THE PERCEPTION AND ACQUISITION OF PHARYNGEALIZED FRICATIVES BY AMERICAN LEARNERS OF ARABIC AND IMPLICATIONS FOR TEACHING ARABIC PHONOLOGY

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy in the Graduate School of the Ohio State University

By

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The Ohio State University

1987

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TO THE SOUL OF MY FATHER

TO MY MOTHER

ACKNOWLEDGMENTS

I am especially grateful to my wife Ibtissam for her infinite patience and loving care that made the completion of this work possible. I would like to express my sincere thanks to my adviser, Professor Edward Allen, whose constant guidance and encouragement have contributed tremendously to the completion of this research. His comments and suggestions were invaluable to this study. My deep gratitude goes also to Professor Frederic Cadora whose continued support has contributed both to my professional and academic advancement. His insightful remarks have improved the quality of this work. I am sincerely grateful to Professor Sara Garnes for her penetrating questions and editorial remarks. I am indebted to Professor James Coady of Ohio University for the discussions and ideas that contributed to this study. I would like also to express my thanks to Dr. Wayne Cowart and Dr. Mary Beckman for giving me access to the facilities of the Linguistics Laboratory. Dr. Beckman has been extremely generous in offering technical advice throughout the stages of this work both in phonetics and statistics. I am alone responsible for any errors or inconsistencies that may be found in this study. To Lutfi Hussein, Keith Johnson, Ken De Jong, and to the numerous colleagues and students who participated in the experiments, I acknowledge their assistance with appreciation.

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2. Testing Modern Standard Arabic. Submitted for publication in *Al-ᶜArabiyya*, December, 1986.

3. Review of *The Concise Oxford English-Arabic Dictionary*, Ed. N. S. Doniach. Oxford: Oxford University Press, 1983, in *Modern Language Journal*. Submitted March, 1987.

4. Review of *Elementary Modern Standard Arabic*, Abboud, P. et al., 1983, New York: Cambridge University Press. Submitted for publication in *Modern Language Journal* March, 1987.

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CHAPTER ONE

Statement of the Problem

Introduction

Perception of speech sounds plays an integral role in the construction of the phonological system of a language, be it the mother tongue or a second language. Research in language acquisition, in general, and in the acquisition of phonology, in particular, attests to the fact that perception precedes production in the sense that acquirers can only speak when they have learned to perceive the majority of the phonological contrasts to which they have been exposed. It is also considered a prerequisite to phonological development, since the speech signal is the principal information carrier upon which the perceptual process must operate (Zue, 1980). There is unanimous agreement among the researchers in linguistics and psycholinguistics that perception occurs well in advance of production (Smith, 1973; Waterson, 1970; Stampe, 1969; Jakobson, 1968; Lenneberg, 1962). This direct relationship between perception and production is of paramount importance to the researcher in foreign language learning and teaching because insights from the study of perception and production can widen our knowledge base concerning what actually is taking place when the learner is acquiring the sound system of the target language. Also, knowledge derived from this and similar studies will promote our understanding of the learning/acquisition process (the distinction between *learning* and *acquisition* will be made below).

More important, research in foreign language learning should be relatable to a theory of foreign language learning. One basic requirement of such a theory is the notion of a possible developmental sequence, which might be relatively similar to first language (L1) acquisition as has been found by Dulay and Burt (1974), Dulay, Burt, and Krashen (1982), and Ervin-Tripp (1974), or it might be basically different (D. K. Oller, 1974).

This study seeks to answer the questions whether the process of acquisition is developmental and whether it is similar to the L1 process by looking at the perception of the pharyngealized fricatives in Arabic by both English-speaking Americans learning Arabic and native speakers of Arabic.

The Problem

Irregularities in the production data obtained from American learners of Modern Standard Arabic suggest that they develop at various points of their learning transitional phonological systems that, in some cases, differ markedly from the phonological system of the typical native speaker of Arabic. These irregularities are both segmental and suprasegmental and involve a considerable number of phonemes. The present study, however, will not attempt to investigate all the areas in Arabic phonology that are perceived to pose particular difficulty for those learners either in perception or in production. Rather, it will be limited to a single class of Arabic phonemes, namely, the pharyngealized fricatives /s̲/ and /d̲h̲/. (See Appendix A for a key to the Arabic sound system, and refer to the section below on pharyngealization.) Although other obstruents may well be pharyngealized in certain environments, only the aforementioned consonants will be considered because of their phonemic status.

