 2. Recall, however that there were only five instances of the vowel /u/ in this preliminary analysis. In order to see if this is truly a case of merger, we turn to the analyses with the lexical item *tube* included, as shown in Table 6.12.

Table 6.12 Results of the Discriminant Analyses of the Vowel /u/ with the Item *Tube* Included Pronounced by NNS02 Compared to the Native Speaker

Target Vowel	Time 1		Time 2	
	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration
u	u (3)	u (1)	u (4)	u (3)
N= 10	o (3)	o (2)	o (5)	ɔ (6)
	ɔ (3)	ɔ (5)	ɔ (1)	o (1)
	ʊ (1)	ʊ (1)	-----	-----
	-----	Λ (1)	-----	-----
% correct	30	10	40	30
ʊ	ʊ (1)	ʊ (1)	-----	-----
N= 11	u (6)	u (6)	u (6)	u (4)
	o (2)	o (1)	o (4)	o (2)
	ɔ (2)	ɔ (3)	ɔ (1)	ɔ (5)
% correct	9	9	0	0

Several patterns remain when the lexical item *tube* was included in the data whereas others change. It is clear that the vowel /u/ was still a better match than the vowel /ʊ/ to the native speaker's category but is weaker as a category than when the word *boot* was considered alone. Duration continued to decrease the number of correct instances at least for the vowel /u/. The change that we see over time however becomes less a case of

simple merger and more a case of *dispersion* in which the lax vowel /ʊ/ is completely distributed into three other vowel categories (/ɔ/, /u/ and /o/) by Time 2.

6.7. The Mid Back Vowels

The final vowel pair to consider is the mid back vowels as uttered in the words *coat*, *boat*, *code*, *talk*, *caught* and *taught*. Figures 6.7 and 6.8 show the F1/F2 plots of these vowels at two points in time over the period of four years. The vowel plots also include the vowels /ɑ/ and /ʌ/ which become relevant when discussing the confusion categories for the vowel /ɔ/.

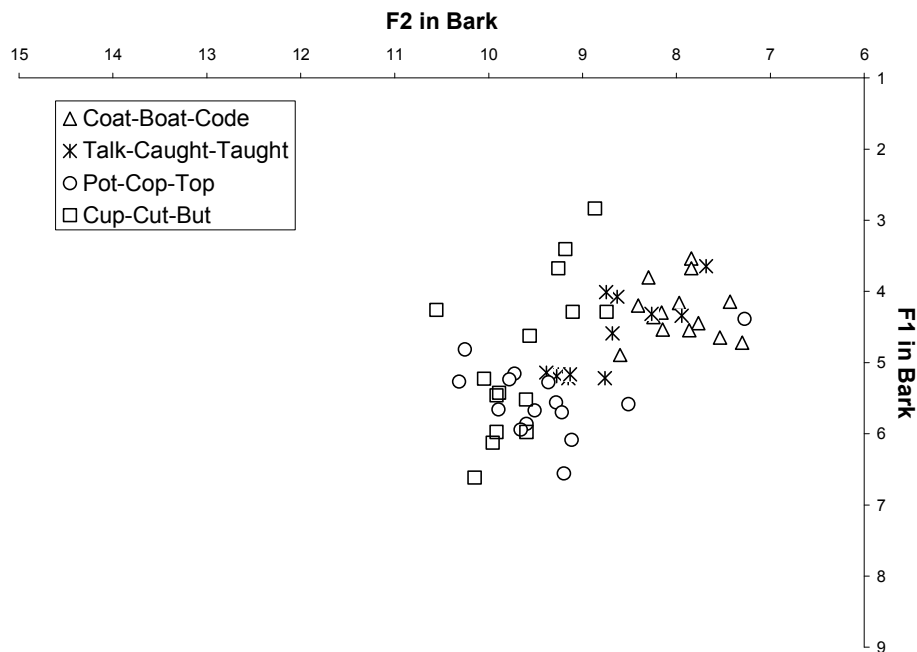


Figure 6.7 F1/F2 plot of the mid back vowels at Time 1 pronounced by NNS02

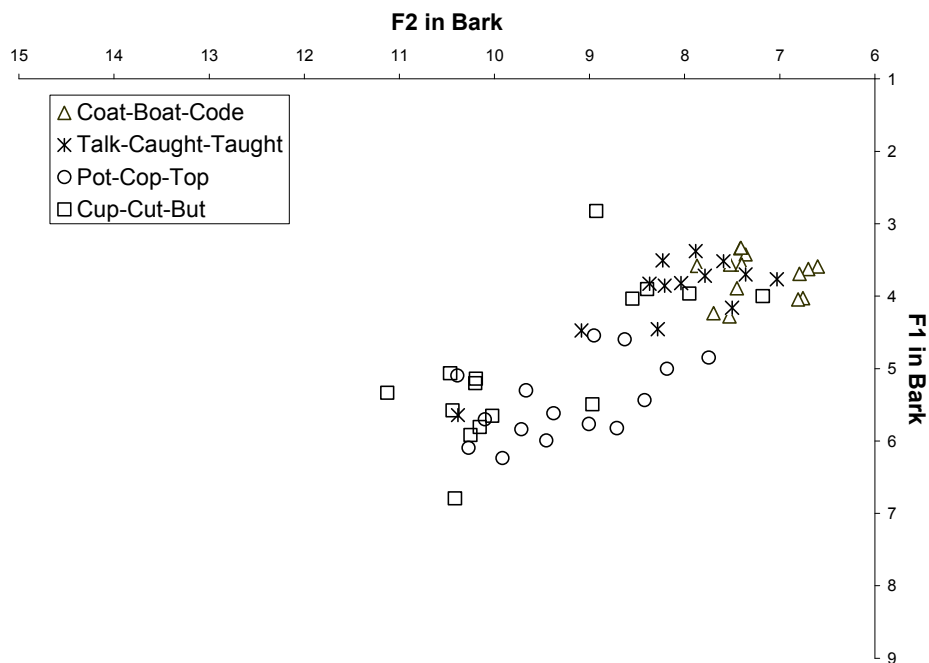


Figure 6.8 F1/F2 plot of the mid back vowels at Time 2 pronounced by NNS02

6.7.1. Distribution of /o/ and /ɔ/ by NNS02

Table 6.13 shows the results of the discriminant analyses when the vowels are considered independently of the native speaker's system.

Table 6.13 Results of the Discriminant Analyses of the Vowels /o/ and /ɔ/ Pronounced by NNS02 across Two Times

Target Vowel	Time 1		Time 2	
	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration
o N=14	o (13)	o (13)	o (13)	o (13)
	ɔ (1)	ɔ (1)	ɔ (1)	ɔ (1)
	% correct	92.8	92.8	92.8
ɔ N=13	ɔ (4)	ɔ (4)	ɔ (6)	ɔ (7)
	ɑ (5)	ɑ (6)	-----	-----
	o (3)	o (3)	o (4)	o (3)
	ʌ (1)	-----	ʌ (1)	ʌ (1)
	-----	-----	ʊ (1)	ʊ (1)
	-----	-----	æ (1)	æ (1)
% correct	30.7	30.7	46.1	53.8

NNS02 distinguished the vowel /o/ from /ɔ/ as well as from other vowels in the system.

At both times and under all conditions, 13 out of 14 instances of /o/ were distinct. This category was completely stable over time and was not affected at all when duration was included as an input parameter. It should be noted that /o/ was longer than /ɔ/ by about 35 msec.

Initially, the vowel /ɔ/ was not differentiated and overlapped into the categories of the vowels /ɑ/, /ʌ/ and /o/. Duration had no effect on the percentage of correct category matches of this vowel at Time 1 and little effect at Time 2.

Longitudinally /o/ maintained its distinctiveness and stability. Likewise the number of times /ɔ/ was confused with /o/ remained relatively stable as well. So we can say that the phonemic distinction between /o/ and /ɔ/ remained the same. There is a change however and this is between the vowel /ɔ/ and its primary confusion category /a/. At Time 1, five to six instances of /ɔ/ were confused with /a/, whereas at Time 2 none were. We can conclude that /ɔ/ is separating from /a/ and being dispersed among several other categories. This dispersion is particularly interesting for two reasons. First, it ultimately improved the classification rate of /ɔ/ since some of the instances originally pronounced as /a/ were dispersed into the target category /ɔ/ and not just non-target categories. Second it may indicate the acquisition of a dialect. One feature of NYCD is the distinction between the vowels /ɔ/ and /a/ as in *caught* and *cot* whereas some American dialects have merged these two vowels. Labov (1966) described this distinction in NYCD and more recently Gordon (2005) and Wong et. al. (2005) confirmed that the distinction is still present in NYCD today. It is therefore possible that as this nonnative speaker was exposed to the speech of the New York City area, he developed the /ɔ/ - /a/ distinction as well. We will see that not all of the nonnative speakers in this study have acquired this distinction.

6.7.2. Comparison of /o/ and /ɔ/ to the Native Speaker

Table 6.14 shows the results of the discriminant analyses when this nonnative speaker's values are compared directly to the native speaker's values for /o/ and /ɔ/

Table 6.14 Results of the Discriminant Analyses of the Vowels /o/ and /ɔ/ Pronounced by NNS02 Compared to the Native Speaker

Target Vowel	Time 1		Time 2	
	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration
o	o (12)	o (4)	o (12)	o (4)
	ɔ (2)	ɔ (9)	ɔ (2)	ɔ (10)
N=14	-----	Λ (1)	-----	-----
% correct	85.7	28.5	85.7	28.5
ɔ	ɔ (3)	ɔ (5)	ɔ (4)	ɔ (9)
	Λ (7)	Λ (7)	Λ (1)	-----
N=13	o (3)	o (1)	o (6)	o (2)
	-----	-----	ɑ (1)	ɑ (1)
	-----	-----	u (1)	-----
% correct	23	38.8	30.7	69.2

When NNS02 was compared to the native speaker values, the vowel /o/ clearly fell into the F1/F2 range of the native speaker's /o/. When duration was included as a parameter it dramatically affected this vowel by decreasing the number of correct instances from 12 to 4 (at both times). This may indicate that while the F1/F2 values for /o/ and /ɔ/ matched the native speaker's the duration values did not. Recall that duration means for /o/ were the longest of the pair for the nonnative speaker but duration means for /ɔ/ were the longest of the pair for the native speaker. It makes sense then that when duration is

included it may cause classification of the nonnative speaker's /o/ to the native speaker's /ɔ/. One final point is that the vowel /o/ was remarkably stable across time as was also seen when this nonnative speaker's system was considered independently.

The vowel /ɔ/ exhibited the opposite pattern. That is to say where /o/ matched better on F1/F2 alone, the vowel /ɔ/ matched better when duration was included. Although the durational relationship between the two vowels does not match the native speaker (/ɔ/ was longer than /o/ for NS1) the duration means of /ɔ/ between native and nonnative speaker are more similar than for /o/.

Longitudinally the vowel /ɔ/ remained relatively stable on the *F1/F2 Only* with respect to how many instances matched the native speaker's category for /ɔ/. The change across time was not with the number of correct matches but in the mismatched instances which showed greater dispersion.

With duration included the vowel /ɔ/ on the other hand improved by four instances or from 38.8% correct to 69.2% correct and duration means of the vowel /ɔ/ increased from Time 1 to Time 2 by about 25 msec¹.

6.8. Summary of the Vowel System of NNS02

At the time of the first recording, with the nonnative speaker's vowels considered independently of the native speaker's vowels, we saw that /a/ and /o/ were clearly distinguished from other vowels. While /æ/, /ʌ/ and /ɔ/ were poorly distinguished from other vowels. There was some evidence of separate categories for the pairs /i/-/ɪ/, /e/-/ɛ/ and /u/-/ʊ/ but roughly an equal number of mismatches occurred between the vowels in each pair. This is not as clear as for the previous participant.

When this nonnative speaker's vowels were initially compared to the native speaker's vowels, we saw that target words containing /i/, /ʌ/, /a/, /u/, and /o/ had a high percentage of correct matches to the F1/F2 values of the native speaker's categories. Target words containing the vowel /e/ most closely matched the native speaker's /ɛ/, the vowel /ʊ/ matched the native speaker's /u/, the vowel /æ/ matched the native speaker's /a/ and the vowel /ɔ/ matched the native speaker's /ʌ/ and /o/.

Several instances of change occurred across time for this speaker. When the system was considered independently, we saw split, shift, merger and dispersion. Split was evident in the distinction of /e/ from /ɛ/ which occurred along with a merger of /ɛ/ and /ɪ/. Shift was evident in the movement of the single high front vowel group from the range of /i/ to the

range of /ɪ/. Dispersion was seen for the vowel /ɔ/ as initial confusion with /ɑ/ dispersed among several preexisting categories.

When this nonnative speaker's vowels were considered in direct comparison to the native speaker's vowels, we saw one notable change. Specifically, we saw dispersion as the vowel /ʌ/, which had been relatively distinct at Time 1, became distributed among several vowel categories.

Chapter 6: Notes

1. So, duration decreased the percentage of correct category matches of /o/ and increased the percentage of correct category matches of /ɔ/. Interestingly, this is exactly what we found with NS1. In the case of the native speaker, duration decreased the percentage of correct category matches at of /o/ while increasing the percentage of correct category matches of /ɔ/. This, however, cannot be considered merger by duration because there is no change in this relationship across time.

Chapter 7: Nonnative Speaker 03

7.1. Background of Nonnative Speaker 03 (NNS03)

Nonnative Speaker 03 (henceforth NNS03) is a male native Spanish speaker born in Bogotá, Colombia. At the time of the first recording he was 25 years old and had lived in the United States for a year and a half. He began studying English at age 15 as part of a high school requirement and continued until age 17. He had no further English training until he came to the United States. When he began his participation in the study he was enrolled in a Voice and Diction course taught by an NCC faculty member who is a speech/language pathologist. He reported watching one hour of TV in English per day, listening to many hours of English radio per day, reading the Associated Press every day, and reading on average four books in English per month for his college courses. He speaks mostly Spanish at home and at work. He speaks both Spanish and English with his friends. At the time of the first interview, NNS03 was a host for a Latin radio program and was trying to move into English radio. He was therefore working to reduce his accent.

7.2. Sample Collection

NNS03 had difficulty with two words on the sentence-reading task (*bead* and *could*), which had to be excluded completely from the sample. Other than the afore mentioned items, only one instance each of *tube*, *coop*, *put*, and *talk* were excluded from the sample. In order to determine intra-rater reliability, 17 items from each sample were randomly selected and re-measured. As indicated in Table 7.1 mean differences between the re-

measure and the original measure were less than 10 msec for duration, less than .20 Bark for F1 and F2 at the 50% point.

Table 7.1 Margin of Error for NNS03

	Mean Difference Between Time 1 Measure and Re- measure	Mean Difference Between Time 2 Measure and Re- Measure	Mean Difference Between Time 3 Measure and Re- Measure
Duration	7.78 msec	4.83 msec	6.37 msec
F1 at 50% Point	0.07 Bark	0.03 Bark	0.06 Bark
F2 at 50% Point	0.19 Bark	0.05 Bark	0.09 Bark

7.3. Category Matches within Lexical Items

As with the previous speakers, discriminant analyses were conducted on the single-item subsets as well as the multiple-item set. Recall the earlier findings regarding classification rates for phonemes within a single-item subset as opposed to those for phonemes produced in the multiple-lexical set. For both native speakers, the eleven vowel system showed better overall category matches in the single-item subset than in the multiple-item set. There were, however, a few vowels for which it did not matter or which had better category matches in the multiple-item set. These were idiosyncratic to the individual speaker. Similar findings occurred when the vowel productions of NNS03 were considered separately from the native speaker's. That is, the eleven vowels showed a higher overall percentage of correct category matches in the single-item subset as compared to the multiple-item set. Table 7.2 shows the classification rates of the phonemes on the *keep sequence* at Time 1 under two conditions (*F1/F2 Only*, and *F1/F2 plus Duration*) as compared to these same conditions across multiple lexical items. This

first comparison considers the vowel system of the nonnative speaker without the native speaker's value's entered into the analysis.

Table 7.2 Single-Item vs. Multiple-Item Comparison of NNS03 at Time 1

Target Vowel	Single-Item Subset		Multiple-Item Set	
	Percent/Number Correctly Matched: F1/F2	Percent/Number Correctly Matched F1/F2 and Duration	Percent/Number Correctly Matched: F1/F2	Percent/Number Correctly Matched: F1/F2 and Duration
i	80 (4/5)	80 (4/5)	0 (0/10)	0 (0/10)
ɪ	80 (4/5)	60 (3/5)	93.3 (14/15)	93.3 (14/15)
e	100 (5/5)	100 (5/5)	80 (12/15)	86.6 (13/15)
ɛ	100 (5/5)	100 (5/5)	86.6 (13/15)	93.3 (14/15)
æ	100 (5/5)	100 (5/5)	80 (8/10)	80 (8/10)
ʌ	100 (5/5)	100 (5/5)	60 (9/15)	66.6 (10/15)
u	100 (5/5)	100 (5/5)	100 (9/9)	88.8 (8/9)
ʊ	50 (2/4)	100 (4/4)	44.4 (4/9)	44.4 (4/9)
o	60 (3/5)	100 (5/5)	80 (12/15)	60 (9/15)
ɔ	100 (5/5)	80 (4/5)	71.4 (10/14)	71.4 (10/14)
ɑ	100 (5/5)	100 (5/5)	60 (9/15)	60 (9/15)
Total	88.8	92.5	70.4	69.7

The pattern we have been seeing in other speakers holds true for NNS03. If we were to consider vowels in one lexical item or phonetic context, virtually all vowel phonemes uttered by this speaker would be considered distinct from other vowels in the system. On the single-item subset, the total correct was 88.8% for F1/F2 and 92.5% when all three parameters (F1/F2 and Duration) were included in the analysis. Whereas the total correct for the multiple-item set was 70.4% (or 69.7% with all three parameters included).

When compared directly to the native speaker's values, the single-item subset vs. multiple-item set made less of a difference. As shown in Table 7.3, the total correct was virtually the same across all contexts.

Table 7.3 Single Item vs. Multiple Item Comparison of NNS03 Using the native Speaker's Data as Criteria (Time 1)

Target Vowel	Single-Item Subset		Multiple-Item Set	
	Percent/Number Correctly Matched: F1/F2	Percent/Number Correctly Matched F1/F2 and Duration	Percent/Number Correctly Matched: F1/F2	Percent/Number Correctly Matched: F1/F2 and Duration
i	80 (4/5)	80 (4/5)	70 (7/10)	70 (7/10)
ɪ	0 (0/5)	0 (0/5)	6.6 (1/15)	6.6 (1/15)
e	80 (4/5)	80 (4/5)	73.3 (11/15)	93.3 (14/15)
ɛ	20 (1/5)	40 (1/5)	80 (12/15)	46.6 (7/15)
æ	100 (5/5)	100 (5/5)	70 (7/10)	70 (7/10)
ʌ	0 (0/5)	0 (0/5)	0 (0/15)	0 (0/15)
u	60 (3/5)	0 (0/5)	33.3 (3/9)	22.2 (2/9)
ʊ	0 (0/4)	0 (0/5)	44.4 (4/9)	44.4 (4/9)
o	60 (3/5)	60 (3/5)	86.6 (13/15)	13.3 (13/15)
ɔ	20 (1/5)	60 (3/5)	0 (0/15)	78.5 (11/15)
ɑ	100 (5/5)	100 (5/5)	100 (15/15)	100 (15/15)
Total	48.1	48.1	51.4	49.2

7.4. The High and Mid Front Vowels

We now consider the high front vowels /i/ and /ɪ/ (as uttered in the words *keep*, *peek*, *pick*, *pit* and *kid*) and the mid vowels /e/ and /ɛ/ as uttered in the words *take*, *gate*, *paid*, *get*, *pet* and *bed*). Figures 7.1, 7.2 and 7.3 show the F1/F2 plots of these vowels across three times. The four targets form two groups, one in the high front region and one in the mid front region. These two groups are most clearly visible on the Time 3 plot.

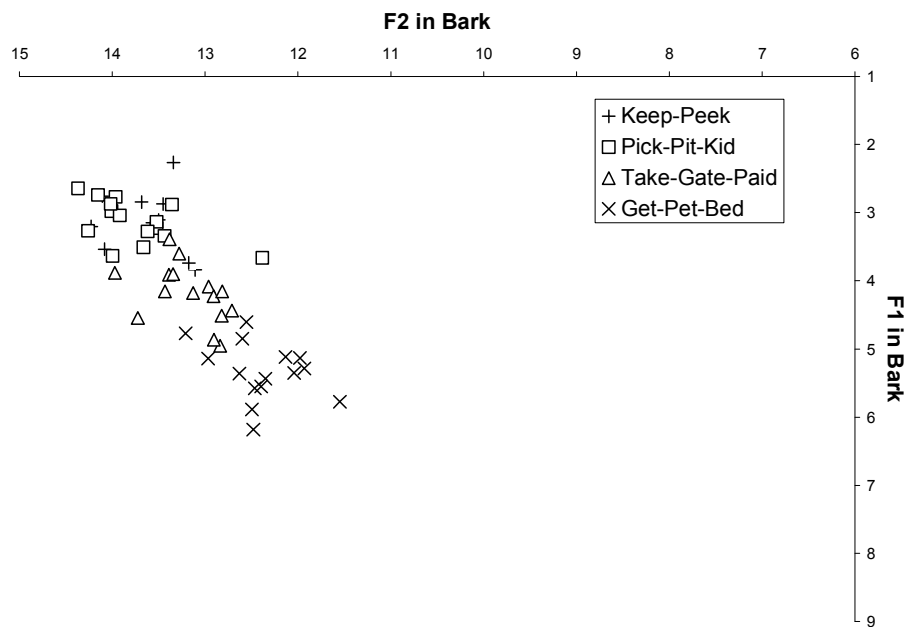


Figure 7.1 F1/F2 plot of the high and mid front vowels at Time 1 pronounced by NNS03

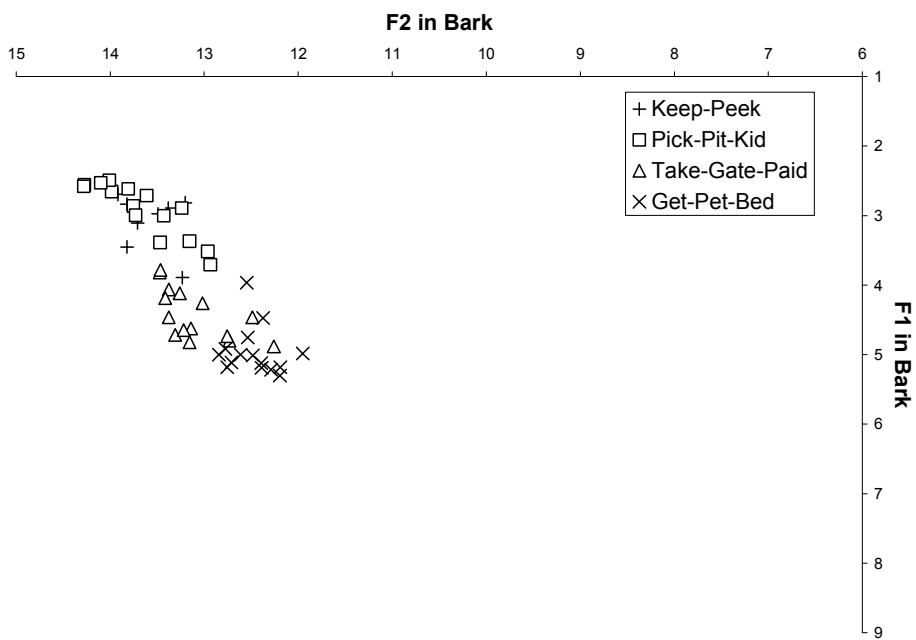


Figure 7.2 F1/F2 plot of the high and mid front vowels at Time 2 pronounced by NNS03

by NNS03

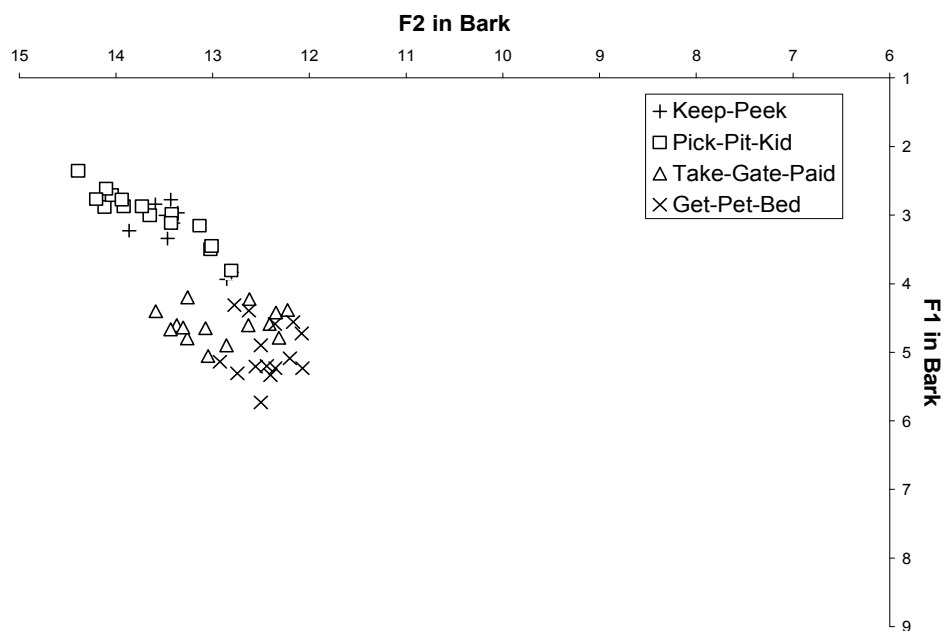


Figure 7.3 F1/F2 plot of the high and mid front vowels at Time 3 pronounced by NNS03

7.4.1. Distribution of /i/, /ɪ/, /e/ and /ɛ/ by NNS03

In order to understand the distribution more clearly we turn to the discriminant analyses.

Table 7.4 shows the results of the analyses for both conditions (*F1/F2 Only* and *F1/F2 plus Duration*) across three points in time.

Table 7.4 Results of the Discriminant Analyses of the Vowels /i/ and /ɪ/ Pronounced by NNS03 across Three Times

Target Vowel	Time 1		Time 2		Time 3	
	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration
i	ɪ (8)	ɪ (9)	ɪ (9)	ɪ (9)	ɪ (8)	ɪ (8)
N=10	e (2)	e (1)	e (1)	e (1)	e (2)	e (1)
	-----	-----	-----	-----	-----	i (1)
% correct	0	0	0	0	0	10
ɪ	ɪ (14)	ɪ (14)	ɪ (14)	ɪ (15)	ɪ (12)	ɪ (11)
N=15	-----	i (1)	-----	-----	i (2)	i (4)
	e (1)	-----	e (1)	-----	e (1)	-----
% correct	93.3	93.3	93.3	100	80	73.3

NNS03 did not clearly differentiate the vowels /i/ and /ɪ/. At Time 1, this speaker produced ten instances of /i/ and fifteen instances of /ɪ/. The discriminant analysis of the F1/F2 values at time one shows that 8 out of 10 attempts at /i/ and 14 out of 15 attempts at /ɪ/ fell into the same F1/F2 range (both /i/ and /ɪ/ were classified as /ɪ/).

Duration means between the two vowels differed by less than 10 msec. When duration was included as an input parameter it had little effect on these contrasts in that it slightly changed the confusion categories but did not generally change the number of times the vowels matched their intended centroids.

There was some change over time in lexical items containing the vowel /ɪ/, in that fewer instances were classified by the discriminant analysis into the target category and more

instances of /ɪ/ were classified as /i/ by Time 3. These were less than the normal variation we saw in the native speakers.

Turning now to the mid front vowels, Table 7.5 shows the results of the analyses on both conditions (*F1/ F2 Only* and *F1/F2 plus Duration*) across three points in time.

Table 7.5 Results of the Discriminant Analyses of the Vowels /e/ and /ɛ/ Pronounced by NNS03 across Three Times

Target Vowel	Time 1		Time 2		Time 3	
	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration
e N= 15	e (12)	e (13)	e (12)	e (13)	e (12)	e (13)
	ɛ (2)	ɛ (1)	ɛ (3)	ɛ (2)	ɛ (3)	ɛ (2)
	ɪ (1)	ɪ (1)	-----	-----	-----	-----
% correct	80	86.6	80	86.6	80	86.6
ɛ N=15	ɛ (13)	ɛ (14)	ɛ (13)	ɛ (14)	ɛ (11)	ɛ (12)
	e (2)	e (1)	e (2)	e (1)	e (6)	e (3)
	% correct	86.6	93.3	86.6	93.3	73.3

NNS03 clearly differentiated the vowels /e/ and /ɛ/. In total, this speaker produced fifteen instances of /e/ and fifteen instances of /ɛ/. A discriminant analysis of the F1/F2 values at Time 1 showed that 12 out of the 15 instances of /e/ were distinct from /ɛ/ (with two falling into the F1/F2 range of /ɛ/ and one falling into the range of /ɪ/). Of the fifteen attempts at the vowel /ɛ/, thirteen were distinct from /e/, with two falling into the F1/F2 range of /e/.

Duration means of these vowels initially differed by about 70 msec. Duration had a small effect on the classification of these vowels in that both /e/ and /ɛ/ were slightly more distinct from each other when duration was included as a parameter

With respect to change over time, the classification rates of /ɛ/ decreased, the number of confusions of /ɛ/ with /e/ increased, there were no other confusion categories, and the classification rates of /e/ did not change. Had the change been greater than the normal variation we saw in the native speakers this change would be identified as a merger, but two instances were not enough to classify this as change.

7.4.2. Comparison of /i/, /ɪ/, /e/ and /ɛ/ to the Native Speaker

We now consider the front vowels in comparison to the native speaker beginning with the high front vowels /i/ and /ɪ/. Table 7.6 shows the results of the discriminant analyses of the vowels /i/ and /ɪ/ as produced by NNS03 in direct comparison to the F1/F2 and duration values of the native speaker.

Table 7.6 Results of the Discriminant Analyses of the Vowels /i/ and /ɪ/ Pronounced by NNS03 Compared to the Native Speaker

Target Vowel	Time 1		Time 2		Time 3	
	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration
i	i (7)	i (7)	i (8)	i (8)	i (7)	i (7)
N=10	e (3)	e (3)	e (2)	e (2)	e (3)	e (2)
	-----	-----	-----	-----	-----	ɪ (1)
% correct	70	70	80	80	70	70
ɪ	ɪ (1)	ɪ (1)	-----	ɪ (4)	ɪ (1)	ɪ (4)
N=15	i (11)	i (11)	i (11)	i (10)	i (11)	i (11)
	e (3)	e (3)	e (4)	e (1)	e (3)	-----
% correct	6.6	6.6	0	26.6	6.6	26.6

When matched against the native speaker data, the majority of both vowels fell into the F1/F2 range of the native speaker's /i/. At Time 1, 7 of 10 attempts at /i/ were matched to the native speaker's F1/F2 values of /i/ (with the remaining three being matched to /e/).

Only 1 of 15 attempts at /ɪ/ was matched to the native speaker's F1/F2 values for /ɪ/. Not surprisingly, of the fifteen attempts at /ɪ/, eleven were matched to /i/.

Duration had no effect on the classification of /i/ but had some effect on the classification of /ɪ/. When duration was included as a parameter in the discriminant analysis, the number of correct classifications of the vowel /ɪ/ increased by three instances. This improvement did not occur at Time 1 but by Time 2, NNS03 was using duration to some extent to differentiate these vowels.

With respect to change across time, the vowel /i/ was relatively stable, only changing by one instance across time. This stability was evident regardless of whether duration was included or excluded from the analysis. The vowel /i/ showed slight improvement from Time 1 to Time 2 and mainly when duration was included in the analysis. As discussed in previous chapters, this pattern is towards split but by duration not by formants.

We now consider the mid front vowels in comparison to the native speaker's data. Table 7.7 shows how the target vowels /e/ and /ɛ/, as produced by NNS03, were distributed in direct comparison to the F1/F2 and duration values of the native speaker.

Table 7.7 Results of the Discriminant Analyses of the Vowels /e/ and /ɛ/ Pronounced by NNS03 Compared to Native Speaker

Target Vowel	Time 1		Time 2		Time 3	
	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration
e	e (11)	e (14)	e (10)	e (13)	e (6)	e (12)
N=15	ɛ (4)	ɛ (1)	ɛ (5)	ɛ (2)	ɛ (9)	ɛ (3)
% correct	73.3	93.3	66.6	86.6	40	80
ɛ	ɛ (12)	ɛ (7)	ɛ (14)	ɛ (14)	ɛ (13)	ɛ (12)
N=14	æ (3)	æ (6)	-----	-----	æ (1)	æ (2)
	-----	e (2)	e (1)	e (1)	e (1)	e (1)
% correct	80	46.6	93.3	93.3	86.6	80

NNS03 produced the vowels /e/ and /ɛ/ closer to the native speaker's vowels than he did the vowels /i/ and /ɪ/. At Time 1, 11 of 15 attempts at /e/ matched the F1/F2 values of the

native speaker's category for /e/ and 12 of 14 attempts at /ɛ/ matched the native speaker's category for /ɛ/.

With duration included as a parameter, there is better classification of the vowel /e/ at all times. On the other hand, duration confounds the classification rates of /ɛ/ at Time1 and Time 3 increasing the number of times /ɛ/ is confused with /æ/.

With respect to change over time, it is fair to say that there was a decrease in the classification rates of the vowel /e/. With all parameters included /e/ decreased from 93% to 80% correct by Time 3. This small change becomes more noteworthy when we consider the F1/F2 parameters alone. The F1/F2 comparison to the native speaker showed an even greater decrease for /e/ (by five instances or from 73% correct to 40%). It should be noted the vowel /e/ was confused with only one other vowel in the native speaker's system, namely /ɛ/. So as the number of attempts that matched /e/ decreased, the number of instances confused with /ɛ/ increased. We refer to the change in the vowel /e/ as a simple merger, with /e/ being the merging category and /ɛ/ being the absorbing category. When duration was included as an input parameter the vowels remained differentiated. Therefore, this particular merger was a loss of formant distinction.

It is also fair to say that the vowel /ɛ/ showed some improvement over time most notably from Time 1 to Time 2 during which the classification increased from 80% correct

(*F1/F2 Only*) to 93.3% correct. The improvement with duration included was even greater (seven instances or from 46.6% to 93.3%). The vowel /ɛ/ became more differentiated and split from its primary confusion category /æ/ (but mainly by duration).

7.5. The Low Vowels and the Mid Central Vowel

Having examined the high and mid front vowels of NNS03 separately and in comparison to the native speaker, we can move to the low and central vowels. As we have seen with other nonnative speakers in this study, the vowel /æ/ is most likely confused with the vowels /ɑ/ and /ʌ/ and vice versa. Although it is customary when reporting data in vowel studies to group the vowel /æ/ with the front vowels and the vowel /ɑ/ with the back vowels, it seems appropriate to discuss /æ/, /ʌ/ and /ɑ/ together. Consider Figures 7.4, 7.5 and 7.6 which show the F1/F2 plots for the vowels /æ/, /ɑ/, /ʌ/ recorded at three points in time over the period of one year. The vowel /æ/ was uttered in the words *cat* and *pat*, the vowel /ʌ/ was uttered in the words *cut*, *cup* and *cut* and the vowel /ɑ/ was uttered in the words *pot*, *cop* and *top*. Not surprisingly there is a great deal of overlap between the three vowels but one can also discern small subgroups of these vowels that are somewhat separate. For example, there are approximately seven instances of /ʌ/ (represented by the symbol □ in the plot) that are higher than the other vowels and a few instances of /ɑ/ that are higher and further back than other instances. We can speculate that these are instances of sound spelling errors in which words containing /ʌ/ and spelled with “u” were

misinterpreted to contain high back vowels and words containing /a / and spelled with “o” were misinterpreted as mid back vowels.

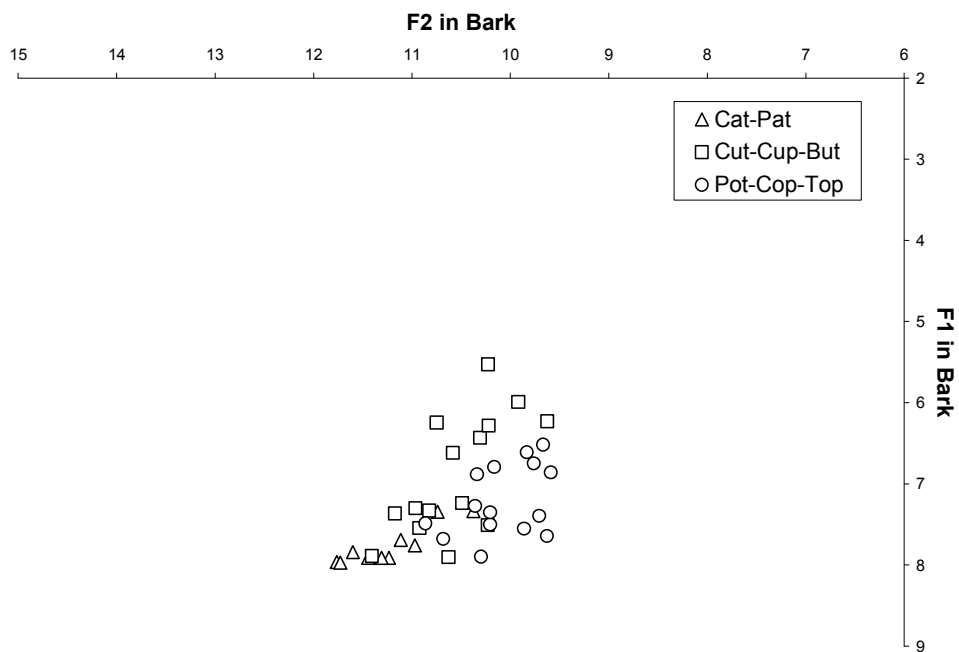


Figure 7.4 F1/F2 plot of the low and central vowels at Time 1 pronounced by NNS03

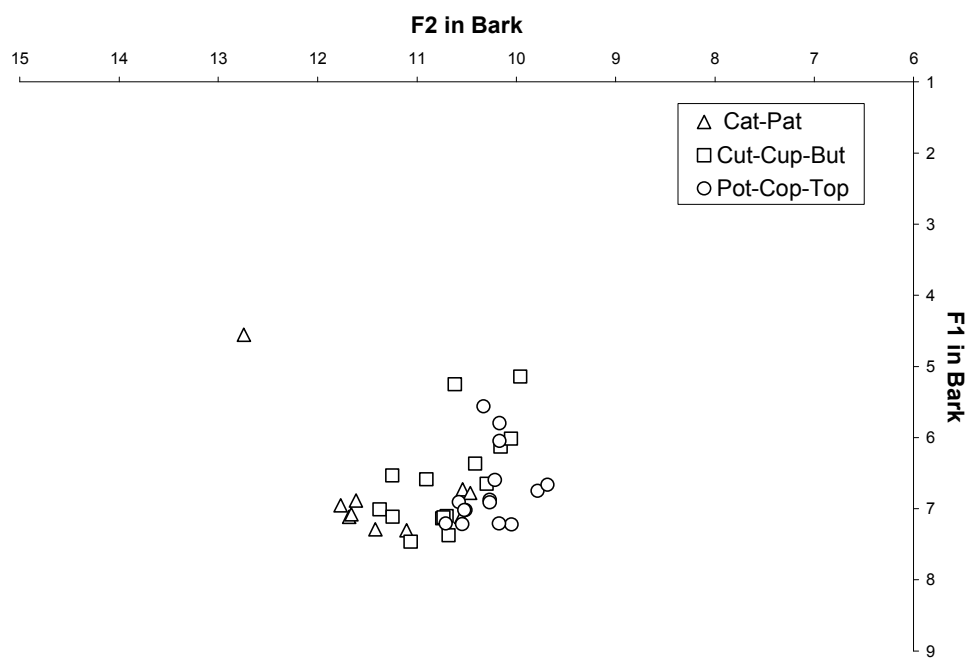


Figure 7.5 F1/F2 plot of the low and central vowels at Time 2 pronounced by NNS03

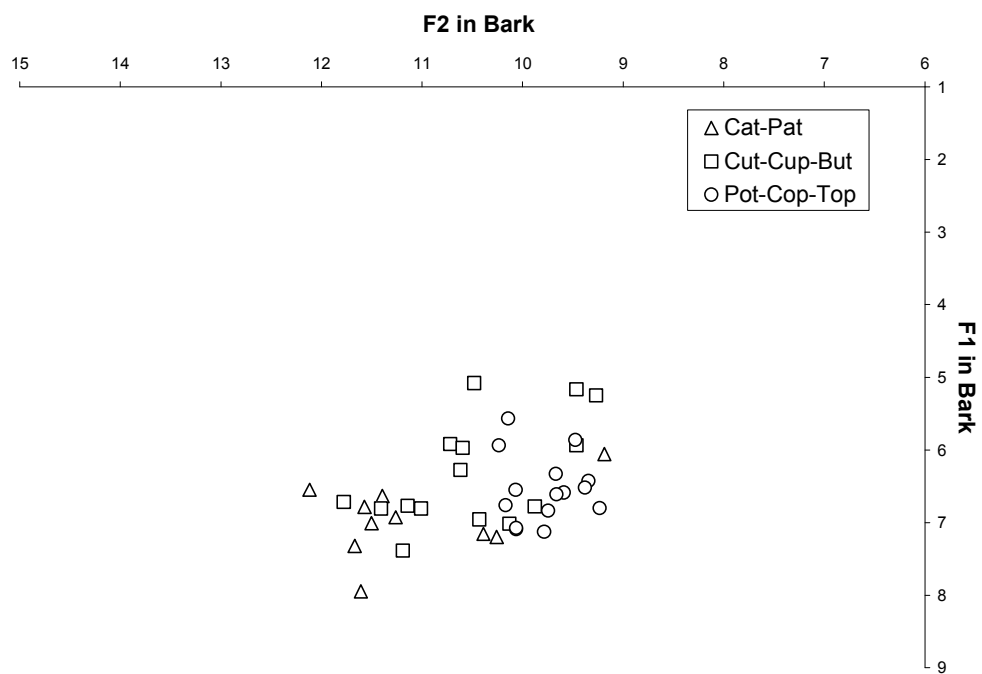


Figure 7.6 F1/F2 plot of the low and central vowels at Time 3 pronounced by NNS03

7.5.1. Distribution of /æ/, /ɑ/ and /ʌ/ by NNS03

In order to understand the distribution more clearly we turn to the discriminant analyses.

Table 7.8 shows the results of the discriminant analyses of these vowels across three times on both conditions (*F1/F2* and *F1/F2 and Duration*) with this nonnative speaker's vowel system considered separately from the native speaker's.

Table 7.8 Results of the Discriminant Analyses of the Vowels /æ/, /ɑ/ and /ʌ/ Pronounced by NNS03 across Three Times

Target Vowel	Time 1		Time 2		Time 3	
	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration
æ N=10	æ (8)	æ (8)	æ (6)	æ (6)	æ (9)	æ (9)
	ʌ (1)	ʌ (1)	ʌ (1)	ʌ (2)	-----	ʌ (1)
	ɑ (1)	ɑ (1)	ɑ (2)	ɑ (1)	ɑ (1)	-----
	-----	-----	e (1)	-----	-----	-----
	-----	-----	-----	ε (1)	-----	-----
% correct	80	80	60	60	90	90
ʌ N=15	ʌ (9)	ʌ (10)	ʌ (5)	ʌ (7)	ʌ (3)	ʌ (2)
	æ (4)	æ (4)	æ (3)	æ (3)	æ (5)	æ (6)
	ɑ (2)	ɑ (1)	ɑ (5)	ɑ (4)	ɑ (4)	ɑ (4)
	-----	-----	ɔ (1)	-----	ɔ (3)	ɔ (2)
	-----	-----	ε (1)	ε (1)	-----	ε (1)
% correct	60	66.6	33.3	46.6	20	13.3
ɑ N=15	ɑ (9)	ɑ (9)	ɑ (12)	ɑ (11)	ɑ (12)	ɑ (11)
	ʌ (4)	ʌ (4)	ʌ (3)	ʌ (4)	ʌ (1)	ʌ (4)
	æ (2)	æ (2)	-----	-----	-----	-----
	-----	-----	-----	-----	ɔ (2)	-----
	-----	-----	-----	-----	-----	-----
% correct	60	60	80	73.3	80	73.3

NNS03 does make some distinction between the vowels /æ/, /ɑ/ and /ʌ/. At Time 1, eight instances of the vowel /æ/, nine instances of the vowel /ʌ/ and nine instances of the vowel

/ɑ/ were considered to be distinct on the F1/F2 parameters. Notice also that at Time 1, the speaker was consistent with the confusion categories in that the three vowels are confused only with each other.

Initially, the vowel /ɑ/ had the longest duration means with /æ/ being shorter by about 20 msec. The vowel /ʌ/ was the shortest of the three but was still longer than the native speaker's /ʌ/ by about 40 msec. At Time 1, duration had virtually no effect on classification rates.

Longitudinally, an interesting change occurred. The number of correct instances of each vowel decreased at Time 2 with the exception of /ɑ/ which increased by 2-3 instances.

The vowels /æ/ and /ʌ/ both dispersed somewhat, increasing the number of other vowels with which they were confused and decreasing the number of correct instances. By Time 3, the number of correct instances of /ʌ/ decreased from 9-10 at Time 1 to 2-3 at Time 3.

As this happened, the number of correct instances of /æ/ and /ɑ/ both increased and the number of other vowels that /ʌ/ is confused with also increased. We can certainly say that the change in /ʌ/ was greater than the normal variation we saw in the native speakers and that this is a case of dispersion in that what was a relatively distinct category has scattered among multiple other categories. The changes in /æ/ and /ɑ/ involved fewer instances and so they may not truly be considered change but they were in the direction of split.

One more matter should be discussed before comparing these vowels to the native speaker's data. The vowel /æ/ has thus far been discussed in the words *cat* and *pat* with the word *bad* treated separately. The inclusion of the word *bad* had little effect on the percentage of correct category matches for this vowel when this nonnative speaker's system was considered independently of the native speaker. None of the relevant vowels (/æ/, /ɑ/ or /ʌ/) differed from the above analysis by more than one instance.

7.5.2. Comparison of /æ/, /ɑ/ and /ʌ/ to the Native Speaker

Next we consider how the vowels /æ/, /ɑ/ and /ʌ/ compared to the native speaker's categories as shown in Table 7.9

Table 7.9 Results of the Discriminant Analyses of the Vowels /æ/, /ɑ/ and /ʌ/ Pronounced by NNS03 Compared to the Native Speaker

Target Vowel	Time 1		Time 2		Time 3	
	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration
æ N=10	æ (7)	æ (7)	æ (6)	æ (6)	æ (7)	æ (7)
	ɑ (3)	ɑ (3)	ɑ (3)	ɑ (3)	ɑ (3)	ɑ (3)
	-----	-----	ε (1)	ε (1)	-----	-----
% correct	70	70	60	60	70	70
ʌ N=15	-----	-----	ʌ (1)	ʌ (1)	ʌ (3)	ʌ (3)
	ɑ (13)	ɑ (13)	ɑ (10)	ɑ (9)	ɑ (8)	ɑ (8)
	æ (2)	æ (2)	æ (4)	æ (4)	æ (4)	æ (4)
	-----	-----	-----	ε (1)	-----	-----
% correct	0	0	6.6	6.6	20	20
ɑ N=15	ɑ (15)	ɑ (15)	ɑ (15)	ɑ (15)	ɑ (15)	ɑ (15)
% correct	100	100	100	100	100	100

At Time 1, the vowel /ɑ/ matched the native speaker's category for /ɑ/ by 15 out of 15 instances (100%) regardless of whether duration was included or not. The next most accurate vowel was /æ/ which matched the native speaker's category for /æ/ at a rate of 70% (7 out of 10) regardless of whether duration was included. The vowel /ʌ/ did not match the native speaker's category for /ʌ/ at all and in fact, 13 out of 15 attempts at this vowel fell into the range of the native speaker's /ɑ/, with the other two attempts matching the native speaker's /æ/

Both /æ/ and /ɑ/ were stable across time but the vowel /ʌ/ improved slightly by Time 3.

Note that at Time 3, three attempts at the vowel /ʌ/ matched the native speaker's category for /ʌ/ where at Time 1 none had. If the number of instances had been greater than the normal variation for the native speakers we would refer to this as split in that an empty or nonexistent category had members at Time3.

The results reported above excluded the lexical item *bad* but there are interesting differences when the lexical item *bad* was included in the discriminant analysis.

Beginning with the vowel /æ/, there was a dramatic difference in classification rates when the lexical item *bad* was included. In fact, at Time 1, all 15 attempts at /æ/ were categorized as /ɑ/ regardless of whether duration was included or not. The vowel /ʌ/ remained at 0% correct and the vowel /ɑ/ remained at 100% correct at Time 1. There was also some change over time when the lexical item *bad* was included in the data.

Specifically, from Time 1 to Time 2, the vowel /æ/ improved from 0% correct to 33% (5 out of 15) correct and was maintained to Time 3. The vowel /ʌ/ improved from 0% correct to 6.6% correct (1 out of 15) at Time 2 to 20% correct (2 out of 15) at Time 3.

The vowel /ɑ/ remained stable at 100% correct across the three recordings.

7.6. The High Back Vowels

NNS03 ultimately wound up with nine usable attempts at the vowel /u/ and nine usable attempts at the vowel /ʊ/. Looking at the Figures 7.7, 7.8, and 7.9, which show the F1/F2 plots of these vowels across three points in time, we can see that five instances of /ʊ/ are separate in the F1/F2 space from the vowel /u/ at Time 1. These are all instances of the word *took*, indicating that NNS03 exhibits fronting of the vowel /ʊ/ after an alveolar. The other instances of /ʊ/ are close to the F1/F2 space of /u/. It should be noted that for the native speakers, an F2 of between 9 and 12 Bark was normal for /ʊ/ regardless of whether there was an alveolar consonant or not. Fronting for the nonnative speaker actually pulled instances of /ʊ/ out of the F2 range of /u/ to make them closer to the native speaker's category.

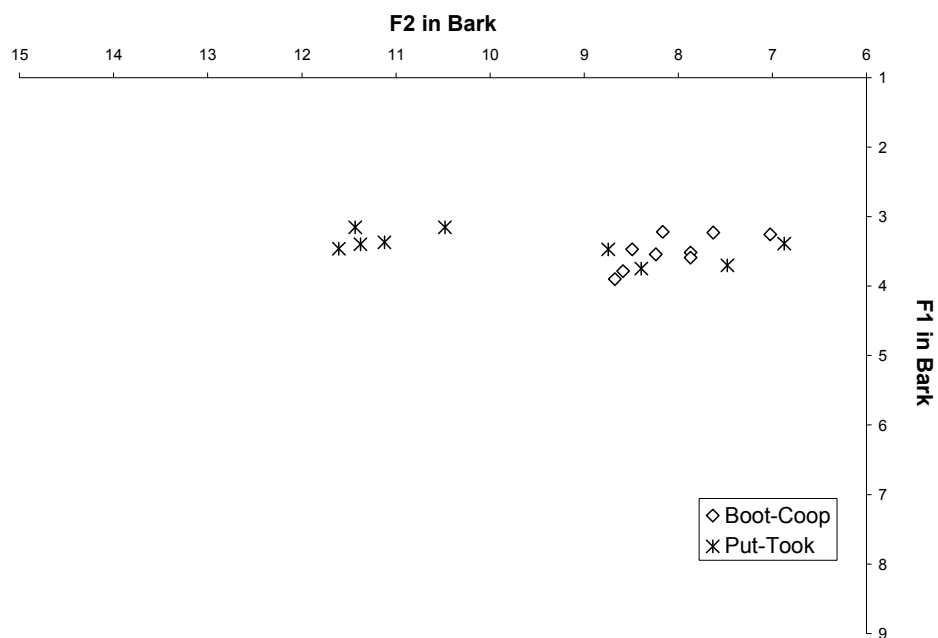


Figure 7.7 F1/F2 plot of the high back vowels at Time 1 pronounced by NNS03

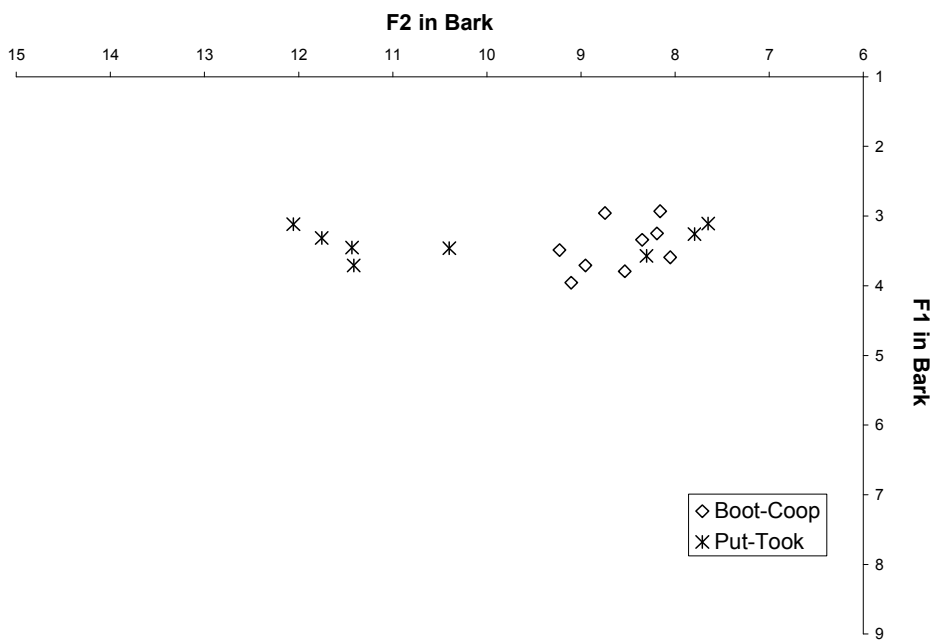


Figure 7.8 F1/F2 plot of the high back vowels at Time 2 pronounced by NNS03

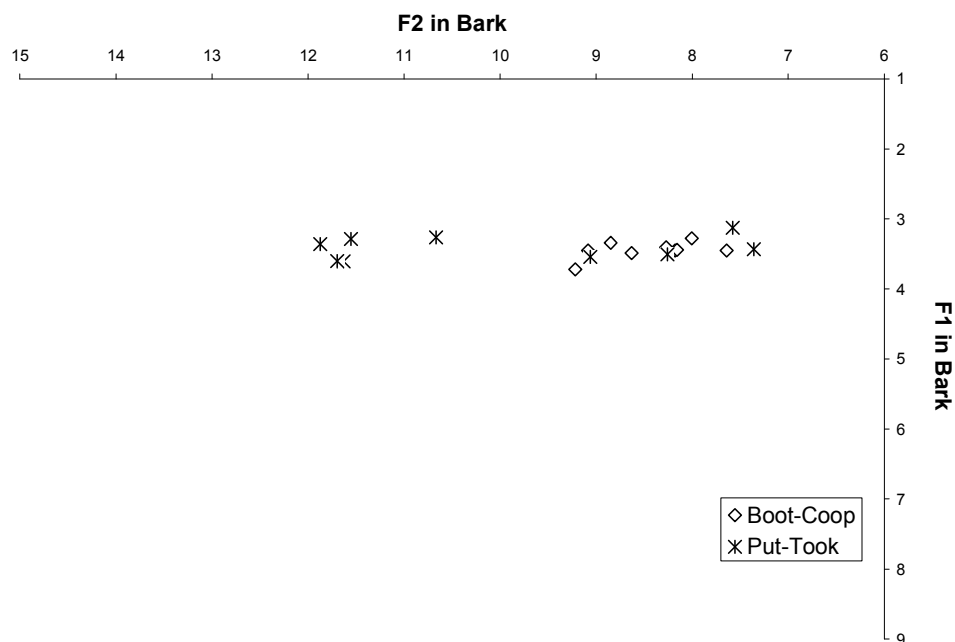


Figure 7.9 F1/F2 plot of the high back vowels at Time 3 pronounced by NNS03

7.6.1. Distribution of /u/ and /ʊ/ by NNS03

In order to understand the distribution more clearly we turn to the discriminant analyses of these vowels. Table 7.10 shows the results of the discriminant analyses of these vowels across three times on both conditions (*F1/F2 Only* and *F1/F2 plus Duration*) with this nonnative speaker's vowel system considered separately from the native speaker's.