Observation of the linguistic performance of American learners of Arabic suggests that, in order to perceive these phonemes, they might use perceptual strategies that are different from those employed by native speakers of Arabic. The assumption in this study is that most learners hear the distinction between the pharyngealized consonants and their plain counterparts on a contiguous vowel, while Arabic speakers hear the distinction on the consonant (Obrecht, 1961; Coady, 1967). Perception, however, is a develomental process. That is, beginning learners may not be able to hear the distinction between the pharyngealized and nonpharyngealized consonants at all. Whereas, at a later stage they will associate pharyngealization with an adjacent vowel, and at fairly advanced stages, they may be able to hear the distinction on the consonant itself. This hypothesis is based on personal observation of the performance of American learners of Arabic for about five years during which the present writer has taught learners with various levels of proficiency.

Pharyngealization

Pharyngealization is a process in Arabic phonology in which a secondary articulation is used to create an extra series of phonemic contrasts with an already existing set of phonemic contrasts (Norlin, 1985; Card, 1983; Ladefoged, 1982; Obrecht, 1961). Pharyngealization applies as a distinctive feature to only four consonants; two stops and two fricatives (/t/, /d/, /s/, /dh/), thus producing a series of pharyngealized consonants (/t̲/, /d̲/, /s̲/, /d̲h̲/). Pharyngealization is defined as the superimposition of a narrowing of the pharynx on a primary articulation of the above consonants as well as of other consonants and vowels (Obrecht, 1961; Ladefoged, 1982). The stricture in the pharynx serves to modify the resonating chamber (Cowell, 1964), or oral cavity. This is accompanied by lowering of the tongue in the middle, which creates two humps. The back hump narrows the pharyngeal passage. Pharyngealization is also characterized by protrusion and pursing of the lips, while in producing the plain counterparts, the lips are spread (Cowell, 1964; Coady, 1967). However, the last two features concerning the lips are barely noticeable, particularly in casual speech.

Traditionally, Arabs have referred to Arabic as *lughatu ddaad* لغة الضاد (the language of /d̲/). The significance of this term is that Arabs consider pharyngealization as a characteristic feature of their language that is rarely found in other languages of the world. They associate it with the consonantal part of the syllable rather than with the vowel.

Pharyngealization, however, is not restricted to the four anterior consonants listed above. It is generally the case that when pharyngealization occurs, it spreads to other surrounding sounds, sometimes crossing syllable boundaries. This effect may be called the feature spread effect, which operates progressively or regressively in a syllable or even a word. This effect is particularly evident on vowels adjacent to the pharyngealized consonant (Norlin, 1985, Cowell, 1964). This topic will be discussed in more detail in Chapter Two.

Part of this study answers the question whether pharyngealization is a consonantal or a vocalic feature to the Arab ear and whether it is so to the American ear as well. However, the study focusses only on the two pharyngealized fricatives /s̠/ and /d̠h̠/ and their plain counterparts /s/ and /dh/. The reason for this choice will be explained in the following chapter.

Purpose of the Study

First of all, this study seeks to identify the strategies employed by the American learners of Arabic in the perception of the pharyngealized consonants under discussion and see whether they are congruent with the strategies used by native speakers of Arabic. The results will have an obvious bearing on our conception of the learning process, particularly on the acquisition of Arabic phonology. In order to determine these strategies, the first hypothesis in this study posits that native speakers of Arabic ascribe pharyngealization to the consonant, while most Americans, or other non-native speakers for that matter, ascribe it to a contiguous vowel. This view is also adopted by many Arabists. Conversely, speakers of Arabic are said to perceive this distinction on the consonant. This is the traditional Arab analysis (Al-Ani, 1970), which is also shared by western students of Arabic (Obrecht, 1961).