Table 7.10 Results of the Discriminant Analyses of the Vowels /u/ and /ʊ/ Pronounced by NNS03 across Three Times

Target Vowel	Time 1		Time 2		Time 3	
	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration
u	u (9)	u (8)	u (8)	u (7)	u (9)	u (8)
N= 9	-----	ʊ (1)	ʊ (1)	ʊ (2)	-----	ʊ (1)
% correct	100	88.8	88.8	77.7	100	88.8
ʊ	ʊ (4)	ʊ (4)	ʊ (2)	ʊ (4)	ʊ (4)	ʊ (5)
N=9	u (4)	u (4)	u (4)	u (3)	u (4)	u (3)
	e (1)	e (1)	e (1)	-----	-----	-----
	-----	-----	ɪ (2)	ɪ (2)	-----	-----
	-----	-----	-----	-----	i (1)	i (1)
% correct	44.4	44.4	22.2	44.4	44.4	55.5

NNS03 had some distinction between the vowels /u/ (as uttered in the words *boot* and *coop*) and /ʊ/ (as uttered in the words *put* and *took*). A discriminant analysis of F1/F2 values indicated that at Time 1, 9 out of 9 attempts (100%) at this vowel were classified as distinct from /ʊ/ as well as other vowels in this study. Only 4 out of 9 attempts at the vowel /ʊ/ were distinct, with four attempts falling into the F1/F2 range of /u/.

Initially, duration means for these vowels differed by about 60 msec. When duration was included as an input parameter it had little effect this distinction, increasing the number of accurate attempts at /ʊ/ by one or two and decreasing the number of accurate attempts at /u/ by one.

With respect to change over time these vowel remained relatively stable. The only notable change was for the vowel /ʊ/ at Time 2 (on *F1/F2 Only* condition). In this case, the classification rate of the vowel /ʊ/ dropped by 50% (from four correct instances to two correct instances) and the number of categories with which it was confused increased.

As with the other speakers, the first data set reported excluded the word *tube*. With the word *tube* included in the analysis, the accuracy of /u/ is 76.9% (10 out of 13) and the accuracy of the /ʊ/ remains at 44.4% (or 4 out of 9). The patterns of stability are comparable to those described above.

7.6.2. Comparison of /u/ and /ʊ/ to the Native Speaker

When compared to the F1/F2 values of the native speaker, the classification rates of the vowels /u/ and /ʊ/ were lower and decreased over time (as shown in 7.11).

Table 7.11 Results of the Discriminant Analyses of the Vowels /u/ and /ʊ/ Pronounced by NNS03 Compared to the Native Speaker

Target Vowel	Time 1		Time 2		Time 3	
	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration
u	u (3)	u (2)	u (4)	u (1)	u (1)	u (1)
N= 9	ɔ (5)	ɔ (7)	ɔ (4)	ɔ (7)	ɔ (6)	ɔ (8)
	o (1)	-----	-----	o (1)	o (1)	-----
	-----	-----	Λ (1)	-----	Λ (1)	-----
	% correct	33.3	22.2	44.4	11	11
ʊ	ʊ (4)	ʊ (4)	ʊ (1)	ʊ (1)	ʊ (1)	ʊ (1)
N= 9	ɪ (1)	ɪ (1)	ɪ (4)	ɪ (4)	ɪ (4)	ɪ (4)
	u (1)	-----	u (2)	u (3)	u (1)	u (2)
	o (1)	o (2)	o (1)	o (1)	o (1)	o (1)
	ɔ (2)	ɔ (2)	ɔ (1)	-----	ɔ (2)	-----
	-----	-----	-----	-----	-----	Λ (1)
% correct	44.4	44.4	11	11	11	11

At Time 1, three instances of /u/ and four instances of /ʊ/ were differentiated at least with respect to F1/F2. Duration decreased the classification rates of the vowel /u/, and by Time 3 only one instance if each vowel was classified as matching the correct centroid. Although it would be a stretch by any criteria to say that the vowels /u/ and /ʊ/ were ever truly accurate matches to this native speaker's categories, we can certainly say that whatever small differentiation that was initially made had disappeared by Time 3. The type of change for both vowels would be dispersion. Although technically dispersed already at Time 1, that dispersion increased by Time 3.

7.7. The Mid Back Vowels

Finally, we consider the mid back vowels /o/ and /ɔ/ as uttered in the words *coat*, *boat*, *code* and *talk*, *caught*, and *taught*. The F1/F2 plots of these vowels are shown below in Figures 7.10, 7.11 and 7.12. The plots also include the vowels /ɑ/ and /ʌ/ because these are primary confusion categories for this pair, although this confusion will not be apparent until this nonnative speaker is compared to the native speaker

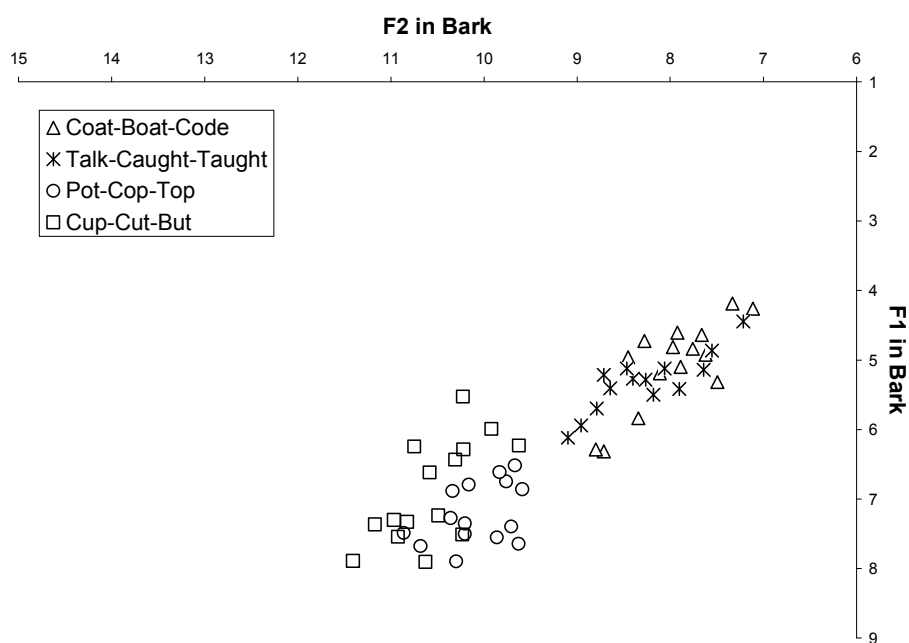


Figure 7.10 F1/F2 plot of the mid back vowels at Time 1 pronounced by NNS03

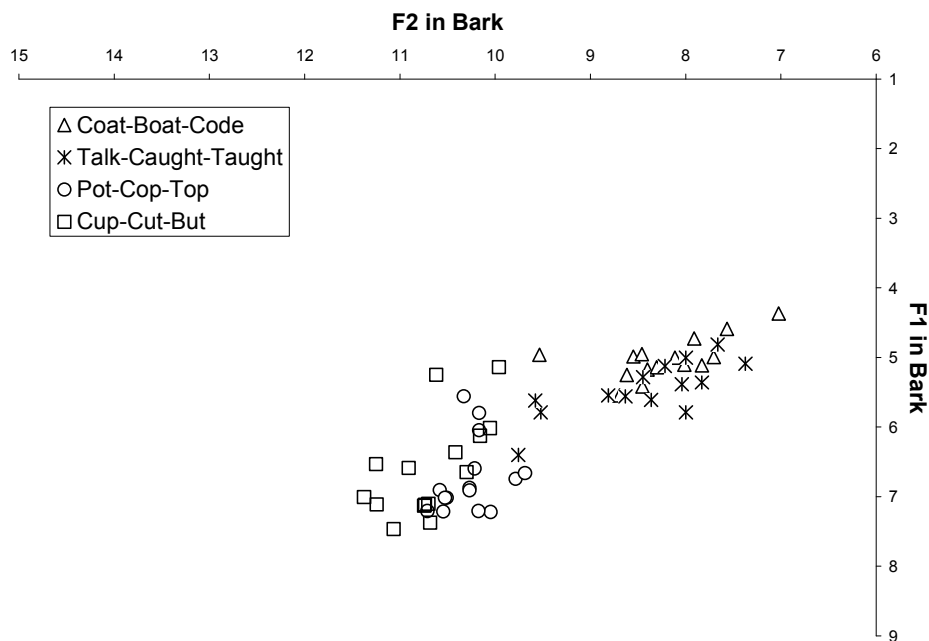


Figure 7.11 F1/F2 plot of the mid back vowels at Time 2 pronounced by NNS03

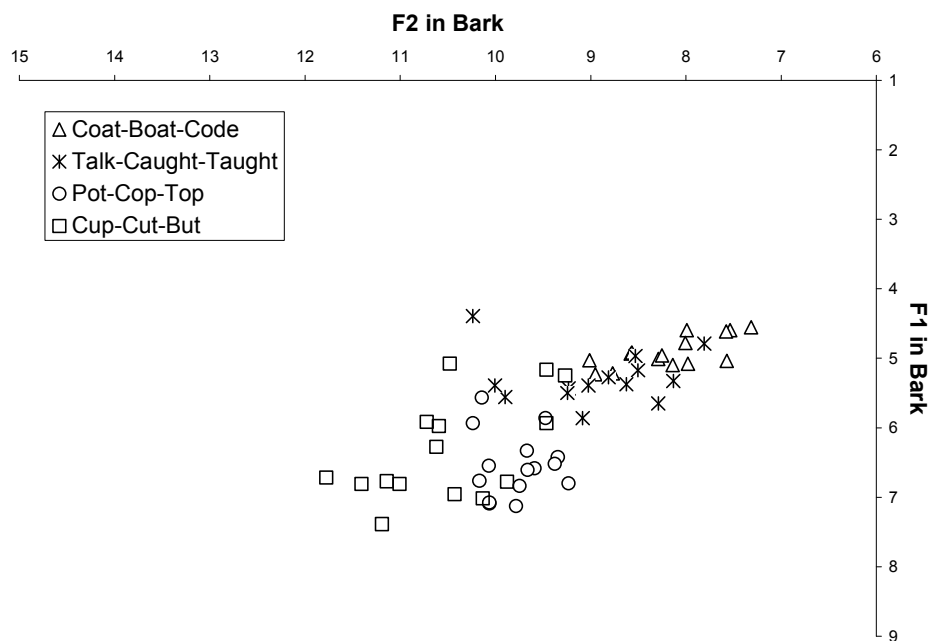


Figure 7.12 F1/F2 plot of the mid back vowels at Time 3 pronounced by NNS03

7.7.1. Distribution of /o/ and /ɔ/ by NNS03

We first consider the results of the discriminant analyses of these vowels independently of the native speaker's vowels as shown in 7.12.

Table 7.12 Results of the Discriminant Analyses of the Vowels /o/ and /ɔ/ Pronounced by NNS03 across Three Times

Target Vowel	Time 1		Time 2		Time 3	
	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration
o N=15	o (12)	o (9)	o (12)	o (12)	o (12)	o (13)
	ɔ (3)	ɔ (6)	ɔ (3)	ɔ (3)	ɔ (3)	ɔ (2)
	% correct	80	60	80	80	80
ɔ N=14	ɔ (10)	ɔ (10)	ɔ (8)	ɔ (8)	ɔ (9)	ɔ (10)
	o (4)	o (4)	o (5)	o (5)	o (4)	o (3)
	-----	-----	ɑ (1)	ɑ (1)	-----	-----
	-----	-----	-----	-----	ʊ (1)	ʊ (1)
	% correct	71.4	71.4	57.1	57.1	64.2

NNS03 differentiated the vowels /o/ and /ɔ/ to some extent. At Time 1, 12 out of 15 attempts (80%) were classified as correct matches and 10 out of 14 attempts at /ɔ/ (71.4%) were considered classified as correct matches on the *F1/F2 Only* condition.

Initially differences between duration means were about 10 msec. When duration was included as an input parameter, the classification rate of /o/ decreased from twelve correct to nine correct (at Time 1), stayed the same at Time 2 and increased by 1 instance at Time 3. Duration had no effect on the vowel /ɔ/ at Times 1 or 2 and a negligible effect at Time 3.

These vowels were relatively stable over time, changing by no more than one or two instances.

7.7.2. Comparison of /o/ and /ɔ/ to the Native Speaker

When compared to the F1/F2 values of the native speaker the results are strikingly different. In order to see this, consider Table 7.13 below first looking at the vowels at Time 1 on the *F1/F2 Only* condition compared to the *F1/F2 plus Duration* condition.

Table 7.13 Results of the Discriminant Analyses of the Vowels /o/ and /ɔ/ Pronounced by NNS03 Compared to the Native Speaker

Target Vowel	Time 1		Time 2		Time 3	
	NS Match /# of Tokens F1/F2	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2	NS Match /# of Tokens F1/F2 Duration
o N=15	o (13)	o (2)	o (12)	o (2)	o (12)	o (3)
	-----	ɔ (12)	-----	ɔ (12)	-----	ɔ (12)
	ɑ (2)	ɑ (1)	-----	-----	-----	-----
	-----	-----	Λ (3)	Λ (1)	Λ (3)	-----
% correct	86.6	13.3	80	13.3	80	20
ɔ N=14	-----	ɔ (11)	-----	ɔ (10)	-----	ɔ (7)
	o (9)	o (1)	o (9)	o (1)	o (5)	o (1)
	Λ (3)	-----	Λ (2)	-----	Λ (7)	Λ (3)
	ɑ (2)	ɑ (2)	ɑ (3)	ɑ (3)	ɑ (2)	ɑ (3)
	% correct	0	78.5	0	71.4	0

At Time 1, the vowel /o/ had thirteen correctly matched instances on the F1/F2 condition and the vowel /ɔ/ had zero, with most attempts falling into the F1/F2 range of the native speaker's /o/. With duration included we see virtually the opposite results. That is, the

eleven instances of the vowel /ɔ/ matched the native speaker's category for /ɔ/ and only two instances of the vowel /o/ matched the native speaker's with most attempts categorized as native speaker's /ɔ/. This same pattern held true across the three times, although at Time 3 the vowel /ɔ/ decreased by four instances with all parameters included.

7.8. Summary of the Vowel System of NNS03

When considered independently of the native speaker, NNS03 showed evidence of differentiation between virtually all phonemically relevant pairs with perhaps the exception of /u/ and /ʊ/.

When matched to the native speaker initially, there was no evidence of a category for /ɪ/, with both /i/ and /ɪ/ matching the native speaker's /i/. The vowels /e/ and /ɛ/ were differentiated and both were strong categories matches for their respective targets. The vowel /ɑ/ was an excellent match for its target category, the vowel /æ/ matched roughly 70% of the time and the vowel /ʌ/ did not match at all. The vowels /u/ and /ʊ/ were poor matches to the native speaker's vowels. The vowels /o/ and /ɔ/ were highly confounded by duration, with /o/ being a strong match on F1/F2 but a poor match when duration was included and /ɔ/ being a strong match when duration was included but a poor match on F1/F2 alone.

There were several small changes throughout this sample, but only two exhibited enough change to be considered greater than normal variation. First, when the native speaker was considered independently we saw that /ʌ/ underwent dispersion and as this happened /æ/ and /ɑ/ showed increases in their classification rates.

Second when the nonnative speaker's vowels were compared directly to the native speaker's vowels, we saw /e/ merge into /ɛ/ on the F1/F2 parameters and we saw that lexical items containing the vowel /ɛ/ concentrated and had fewer confusion with /æ/ with respect to duration.

Chapter 8: Analysis of Nonnative Speaker 04

8.1. Background of Nonnative Speaker 04 (NNS04)

Nonnative Speaker 04 (henceforth NNS04) is a male native Spanish speaker, born in Cartagena, Colombia. At the time of the first recording he was 42 years old and had lived in the United States for six months. He began studying English in Colombia at age twelve as part of a high school requirement and continued for eight years. He reported watching about three hours of TV in English per day, reading two newspapers in English per week and reading one book in English per month. He speaks English at both of his workplaces, speaks English at home with his American relatives and speaks English with his friends, most of whom are ESL students but do not speak Spanish as their native language.

8.2. Sample Collection

NNS04 had some difficulty with the sentence-reading task and 41 items were excluded leaving a total of 124. While most vowels were still represented by 10 or more tokens, the vowels /ɔ/ and /u/ were represented by 3 tokens and 5 tokens respectively. The small number of tokens for these vowels makes it difficult to draw conclusions and this issue is discussed subsequently.

In order to determine intra-rater reliability, 17 items from each sample were randomly selected and re-measured. As shown in Table 8.1 below, mean differences between the original measure and the re-measure were less than 10 msec for duration, less than .15 Bark for F1 and F2 at the 50% point.

Table 8.1 **Margin of Error for NNS04**

	Mean Difference Between Time 1 Measure and Re- measure	Mean Difference Between Time 2 Measure and Re- Measure	Mean Difference Between Time 3 Measure and Re- Measure
Duration	5.22 msec	8.27msec	9.97 msec
F1 at 50% Point	0.04 Bark	0.06 Bark	0.04 Bark
F2 at 50% Point	0.11 Bark	0.13 Bark	0.14 Bark

8.3. **Category Matches within Lexical Items**

The single-item subset and multiple-item set comparisons become even more important for NNS04 given the fact that some of his data has been reduced to five or less instances in a single word. Prior to looking at the entire data set one would need to know how the reduction in contexts could potentially affect the analyses of this speaker's vowels system. Table 8.2 below shows the single-item subset and the multiple-item set at Time 1 on both conditions (*F1/F2 Only and F1/F2 plus Duration*). It should be noted that the words *tube* and *talk* are substituted for *boot* and *taught* because NNS04 did not pronounce these items in a way that would be meaningful to the analysis.

Table 8.2 Single-Item vs. Multiple-Item Comparison of NNS04 at Time 1

Target Vowel	Single-Item Subset		Multiple-Item Set	
	Percent/Number Correctly Matched: F1/F2	Percent/Number Correctly Matched F1/F2 and Duration	Percent/Number Correctly Matched: F1/F2	Percent/Number Correctly Matched: F1/F2 and Duration
i	80 (4/5)	80 (4/5)	10 (1/10)	10 (1/10)
ɪ	60 (3/5)	80 (4/5)	100 (15/15)	100 (15/15)
e	80 (4/5)	100 (5/5)	80 (12/15)	93.3 (14/15)
ɛ	60 (3/5)	100 (5/5)	80 (12/15)	93.3 (14/15)
æ	100 (5/5)	100 (5/5)	87.5 (7/8)	87.5 (7/8)
ʌ	75 (3/4)	75 (3/4)	77.7 (7/9)	77.7 (7/9)
u	80 (4/5)	100 (5/5)	40 (2/5)	80 (4/5)
ʊ	100 (5/5)	100 (5/5)	70 (7/10)	60 (7/10)
o	100 (5/5)	100 (5/5)	60 (9/15)	73.3 (11/15)
ɔ	33.3 (1/3)	66.6 (2/3)	0 (0/3)	0 (0/3)
ɑ	80 (4/5)	80 (4/5)	57.1 (8/14)	78.5 (11/14)
Total	78.8	90.3	60.2	68.5

As we have seen in other speakers, when the system is considered as an entity unto itself and not in direct comparison to the native speaker's data, there is a difference between the percentages of correct matches of vowels uttered across lexical items as opposed to within lexical items. In the *keep* sequence, when each vowel was uttered in only one lexical item, the total correct was 78.8% with F1/F2 as the only parameters and 90.3% with F1/F2 and duration as the parameters. This is compared to 60.2% and 68.5% correct when the vowels are considered across three lexical items.

When compared to the native speaker's vowels, the two conditions made little difference in overall percentage of correct category matches as shown in Table 8.3. In fact, when compared to the native speaker, there are only a few vowels that have better classification rates in the single-item subset. It should be noted that the inclusion of more vowels in

varied contexts affected the analysis of the entire system. This can be seen by looking at the vowels /u/ and /ɔ/ in Table 8.2 and 8.3. Note that these vowels did not occur in multiple items for the reasons discussed earlier. Yet the percentage of correct category matches differed across the two conditions. Take the vowel /u/ for example. The number of correct matches was 0-1 in the single-item subset but 3-4 in the multiple-item condition, even though the words *boot* and *coop* were both excluded thus leaving only one lexical item. As more vowels are added, the discriminant analysis recalculates the centroids and reorganizes the groupings.

Table 8.3 Single Item vs. Multiple Item Comparison of NNS04 Using the Native Speaker's Data as Criteria (Time 1)

Target Vowel	Single-Item Subset		Multiple-Item Set	
	Percent/Number Correctly Matched: F1/F2	Percent/Number Correctly Matched F1/F2 and Duration	Percent/Number Correctly Matched: F1/F2	Percent/Number Correctly Matched: F1/F2 and Duration
i	60 (3/5)	60 (3/5)	90 (9/10)	80 (8/10)
ɪ	0 (0/5)	0 (0/5)	0 (0/15)	6.6 (1/15)
e	40 (2/5)	80 (4/5)	80 (12/15)	93.3 (14/15)
ɛ	100 (5/5)	100 (5/5)	53.3 (8/15)	40 (6/15)
æ	0 (0/5)	0 (0/5)	0 (0/8)	0 (0/8)
ʌ	25 (1/4)	25 (1/4)	44.4 (4/9)	55.5 (5/9)
u	20 (1/5)	0 (0/5)	80 (4/5)	60 (3/5)
ʊ	0 (0/5)	0 (0/5)	10 (1/10)	0 (0/10)
o	80 (4/5)	100 (5/5)	86.6 (13/15)	20 (3/15)
ɔ	33.3 (1/3)	33.3 (1/3)	0 (0/3)	0 (0/3)
ɑ	0 (0/5)	0 (0/5)	0 (0/14)	0 (0/14)
Total	32.6	36.5	40.4	32.3

8.4. The High and Mid Front Vowels

Having looked at the single-item subsets we now turn to the vowels across the entire data set, beginning with the high and mid front vowels. Figures 8.1, 8.2 and 8.3 show the F1/F2 plots of the vowels /i/, /ɪ/, /e/ and /ɛ/ as uttered in the words *keep, peek, pick, pit, kid, take, gate, paid, get, pet* and *bed*. As we can see immediately from the F1/F2 plots, there are two major groupings for these four target vowels.

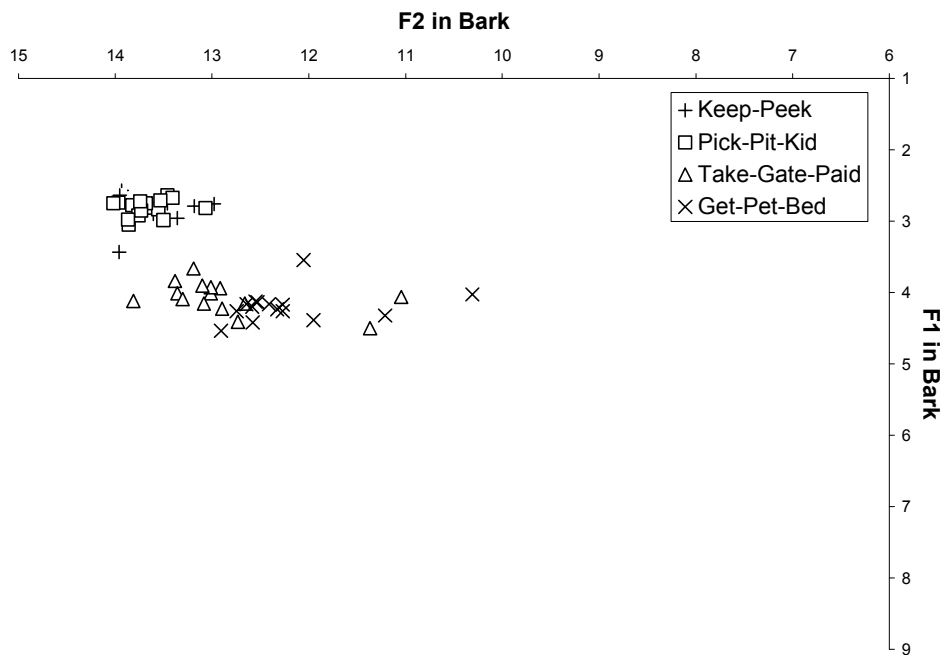


Figure 8.1 F1/F2 plot of the high and mid front vowels at Time 1 pronounced by NNS04

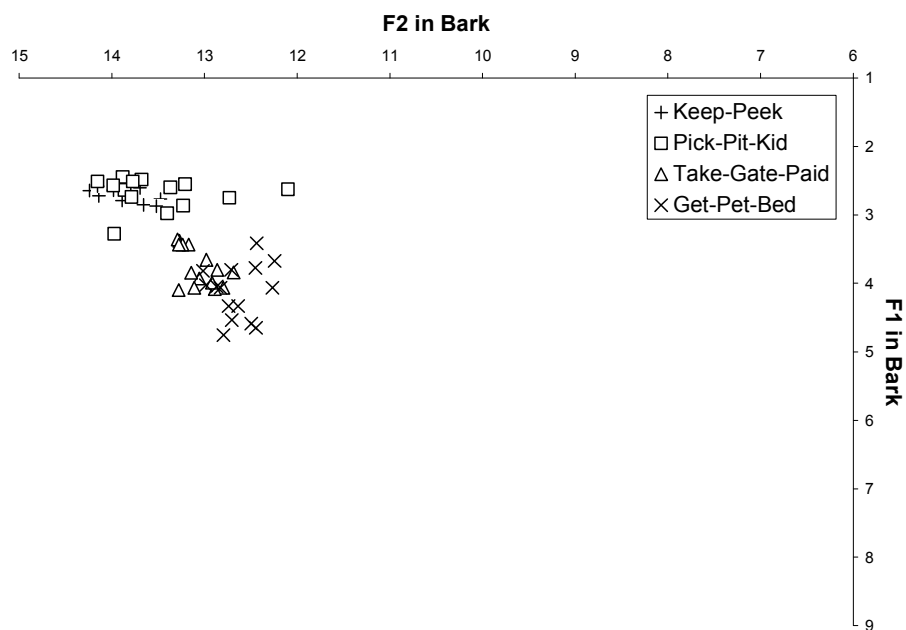


Figure 8.2 F1/F2 plot of the high and mid front vowels at Time 2 pronounced by NNS04

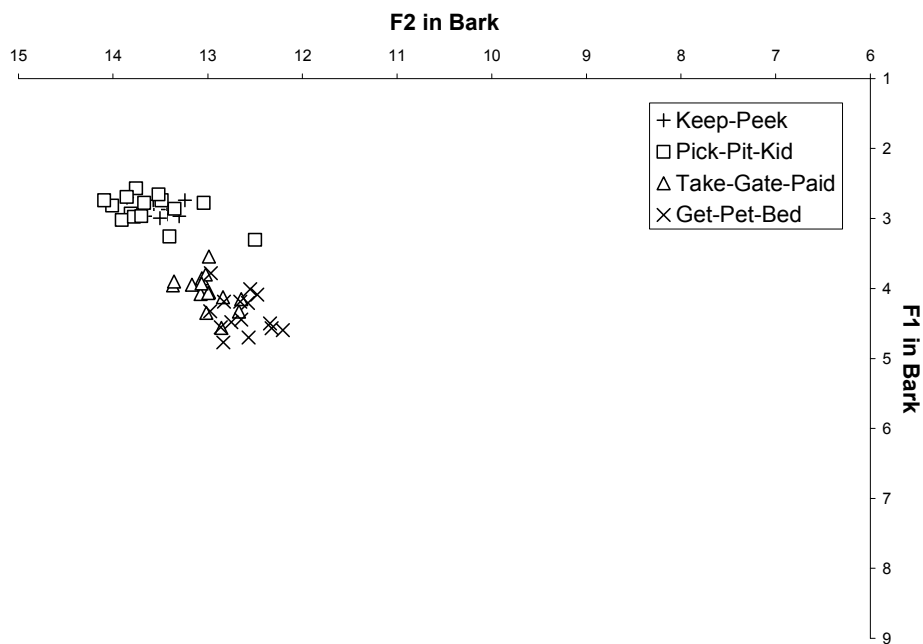


Figure 8.3 F1/F2 plot of the high and mid front vowels at Time 3 pronounced by NNS04

8.4.1. Distribution of /i/, /ɪ/, /e/ and /ɛ/ by NNS04

In order to understand these groupings, we can examine the results of the discriminant analyses as shown in Table 8.4

Table 8.4 Results of the Discriminant Analyses of the Vowels /i/ and /ɪ/ Pronounced by NNS04 across Three Times

Target Vowel	Time 1		Time 2		Time 3	
	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2 Duration
i N=10	i (1) ɪ (9) -----	i (1) ɪ (9) -----	i (1) ɪ (9) -----	----- ɪ (9) e (1)	----- ɪ (10) -----	----- ɪ (10) -----
% correct	10	10	10	0	0	0
ɪ N=15	ɪ (15) ----- -----	ɪ (15) ----- -----	ɪ (14) i (1) -----	ɪ (12) i (3) -----	ɪ (14) ----- e (1)	ɪ (13) i (2) -----
% correct	100	100	93.3	80	93.3	86.6

NNS04 did not clearly distinguish the vowels /i/ and /ɪ/. In total, this speaker attempted 10 instances of /i/ and 15 instances of /ɪ/. A discriminant analysis of the F1/F2 values at Time 1 shows that 24 were considered to be the same category. At the first recording, duration means for these two vowels were virtually identical and duration did not affect the differentiation of these vowels at all when included as an input parameter. These vowels remained stable across time.

Next consider the mid front vowels in Table 8.5. NNS04 differentiated the vowels /e/ and /ɛ/.

Table 8.5 Results of the Discriminant Analyses of the Vowels /e/ and /ɛ/ Pronounced by NNS04 across Three Times

Target Vowel	Time 1		Time 2		Time 3	
	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration
e	e (12)	e (14)	e (11)	e (12)	e (11)	e (12)
N= 15	ɛ (3)	ɛ (1)	ɛ (4)	ɛ (2)	ɛ (4)	ɛ (3)
	-----	-----	-----	ɪ (1)	-----	-----
% correct	80	93.3	73.3	80	73.3	80
ɛ	ɛ (12)	ɛ (14)	ɛ (12)	ɛ (13)	ɛ (11)	ɛ (13)
N=15	e (3)	e (1)	e (3)	e (2)	e (4)	e (2)
% correct	80	93.3	80	86.6	73.3	86.6

In total the speaker attempted fifteen instances of each of these vowels. A discriminant analysis of the F1/F2 values shows that twelve of the attempts at /e/ and twelve of the attempts at /ɛ/ were categorized as distinct from each other and from other vowels in the system. Three attempts at /e/ were considered to be /ɛ/ and three attempts at /ɛ/ were considered to be /e/. At Time 1, duration means between these vowels differed by about 86 msec with /e/ being the longer of the two. When included as an input parameter, duration improved the differentiation of these vowels slightly in that each vowel had fourteen correct attempts and only one instance that fell into the other category.

With respect to change over time, these vowels were relatively stable and maintained differentiation over time.

8.4.2. Comparison of /i/, /ɪ/ /e/ and /ɛ/ to the Native Speaker

We now turn to a comparison of the high and mid front vowels produced by NNS04 as compared to the native speaker's vowels. Beginning with the vowels /i/ and /ɪ/ we see that when matched against the native speaker data, the majority of attempts fell into the F1/F2 range of /i/. Table 8.6 shows the results of the discriminant analyses when the nonnative speaker's values of /i/ and /ɪ/ are evaluated against the native speaker's values.

Table 8.6 Results of the Discriminant Analyses of the Vowels /i/ and /ɪ/ Pronounced by NNS04 Compared to the Native Speaker

Target Vowel	Time 1		Time 2		Time 3	
	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2	NS Match /# of Tokens F1/F2 Duration
i N=10	i (9) e (1) -----	i (8) e (1) ɪ (1)	i (10) ----- -----	i (10) ----- -----	i (10) ----- -----	i (10) ----- -----
% correct	90	80	100	100	100	100
ɪ N=15	----- i (15) -----	ɪ (1) i (14) -----	ɪ (1) i (13) e (1)	ɪ (3) i (11) e (1)	ɪ (1) i (13) e (1)	ɪ (2) i (13) -----
% correct	0	6.6	6.6	20	6.6	13.3

At Time 1, 9 out of 10 attempts at /i/ were matched to the native speaker F1/F2 values of /i/ but 0 out of 15 attempts at /ɪ/ were matched to the native speaker values for /ɪ/. Not surprisingly all fifteen attempts at /ɪ/ were matched to /i/.

Duration had a very small effect on the classification rates of these vowels. When duration was included as a parameter in the discriminant analysis, the percentage of correct attempts at the vowel /i/ decreased slightly from 90% correct to 80% correct, with eight of ten attempts matching the native speaker's /i/, one matching /ɪ/ and one of the attempts matching /e/. Duration improved the classification rate of the vowel /i/ from 0 out of 15 to 1 out of 15 (or 6.6 correct).

With respect to change across time, the vowel /i/ improved slightly in that the few mismatches at Time 1 were eliminated by Time 2 and all 10 attempts were matched to the native speaker's /i/. This accuracy was maintained into Time 3. The vowel /i/ also showed slight improvement from Time 1 to Time 2 with no initial correct attempts to three correct attempts. This change however was not greater than the normal variation we saw in the nonnative speakers.

The mid front vowels were better matches for the native speaker's vowels. Table 8.7 shows the results of the discriminant analyses for the vowels /e/ and /ɛ/ when evaluated against the native speaker's centroids.

**Table 8.7 Results of the Discriminant Analyses of the Vowels /e/ and /ɛ/
Pronounced by NNS04 Compared to the Native Speaker**

Target Vowel	Time 1		Time 2		Time 3	
	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration
e N=15	e (12) ε (2) ----- o (1) u (1)	e (14) ----- o (1) -----	e (15) ----- ----- -----	e (15) ----- ----- -----	e (13) ε (2) ----- -----	e (15) ----- ----- -----
% correct	80	93.3	100	100	86.6	100
ε N=15	ε (8) e (5) ɪ (1) ʌ (1)	ε (6) e (7) ɪ (1) ʌ (1)	ε (6) e (6) ɪ (3) -----	ε (4) e (9) ɪ (2) -----	ε (8) e (7) ----- -----	ε (10) e (5) ----- -----
% correct	53.3	40	40	26.6	53.3	66.6

At Time 1, 12 out of 15 attempts (80%) at the vowel /e/, twelve were matched to the native speaker's category for /e/. Of the 15 attempts at the vowel /e/ eight were matched to native speaker's category for /ε/. For the most part, the primary confusion category for each was the mid counterpart: /e/ was confused with /ε/ and vice versa. Duration improved the classification rate of the vowel /e/ at Time 1 by one instance but decreased the classification rate of /ε/ by two instances.

With respect to change across time, there was a slight increase in the classification of /e/ coupled with a slight decrease in the classification of /ε/ from Time 1 to Time 2. Note also that the vowel /ε/ was confused with /e/ more often at Time 2 than it had been at

Time 1. By Time 3, with all parameters entered into the discriminant analysis, all 15 attempts at /e/ matched the native speaker's category for /e/ and 10 of the 15 attempts at /ɛ/ matched the native speaker's category for /ɛ/. Additionally all other confusion categories were eliminated by Time 3 except for /ɛ/ and /e/.

8.5. The Low Vowels and the Mid Central Vowel

For the other nonnative speakers discussed thus far, the vowels /æ/, /ʌ/, and /ɑ/ were considered together in previous chapters because they were primarily confused with each other in one way or another. This held true for NNS04 for the vowels /æ/ and /ʌ/, which were confused with each other and with the native speaker's category for /ɑ/. But the low back vowel /ɑ/ presented a different pattern for this speaker in that it was confused most frequently with the vowel /o/ (both independently of the native speaker's data and when compared directly to the native speaker's vowels). It is reasonable to assume that spelling may have caused a mid back pronunciation of the vowel /ɑ/ in that all target words eliciting the vowel were actually spelled with the letter "o" (as in *pot*, *cop* and *top*). This sound-spelling confusion was difficult to avoid if the monosyllabic CVC context was to be maintained across the target words. So, we now consider the low vowels and the mid central vowel with two caveats. First, the mid back vowel /o/ will be included in the discussion and the vowel plots so the overlap between /ɑ/ and /o/ can be seen. Second, all conclusions with respect to the vowel /ɑ/ are made under the assumption that the speaker

may have thought he should be pronouncing /o/. Figures 8.4, 8.5 and 8.6 show the F1/F2 plots of these three vowels across three points in time with the vowel /o/ included.

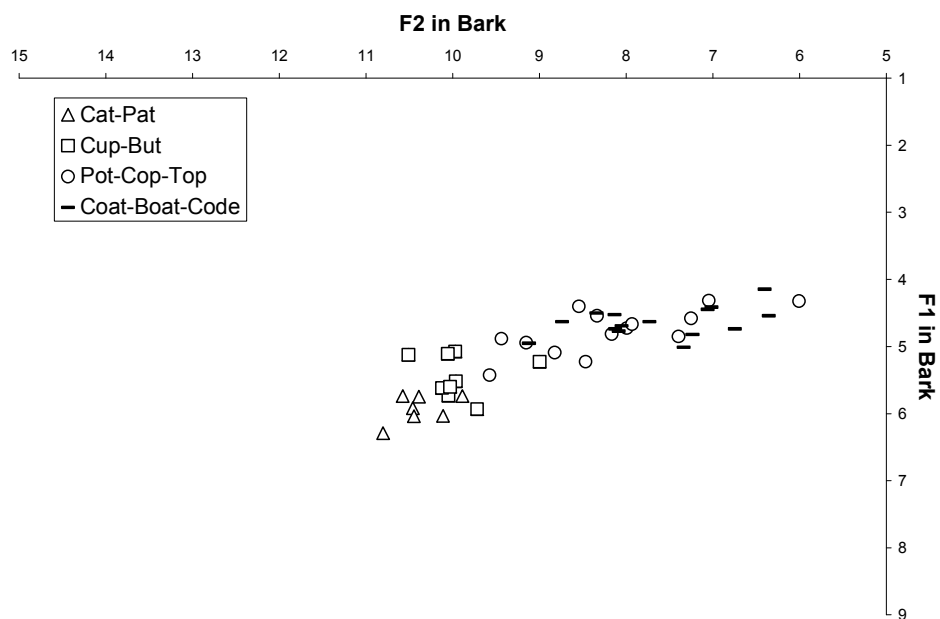


Figure 8.4 F1/F2 plot of the low and central vowels at Time 1 pronounced by NNS04

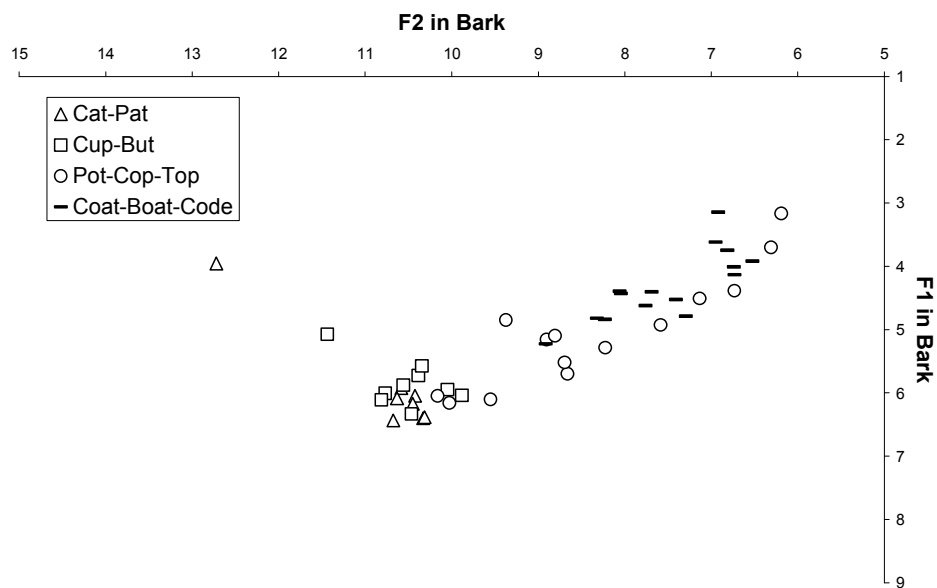


Figure 8.5 F1/F2 plot of the low and central vowels at Time 2 pronounced by NNS04

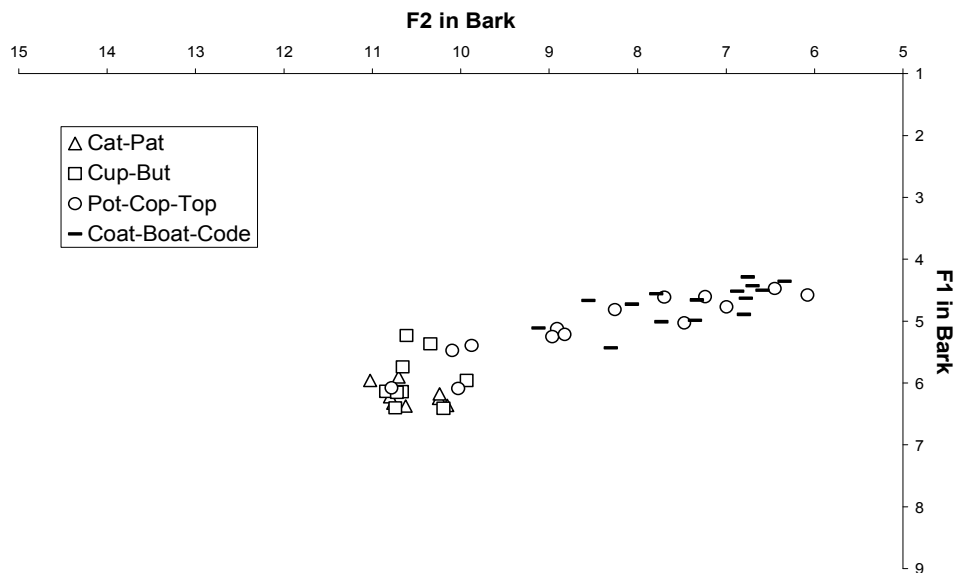


Figure 8.6 F1/F2 plot of the low and central vowels at Time 3 pronounced by NNS04

8.5.1. Distribution of /æ/, /ɑ/ and /ʌ/ by NNS04

Looking to the discriminant analysis, we see that when this nonnative speaker was considered independently of the native speaker, there was some distinction between the three vowels, with /æ/ and /ʌ/ being the most differentiated. Table 8.8 shows the results of the discriminant analysis of these vowels across three times and two conditions (*F1/F2 only and F1/ F2 plus Duration*).

Table 8.8 Results of the Discriminant Analyses of the Vowels /æ/, /ɑ/ and /ʌ/ Pronounced by NNS04 across Three Times

Target Vowel	Time 1		Time 2		Time 3	
	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration
æ N=8	æ (7)	æ (7)	-----	æ (5)	æ (6)	æ (7)
	ʌ (1)	ʌ (1)	ʌ (7)	ʌ (2)	ʌ (2)	ʌ (1)
	-----	-----	ε (1)	-----	-----	-----
	-----	-----	-----	e (1)	-----	-----
% correct	87.5	87.5	0	62.5	75	87.5
ʌ N=9	ʌ (7)	ʌ (7)	ʌ (8)	ʌ (7)	ʌ (5)	ʌ (6)
	æ (2)	æ (2)	æ (1)	æ (2)	æ (4)	æ (3)
	% correct	77.7	77.7	88.8	77.7	55.5
ɑ N=14	ɑ (8)	ɑ (11)	ɑ (7)	ɑ (7)	ɑ (5)	ɑ (7)
	o (5)	o (2)	o (4)	o (4)	o (6)	o (4)
	ʌ (1)	ʌ (1)	ʌ (3)	ʌ (3)	ʌ (2)	ʌ (2)
	-----	-----	-----	-----	æ (1)	æ (1)
% correct	57.1	78.5	50	50	35.7	50

At Time 1, 7 out of 8 attempts at the vowel /æ/ were differentiated from other vowels in the system. Similarly, 7 out of 9 attempts at the vowel /ʌ/ were differentiated from other

vowels in the system. The vowels /æ/ and /ʌ/ each had only one confusion category (each other). At time 1, duration means between these two vowels differed by about 51 msec with /æ/ being the longer of the two. When duration was included as an input parameter the percentage of correct matches was not affected.

With respect to change across time, the vowel /ʌ/ showed a slight decrease by Time 3.

The vowel /æ/ showed a dramatic drop at Time 2 in that there is no F1/F2 distinction at all between the vowels /æ/ and /ʌ/. This decrease can be considered a merge in that two vowels that were somewhat distinct in the F1/F2 space at Time 1 were no longer distinct at Time 2. In fact, NNS04 relied heavily on duration to differentiate these vowels. By Time 3, the distinction returns to roughly its state at Time 1 with some decrease in the accuracy of /ʌ/. Overall, this is a pattern of merger followed by a subsequent split. It should be noted that at Time 2 when the lexical item *bad* is included in the discriminant analysis, the classification of /æ/ increased to 92% with 12 of 13 attempts differentiated from other vowels on the F1/F2 parameters and 8 of 13 attempts differentiated on all three parameters.

The vowel /a/ showed some differentiation in that at Time 1, 8 of 14 instances were classified as matching the intended centroid. The vowel /a/ had duration means that were shorter than /æ/ by about 20 msec and longer than /ʌ/ by about 30 msec. When duration was included as an input parameter, it improved the classification of /a/ at Time 1 by

increasing the number of correct attempts from 8 to 11. Time 2 showed a drop in the classification rate with more instances of /ɑ/ being confused with /ʌ/. Time 3 shows an even greater decrease in F1/F2 the classification rate with duration improving accuracy but bringing in additional confusion categories

8.5.2. Comparison of /æ/, /ɑ/ and /ʌ/ to the Native Speaker

Next we compare the vowels /æ/, /ɑ/ and /ʌ/ to the native speaker's system as shown in 8.9.

Table 8.9 Results of the Discriminant Analyses of the Vowels /æ/, /ɑ/ and /ʌ/ Pronounced by NNS04 Compared to the Native Speaker

Target Vowel	Time 1		Time 2		Time 3	
	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2	NS Match /# of Tokens F1/F2 Duration
æ N=8	-----	-----	-----	-----	-----	-----
	ɑ (8)	ɑ (8)	ɑ (7)	ɑ (7)	ɑ (8)	ɑ (8)
	-----	-----	e (1)	e (1)	-----	-----
	0	0	0	0	0	0
ʌ N=9	ʌ (4)	ʌ (5)	-----	-----	-----	ʌ (1)
	ɑ (5)	ɑ (4)	ɑ (8)	ɑ (8)	ɑ (9)	ɑ (7)
	-----	-----	ε (1)	ε (1)	-----	ε (1)
	44	55	0	0	0	11
ɑ N=14	-----	-----	ɑ (3)	ɑ (3)	ɑ (3)	ɑ (3)
	o (9)	o (9)	o (5)	o (2)	o (7)	o (2)
	ʌ (4)	ʌ (4)	ʌ (5)	ʌ (5)	ʌ (4)	ʌ (5)
	ɔ (1)	ɔ (1)	-----	ɔ (4)	-----	ɔ (4)
	-----	-----	u (1)	-----	-----	-----
	0	0	21.4	21.4	21.4	21.4

The vowel /æ/ for NNS04 was confused with native speaker /ɑ/. This does not change over time and the inclusion of duration as an additional input parameter had no effect on the classification of this vowel. It should be noted that when the lexical item *bad* was included in the discriminant analysis the classification was still 0% and all 15 instances of /æ/ were considered to most closely approximate native speaker's /ɑ/.

At Time 1, the vowel /ʌ/ matched the native speaker's category for /ʌ/ 4 out of 9 times (44% correct). With the inclusion of duration as an additional input parameter the classification rate increased to 5 out of 9 (55%). This differentiation was completely lost by Time 2, at which time /ʌ/ merged with /ɑ/. It remained merged with /ɑ/ at Time 3.

The vowel /ɑ/ primarily matched the native speaker's /o/ at Time 1 with some instances being confused with /ʌ/ or /ɔ/. By Time 3, with all parameters included, three instances of /ɑ/ were accurate and there was some evidence that /ɑ/ was moving lower and more central.

8.6. The High Back Vowels

We now turn to the high back vowels /u/ and /ʊ/ as uttered in the words *tube*, *put* and *took*. As mentioned in the beginning of this chapter all instances of the word *could*, *boot* and *coop* were omitted because the speaker simply did not know how to pronounce them. The 10 instances of /ʊ/ that remained in the words *took* and *put* were sufficient to

examine this vowel but only five instances of the vowel /u/ that remained occurred in the word *tube*. Given the small number of instances of the target vowel and the fact that they occurred in the word *tube* which was treated separately in the other speakers, we can draw only tentative conclusions regarding the vowel /u/ and its relationship to /ʊ/. Figures 8.7, 8.8 and 8.9 show the F1/F2 plots of the vowels /u/ and /ʊ/ as pronounced by NNS04 across three times. Note that at Time 1 these vowels overlapped almost completely in the high back space.

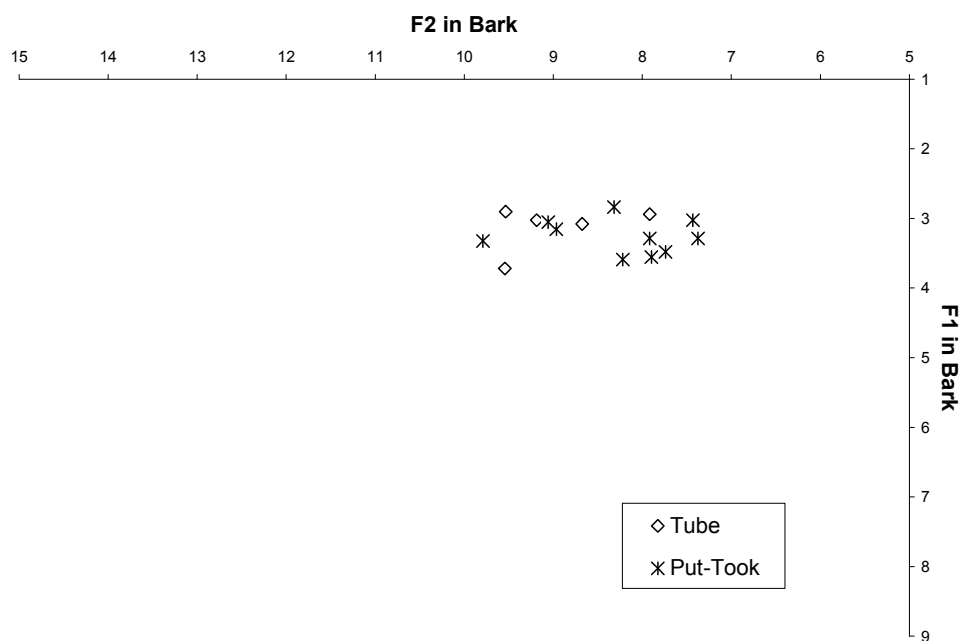


Figure 8.7 F1/F2 plot of the high back vowels at Time 1 pronounced by NNS04

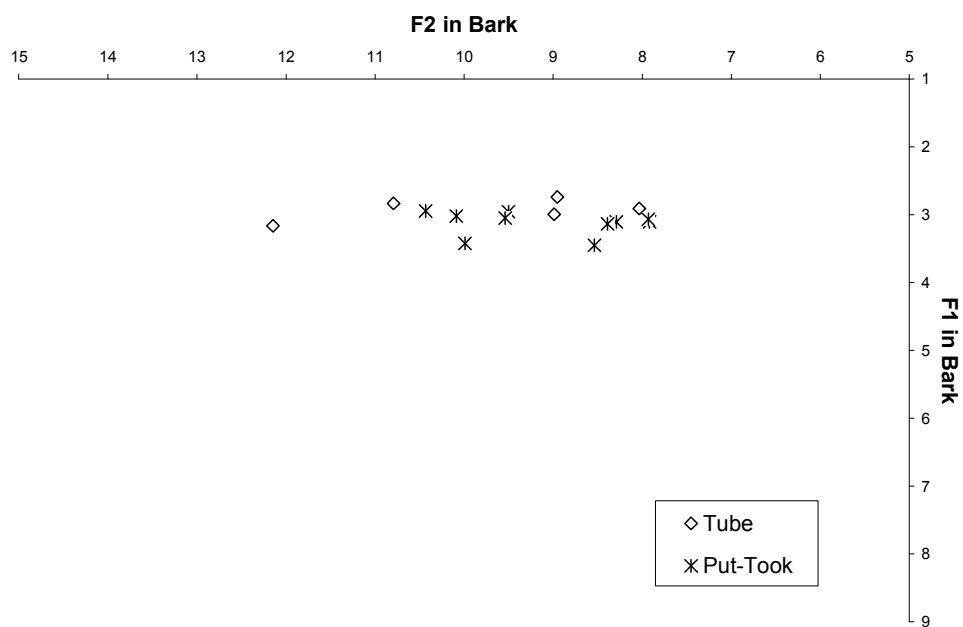


Figure 8.8 F1/F2 plot of the high back vowels at Time 2 pronounced by NNS04

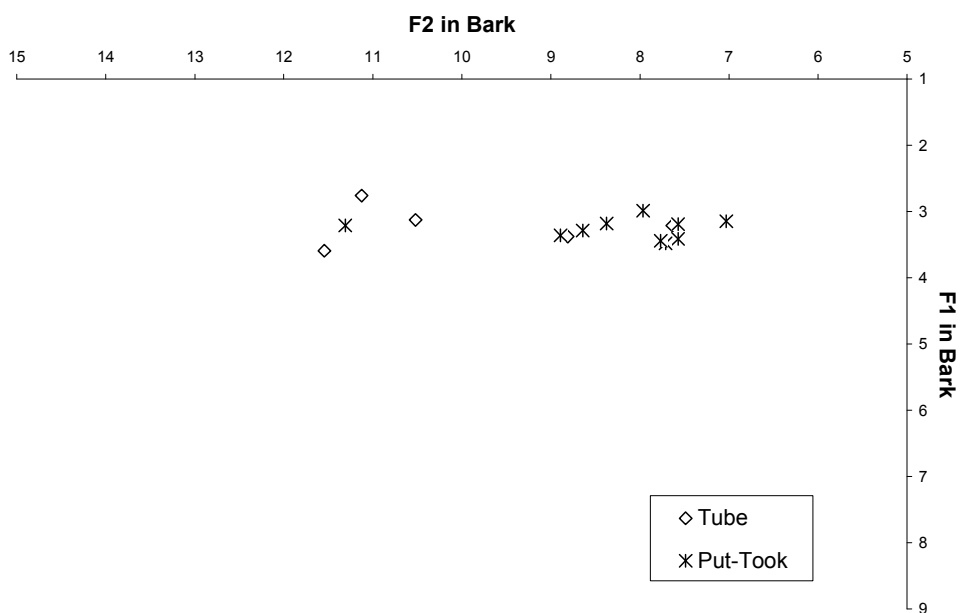


Figure 8.9 F1/F2 plot of the high back vowels at Time 3 pronounced by NNS04

8.6.1. Distribution of /u/ and /ʊ/ by NNS04

In order to understand this distribution more clearly we turn to the discriminant analyses.