The study also advances a developmental hypothesis that states that the distinction between the pharyngealized consonants and their plain counterparts by American learners of Arabic would proceed in step with their proficiency level. Their perception of pharyngealization is assumed to be null at the beginning level. Then they would perceive the distinction on the vowel at an intermediate stage. Finally, they ascribe pharyngealization to the consonant at an advanced stage .

Further, the study includes a distributional hypothesis that addresses the question of whether the vocalic environment would make a difference in the perception of pharyngealization. In other words, the study seeks to find out if the adjacent vowel would affect the perception of a pharyngealized consonant and to what degree.

The proposed hypotheses are tested by two experiments. The first one is a phoneme monitoring task in which native and nonnative speakers of Arabic participate. The nonnative speakers are all American learners of Arabic who are or have enrolled in Arabic courses. The stimuli they listen to are made up of 96 tokens of CV syllables representing 12 different types, or syllables. Half the tokens (48) are sequences of unmanipulated speech, that is, the component segments of a sequence are not changed or modified and are presented in the sequence in which they occur naturally. However, they are electronically synthesized from their original component segments. The other half is manipulated, synthetic speech, which is obtained by digitalizing the syllables on the computer and then electronically splicing each CV sequence in the following manner. Two meaningless syllables are taken, one pharyngealized and the other plain, say /saa/ and /saa/. These are digitalized and spliced, i.e., the consonants are separated from the vowels. The pharyngealized vowel /aa/ following /s/ is cut off from its environment and appended to /s/, and , similarly, the plain vowel /aa/ is appended to /s/, thus producing a new synthetic, cross-spliced set of syllables; /saa/ and /saa/. These latter sequences are not normally produced in speech. The subjects, who listen to both types of stimuli and are unaware of the cross-splicing that has been made, are directed to listen to the four syllables (the natural sequences and the cross-spliced ones) and mark in their answer sheets the spaces corresponding to each one of these sounds. This experiment tests the validity of the first hypothesis outlined above, which claims that American learners of Arabic ascribe pharyngealization to the vowel, while Arabic-speaking subjects ascribe it to the consonant.

The first experiment also tests the developmental hypothesis, or the relationship between perception and level of proficiency, since the nonnative subjects are divided into three levels of proficiency based on the actual length of time they have studied Arabic. Further, the experiment provides evidence to support or refute the distributional hypothesis, or the relationship between perception and the vocalic environment.

The second experiment is a production task in which only nonnative speakers of Arabic participate. They simply make tape recordings of the twelve syllables under consideration. The experiment is designed to test the last hypothesis concerning the degree of correspondence between production and level of proficiency.

Significance of the Problem

One of the important fields of research in foreign language education is that of the learning process. This is a vast area that has to do with cognition, perception and production. Studies in this field have investigated, among other things, the design and content of the learning material, processing of the material by the learner, and production as a reflection of the cognitive and psychological processes that take place within the learner (Smith, 1971 and 1975; Goodman, 1967; Ausubel, 1968; Gagné, 1965; Richards, 1975). Akmajian et al. (1984) posit a comprehension model that breaks down the process of comprehension into subcapabilities. The first one is the Speech Recognition capability. It is followed by the Syntactic Parsing capability, the Interpretation capability, and finally the Pragmatic Interpretation capability. The domain of this study is restricted to the first capability.

Perception of the linguistic input is crucial for learning and comprehension. Visual perception, in particular, has received considerable attention by researchers who have investigated the process at the featural, letter, word, sentence, and even at the higher-order discourse levels. Research in reading, particularly concerning text-based knowledge, has covered a wide area and made significant progress in its field drawing on linguistic and psychological analyses (Adams, 1980; Huggins and Adams, 1980; Woods, 1980). The enormous thrust of reading research has lately been in the area of higher-order processes within the framework of the schema theoretic model (Rumelhart, 1980; Rumelhart & Ortony, 1977) or the psycholinguistic model (Goodman, 1967 and 1971; Coady, 1979). Researchers in this field are too numerous to cite.

On the other hand, research concerning the effect of acoustic detail on perceiving and processing the aural message from the perspective of foreign language learning has not caught up with the advances made by research on the role of visual information in reading. The psycholinguistic literature (Clark & Clark, 1977; Carroll, 1986) provides many instances of research that attempt to investigate speech perception at various levels of processing, but this has been done mostly on native speakers and has provided little insight into what the perception of acoustic detail might offer to understanding foreign language learning better. Visual and acoustic detail play a fundamental role in speech understanding and comprehension of the written word. Tarone (1978) argues that the acquisition of the phonology of the target language is as essential as acquiring its syntax. Research into language acquisition should not be concentrated mainly on syntax. Other levels of language are as important as syntax. The present writer, however, recognizes the importance of the metacognitive strategies involved in comprehension that are at a higher level than either visual or auditory perception, but this fact cannot be taken as a pretext to ignore the important role of acoustic and visual detail.

With regard to the less commonly taught languages in the United States, auditory perception has not received adequate attention although it has a role in the interpretation of oral language. Tarone (1978) reports that when Schumann summarized existing second language acquisition research in 1976, he found absolutely no studies on the phonology of interlanguage. One reason for the paucity of research in this area of foreign language education could be attributed to the fact that although the less commonly taught languages do receive scholarly attention, they are usually studied and analyzed from a purely linguistic point of view. Tarone (1978) attributed the dearth of literature in this area to "the commonly held belief ... that the learner's pronunciation of the sounds of a second language is influenced more strongly by negative transfer from the first language than is the learner's interlanguage grammar." The other reason she cited was the conviction on the part of many researchers that "pronunciation of a second language is simply not very important."

Linguistic research that is relevant to the learning process is not abundant. This is particularly true in the case of Arabic. There is a respectable body of research that covers a vast array of linguistic topics, but no study to my knowledge has investigated the learning process in Arabic as the problem. However, now that Arabic is considered a strategic language, it has gained markedly in enrollment. Interest in updating its teaching materials, pedagogical methods, and in facilitating its learning should stimulate serious research in its somewhat unique properties as they bear on its learnability by nonnative speakers of Arabic, specifically for native speakers of English. The present study can, then, be viewed as a contribution to deeper understanding of the process of learning Arabic as a foreign language because perception and acquisition of the phonological contrasts of a language are important stages in the learning process.

In the proposed study 'perception' means the process of receiving and interpreting phonological information. The interest here is with perceptual discrimination of a limited area of Arabic phonology, namely, the pharyngealized fricatives. Also, the study is concerned with phonological perception, which can be defined as the classification of speech sounds into the minimal units that signify meaningful differences. Thus, this study seeks to investigate not only the perceptual strategies employed by American learners of Arabic, but also the role of perception in the construction, or acquisition, of the phonological system, which is part of the learners' interlanguage (see Selinker, 1971 and Corder, 1971 for studies in and definition of interlanguage). Another objective is to relate the subject of perception and pronunciation to other branches of the study of foreign language learning.

Insights gained from this study will have some pedagogical application. One such use could be the establishment of a set of principles and procedures for auditory and performance training. The reason for the need of such a set is that perception and pronunciation are components of the speaking skill, which is receiving growing attention in the communicative approach to language learning and teaching. They are concerned with the manner of speaking, or *how* speech is perceived and produced not in *what* is perceived or produced. Perception helps in the construction of the phonological system of the learner, and pronunciation follows as a manifestation of the motor abilities developed by the learner. The communicative message may fail to take place if it is distorted or partial. Only research in problem areas can shed light on possible solutions.

Theoretical Bases

The Role of Perception: No foreign language educator would seriously doubt the role of phonology in developing overall proficiency in learning a foreign language. Knowing a language without being able to speak it is possible, but with such a glaring deficiency the learner can hardly be considered proficient. Speaking is based on the ability to produce the sounds of the language in a manner consistent with or reasonably close to the way its native speakers produce them. Nevertheless, production cannot materialize without the ability to perceive these sounds. As has already been noted, researchers in child language and linguistics agree on the fundamental role of perception in production. Furthermore, FL teaching methods that espouse a clear communicative orientation, like Suggestopedia, the Silent Way, Total Physical Response, and Community Language Learning (Stevick, 1980; Underwood, 1984) confirm this view by giving priority to listening over speaking. The Natural Approach of Terrell (1977) and Krashen and Terrell (1983) is made up of three stages, the first of which is a prespeaking stage that emphasizes listening comprehension based on exposing the learner to a fair amount of comprehensible input.