Table 8.10 shows the result of the analyses across three times on two conditions when the nonnative speaker's vowels were considered independently of the native speaker's data.

Table 8.10 Results of the Discriminant Analyses of the Vowels /u/ and /ʊ/ Pronounced by NNS04 across Three Times

Target Vowel	Time 1		Time 2		Time 3	
	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration
u N=5	u (2)	u (4)	u (1)	u (1)	u (2)	u (2)
	ʊ (3)	ʊ (1)	ʊ (3)	ʊ (3)	ʊ (2)	ʊ (2)
	-----	-----	e (1)	e (1)	e (1)	e (1)
% correct	40	80	20	20	40	40
ʊ N=10	ʊ (7)	ʊ (6)	ʊ (8)	ʊ (8)	ʊ (9)	ʊ (9)
	u (3)	u (4)	u (2)	u (2)	u (1)	u (1)
% correct	70	60	80	80	90	90

At Time 1, 2 out of the 5 attempts at /u/ were considered differentiated from /ʊ/. Duration means between the two vowels at Time 1 differed by about 46 msec with /u/ being the longer of the two. When duration was included as an input parameter the number of correct attempts increased to 4 out of 5 attempts indicating that duration was used by the nonnative speaker to differentiate these vowels. The vowel /ʊ/ was somewhat more differentiated in that 7 out of 10 attempts were correct category matches. For the most part, duration did not affect the classification of /ʊ/.

With respect to change over time, the classification of /u/ steadily increased from 70% correct to 80% correct to 90% correct. This change was small (only one or two instances) but was towards distinction. The vowel /u/ changed in two ways. First, /u/ generally became less distinct. Second, it increased its number of confusions with /ʊ/ and added a confusion with /e/. Again, although this change was small it was toward merger.

8.6.2. Comparison of /u/ and /ʊ/ to the Native Speaker

We next look at the vowels /u/ and /ʊ/ in direct comparison to the native speaker's data as shown in 8.11.

Table 8.11 Results of the Discriminant Analyses of the Vowels /u/ and /ʊ/ Pronounced by NNS04 Compared to the Native Speaker

Target Vowel	Time 1		Time 2		Time 3	
	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2	NS Match /# of Tokens F1/F2 Duration
u	u (4)	u (3)	u (1)	u (1)	u (3)	u (2)
N=5	ʊ (1)	ɔ (2)	ʊ (2)	ʊ (2)	ʊ (1)	ʊ (1)
	-----	-----	i (1)	i (1)	ɪ (1)	ɔ (1)
	-----	-----	ɛ (1)	ɛ (1)	-----	ɪ (1)
% correct	80	60	20	20	60	40
ʊ	ʊ (1)	-----	ʊ (9)	ʊ (9)	ʊ (3)	ʊ (2)
N=10	u (3)	u (4)	-----	u (1)	u (5)	u (7)
	o (3)	o (5)	-----	-----	-----	-----
	ɔ (3)	ɔ (1)	-----	-----	ɔ (2)	ɔ (1)
	-----	-----	e (1)	-----	-----	-----
% correct	10	0	90	90	30	20

At Time 1, the discriminant analysis matched 4 out of 5 attempts at /u/ to the native speaker's /u/. The vowel /u/ was also most frequently matched to /u/. Duration had little effect on either of these vowels at Time 1 changing the number of correct category matches by one instance.

The most notable change over time was the decrease in the number of correct category matches of /u/ that occurred along with an ample increase in the number of correct category matches of /u/ from Time 1 to Time 2. The decrease in /u/ from four correct instances to one correct instance on F1/F2 is in the direction of dispersion. The Time 2 increase in the number of correct category matches of /u/ was in the direction of concentration in that vowels in lexical items containing /u/ as the target were initially dispersed, but concentrated into the category of /u/. The Time 2 categorization did not last. By Time 3 the vowels returned to their original state although both were somewhat reduced in the number of correct category matches when Time 3 was compared to Time 1.

8.7. The Mid Back Vowels

The mid back vowels /o/ and /ɔ/ are considered here along with the low vowel /ɑ/ (which in fact is not low but mid for this speaker) and the central vowel /ʌ/. The F1/F2 plots for these vowels (shown in Figures 8.10, 8.11 and 8.12) indicate that not only did /o/ and /ɔ/ overlap with each other but they also overlapped with /ɑ/ and to a lesser extent /ʌ/. We

proceed to the discussion of these vowels, bearing in mind that there were only three instances of the vowel /ɔ/ so conclusions regarding this vowel are purely speculative. Note that in the vowel plots below, a few instances of the vowel /o/ are concentrated in the mid back portion of the vowel plot overlapping only with /ɑ/, which has encroached into the space of /o/ (as discussed in the previous section). The three instances of /ɔ/ are somewhat more centralized but overlap with both /ɑ/ and the remaining instances of /o/.

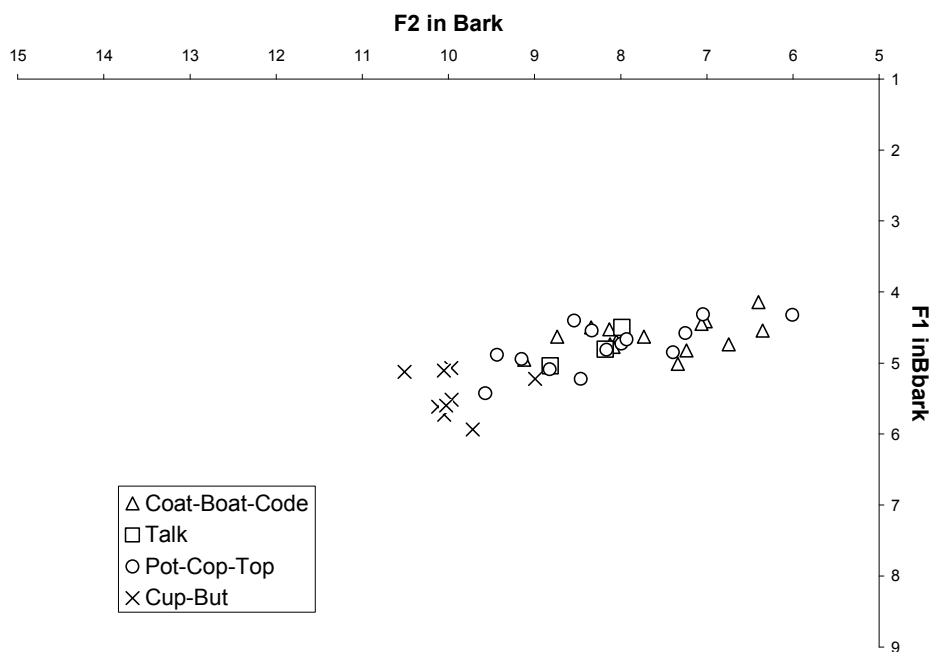


Figure 8.10 F1/F2 plot of the mid back vowels at Time 1 pronounced by NNS04

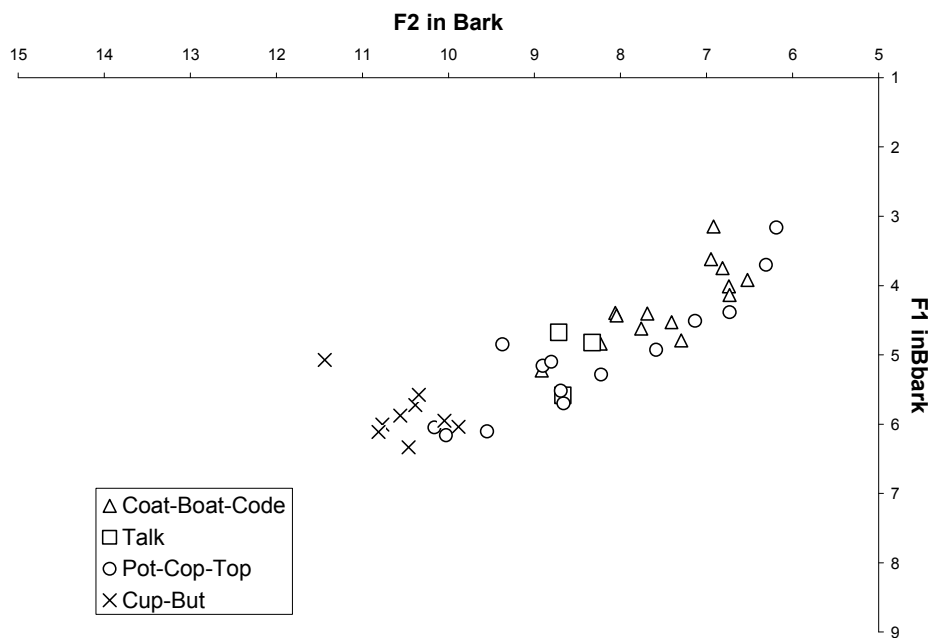


Figure 8.11 F1/F2 plot of the mid back vowels at Time 2 pronounced by NNS04

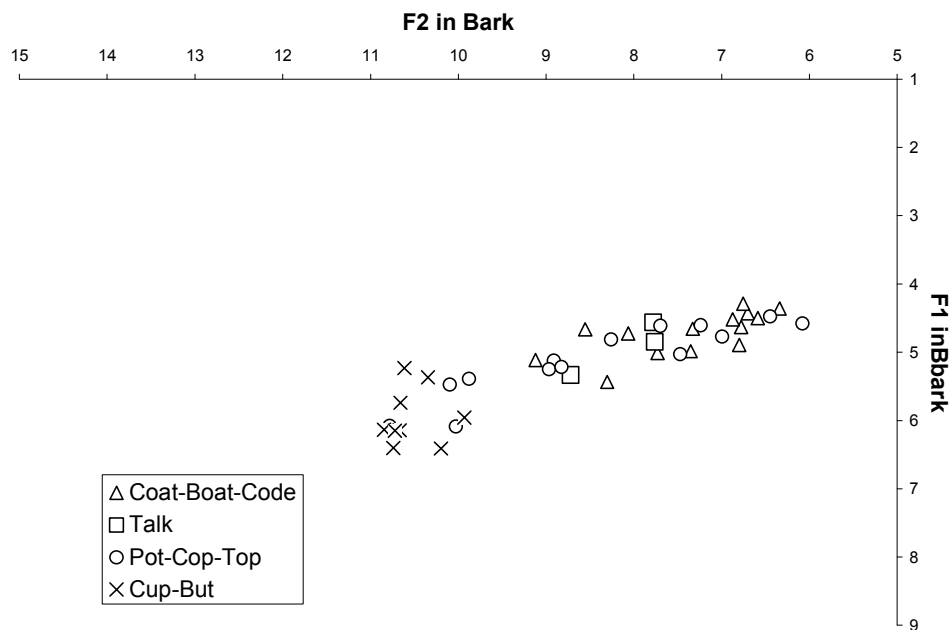


Figure 8.12 F1/F2 plot of the mid back vowels at Time 3 pronounced by NNS04

8.7.1. The Distribution of /o/ and /ɔ/ by NNS04

In order to understand the distribution more clearly, we look at the results of the discriminant analyses on both conditions across three points in time as shown in Table 8.12.

Table 8.12 Results of the Discriminant Analyses of the Vowels /o/ and /ɔ/ Pronounced by NNS04 across Three Times

Target Vowel	Time 1		Time 2		Time 3	
	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration
o	o (9)	o (11)	o (12)	o (12)	o (12)	o (11)
N=15	a (6)	a (4)	a (3)	a (3)	a (3)	a (4)
% correct	60	73.3	80	80	80	73.3
ɔ	a (2)	a (3)	a (3)	a (3)	a (2)	a (2)
N=3	o (1)	-----	-----	-----	o (1)	o (1)
% correct	0	0	0	0	0	0

When this nonnative speaker's system is considered independently of the native speaker's system we see that at Time 1 the vowel /o/ is relatively distinct but often confused with the vowel /a/. The vowel /ɔ/ on the other hand does not exist as a category; virtually all instances are closer to this speaker's /a/ centroid (which was pronounced more like /o/ than like /a/). Duration means of the vowels /o/ and /ɔ/ differed by about 46 msec at Time 1 with /o/ being the longer of the two. Duration means of the vowels /ɔ/ and /a/ differed by less than 10 msec. When included as an input parameter, duration helped to differentiate /o/ somewhat but had little effect on the vowel /ɔ/. With respect to change

over time, the position of the vowel /o/ in the F1/F2 space becomes more distinct (by three instances or from 60% correct to 80% correct). The vowel /ɔ/ barely changes over time.

8.7.2. Comparison of /o/ and /ɔ/ to the Native Speaker

When the native speaker's data is used as the criteria for vowel categories we see a different picture of this nonnative speaker's productions. The confusion we previously saw between the mid vowels and the vowel /a/ is no longer at issue. We can see that the previous confusion was a function of a raised pronunciation of /a/ which the native speaker does not exhibit. To determine whether the nonnative speaker differentiates between the vowels /o/ and /ɔ/, we look at Table 8.13 below, which shows the results of the discriminant analyses of the mid back vowels as uttered by NNS04 as compared to the native speaker's values.

Table 8.13 Results of the Discriminant Analyses of the Vowels /o/ and /ɔ/ Pronounced by NNS04 Compared to the Native Speaker

Target Vowel	Time 1		Time 2		Time 3	
	NS Match /# of Tokens F1/F2	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2	NS Match /# of Tokens F1/F2 Duration
o N=15	o (13)	o (3)	o (14)	o (1)	o (14)	o (4)
	ɔ (1)	ɔ (12)	-----	ɔ (14)	-----	ɔ (10)
	ʌ (1)	-----	ʌ (1)	-----	ʌ (1)	ʌ (1)
% correct	80	20	93.3	6.6	93.3	26.6
ɔ N=3	-----	-----	ɔ (1)	ɔ (1)	-----	ɔ (2)
	o (2)	o (2)	o (1)	o (2)	o (2)	-----
	ʌ (1)	ʌ (1)	ʌ (1)	-----	ʌ (1)	ʌ (1)
% correct	0	0	33.3	33.3	0	66.6

At Time 1, 13 out of 15 attempts at /o/ or 80% matched the F1/F2 values for the native speaker's values for /o/ whereas, none of the attempts at /ɔ/ matched and most were confused with the native speaker's /o/.

When added as an additional input parameter, duration lowered the classification rates of the vowel /o/ by decreasing the number of correct instances from thirteen to three and increasing the number of times /o/ was confused with /ɔ/ from one to twelve. Recall that for the native speaker the vowel /ɔ/ was actually the longer of the two in this pair. For NNS04 /o/ is the longer of the two (and had duration means that were about 60 msec longer than the native speaker's means for /o/). The inclusion of duration as an additional parameter had no effect on /ɔ/ at Time 1.

With respect to change over time it is reasonable to conclude that there are very small changes in both of these vowels toward distinction from each other and toward the native speaker's categories. These changes, however, are not greater than those we saw in the native speakers.

8.8. Summary of the Vowel System of NNS04

NNS04 was among the oldest speakers and had spent the least amount of time in the country. He therefore struggled with the elicitation task and many of his errors were related to sound-spelling confusions.

When his vowel system was considered as an entity unto itself, it was clear that he made no distinction between the vowels /i/ and /ɪ/ or between the vowels /u/ and /ʊ/. The vowels /e/ and /ɛ/ were distinguished, the vowels /æ/, /ʌ/ and /ɑ/ showed some differentiation. The vowel /o/ was differentiated but /ɔ/ was generally collapsed with /ɑ/.

When compared to the native speaker, the vowels /i/ and /ɪ/ both matched NS /i/. The vowels /e/ and /ɛ/ were both relatively good matches for their respective targets but /e/ had more correct category matches than /ɛ/. The vowel /æ/ matched the native speaker's /ɑ/. The vowel /ʌ/ corresponded in some cases to the native speaker's /ʌ/ but mostly to /ɑ/. The vowel /ɑ/ matched the native speaker's /o/ and /ʌ/. The vowels /u/ and /ʊ/ both

matched the native speaker's /u/. The vowel /o/ matched the native speaker's /o/ but the vowel /ɔ/, matched the native speaker's /o/ and /ʌ/.

There were few changes in the vowel system of NNS04 that were greater than the variation we saw for the native speakers. One such change occurred when the speaker's vowels were compared to native speaker. Under this condition we saw the vowel /ʌ/ merged with and /ɑ/ in both F1/F2 and Duration. We also saw a case of concentration during which lexical items containing the target vowel /u/ were initially dispersed but concentrated at Time 2. This concentration was short-lived in that we saw dispersion again at Time 3.

Chapter 9: Analysis of Nonnative Speaker 05

9.1. Background of Nonnative Speaker 05 (NNS05)

Nonnative Speaker 05 (henceforth NNS05) is a female native speaker of Spanish, born in Guatemala. At the time of the first recording she was 20 years old and had lived in the United States for seven months. She began studying English in Guatemala when she was seventeen and was enrolled in the first level of ESL (low-beginner) at Nassau Community College. According to a self-report, she had been watching about one-half hour of American television per day, had not been reading newspapers or books in English, not even for her classes. At the time of her interview she was speaking Spanish at home, at work and with her friends.

It should be noted that this speaker had the lowest communicative ability of all of the nonnative speakers in this study. She used her brother to translate when she came to inquire about the study and brought him in to help her understand the instructions at the first recording. It should not be surprising that she had difficulty reading the sentences and that her vowel attempts are far more varied than the other speakers. That is to say, instead of having one or two confusion categories for each vowel she had four, five or even six categories with which her attempts were confused.

9.2. Sample Collection

As stated, NNS05 had some difficulty with the sentence-reading task. Forty-three words were discarded across three times leaving a total of 122 words. It is not the case that all 43 words were misread at all three times but any instance of a word that was misread at one time was also discarded at the other times. If, for example, the word *pet* was misread in the second sentential context at Time 2, it was excluded in the second sentential context at Times 1 and 3 as well. This way of excluding items was motivated by the need to maintain the various sentential contexts across the three times.

In order to determine intra-rater reliability, 17 items from each sample were randomly selected and re-measured. As shown in Table 9.1, mean differences between the original measure and the re-measure for duration were slightly above 10 msec for Time 1 but below 10 msec for Times 2 and 3. Mean differences between the original measure and the re-measure for F1 and F2 were below .21 Bark at the 50% point.

Table 9.1 **Margin of Error for NNS05**

	Mean Difference Between Time 1 Measure and Re- measure	Mean Difference Between Time 2 Measure and Re- Measure	Mean Difference Between Time 3 Measure and Re- Measure
Duration	11.78 msec	7.68 msec	5.16 msec
F1 at 50% Point	0.12 Bark	0.07 Bark	0.06 Bark
F2 at 50% Point	0.20 Bark	0.13 Bark	0.10 Bark

9.3. Category Matches within Lexical Items

When considering the single-item subset compared to the multiple-lexical item set, NNS05 patterned similarly to the other nonnative speakers in the study. There were notable differences in the total classification between the two conditions when the nonnative speaker's system was considered independently of the native speakers (as shown in Table 9.2).

Table 9.2 Single-Item vs. Multiple-tem Comparison of NNS05 at Time 1

Target Vowel	Single-Item Subset		Multiple Item Set	
	Percent/Number Correctly Matched: F1/F2	Percent/Number Correctly Matched F1/F2 and Duration	Percent/Number Correctly Matched: F1/F2	Percent/Number Correctly Matched: F1/F2 and Duration
i	80 (4/5)	80 (4/5)	91.6 (11/12)	75 (9/12)
ɪ	33.3 (1/3)	66.6 (2/3)	63.6 (7/11)	72.7 (8/11)
e	60 (3/5)	80 (4/5)	28.5 (4/14)	71.4 (10/14)
ɛ	80 (4/5)	60 (3/5)	58.3 (7/12)	66.6 (8/12)
æ	60 (3/5)	80 (4/5)	62.5 (5/8)	62.5 (5/8)
ʌ	40 (2/5)	80 (4/5)	0 (0/5)	20 (1/5)
u	25 (1/4)	75 (3/4)	14.2 (1/7)	14.2 (1/7)
ʊ	80 (4/5)	80 (4/5)	35.7 (5/14)	28.5 (4/14)
o	80 (4/5)	80 (4/5)	58.3 (7/12)	75 (9/12)
ɔ	25 (1/4)	75 (3/4)	44.4 (4/9)	66.6 (6/9)
ɑ	80 (4/5)	100 (5/5)	55.5 (5/9)	55.5 (5/9)
Total	60.7	78.4	49.5	58.4

Note that the classification rate with F1/F2 as the only parameters was 60.7% in the single-item subset as opposed to 49.5% in the multiple-item set. When duration was included as a parameter the differences were greater with a classification rate of 78.4% in the single-item subset compared to 58.4% in the multiple-item set. With all three

parameters included, 9 of the 11 vowels had better category matches than in the single-item subset.

Now consider Table 9.3 which compares the single-item subset and the multiple-item set when both were classified using the category centroids established for the female native speaker's data.

Table 9.3 **Single-Item vs. Multiple-Item Comparison of NNS05**
Using the Native Speaker's Data a Criteria (Time 1)

Target Vowel	Single-Item Subset		Multiple-Item Set	
	Percent/Number Correctly Matched: F1/F2	Percent/Number Correctly Matched F1/F2 and Duration	Percent/Number Correctly Matched: F1/F2	Percent/Number Correctly Matched: F1/F2 and Duration
i	100 (5/5)	100 (5/5)	100 (12/12)	100 (12/12)
ɪ	0 (0/3)	0 (0/3)	9 (1/11)	9 (1/11)
e	80 (4/5)	80 (4/5)	57.1 (8/14)	64.2 (9/14)
ɛ	0 (0/5)	0 (0/5)	8.3 (1/12)	8.3 (1/12)
æ	40 (2/5)	80 (4/5)	50 (4/8)	50 (4/8)
ʌ	20 (1/5)	0 (0/5)	40 (2/5)	0 (0/5)
u	75 (3/4)	50 (2/4)	85.7 (6/7)	71.4 (5/7)
ʊ	0 (0/5)	0 (0/5)	7.14 (1/14)	7.14 (1/14)
o	60 (3/5)	80 (4/5)	75 (9/12)	66.6 (8/12)
ɔ	0 (0/4)	0 (0/4)	0 (0/9)	11.1 (1/9)
ɑ	0 (0/5)	0 (0/5)	0 (0/9)	0 (0/9)
Total	35.2	37.2	38.9	37.1

Note that there was little difference between the two conditions with respect to how well NNS05 matches the native speaker's categories regardless of whether duration was included as a parameter or not.

9.4. High and Mid Front Vowels

Having considered the vowels in the reduced data set, we turn to the vowels across the complete data set. We begin with the high front vowels as uttered in the words *keep*, *peek*, *bead*, *pick*, *pit* and *kid* and the mid front vowels as uttered in the words *take*, *gate*, *paid*, *get*, *pet* and *bed*. Figures 9.1, 9.2 and 9.3 show the F1/F2 plots of these vowels across three times. Although there was extensive overlap between the four target vowels, one can discern two categories: a high front grouping and a mid front grouping.

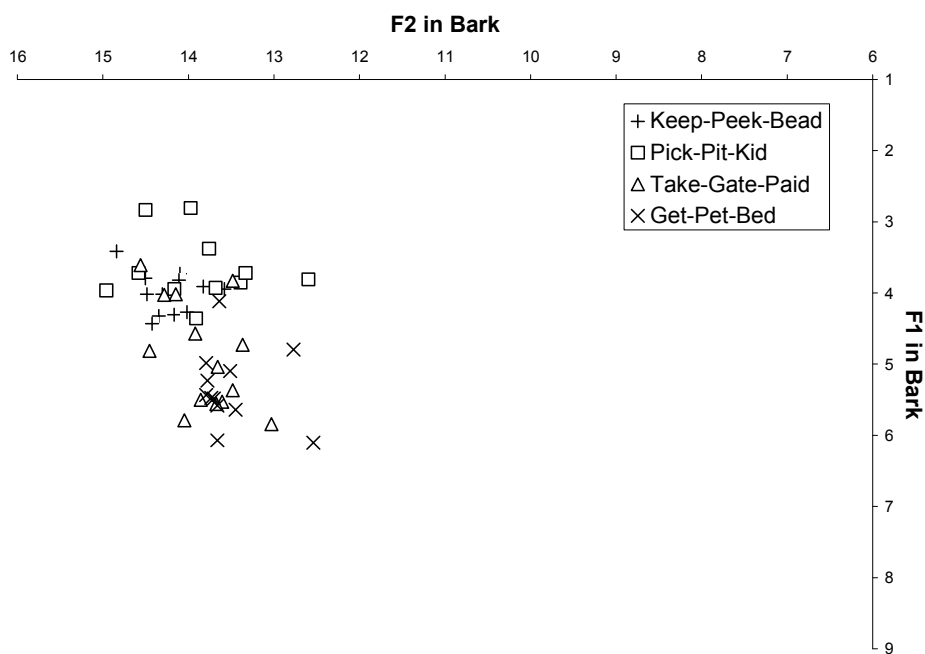


Figure 9.1 F1, F2 plot of the high and mid front vowels at Time 1 pronounced by NNS05

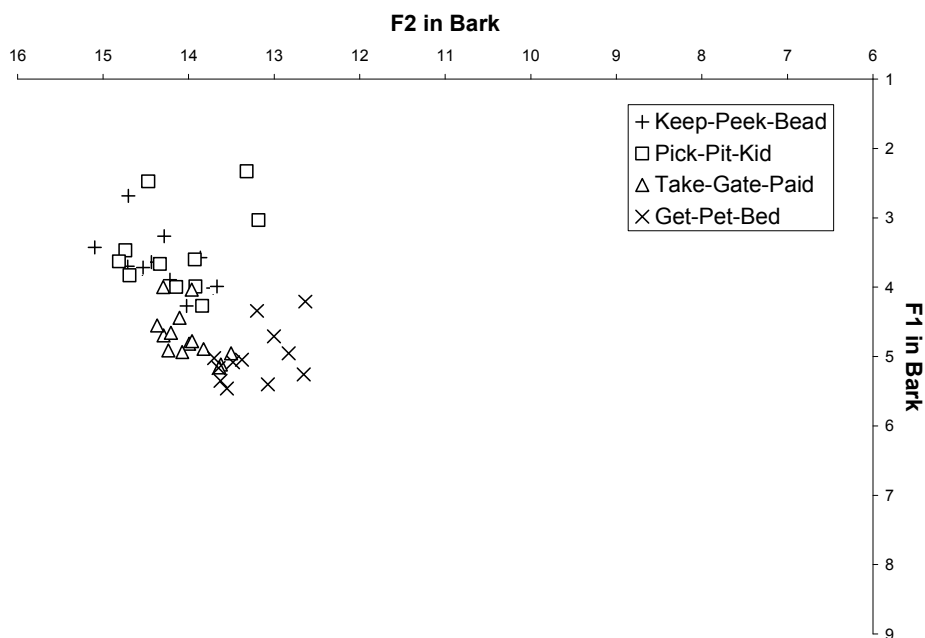


Figure 9.2 F1/F2 plot of the high and mid front vowels at Time 2 pronounced by NNS05

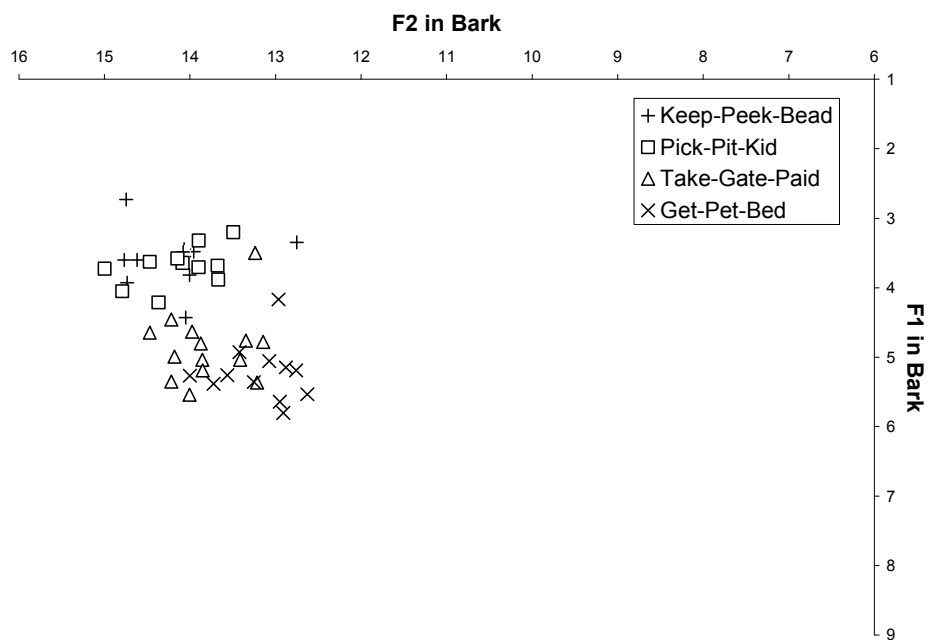


Figure 9.3 F1/F2 Plot of the High and Mid Front Vowels at Time 3 pronounced by NNS05

9.4.1. Distribution of /i/, /ɪ/, /e/ and /ɛ/ by NNS05

In order to understand the distribution more clearly we can consider the results of the discriminant analyses beginning with the vowels /i/ and /ɪ/. Table 9.4 shows these results when the nonnative speaker's data is considered independently of the native speaker's data.