Learning and Acquisition: The distinction between learning and acquisition is not of significant importance in this study. Nevertheless, it should be pointed out that phonology is believed to be acquired rather than learned in order for perception and production to operate spontaneously. Krashen's (1982) definition, that the acquisition process is subconscious and that the acquirer is unaware of it, is particularly true of the acquisition of the phonological system. Learning facts about the system and its rules is not the same as using the rules and being unaware of them. In a foreign language, or any language, one does not pause to think about the distinctive features of a particular sound. It just happens that speech sounds are produced too quickly to allow for the application of knowledge about them. The process must be fast and unmediated.

Perceptual Processing: From the psycholinguistic point of view, speech perception is examined from two perspectives; bottom up and top down processing (Clark & Clark, 1977). The first process utilizes acoustic properties of the speech input in identifying the segments and larger units. The other process, top down, uses, syntactic, semantic, and discourse constraints to help in the perception of speech. While recognizing the importance of top down processing, this study is concerned with bottom up processing, that is, how phonetic features aid in recognizing and distinguishing speech sounds. More specifically, the interest here is in how the feature of pharyngealization is utilized by American learners of Arabic in processing the linguistic input.

Testing Perception: The study of perception is said to be indirect since we have no direct access to what is going on in the ear and the brain (Clark & Clark, 1977). Therefore, methods have been developed to find out what takes place during perception. One of these methods is the use of synthesized speech in which acoustic properties of speech sounds are manipulated. In the present study, the perception of pharyngealization is studied by making use of synthetic speech and the facts already known about the acoustic properties of this feature. Pharyngealization is a coarticulation that involves a degree of backness. Therefore, the distance between the first formant (F1) and the second formant (F2) of the acoustic spectrogram of the vowel is of interest because one definition of pharynealization is that it is the superimposition of the most back vowel on the primary articulation (Ladefoged, 1982). Expressed differently, pharyngealization "may be defined acoustically as a lowering of the second formant" (Coady, 1967: 15). Obrecht found that the only universal cue of pharyngealization was the alteration of F2 (1961). In order to test the effect of the height of the second formant on perception, the synthesized tokens used in this experiment control for vowel quality by having the individual segments within the sequence vary so that the same consonantal part is followed alternatively by a plain vowel and a pharyngealized one, or in other words, the consonantal segment is followed by vowels having high and low F2s.

Subjects

The subjects participating in the experiments fall into two groups; native speakers of Arabic and native speakers of English. The latter group is subdivided into three subgroups according to level of proficiency based on the duration of the study; beginning, intermediate, and advanced. Duration of studying Arabic is determined by the number of credit hours accumulated up to the time of the experiment. All the English-speaking subjects have taken or are taking Arabic courses. The Arabic-speaking subjects are graduate and undergraduate students at the Ohio State University. All subjects in both groups are ignorant of the nature of this investigation and its purpose.

Null Hypotheses

H01-- There is no difference among the subjects in the perception of the target consonants attributable to their linguistic background.

H02-- There is no difference among the American subjects in the perception of the target consonants attributable to their level of proficiency.

H03-- There is no difference among the subjects in the perception of the target consonants attributable to the following vowel.

H04-- There is no difference among the subjects in the perception of the target consonants attributable to the consonant.

H05-- There is no difference in the production of the target consonants among the American subjects attributable to their level of proficiency.

Definitions

Phoneme: A minimal unit of speech that signifies a difference in meaning and that has the perceptual properties of being recognized and differentiated from other phonemes (Serra-Raventos, 1974). The phonetic components that are required to distinguish meanings are called distinctive features, like voicing and places and manner of articulation (Deneen, 1967). Phonemes are sometimes defined as bundles of distinctive features (Chomsky & Halle, 1968).

Perception: The process by which information is received and interpreted. In this study, it means the recognition of the phonetic cues and their assignment to classes (Clark & Clark, 1977).