Table 9.4 Results of the Discriminant Analyses of the Vowels /i/ and /ɪ/ Pronounced by NNS05 across Three Times

Target Vowel	Time 1		Time 2		Time 3	
	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2 Duration
i N=12	i (11)	i (9)	i (7)	i (4)	i (11)	i (6)
	ɪ (1)	ɪ (2)	ɪ (2)	ɪ (6)	-----	ɪ (5)
	-----	e (1)	e (3)	e (2)	e (1)	e (1)
% correct	91.6	75	58.3	33.3	91.6	50
ɪ N=11	ɪ (7)	ɪ (8)	ɪ (3)	ɪ (5)	ɪ (2)	ɪ (7)
	i (3)	i (3)	i (7)	i (6)	i (9)	i (4)
	e (1)	-----	e (1)	-----	-----	-----
% correct	63.3	72.7	27.2	45.4	18.1	63.6

NNS05 makes some distinction on the F1/F2 parameters between the vowels /i/ and /ɪ/ at Time 1. Eleven of the 12 attempts at the vowel /i/ are considered to be distinct from /ɪ/ as well as the other vowels in the system. Seven of the 12 attempts at the vowel /ɪ/ were distinct with three attempts falling into the F1/F2 range of /i/ and one falling into the F1/F2 range of /e/. Initially duration means of the two vowels differed by over 50 msec with /i/ being the longer of the two. This differs from the female native speaker in that

mean differences between /i/ and /ɪ/ were less than 20 msec and her vowels were both shorter than this nonnative speaker's vowels. The inclusion of duration as an additional input parameter changed the rate of classification at Time 1 by decreasing the number of matches to /i/ by two instances and increasing the number of matches to /ɪ/ by one instance.

With respect to change across time, the vowel /ɪ/ clearly became less differentiated in the F1/F2 space. At Time 1 seven instances of /ɪ/ were differentiated on the F1/F2 parameters, whereas at Time 3 only two instances were differentiated. With duration included as a parameter, there were more correct category matches for /ɪ/, but there was still a decrease in the number of correct category matches from Time 1 to Time 2 even with duration included. Since the vowel /i/ had the same number of correct instances at Time 3 on the F1/F2 parameters, the change in /ɪ/ will be referred to as merger. In this case, /ɪ/ was the merging vowel and /i/ was the absorbing vowel.

We turn now to the mid front vowels /e/ and /ɛ/. Table 9.5 shows the results of the discriminant analyses when the nonnative speaker's vowels are considered independently of the native speaker.

**Table 9.5 Results of the Discriminant Analyses of the Vowels /e/ and /ɛ/
Pronounced by NNS05 across Three Times**

Target Vowel	Time 1		Time 2		Time 3	
	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration
e N= 14	e (4)	e (10)	e (9)	e (11)	e (12)	e (11)
	ɛ (6)	ɛ (1)	ɛ (3)	ɛ (1)	ɛ (1)	ɛ (2)
	i (3)	i (2)	i (2)	i (2)	i (1)	i (1)
	ɪ (1)	ɪ (1)	-----	-----	-----	-----
% correct	28.5	71.4	64.2	78.5	85.7	78.5
ɛ N=12	ɛ (7)	ɛ (8)	ɛ (10)	ɛ (9)	ɛ (7)	ɛ (9)
	e (3)	e (2)	e (2)	e (3)	e (5)	e (2)
	æ (1)	æ (1)	-----	-----	-----	æ (1)
	i (1)	-----	-----	-----	-----	-----
	-----	ɪ (1)	-----	-----	-----	-----
% correct	58.3	66.6	83.3	75	58.3	75

At Time 1 there is a good deal of overlap between the vowels /e/ and /ɛ/ with only 4 out of 14 attempts at /e/ matching their intended centroid, six falling into the F1/F2 range of /ɛ/, three falling into the F1/F2 range of /i/ and 1 falling into the F1/F2 range of /ɪ/. The vowel /ɛ/ was somewhat better in that 7 of the 12 attempts at /ɛ/ are distinct in the F1/F2 space, three were categorized as /e/, one as /æ/ and one as /i/.

Duration means between these vowels initially differed by about 51 msec with /e/ being the longer of the two. At Time 1, when duration was included as an input parameter, the classification rate of /e/ improved from four correct instances to ten correct instances.

The classification rate of /ɛ/ improved by one instance.

With respect to change across time, the vowel / ϵ / showed a slight improvement by Time 3. The vowel / ϵ / clearly became more differentiated in the F1/F2 space, increasing from four correct instances to twelve correct instances on the F1/F2 parameters. Since the percentage of correct category matches of / ϵ / is maintained and the percentage of correct category matches of / ϵ / improved by eight instances on the F1/F2 parameters, we can consider this a case of split.

9.4.2. Comparison of /i/, /ɪ/ /e/ and /ɛ/ to the Native Speaker

We now compare the high and mid front vowels to the native speaker's categories for these vowels. Beginning with /i/ and /ɪ/, we examine the results of the discriminant analyses of this nonnative speaker's data evaluated against the native speaker's data as shown in Table 9.6.

Table 9.6 Results of the Discriminant Analyses of the Vowels /i/ and /ɪ/ Pronounced by NNS05 Compared to the Native Speaker

Target Vowel	Time 1		Time 2		Time 3	
	NS Match /# of Tokens F1/F2	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2	NS Match /# of Tokens F1/F2 Duration
i	i (12)	i (12)	i (12)	i (12)	i (12)	i (11)
N=12	-----	-----	-----	-----	-----	u (1)
% correct	100	100	100	100	100	91.6
ɪ	ɪ (1)	ɪ (1)	-----	-----	-----	-----
N=11	i (10)	i (10)	i (11)	i (11)	i (11)	i (11)
% correct	9	9	0	0	0	0

When matched to the natives speaker's data the results are clear; these vowels are not differentiated and virtually all instances were categorized as closest to the native speaker's /i/. Duration did not help this distinction and there was virtually no change over time.

Now consider the mid vowels /e/ and /ɛ/ when evaluated against the native speaker's values (as shown in Table 9.7).

Table 9.7 Results of the Discriminant Analyses of the Vowels /e/ and /ɛ/ Pronounced by NNS05 Compared to the Native Speaker

Target Vowel	Time 1		Time 2		Time 3	
	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration
e N=14	e (8)	e (9)	e (8)	e (10)	e (11)	e (11)
	i (5)	i (4)	i (6)	i (4)	i (3)	i (3)
	ɛ (1)	-----	-----	-----	-----	-----
	-----	æ (1)	-----	-----	-----	-----
% correct	57.1	64.2	57.1	71.4	78.5	78.5
ɛ N=12	ɛ (1)	ɛ (1)	-----	-----	ɛ (3)	ɛ (2)
	e (9)	e (9)	e (10)	e (10)	e (8)	e (8)
	ɪ (1)	ɪ (1)	ɪ (2)	ɪ (2)	ɪ (1)	ɪ (2)
	i (1)	i (1)	-----	-----	-----	-----
% correct	8.3	8.3	0	0	25	16.6

At both Time 1 and Time 2, the vowel /e/ showed some distinction from /ɛ/ and the other vowels in the system. On the F1/F2 parameters, 8 of 14 attempts matched the native speaker's category for /e/. The vowel /ɛ/, on the other hand, had only 1 out of 12 attempts

that matched the native speakers category for /ε/ at Time1 and none did at Time 2.

Duration improved the percentage of correct category matches of /e/ slightly but did not improve the percentage of correct category matches of /ε/.

With respect to change across time, the vowel /e/ improved slightly by Time 3.

Interestingly, as the vowel /e/ improved we see a hint of improvement for the vowel /ε/ as well. At this point there is not enough improvement to call this a split but the vowels seem to be going in that direction.

9.5. The Low Vowels and the Mid Central Vowel

Moving away from the high and mid front vowels we now consider the low front vowel /æ/ (in the words *cat* and *pat*), the mid central vowel /ʌ/ (in the word *but*), and the low back vowel /ɑ/ (in the words *cop* and *top*). Figures 9.4, 9.5 and 9.6 show the F1/F2 plots of these vowels across three points in time.

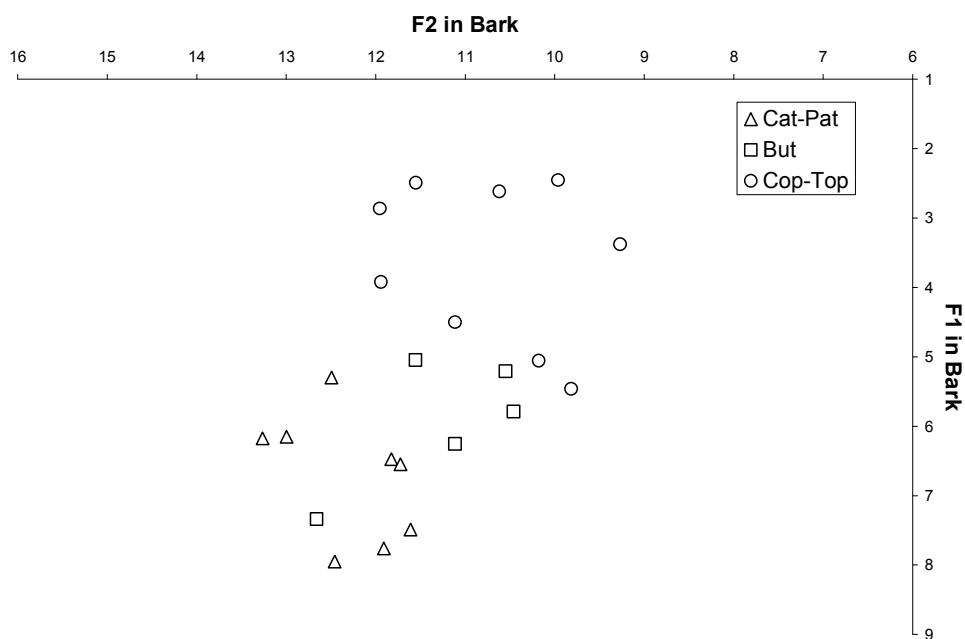


Figure 9.4 F1/F2 plot of the low and central vowels at Time 1 pronounced by NNS05

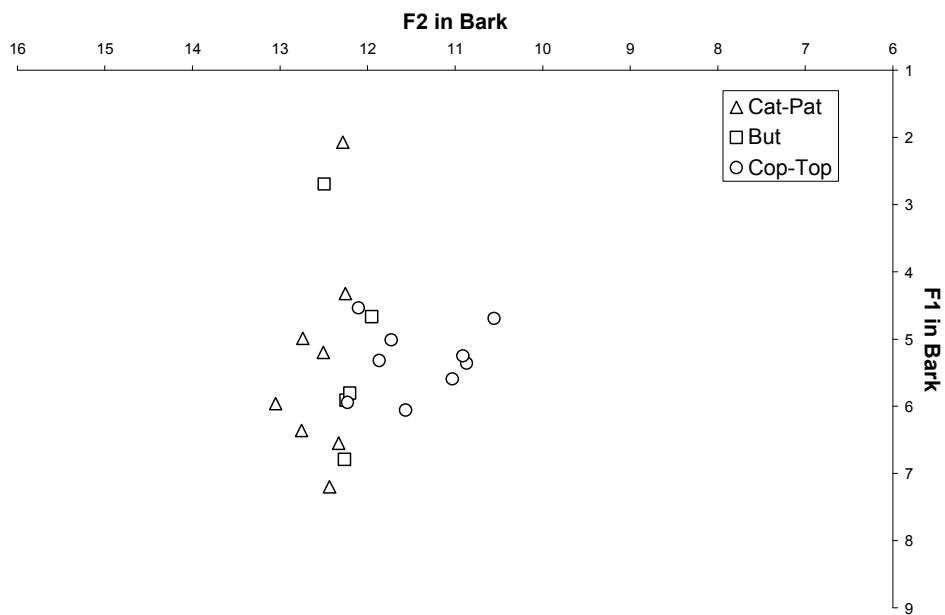


Figure 9.5 F1/F2 plot of the low and central vowels at Time 2 pronounced by NNS05

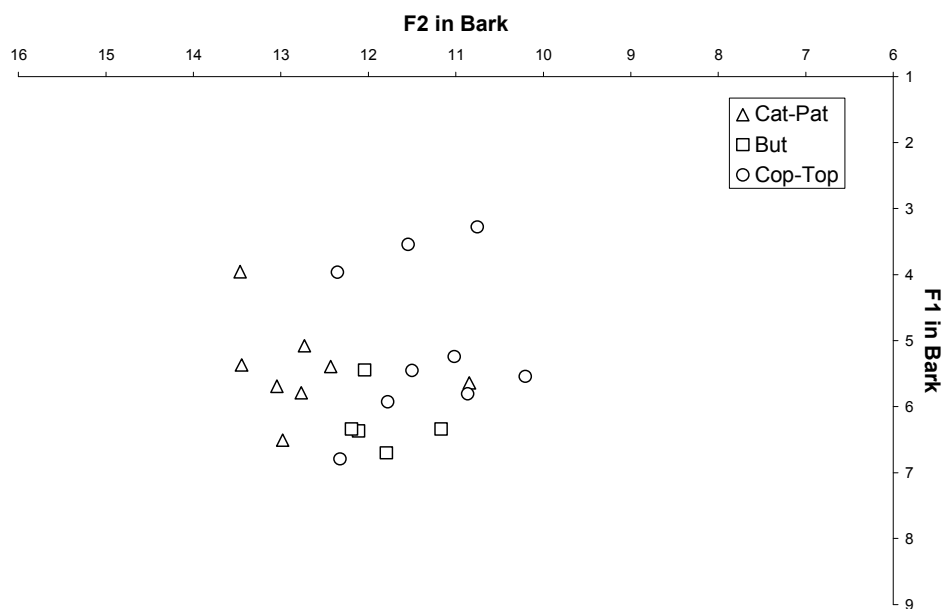


Figure 9.6 F1/F2 plot of the low and central vowels at Time 3 pronounced by NNS05

9.5.1. Distribution of /æ/, /ɑ/ and /ʌ/ by NNS05

Looking first at the three vowels independently of the native speaker's data, Table 9.8 shows the results of the discriminant analysis on both conditions (*F1/F2 Only and F1/F2 plus Duration*).

Table 9.8 Results of the Discriminant Analyses of the Vowels /æ/, /ɑ/ and /ʌ/ Pronounced by NNS05 across Three Times

Target Vowel	Time 1		Time 2		Time 3	
	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration
æ N=8	æ (5)	æ (5)	æ (5)	æ (4)	æ (1)	æ (4)
	ε (3)	ε (3)	ε (2)	ε (3)	ε (4)	ε (2)
	-----	-----	ɪ (1)	ɪ (1)	ɪ (1)	ɪ (1)
	-----	-----	-----	-----	o (1)	o (1)
	-----	-----	-----	-----	ʌ (1)	-----
	62.5	62.5	62.5	50	12.5	50
ʌ N=5	-----	ʌ (1)	-----	ʌ (2)	ʌ (4)	ʌ (4)
	æ (1)	æ (1)	æ (2)	æ (1)	-----	-----
	-----	-----	ɑ (1)	ɑ (1)	ɑ (1)	ɑ (1)
	ɔ (3)	ɔ (2)	ɔ (1)	-----	-----	-----
	o (1)	o (1)	-----	-----	-----	-----
	0	20	0	40	80	80
ɑ N=9	ɑ (5)	ɑ (5)	ɑ (2)	ɑ (4)	ɑ (1)	ɑ (2)
	o (2)	o (2)	o (1)	-----	o (2)	o (2)
	ʊ (2)	ʊ (2)	-----	ʊ (1)	ʊ (2)	ʊ (2)
	-----	-----	ɔ (4)	ɔ (2)	ɔ (1)	-----
	-----	-----	-----	ʌ (1)	ʌ (2)	ʌ(1)
	-----	-----	æ (1)	æ (1)	-----	æ (1)
	-----	-----	ε (1)	-----	-----	ε (1)
	-----	-----	-----	-----	e (1)	-----
	55.5	55.5	22.2	44.4	11.1	22.2

At Time 1, 5 out of 8 instances of the vowel /æ/ were differentiated on the F1/F2

parameters and 5 out of 9 attempts at /ɑ/ were differentiated. The vowel /æ/ was most

often confused with /ε/ at Time 1 and the vowel /ɑ/ was produced rather high in the F1/F2

space (perhaps indicating a sound-spelling error similar to that which we saw in NNS04).

The vowel /ʌ/ simply did not have its own category, with zero attempts matching the intended category and the primary confusion category being /ɔ/.

Initially duration means of these vowels were very similar, differing among the three vowels by only about 10 msec. Duration did not affect classification rates of the vowels /æ/ and /ɑ/ at Time 1 and improved the classification of the vowel /ʌ/ by only one instance.

Time 3 brought about interesting changes for these vowels. First we notice that the classification of /ʌ/ improved by Time 3 at which point, 4 out of 5 attempts were differentiated. At the same time the classification rates of the vowels /æ/ and /ɑ/ decreased, especially with respect to F1/F2. Note that the five correct attempts at /æ/ at Time 1 decreased to one correct by Time 3 when only F1/F2 are considered. Likewise the five correct attempts at /ɑ/ decreased to one correct by Time 3 on those same parameters. Also note that the number of confusion categories for these vowels increased as the number of correct matches decreased. At Time 1, the vowel /æ/ only had one confusion category (/ɛ/) and the vowel /ɑ/ had only two (/ʊ/ and /o/). By Time 3, the vowels /æ/ and /ɑ/ are confused with four or five other vowels on the F1/F2 parameters. When duration was included as a parameter the number of correct category matches increased slightly but more so for /æ/ than /ɑ/.

Recall that in this initial set of analyses the lexical item *bad* was excluded. The inclusion of the item *bad* yielded different numbers but similar patterns of change. With the item *bad* included NNS05 started with a classification rate of 69.2% correct (both with and without duration) and decreased to 46.1% correct on the F1/F2 parameters and 61.5% when duration was included. The pattern for /ʌ/ remained the same as well, starting with 0% and 20 % correct and increasing by Time 3 to 40% and 80% correct. The vowel /ɑ/ began at 44.4% correct on both conditions when the lexical item *bad* was included and ended up at 0% correct (on the F1/F2 parameters) and 33.3% (on F1/F2 and duration).

Tentatively we can conclude that the vowel /ʌ/ underwent split from the categories with which it was confused. We refer to this as split because the category /ʌ/ had virtually no members at Time 1 (i.e. didn't exist) but did have members at Time 3. This is in essence the creation of a new category. The vowels /æ/ and /ɑ/ have both undergone dispersion in that instances of vowels containing these words have scattered among other vowel categories.

9.5.2. Comparison of /æ/, /ɑ/ and /ʌ/ to the Native Speaker

Next consider the result of the discriminant analyses of vowels /æ/, /ɑ/ and /ʌ/ when the native speaker's vowels are used to set the criteria (Table 9.9).

Table 9.9 Results of the Discriminant Analyses of the Vowels /æ/, /ʌ/ and /ɑ/ Pronounced by NNS05 Compared to the Native Speaker

Target Vowel	Time 1		Time 2		Time 3	
	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration
æ N=8	æ (4)	æ (4)	æ (2)	æ (2)	æ (1)	æ (1)
	ε (3)	ε (1)	ε (2)	ε (1)	ε (3)	ε (1)
	-----	-----	-----	e (2)	e (1)	e (4)
	-----	ɪ (1)	ɪ (3)	ɪ (2)	ɪ (1)	-----
	-----	-----	i (1)	i (1)	i (1)	i (1)
	ɑ (1)	ɑ (2)	-----	-----	-----	-----
	-----	-----	-----	-----	ʌ (1)	-----
	-----	-----	-----	-----	-----	o (1)
% correct	50	50	25	25	12.5	12.5
ʌ N=5	ʌ (2)	-----	-----	-----	ʌ (1)	ʌ (1)
	æ (1)	æ (1)	æ (1)	æ (1)	æ (3)	-----
	-----	-----	ε (2)	ε (2)	ε (1)	ε (4)
	o (1)	o (2)	-----	-----	-----	-----
	-----	-----	ɪ (1)	ɪ (1)	-----	-----
	-----	-----	i (1)	i (1)	-----	-----
	ʊ (1)	-----	-----	-----	-----	-----
	-----	u (1)	-----	-----	-----	-----
-----	ɑ (1)	-----	-----	-----	-----	
% correct	40	0	0	0	20	20
ɑ N=9	-----	-----	-----	-----	-----	-----
	u (4)	u (6)	u (1)	u (1)	u (2)	u (3)
	o (2)	o (2)	-----	o (3)	o (1)	o (2)
	-----	-----	ʊ (3)	ʊ (1)	ʊ (2)	ʊ (1)
	-----	-----	ε (3)	ε (1)	ε (1)	ε (1)
	ɪ (1)	-----	ɪ (1)	ɪ (1)	ɪ (1)	ɪ (1)
	-----	-----	ʌ (1)	ʌ (1)	ʌ (1)	-----
	-----	i (1)	-----	æ(1)	æ (1)	æ (1)
i (2)	-----	-----	-----	-----	-----	
% correct	0	0	0	0	0	0

At Time 1, none of the three vowels matched the native speaker's categories very well. Four out of 8 attempts at /æ/ matched the native speaker's categories for /æ/. Two of the 5 attempts at /ʌ/ matched the native speaker's category for /ʌ/. None of the nine attempts at /ɑ/ matched the native speaker's category for /ɑ/. When duration was included as a parameter there was no change in correct category matches for /æ/ at Time 1, the two correct category matches for /ʌ/ were eliminated, and the confusion categories for /ɑ/ changed, but no additional category matches were added.

With respect to change over time, all of the vowels decreased in classification rates with respect to the native speaker's data. These changes, however, were small, and we can summarize these vowels as being stable with respect to change over time and widely dispersed among native speaker's categories.

When the lexical item *bad* was included in the comparison of nonnative to native vowel categories, there was little difference in the way that the vowel /æ/ matched the native speaker's category for /æ/. At Time 1, with only *pat* and *cat* in the data set, only 4 of 8 attempts (50%) matched. At Time 1, with *bad* included, 6 out of 11 attempts (46.1%) at /æ/ matched the F1/F2 range of the native speaker. When duration was added as a parameter, the number of correct attempts at /æ/ increased from four to nine.

9.6. The High Back Vowels

We turn now to the high back vowels /u/ and /ʊ/ as uttered in the words *boot*, *coop*, *took*, *put* and *could*. The F1/F2 plots of these vowels across three points in time are shown in Figures 9.7, 9.8 and 9.9 below. A preliminary examination indicates that there was overlap between the vowels but that several instances of /ʊ/ were more centralized in the vowels space.

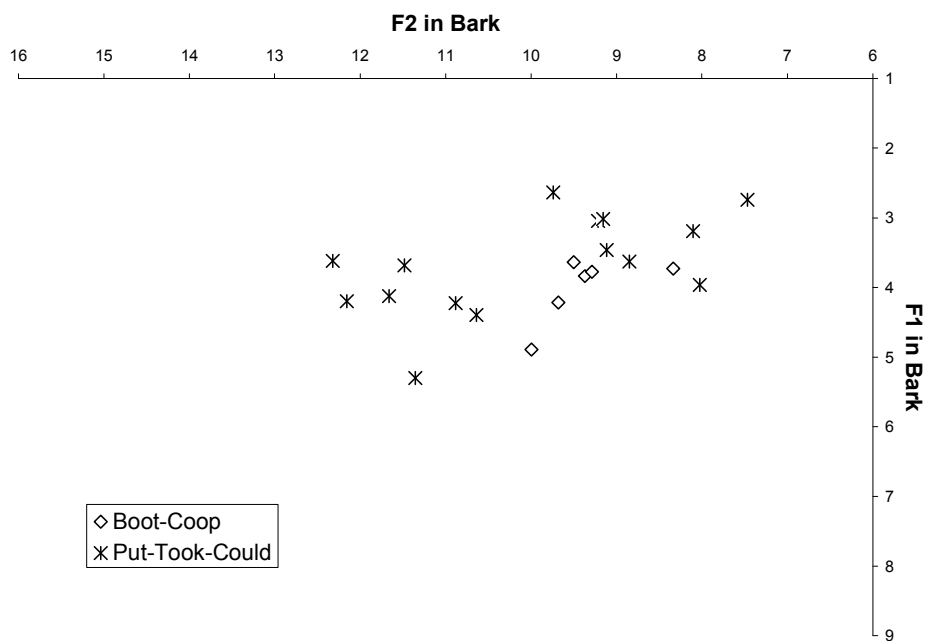


Figure 9.7 F1/F2 plot of the high back vowels at Time 1 pronounced by NNS05

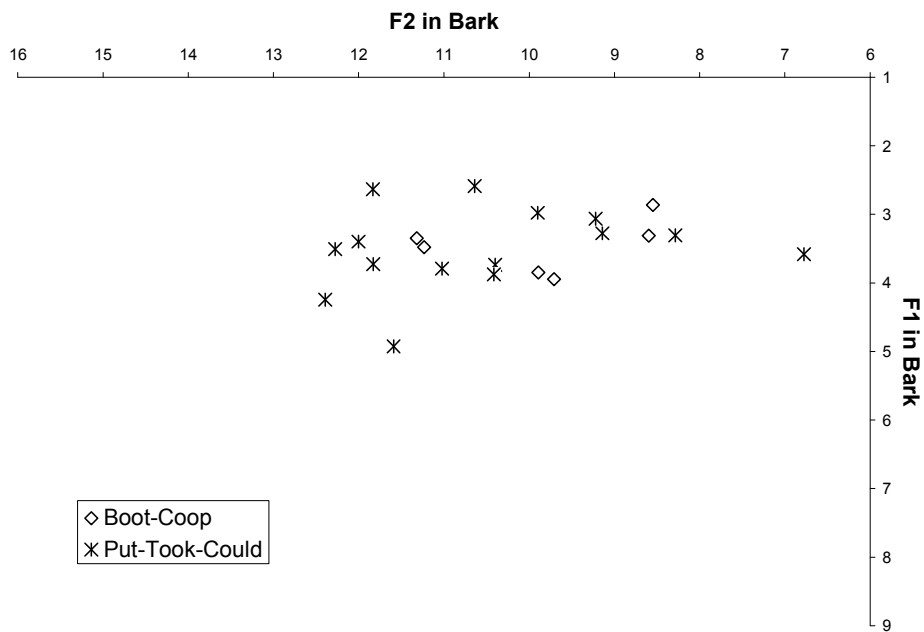


Figure 9.8 F1/F2 plot of the high back vowels at Time 2 pronounced by NNS05

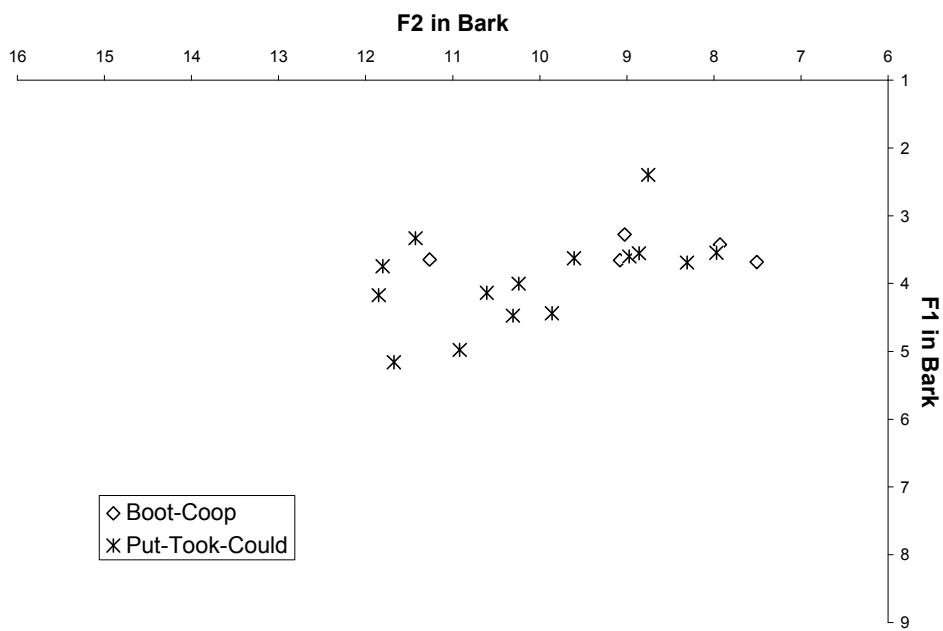


Figure 9.9 F1/F2 plot of the high back vowels at Time 3 pronounced by NNS05

9.6.1. Distribution of /u/ and /ʊ/ by NNS05

We first examine the vowels /u/ and /ʊ/ independently of the native speaker's data. Table 9.10 shows the results of the discriminant analyses on both conditions across three points in time.

Table 9.10 Results of the Discriminant Analyses of the Vowels /u/ and /ʊ/ Pronounced by NNS05 across Three Times

Target Vowel	Time 1		Time 2		Time 3	
	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration
u	u (1)	u (1)	u (2)	u (2)	u (3)	u (3)
N= 7	ʊ (5)	ʊ (5)	ʊ (5)	ʊ (5)	ʊ (3)	ʊ (4)
	o (1)	o (1)	-----	-----	o (1)	-----
% correct	14.2	14.2	28.5	28.5	42.8	42.8
ʊ	ʊ (5)	ʊ (4)	ʊ (8)	ʊ (7)	ʊ (7)	ʊ (7)
N=14	u (4)	u (4)	u (4)	u (4)	u (4)	u (3)
	ɑ (3)	ɑ (4)	ɑ (1)	ɑ (1)	ɑ (2)	ɑ (3)
	ɪ (1)	ɪ (1)	-----	ɪ (1)	-----	-----
	ɔ (1)	-----	-----	-----	ɔ (1)	-----
	-----	-----	ε (1)	ε (1)	-----	-----
	-----	Λ (1)	-----	-----	-----	-----
% correct	35.7	28.5	57.1	50	50	50

At Time 1, only 1 out of seven attempts (14.2%) at the vowel /u/ were differentiated in the F1/F2 space. The vowel /ʊ/ was somewhat more differentiated in that 5 out of 14 attempts at this vowel were correct matches to the intended centroid on the F1/F2 parameters.

Duration means of the two vowels differed by about 47 msec with /u/ being the longer of the two. When duration was included as an input parameter it did not affect the classification of the vowel /u/ and decreased the number of correct category matches of /u/ by one attempt.

With respect to change across time, both vowels showed slightly better classification. The vowel /u/ increased from one correct attempt to three correct attempts by Time 3. The vowel /ʊ/ improved from five correct attempts to seven correct attempts at Time 3. At first it seems that the vowel /u/ is becoming more distinct from /ʊ/ in that there are more correct instances of /u/ and fewer instances of confusion with /ʊ/. But the number of times /ʊ/ was confused with /u/ did not decrease. The apparent distinction between /u/ and /ʊ/ is really due to the concentration of lexical items that were previously dispersed. Overall, the differences are too small to truly be considered change.

A note about the lexical item *tube* is necessary here. As we saw above with the lexical item *bad*, the numbers change but the patterns of change remained analogous whether the item *tube* was included or not. At Time 1 with *tube* included, /u/ was at 0% correct (only one less than when *tube* was excluded). Duration improved this to 27.2% correct (or 3 out of 11). By Time 3 the vowel /u/ showed an improvement in classification to 45.5% correct (or 5 out of 11 attempts) regardless of whether duration was included. The vowel

/ʊ/ maintained its classification across time at about 42% correct (or 6 out of 14) and showed similar duration effects. The additional items indicate that /u/ may indeed be undergoing a split from /ʊ/.

9.6.2. Comparison of /u/ and /ʊ/ to the Native Speaker

When compared to the native speaker's data (as shown in Table 9.11) it is clear that the vowel /u/ was the better match. Although there were slight differences with duration and slight differences across time, for the most part these vowels do not change with respect to the native speaker's categories.

Table 9.11 Results of the Discriminant Analyses of the Vowels /u/ and /ʊ/ Pronounced by NNS05 Compared to the Native Speaker

Target Vowel	Time 1		Time 2		Time 3	
	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration
u	u (6)	u (5)	u (7)	u (7)	u (5)	u (4)
N=7	o (1)	o (2)	-----	-----	o (1)	o (2)
	-----	-----	-----	-----	ɔ (1)	ɔ (1)
% correct	85.7	71.4	100	100	71.4	57.1
ʊ	ʊ (1)	ʊ (1)	ʊ (1)	ʊ (1)	ʊ (2)	ʊ (1)
N=14	u (9)	u (9)	u (7)	u (8)	u (9)	u (11)
	ɪ (3)	ɪ (2)	ɪ (4)	ɪ (3)	ɪ (2)	-----
	o (1)	o (1)	-----	-----	o (1)	o (2)
	-----	-----	i (1)	i (1)	-----	-----
	-----	-----	ɔ (1)	ɔ (1)	-----	-----
	-----	e (1)	-----	-----	-----	-----
% correct	7.1	7.1	7.1	7.1	14.2	7.1

Note that the vowel /u/ is a better match to the intended native speaker's centroid than /ʊ/ is. Six of the seven attempts at /u/ matched the native speaker's F1/F2 values for /u/ whereas only one of the fourteen attempts at /ʊ/ does.

With the lexical item *tube* included the numbers are different but the change is analogous to what we have already seen. The vowel /u/ was the better match to the native speaker's category. It improved slightly at Time 2 and stabilized by Time 3.

9.7. The Mid Back Vowels

The final pair for consideration is the mid back pair including the vowel /o/ (as uttered in the words *coat*, *code* and *boat*) and the vowel /ɔ/ as uttered in the words (*taught*, *talk* and *caught*). Figures 9.10, 9.11 and 9.12 show the F1/F2 plots of these vowels across three points in time. It is apparent from the F1/F2 plots that these vowels overlapped with each other but were also dispersed among the central and low vowels as well.

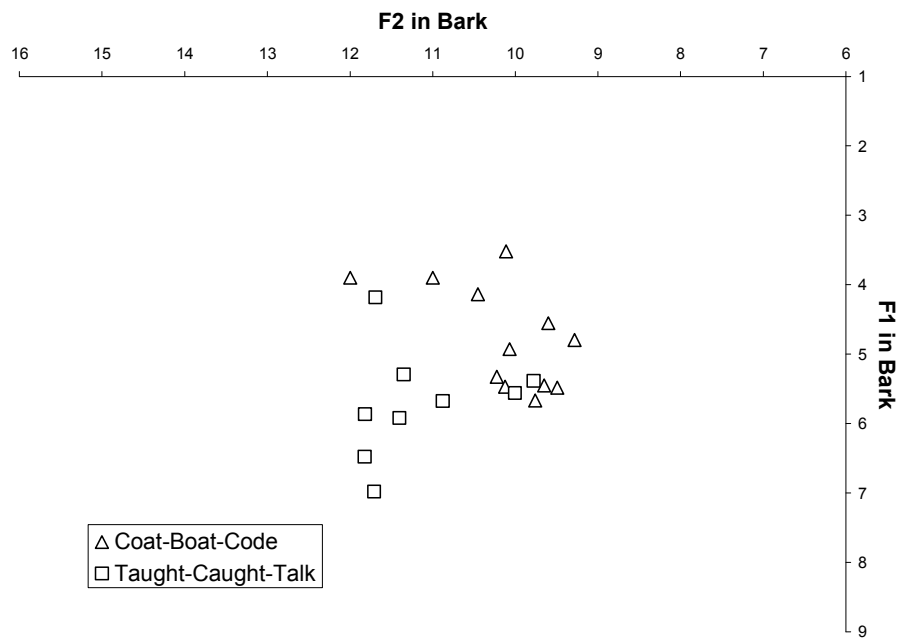


Figure 9.10 F1/F2 plot of the mid back vowels at Time 1 pronounced by NNS05

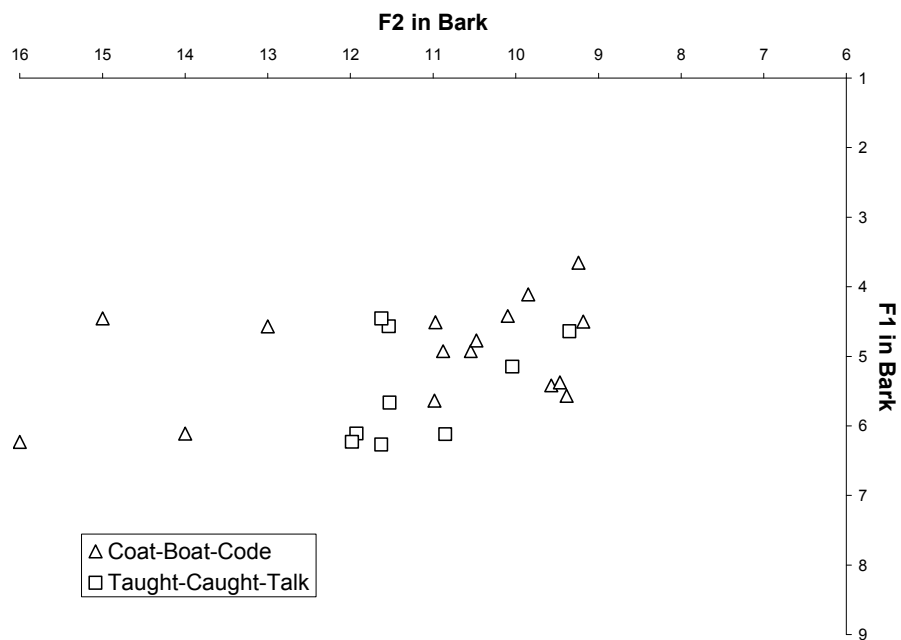


Figure 9.11 F1/F2 plot of the mid back vowels at Time 2 pronounced by NNS05

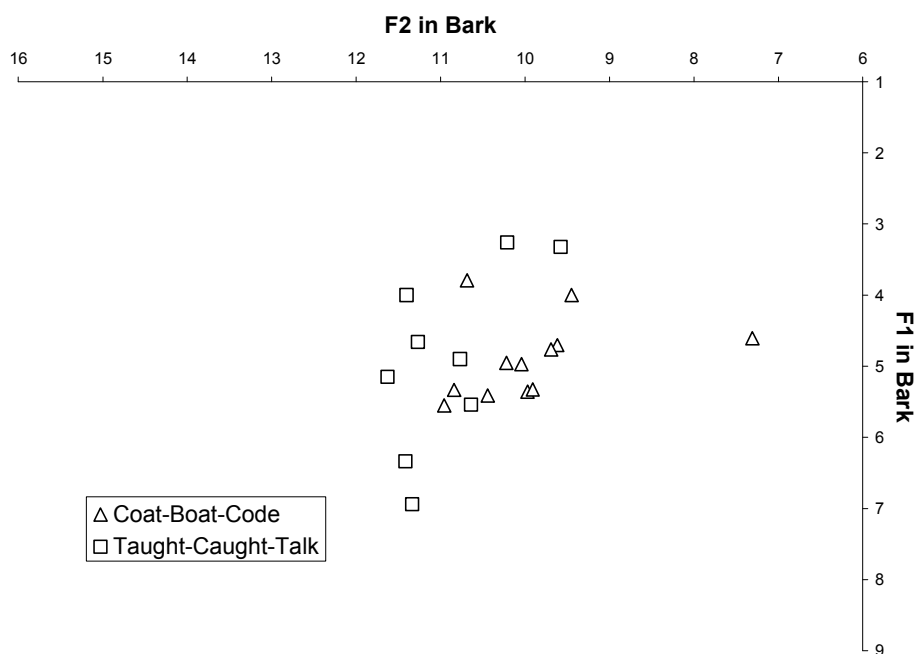


Figure 9.12 F1/F2 plot of the mid back vowels at Time 3 pronounced by NNS05

9.7.1. The Distribution of /o/ and /ɔ/ by NNS05

The results of the discriminant analyses confirm our impression of the mid back vowels. These results are shown in Table 9.12 with this nonnative speaker's vowels considered independently of the native speaker's data.

Table 9.12 Results of the Discriminant Analyses of the Vowels /o/ and /ɔ/ Pronounced by NNS05 across Three Times

Target Vowel	Time 1		Time 2		Time 3	
	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration	Match /# of Tokens F1/F2	Match /# of Tokens F1/F2 Duration
o N=12	o (7)	o (9)	o (9)	o (10)	o (7)	o (6)
	ʊ (3)	ʊ (2)	ʊ (2)	ʊ (1)	ʊ (2)	ʊ (2)
	ɔ (1)	ɔ (1)	ɔ (1)	-----	ɔ (1)	ɔ (2)
	u (1)	-----	-----	-----	u (1)	u (1)
	-----	-----	-----	ɑ (1)	ɑ (1)	ɑ (1)
% correct	58.3	75	75	83.3	58.3	50
ɔ N=9	ɔ (4)	ɔ (6)	ɔ (4)	ɔ (5)	ɔ (1)	ɔ (5)
	o (2)	o (1)	o (2)	o (2)	o (1)	-----
	ɑ (1)	-----	ɑ (3)	ɑ (2)	ɑ (2)	ɑ (2)
	-----	-----	-----	-----	ʊ (3)	ʊ (2)
	-----	ʌ (1)	-----	-----	ʌ (2)	-----
æ (2)	æ (1)	-----	-----	-----	-----	
% correct	44.4	66.6	44.4	55.5	11.1	55.5

At Time 1, 7 out of 12 attempts at the vowel /o/ were differentiated and 4 out of 9

attempts at the vowel /ɔ/ were differentiated on the F1/F2 parameters.

Duration means between these vowels differed by about 25 msec and surprisingly the vowel /ɔ/ was longer for NNS05 (as it was for both native speakers). When duration was included as an input parameter it improved classification rates of both vowels by two instances each.

With respect to change over time we see improvement in classification rates for the vowel /o/, at which point the number of correct matches increased by two instances on the F1/F2 parameter and one instance when duration was included. There was no notable change for /ɔ/ from Time 1 to Time 2. By Time 3 both vowels decreased in terms of distinctness with the most notable decrease for /ɔ/ on the F1/F2 condition. Both vowels were being dispersed to other vowel categories. But these changes were small so we will simply say that what began as widely dispersed and poorly distinguished vowels ended up the same at Time 3.

9.7.2. Comparison of /o/ and /ɔ/ to the Native Speaker

Next consider the mid back vowels in direct comparison to the native speaker's data as shown in Table 9.13. When compared directly to the native speaker's categories, the vowel /o/ is a relatively good match for native speaker's /o/, but the vowel /ɔ/ is a poor match, being confused with as many as six other vowels on the F1/F2 only condition. Duration improved the percentage of correct category matches of /o/ slightly and consistently across the three times. Duration had little effect on the percentage of correct category matches of /ɔ/. Although this native speaker did produce the same duration relationship between the two vowels as the native speaker (/ɔ/ longer than /o/), we should keep in mind that duration did not significantly affect the rates of classification of these vowels in the native speaker either.

Table 9.13 The Results of the Discriminant Analyses of the Vowels /o/ and /ɔ/ Pronounced by NNS05 Compared to the Native Speaker

Target Vowel	Time 1		Time 2		Time 3	
	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration	NS Match /# of Tokens F1/F2 Duration
o N=12	o (9)	o (8)	o (3)	o (5)	o (7)	o (9)
	u (3)	u (3)	u (6)	u (6)	u (2)	u (2)
	-----	ɔ (1)	ɔ (1)	ɔ (1)	ɔ (1)	ɔ (1)
	-----	-----	ʊ (1)	-----	ʊ (1)	-----
	-----	-----	ʌ (1)	-----	ʌ (1)	-----
% correct	75	66.6	25	41.6	58.3	75
ɔ N=9	-----	ɔ (1)	-----	-----	-----	-----
	-----	u (1)	-----	u (2)	u (4)	u (6)
	o (2)	o (4)	o (2)	o(3)	-----	o (1)
	æ (2)	æ (3)	æ (1)	æ (3)	-----	æ (1)
	ε (2)	-----	ε (3)	ε (1)	-----	-----
	ʊ (1)	-----	ʊ(1)	-----	ʊ (2)	-----
	ʌ (1)	-----	ʌ (1)	-----	ʌ (2)	-----
	-----	-----	-----	-----	ɑ (1)	ɑ (1)
	ɪ (1)	-----	ɪ (1)	-----	-----	-----
% correct	0	11.1	0	0	0	0

With respect to change across time, the only notable change is a sharp decrease at Time 2 in the percentage of correct category matches of /o/. Note that at Time 1, 8 to 9 instances of /o/ were categorized with the native speaker's category for /o/ whereas at Time 2 only 3 to 5 attempts matched the native speaker's /o/. This sharp decline, which was clearly a case of dispersion, ultimately concentrated again by Time 3.

9.8. Summary of the Vowel System of NNS05

We can summarize the vowel system of NNS05 by looking at the distinctions made and how they changed over time both independently of and in comparison to the native speaker.

At the initial recording, when NNS05 was considered independently of the native speaker, we saw that there was some differentiation between the pair /i/ -/ɪ/ with /i/ being more consistently classified with its intended category. The vowels /e/ and /ɛ/ showed less differentiations with /ɛ/ being more consistently classified with its intended target.

The vowel /ʌ/ virtually did not exist as a separate vowel and /æ/ and /ɑ/ showed differentiation in only about half the instances. The vowels /u/ and /ʊ/ were poorly differentiated with /ʊ/ being more consistently classified. Finally, the vowels /ɔ/ and /o/ showed differentiation from other vowels in only about half of the instances.

In direct comparison to the native speaker, the vowels /i/ and /ɪ/ both matched the native speaker's /i/ with virtually no differentiation between them. The vowels /e/ and /ɛ/ both matched the native speaker's /e/ with virtually no differentiation between them. The vowels /æ/ and /ʌ/ matched the corresponding native speaker's vowels roughly half of the time but the vowel /ɑ/ did not correspond to native speaker /ɑ/ at all. The vowels /u/ and /ʊ/ matched the native speaker's /u/ with no differentiation between the two. The vowels

/o/ matched native speaker's /o/ and the vowel /ɔ/ matched numerous other vowels across the F1/F2 space.

There were several instances of change across time, all of which were observed when this nonnative speaker's system was considered independently as an entity unto itself. The first was a simple merger of /ɪ/ into /i/ with respect to F1/F2 distinctions. We also saw dispersion of the vowels /æ/ and /ɑ/ which initially were distinct at Time 1 but both ultimately ended up dispersed among multiple other vowels.

We saw two cases of split when this nonnative speaker's system was considered independently from the native speaker's system. The vowel /e/ split from /ɛ/ in the F1/F2 space (although this pair had been differentiated by duration so the split is only apparent when one examines the F1/F2 parameters). The vowel /ʌ/, which was initially nonexistent as a category, became more differentiated spectrally and temporally by Time 3.

NNS05 did not exhibit change with respect to moving towards native speaker contrasts. Any change observed in direct comparison to the native speaker's system was less than the normal variation exhibited by the native speaker's in this study.

Chapter 10: Change Over Time in an L2 Vowel System

10.1. Introduction

The research presented in the preceding chapters sought to observe and describe the vowel systems of L2 learners. Although the study focused on only one learning relationship (that of Spanish speakers learning American English vowels), several findings are relevant to second language acquisition in general and directions for future research. We begin with a summary of the findings regarding the types of change observed and then discuss findings relevant to future SLA research.

10.2. Summary of Observed Change

Chapter 2 identified several types of sound change likely to occur in language and by extension in L2 acquisition. The types were based largely on Labov (1994) and included Split, Merger and Shift. Each type of change was defined on the basis of what the movement entailed and also on the basis of what function the movement served with respect to creating, eliminating and maintaining phonemic contrasts. Chapter 2 also identified two other types of change (dispersion and concentration) that seemed specific to L2 learners but may in fact be subtypes of split, merger and shift.

10.2.1. Split

To begin, we can summarize the phonemic splits that were observed across the nonnative speakers. We saw several cases of split in NNS01 during which there was little or no

acoustic evidence of a phonemic category at Time 1 but a new category was formed or was being formed at some subsequent point. The first of these involved the split of /i/ into /i/ and /ɪ/. This split was accomplished via duration differences rather than spectral changes and reinforces previous findings that learners may rely on durational cues to distinguish phonemes in a new language. This is supported by research from cross-linguistic perception studies. Bohn (1995), for example, found that while English listeners relied almost entirely on spectral cues to identify stimuli on the English *beat-bit* and *bet- bat* continuum, German and Spanish listeners relied heavily on duration cues and Mandarin listeners relied almost exclusively on duration cues (1995:299). The second split for NNS01 involved /ɛ/ becoming more distinct from /e/ at Time 2 mainly with respect to spectral values (although a duration distinction was already present). There was a subsequent merger of these phonemes at Time 3 which will be discussed under section 10.2.2. The third split involved /ɑ/ becoming more distinct from /ɔ/ with respect to F1/F2 proximity. The final split for NNS01 can be seen in the vowel /o/ which initially matched the native speaker's /ɔ/ at Time 1 but by Time 3 even more tokens were categorized as similar to the native speaker's /o/ on F1/F2. Other speakers showed evidence of split as well. NNS02 showed one instance of split during which the vowel /ɔ/ became more distinct from /ɑ/. NNS03 showed one case of split in which /ɛ/ and /æ/ became distinct but mainly by duration. Finally NNS05 showed evidence of split involving /ʌ/ which initially did not exist as a vowel with separate F1/F2 values but did so by Time 3. The instances of split are summarized in Tables 10.1 and 10.2 below. Table 10.1 shows all

cases of split when nonnative speakers' vowels were considered independently of the native speakers' vowels. Table 10.2 shows all cases of split when the nonnative speakers' were evaluated against the centroids of the native speakers' vowels.

Table 10.1 Summary of Split across Nonnative Speakers when Vowels were Considered Independently

Speaker	Type of Change	Parameter	Summary of Change
NNS01	Split	Duration	/ɪ/ and /i/ moved toward differentiation
NNS01	Split	F1/F2	/ɛ/ and /e/ moved toward differentiation at Time 2 but subsequently merged
NNS01	Split	F1/F2	/ɑ/ and /ɔ/ moved toward differentiation
NNS04	Split	F1/F2	the Time 2 merger between /æ/ and /ʌ/ subsequently splits at Time 3
NNS05	Split	F1/F2	/e/ and /ɛ/ moved toward differentiation
NNS05	Split	F1/F2	/ʌ/, which did not exist as a category at Time 1, was somewhat differentiated at Time 3
NNS02	Split	F1/F2	/e/ and /ɛ/ moved toward differentiation but was coupled with a merger between /ɛ/ and /ɪ/

Table 10.2 Summary of Split across Nonnative Speakers in Comparison to the Native Speakers

Speaker	Type of Change	Parameter	Summary of Change
NNS01	Split	F1/F2	/o/ (initially matched to native speaker /ɔ/) matched native speaker's /o/ by Time 3
NNS03	Split	Duration	/ɛ/ (initially matched to native speaker /æ/) matched native speaker's /ɛ/ by Time 3

10.2.2. Merger

Merger also occurred in the vowel systems of the nonnative speakers in this study.

Merger was evidenced by the presence of a phonemic contrast at one point in time that was not present at a later point in time, effectively eliminating the contrast. Recall the discussion from Chapter 2 in which a distinction was made between transfer from L1 and merger. The cases of merger summarized here are specifically changes over time. They are not simply cases of transfer, where the speaker was using a single L1 phoneme to pronounce two separate phonemes in the L2.

NNS01 showed two instances of merger both of which were related to splits at either an earlier point in time or in another vowel contrast. The first is a Time 3 merger between /e/ and /ɛ/ which had previously moved toward distinction at Time 2. This merger constitutes backsliding, during which a contrast that had been learned reverted to an earlier stage.

The second merger seen in NNS01 was the merger between /ʌ/ and /ɑ/ which may have

resulted from the split between /ɑ/ and /ɔ/ in this speaker. That is to say as /ɑ/ became more differentiated from /ɔ/ it moved into the F1/F2 space of /ʌ/. NNS02 also had some vowels merge. In this speaker we saw a merger between /ɛ/ and /ɪ/ that occurred along with a split of /e/ and /ɛ/. As /e/ and /ɛ/ became more differentiated /ɛ/ became less differentiated from /ɪ/. NNS03 merged the vowels /e/ and /ɛ/ when his vowel system was compared directly to the native speaker's. NNS04 initially had a distinction between /æ/ and /ʌ/ which then merged at Time 2 (and subsequently split again at Time 3). This speaker also merged /ʌ/ with /ɑ/ when his vowels were compared directly to the native speaker's. Finally, NNS05 merged /ɪ/ with /i/ even though there had initially been some differentiation of these two vowels. The cases of merger observed in this study are summarized in Tables 10.3 and 10.4. Table 10.3 shows all cases of merger when nonnative speakers' vowels were considered independently of the native speakers' vowels. Table 10.4 shows all cases of merger when the nonnative speakers' were evaluated against the centroids of the native speakers' vowels.

Table 10.3 Summary of Merger across Nonnative Speakers when Vowels were Considered Independently

Speaker	Type of Change	Parameter	Summary of Change
NNS01	Merger	F1/F2	/e/ and /ɛ/ merged at Time 3 (after a Time 2 split)
NNS01	Merger	F1/F2 Independent of and in Comparison to Native Speaker	/ʌ/ merged with /ɑ/ - perhaps related to /ɑ/ splitting from /ɔ/
NNS04	Merger	F1/F2	/æ/ merged with /ʌ/ but showed some differentiation again at Time 3
NNS05	Merger	F1/F2	/ɪ/ merged with /i/

Table 10.4 Summary of Merger across Nonnative Speakers in Comparison to the Native Speakers

Speaker	Type of Change	Condition	Summary of Change
NNS01	Merger	F1/F2 Independent of and in Comparison to Native Speaker	/ʌ/ merged with /ɑ/ (perhaps related to /ɑ/ splitting from /ɔ/)
NNS02	Merger	F1/F2	/ɛ/ merged with /ɪ/
NNS03	Merger	F1/F2	/e/ merged with /ɛ/
NNS04	Merger	F1/F2	/ʌ/ merged with /ɑ/

10.2.3. Shift

The third type of change we saw in the nonnative speakers was shift. The cases summarized below are those of simple shift. We have not seen chain shift (either minimal or extended) and reasons for this will be addressed subsequently. The first case of shift involved the movement of a single phoneme to another vowel space. Initially, NNS02 produced a single vowel phoneme in the range of the native speaker's /i/. Over time, this single vowel phoneme did not split but moved in the acoustic space to match the native speaker's /i/. Since this movement did not create or eliminate contrasts and since it only involved one movement of one vowel, we have referred to it as a simple shift.

The second case of shift was seen in NNS01, during which a poorly differentiated pair of vowels produced closest to the centroid of one member of the pair shifted toward the centroid of the other member of the pair. This was the case with the production of /e/ and /ɛ/ when NNS01 was compared directly to the native speaker. Initially, NNS01 produced a greater number of the lexical items in the range of the native speaker's /e/ regardless of what the target phoneme actually was. Over time this shifted in that most of the target words matched the native speaker's. NNS01 also showed a similar pattern of shift for the vowels /ʌ/ and /ɑ/. The cases of shift observed in this study are summarized in Tables 10.5 and 10.6. Table 10.5 shows all cases of shift when the nonnative speakers' vowels were considered independently of the native speakers' vowels. Table 10.6 shows all cases of shift when the nonnative speakers' were evaluated against the centroids of the native speakers' vowels.

Table 10.5 Summary of Shift across Nonnative Speakers when Vowels were Considered Independently

Speaker	Type of Change	Parameter	Summary of Change
NNS01	Shift	F1/F2	/ʌ/ and /ɑ/ were primarily matched to /ʌ/ but shifted together to match /ɑ/.

Table 10.6 Summary of Shift across Nonnative Speakers in Comparison to the Native Speakers

Speaker	Type of Change	Parameter	Summary of Change
NNS02	Shift	F1/F2	/i/ and /ɪ/ were primarily matched to the native speaker's centroid for /i/ but shifted together to match the native speaker's centroid for /ɪ/.
NNS01	Shift	F1/F2	/e/ and /ɛ/ initially matched the native speaker's centroid for /e/ but shifted together to match the native speaker's centroid for /ɛ/.

A note about chain shifts is necessary before moving on to the remaining types of changes. There was no clear evidence of chain shifting, in which one vowel moves into the space left empty by another vowel. There are several possible reasons for this. First, it may be the case that chain shifting takes longer to occur than other types of change and therefore would not be observable over the period of this study. More likely however, it is due to the nature of the discriminant analysis itself. That is to say, discriminant analysis places vowels into groups. Therefore, there may be no such thing as unoccupied space under this analysis. Discriminant analysis may look at all movement as either into a

grouping or out of a grouping without having the power to see a new group. This analysis is better for observing merger, splits and simple shifts.

10.2.4. Dispersion and Concentration

In addition to splits, mergers and simple shifts, we saw two additional types of change that were specific to the learning of sound-spelling correspondences: dispersion and concentration. In dispersions, lexical items that original belonged to a single group were scattered over several preexisting groups. NNS02 originally pronounced target words containing /ʌ/ with relative distinction but over time dispersed these lexical items among several other phoneme groupings. NNS03 showed the same dispersion with the vowel /ʌ/. NNS05 had two cases of dispersion, one in which target words containing /æ/ were produced as distinct from his other vowels, but then later dispersed. The other case occurred with target words containing /a/ that were consistently matched to their intended centroid at Time 1 but were later dispersed. The cases of dispersion observed in this study are summarized in Tables 10.7 and 10.8. Table 10.7 shows all cases of dispersion when the nonnative speakers' vowels were considered independently of the native speakers' vowels. Table 10.8 shows all cases of dispersion when the nonnative speakers' were evaluated against the centroids of the native speakers' vowels.

Table 10.7 Summary of Dispersion across Nonnative Speakers when Vowels were Considered Independently

Speaker	Type of Change	Parameter	Summary of Change
NNS02	Dispersion	F1/F2	/ʌ/ initially matched its intended centroid but was subsequently dispersed among other centroids
NNS03	Dispersion	F1/F2	/ʌ/ initially matched its intended centroid but was subsequently dispersed among other centroids
NNS05	Dispersion	F1/F2	/æ/ initially matched its intended centroid but was subsequently dispersed among other centroids
NNS05	Dispersion	F1/F2	/ɑ/ initially matched its intended centroid but was subsequently dispersed among other centroids

Table 10.8 Summary of Dispersion across Nonnative Speakers in Comparison to the Native Speakers

Speaker	Type of Change	Parameters	Summary of Change
NNS02	Dispersion	F1/F2	/u/ initially matched the native speaker's centroid (to some extent) but was subsequently dispersed among other centroids.

Finally, two cases of concentration were observed. Concentration is essentially the opposite of dispersion. During concentration, lexical items containing a single target phoneme are initially scattered among existing phoneme categories but are then concentrated into a single category. Concentration was observed in NNS01 where target words containing the vowels /o/ and /ɔ/ were initially scattered among several categories

but ended up with more of the target words matching their intended vowel centroid. Concentration was also observed in NNS05 during which the target words containing the vowels /u/ and /ʊ/ were initially dispersed across several other vowel centroids but later had more target words matching the intended centroids. Finally concentration was seen in NNS04 during which lexical items containing the target vowel /ʊ/ had initially been scattered across other vowel centroids but ultimately showed more matches to the intended centroid.

The cases of concentration observed in this study are summarized in Tables 10.9 and 10.10. Table 10.9 shows all cases of concentration when the nonnative speakers' vowels were considered independently of the native speakers' vowels. Table 10.10 shows all cases of concentration when the nonnative speakers' were evaluated against the centroids of the native speakers' vowels.

Table 10.9 Summary of Concentration across Nonnative Speakers when Vowels were Considered Independently

Speaker	Type of Change	Parameter	Summary of Change
NNS01	Concentration	F1/F2	/ɔ/ was initially dispersed but concentrated to match its intended centroid
NNS05	Concentration	F1/F2	/u/ and /ʊ/ were initially dispersed but concentrated to match their intended centroids

Table 10.10 Summary of Concentration across Nonnative Speakers in Comparison to the Native Speakers

Speaker	Type of Change	Condition	Summary of Change
NNS04	Concentration	F1/F2 and Duration	/ʊ/ was initially dispersed but concentrated to match the native speaker's centroid (this was paired with a dispersion of /u/)

10.3. Discussions

Having summarized the observations of change we can now discuss the methodological limitations of this study and directions for future research.

10.3.1. Considering the Learner's System Independently of the Target

The nature of Interlanguage (IL) has been discussed for many years in the L2 literature. Seminal papers such as Selinker (1972) have proposed the idea that IL is a system unto itself unlike either the native language or the target language. Production and perception studies have supported this perspective showing that some productions have intermediate phonetic properties that are not identical to the target language but are also not identical to the native language. This study confirms the importance of examining learner's productions independently of the target language. In fact, many of the changes were observed when phonemic contrasts were considered independently of how they matched the native speakers' contrasts. L2 learners are indeed changing even if those changes do not match the target norms. It is possible that some of the changes may have simply been

variability and not a true trajectory. But it can be reasonably argued that the changes that served to differentiate vowels were worthwhile steps towards acquisition even if the speaker does not yet match native pronunciation.

10.3.2. The Nature of the Native Speaker

In many studies we find that the data from native speakers and the learners are compiled via separate research. That is, the experiments involve the learners themselves but the native system is extrapolated from previous studies. This particular study is guilty of this with respect to the Spanish data in that all insights into the vowel system of Spanish came from other speakers in another study on different tasks and data.

This study did, however, test native English speakers on the same data as the nonnative speakers over the same period of time. In doing so, a more realistic picture of the input that nonnative speakers receive emerged. In this particular study we saw a great deal of overlap in the vowel phonemes as produced by the native speakers, we saw differences in the way duration was used by the native speakers, we saw allophonic variation, and dialectal variation. We also saw a potential connection between the nature of the native speakers' productions and acquisition by the nonnative speakers. This connection can be seen in dialect specific features (such as the difference between /ɔ/ and /ɑ/) as well as allophonic variations (such as the fronting of /u/ after alveolars) which some of the nonnative speakers were acquiring. Recall too that for both native speakers, the vowel /ʌ/ showed the poorest category differentiation of all the vowels. In turn we saw that two of

the five cases of dispersion involved this same vowel. Although we cannot show a definite relationship between what the native speakers produced and what the nonnative speakers acquired, a possible relationship is worth future consideration. This insight comes only from knowing how native speakers from the learners target dialect performed on the same set of elicitation tasks and data. Thus, it would be useful in future SLA research to know the target rather than extrapolating it.

10.3.3. Limitations of the Study

There are several limitations to the research presented here, which are addressed in this section. First, this study looked at only one learning relationship. Although there are practical reasons for this method, it leaves us with gaps in our understanding of how sound systems change during L2 acquisition. As noted earlier, Spanish speakers learning English are faced with the expansion of a vowel system when learning English but this is not so for all learning relationships. SLA research certainly needs longitudinal descriptive studies of a variety of L1s and target languages.

Additionally, this study was limited to the vowels. It is certainly possible that consonant contrasts and vowel contrasts do not behave the same way or change at the same rate. So, studies that involve a more comprehensive examination of change throughout the entire phonological system are also necessary.

Most importantly, this study was limited by the sentence elicitation task. This means of elicitation was used in an attempt to create a controlled but realistic linguistic

environment. It is clear, however, that sound-spelling correspondences presented errors in pronunciation that may or may not have occurred if the participants had not been reading. In this study the orthography produced an additional level of representation for the speakers. This is not to suggest that the role of orthography should be completely ignored. Only that studies of linguistic change that rely on spontaneous speech which requires the speaker to construct a grammar and not read, or repeat are certainly needed.

Finally, as noted earlier, this study focuses on the phoneme as the atomic unit devoid of internal structure. This was not a theoretical assumption but rather a limitation of the statistical analysis. Further analysis is required to look at the role of the feature in longitudinal studies study such as this one.

10.3.4. The Nature of Change in L2 Acquisition

In this study we have seen that nonnative speakers show evidence of transfer from L1 when speaking an L2. Transfer was evident in both the number and types of phonemic contrasts made as well as in the phonetic properties of the sounds produced. Change occurred in both the native speakers and the nonnative speakers and while seemingly different, there was one fundamental property of both: the preservation of phonemic contrasts. The native speakers showed changes in phonetic properties across time in terms of which categories overlapped, in terms of how duration was used and in terms of how individual vowel groups were located in the acoustic space. But, through all the low level phonetic changes, the eleven phonemes were generally maintained as distinctive by the native speakers. Similarly, although the nonnative speakers were clearly attempting to

learn new contrasts and reorganized their vowels towards this end, the tendency to preserve the number of phonemic contrasts in their L1 was also evident. An obvious conflict between the need to change and the tendency to preserve emerged. This conflict between change and preservation was seen in several ways throughout the study. First, we saw cases of split which would ostensibly create an additional phoneme but were coupled with mergers of neighboring contrasts. The subsequent merger ultimately returned the system to the same number of contrasts it began with. The conflict was also seen in cases of shift during which a single phoneme transferred from L1 (in place of separate phonemes in the L2) would shift around in the vowel space but never quite separate. It was as if the learner knew that the productions weren't matching the target but couldn't quite get that separation to occur. Finally, the conflict between change and preservation was evident in the cases in which a split occurred but then merged again at a later point in time. We have evidence from previous research that learners who are faced with splitting a single phoneme into two contrasting phonemes have more difficulty than if they were faced with suppressing a contrast (Brière, 1966). We also know from sociolinguistic research that splits occur less frequently than mergers or shifts and that once merged, phonemes do not tend to unmerge (Garde's principle attributed to Labov, 1994). By all accounts the learners in this study faced a difficult task but provided us with useful insight into the process of acquiring an L2 vowel system.

This study attempted to fill in gaps in our knowledge of second language acquisition by observing and describing an entire subsystem of the larger phonological system in L2 learners. It is necessary that research in the field of second language acquisition continue

to examine both the parts of the system as well as the whole system. Future research should also include studies of perception in conjunction with production. It would be interesting to determine if changes in the nonnative speakers that did not quite match the native speakers' vowels were evidence of improved accuracy in perception. Was it the case that the learners were starting to perceptually differentiate target contrasts but had not yet learned how to produce those contrasts?

The implications of this study for teaching and assessment cannot be overlooked. If in fact a split in one area of the system can result in merger in another area, then assessment of L2 pronunciation must also take the whole system into consideration and not just individual sounds or contrast. Teachers must also consider that vowels can be acoustically differentiated and contrasts can be made, even if those differentiations do not match the native speakers' productions. Although native proficiency is often taken to be the ultimate goal of L2 acquisition, one must consider that learners have other goals. These include (at least for pronunciation) making contrasts that may in turn help them achieve intelligibility. Yet, once vowel contrasts are made and some level of intelligibility is achieved, it seems that strong social or psychological factors would be needed to motivate change to continue towards native-like proficiency. The findings of this study support a growing view of language teaching; L2 learners are not simply failed native speakers. As Cook (1999) suggests, "...L2 learners should be considered as speakers in their own right, not as approximations to monolingual native speakers (p. 185)."

Appendixes

Appendix A: Questionnaire

Identification Number _____

1. Age _____
2. Country where you were born _____
3. City where you were born _____
4. Native language _____
5. Do you speak any other language(s) besides English and your native language? Please specify . _____
6. How long have you been in the United States? _____
7. Have you lived in any English speaking country other than the United States? Please specify. _____
8. At what age did you begin studying English? _____
 What was the nature of this study (high school requirement, travel abroad, etc.)?

-
9. How many years have you studied English (total)? _____
 Number of years in your country _____
 Number of years in this country _____
 Number of years in any other country _____
 10. Have you ever received pronunciation training? _____
 Where did you receive this training? _____
 Was your teacher a native speaker of English? _____
 11. Do you watch American TV? (hours per day) _____
 12. Do you read American newspapers? (times per week) _____
 13. Do you read books in English? (number per month) _____
 14. What language or languages do you use at work? _____
 15. What language do you speak at home? _____
 16. What language do you speak with your friends? _____

Appendix B: Sentences for the Reading Task**Block 1**

Management held a seminar on how to keep staff motivated.

Did you pick him first or last?

He was instructed to take one and put the rest of them back.

My dog likes it when I pet her head.

When I was a child my favorite book was the Cat in the Hat.

That big cut you have is really nasty.

He was trying to catch a fish, but he caught an old boot instead.

The three of them took forever.

You'll want to coat the chicken with egg before you dip it in the batter.

When you talk to your teacher ask him about the final exam.

The water in the pot boiled over because the flame was too high.

Block 2

You should keep your seat belt on until the ride stops.

Did somebody pick at the birthday cake ahead of time?

The class will take the exam during the first hour.

One pet is enough in this tiny apartment.

My old cat greets me when I get home from work at night.

Make sure you cut the paper according to the instructions.

When one boot drops the other will surely follow.

We drove to South Carolina and it took us sixteen hours.

The wool coat I bought just isn't as warm as I thought.

The three of them talk forever.

A large pot of butter contains a lot of fat.

Block 3

They say to keep your chin up even when times are tough.

We should pick names out of a hat so the contest is fair.

We have to take the trash out on the first of the month.

When I pet the dog he tried to bite me.

That big cat you have is really nasty.

Lucy cut class on Tuesday, but her teacher didn't know.

One boot fit but the other didn't.

I didn't yell at her but it took all of my strength not to.

She left her coat on the chair and when she got back it was gone.

The baby couldn't talk yet but she found other ways to express herself.

They say that there's a pot of gold at the end of the rainbow.

Block 4

Does John keep his money in the First International Bank?

I always pick the same six numbers every week, but I never win the lottery.

Did Mary take any medicine for her cold?

The pet was larger than I thought.

The black cat liked tuna fish; the white cat wouldn't go near it.

First you choose the fabric, then you cut the pattern.

What will you do with only one boot to wear?

We didn't like him because he always took more than his fair share.

I think the one coat in the winter isn't enough.

Who did you talk to when you called the office?

The flower pot was leaking and the water was ruining the carpet.

Block 5

Her boss told her to keep up the good work.

Her mother told her to pick up her clothes.

Would it take a lot of time to organize a second staff party?

When you're a kid having a pet is a big responsibility.

The hungry cat came running when it heard the can-opener.

The famous singer cut her first album twenty years ago.

The whole boot strap was ripped to pieces.

The boy took three tries before he finally got the ball in the basket.

The wind started to blow and I wished I had brought a coat with me.

If you would just talk to him, I'm sure you could straighten the whole thing out.

That stainless steel pot you bought is too big to fit in the cabinet.

Block 6

Did someone peek at the birthday cake before the party?

The pit was larger than I thought.

He doesn't get paid to work there; he's just a volunteer.

I know he's upset now, but he'll get over it in time.

First you should put the soil in and then you should pat it down with your fingers.

There's never a cup around when you need one.

When we hit the tree the inner tube lost a lot of air.

He didn't know he could ski well until he tried it.

The bomb code left by the officer, was top secret.

I think the one caught in the winter isn't enough.

She graduated at the top of her class.

Block 7

Do you peek at your presents before your birthday?
Don't eat the pit from a peach, it could make you sick.
They couldn't agree on how much he should get paid per hour.
He was the last one to get married.
A large pat of butter contains a lot of fat.
The beautiful cup that my friend bought me broke in the dishwasher.
The old tube of toothpaste was empty.
I wonder if the secretary could mail this today.
The computer reads the price from the code label on the box.
I missed the beginning of my favorite show but I caught the last twenty minutes.
The spikes on top of the gate stop people from climbing over.

Block 8

Lisa should peek out the window to see if they are coming?
We built a pit for our fire and had a camp-out.
I finally paid back all of my debts and cut up my credit cards.
The defendants will get twenty years in jail if convicted.
My grandfather used to pat my head when I did something good.
Put an extra cup on the table, in case another person shows up.
The large tube leaked so we couldn't use it.
The dog learned many tricks; it could lie down, sit up and play dead.
The children used a code language to communicate with each other.
The girl caught three fish but none big enough to eat.
Once you get to the top of the escalator the shoe department is on the left.

Block 9

Take a peek at his work and tell me if you think its good.
The garbage pit was illegal, and the company got a huge fine.
He gets paid too much for such an easy job.
I hope she will get out of work soon.
Be sure to pat it gently otherwise the dough will rip.
Which cup is yours and which is mine?
I buy toothpaste in a pump because the tube never works.
Jen knew she could make the team if she practiced enough.
The computer code Lisa uses is more complicated than the one John uses.
Mother caught them smoking in her room.
She was on top of the problem before anyone knew about it.

Block 10

Will you peek over the fence and see if our ball is there?
 The thought of it gave her a queasy feeling in the pit of her stomach.
 The owner paid some of her employees in cash and some by check.
 The students will all get good grades because the class is easy.
 My dog likes it when I pat her head.
 He always leaves his cup in the sink without washing it.
 The tunnel was closed because one tube needed work.
 I didn't know she could sing so well.
 Bar code labels are quite common in the grocery stores.
 The professor caught a cold and couldn't give his speech.
 It took all day but we finally reached the top of the mountain.

Block 11

The one bead lost its color after a few years.
 The sneaky kid left before his mother found out.
 My remote controlled gate and garage door don't always work.
 The king bed we ordered didn't fit in the room.
 The one bad part of the trip was coming home.
 All but one of the children played with the blocks.
 If the birds are trained they will return to the coop every time.
 When you're done, be sure to put it back on the shelf.
 We took a nice long boat ride down the river.
 Once she taught him the basics, he learned to play the guitar easily.
 The undercover cop stopped the car before anyone got hurt.

Block 12

A green bead for each earring will complete the design.
 The father hates roller coasters but the kid loves them.
 The tall gate at the end of the driveway was over a hundred years old.
 The queen bed she ordered was guaranteed to last for ten years.
 If John studies hard, he won't get bad grades.
 All but one of the puppies had black and white spots.
 We used to keep different kinds of birds in the coop out back.
 She couldn't put up with her boss so she quit.
 The notice said that all boat activity must stop after ten o'clock.
 The accident taught her a lesson and she soon stopped drinking.
 The stolen car was found thanks to a resourceful cop from the eleventh precinct

Block 13

One bead fell off, but the rest of them stayed on.
 A careful kid will look both ways before crossing the street.
 The wooden gate on her house was smashed in the bad storm.
 Last week I bought a full bed linen set.
 The real bad lines of the movie got edited out.

She was able to get in touch with all but one of her classmates.
The pigeon coop on our roof held at least fifty birds.
Make sure you put a fork at each place setting.
All fishing boat passengers should wait at the dock.
I couldn't remember any of the techniques they taught me in self-defense class
There's never a cop around when you need one.

Block 14

One little bead for a necklace just isn't enough.
What kind of vegetables does your kid like?
A strong gate on a fence is good protection against crime.
All of the bed linens should be washed twice a week.
The one bad thing about the summers is the humidity.
I got good grades in all but one of my classes.
He carelessly put a glass on the edge of the table and it got knocked off.
It is not surprising that all boat owners share a love of water.
It is sad that the coop door was left open because most of the birds flew away.
He was the one who taught the overworked staff how to manage job stress.
The friendly cop who patrols our neighborhood is good with the kids.

Block 15

All of the famous bead retailers are in Manhattan.
It turned out that one kid left his coat home, so we had to go back and get it.
The iron gate on the fence kept out intruders.
After the guest left, the maid realized he had stolen some bed linens.
Not all bad lives start out that way.
Everyone but Mary was invited to the party.
The pigeon coop in the yard was old and rusty.
Please put a thirty-three cent stamp in the upper right corner.
The one boat he owned cost a lot of money.
My mother taught me everything I know.
The strict cop stopped the kids from drinking on the corner.

References

- Adjemian, C. (1976). On the nature of interlanguage systems. *Language Learning*, 26(2), 297-320.
- Aoyama, K., Flege, J.E., Guion, S. Akahane-Yamada, R. & Yamada, T. (2004). Perceived phonetic dissimilarity and L2 speech learning: The case of Japanese /r/ and English /l/ and /r/. *Journal of Phonetics*, 32, 233-250.
- Bohn, O. S. (1995). Cross language speech perception in adults: First language transfer doesn't tell it all. In W. Strange (Ed.), *Speech Perception and Linguistic Experience: Theoretical and Methodological Issues*. Timonium, MD: York Press.
- Bradlow, A. R. (1995). A comparative acoustic study of English and Spanish vowels. *The Journal of the Acoustical Society of America*, 97(3), 1916-1924.
- Briere, E. J. (1966). An investigation of phonological interference. *Language*, 42(4), 768-796.
- Carlisle, R. S. (1991). The influence of environment on vowel epenthesis in Spanish/English interphonology. *Applied Linguistics*, 12(1), 76-95.
- Chomsky, N. & Halle, M. (1968). *The Sound Pattern of English*. New York: Harper Row.
- Cook, V. (1999). Going beyond the native speaker in language teaching. *TESOL Quarterly*, 33(2), 185-209.
- Dubach Green, A. (2001). The tense-lax distinction in English vowels and the role of parochial and analogical constraints. *Linguistics in Potsdam*, 16, 32-57.
- Durand, J. (2005). Tense/lax, the vowel system of English and phonological theory. In P. Carr, J. Durand, and J. Anderson (Eds.), *Headhood, Elements, Specification and Contrastivity: Phonological Papers in Honour of John Anderson*. Philadelphia: John Benjamin's Publishing Company.
- Eckman, F. (1977). Markedness and the contrastive analysis hypothesis. *Language Learning*, 27, 315-330.
- Escudero, P. (2000). *Developmental patterns in the adult acquisition of new contrasts: The acoustic cue weighting in the perception of Scottish tense/lax vowels by Spanish speakers*. University of Edinburgh, Scotland, UK.
- Flege, J. E. (1980). Phonetic approximation in second language acquisition. *Language Learning*, 30(1), 117-134.

- Flege, J. E. (1987). The production of "new" and "similar" phones in a foreign language: Evidence for the effect of equivalence classification. *Journal of Phonetics*, 15, 47-65.
- Flege, J. E. (1995). Second language speech learning: Theory, findings, and problems. In W. Strange (Ed.), *Speech Perception and Linguistic Experience*. Timonium, MD: York Press
- Francis, W. & Kučera, H. (1982). *Frequency Analysis of English Usage*. New York, Houghton Mifflin.
- Gordon, M. J. (2005). New York, Philadelphia and other northern cities: Phonology. In B. Kortman. and. E. W. Schneider (Eds.), *A Handbook of Varieties of English: A Multimedia Reference Tool*. Berlin: Walter de Gruyter.
- Hancin-Bhatt, B. (1994). Segment Transfer: a consequence of a dynamic system. *Second Language Research*, 10(3), 241-269.
- Hancin-Bhatt, B. & Govindjee., A. (1999). A computational model of feature competition on L2 phonology. In P. Broeder and J. Murre (Eds.), *Language and Thought in Development: Cross-linguistic studies*. Tübingen: G. Narr Verlag.
- Hillenbrand, J., Clark, M. J., & Nearey, T. M. (2001). Effects of consonant environment on vowel formant patterns. *The Journal of the Acoustical Society of America*, 109(2), 748-763.
- Hillenbrand, J., Getty, L. A., Clark, M. J., & Wheeler, K. (1995). Acoustic characteristics of American English vowels. *Journal of the Acoustical Society of America*, 97(5), 3099-3111.
- Lado, R. (1957). *Linguistics Across Cultures*. Ann Arbor, MA: University of Michigan Press.
- Kent, R. D., & Read, C. (1992). *The Acoustic Analysis of Speech*. San Diego: Singular Publishing Group, Inc.
- Klein, W. (1986). *Second Language Acquisition*. Cambridge: Cambridge University Press.
- Komaki, R., Tajima, K. & Akahane-Yamada, R. (2000). Cross-linguistic perceptual assimilation of English /r/-/l/ by Korean speakers and Japanese speakers. *Journal of the Acoustical Society of America*, 108(5), 2652-2652.
- Labov, W. (1994). *Principles of Linguistic Change: Internal factors*. Cambridge: Blackwell.

- Morrison, G. S. (2004). An acoustic and statistical analysis of Spanish mid-vowel allophones. *Estudios de Fonetica Experimental*, 13, 11-37.
- Morrison, G. S. (2006). *L1 and L2 Production and Perception of English and Spanish Vowels: A Statistical Modeling Approach*. University of Alberta, Edmonton, Alberta, Canada.
- Morrison, G. S. (2008). L1-Spanish speakers' acquisition of the English /i/-/ɪ/ contrast: Duration-based perception is not the initial development stage. *Language and Speech*, 51, 285-315.
- Peterson, G. E., & Barney, H. L. (1952). Control methods used in a study of the vowels. *The Journal of the Acoustical Society of America*, 24(2), 175-184.
- Riney, T. J. (2006). The speech learning model: English and Japanese voice onset time in mature bilingual talkers. *Journal of the Acoustical Society of America*, 120(5), 3171-3171.
- Schachter, J. (1988). Second language acquisition and its relationship to universal grammar. *Applied Linguistics*, 9(3), 219-235.
- Selinker, L. (1972). Interlanguage. *IRAL*, 10(3), 209-231.
- Slifka, J. (2003). *Tense/lax vowel classification using dynamic spectral cues*. Paper presented at the Proceedings of the 15th International Congress of Phonetic Sciences, Barcelona, Spain.
- Strange, W. (1989). Dynamic specification of coarticulated vowels spoken in sentences. *The Journal of the Acoustical Society of America*, 85(5), 2135-2153.
- Strange, W., Akahane-Yamada, R., Trent, S.A., Nishi, K. & Jenkins, J. (1998). Perceptual assimilation of American English vowels by Japanese listeners. *Journal of Phonetics*, 26(4), 311-344.
- Walter, M. A. (2003). *Spanish Tense/Lax Allophony: An Acoustic Investigation*. Unpublished manuscript, MIT.
- Wong, A., Becker, K., Doxsey, J. and Rohena-Madrado, M. (2005). *The low back distinction in New York City dialect*. Paper presented at NWAV34.