Discriminate: This term will be used with reference to the ability to make distinctions in speech perception (Barton, 1978).

Distinguish: Used when referring to the ability to make distinctions in speech production (Barton, 1978).

Language Learning: Conscious knowledge of a second language, knowing the rules in the sense of being aware of them and being able to talk about them (Krashen, 1982).

Language Acquisition: Subconscious learning of language in which the acquirer is not aware that he is learning. There is attention to meaning rather than form (Krashen, 1982).

Pharyngealization: A secondary articulation in which the root of the tongue is drawn back so that the pharynx is narrowed (Ladefoged, 1982). This is considered as a distinctive feature, and when it is applied to a sequence of two Arabic stops and two fricatives (/t/, /d/, /s/, /dh/), it produces a series of four pharyngealized consonants that are phonemic in Arabic (/t̲/, /d̲/, /s̲/, /d̲h̲/). This process is also known in the literature as 'emphasis', and is sometimes incorrectly labelled 'velarization' (see Chapter 2 for a discussion of the terms).

Formant: A group of overtones corresponding to a resonating frequency of the air in the vocal tract (Ladefoged, 1982).

Formant Transitions: Large rises or drops in formant frequency that occur over short durations of time either at the end or the beginning of a syllable. They correspond to the consonantal portion of the syllable (Carroll, 1986).

Steady State: Stable frequency of a formant. It corresponds to the vowel.

Assumptions

The subjects selected from the different groups are assumed to be representative of these groups.

The perceptual strategies of the Arab subjects are assumed to represent those of the average Arabic speaker.

Limitations

The American subjects are selected from a population of students who have taken or are enrolled in Arabic courses at the Ohio State University. Thus, the results may only be generalizable to that population.

The results should be viewed with caution as the stimuli do not represent connected speech, which is avoided to block the feature spread effect. The spread effect may be defined as the superimposition of a phonetic feature, pharyngealization in this case, not only on the intended segment, but also on a whole syllable or word (Cowell, 1964). The spread effect can be particularly invalidating to the results since other obstruents in a single utterance may be considered a cue to pharyngealization because they have the feature themselves.

Sources and Bibliographical Information

Sources relevant to this study were gathered from linguistic literature and from that pertinent to foreign language learning and teaching. Also, an on-line computer database search was conducted in order to identify all the studies that deal with relevant topics. The following descriptors were used in the search: Arabic, pharyngealization, velarization, and emphasis. The search revealed that the ERIC database has five such studies, the Language and Language behavior Abstracts database has 16, and Dissertation Abstracts

International has 14. Several of these documents are used as reference sources in this study and are listed in the bibliography. However, none of them addresses the problems from the perspectives used in this study.

Organization of the Study

The first chapter presents the problem to be investigated, namely the perception of the pharyngealized fricatives by American learners of Arabic, and relates this process to the process of learning a foreign language. It also points out the implications and applications of the results.

Chapter Two lays a relevant background by reviewing the literature pertinent to the learning, or acquisition, of a foreign language and that dealing with phonetic and acoustic studies concerning the two pharyngealized consonants under investigation and their plain counterparts.

Chapter Three describes in detail the experimental design employed to test the hypotheses advanced in this study. It also deals with the preparation and manipulation of the stimuli, the administration of the experiments, and a description of the subjects participating in the experiments. Also, there is a description of the statistical tests used in analyzing the results.

The analysis and discussion of the results are found in the fourth chapter. The fifth chapter draws some conclusions from this study and discusses their value in furthering our understanding of learning and acquisition of a foreign language phonological system through insights from the role of perception in acquiring pharyngealized consonants. It also discusses the contribution of the results to syllabus design, instructional techniques in the area of teaching pronunciation, that is, the role of perception in acquisition. Furthermore, since this study is primarily concerned with the relationship between perception and acquisition, the results will be viewed from this perspective. Also, the results of the experiment can yield useful information that is purely linguistic. It is expected that this study will shed light on the controversy concerning the different analyses of the Arabic sound system, specifically those that have to do with the status of pharyngealization. These can be recommended as possible areas of further research.

CHAPTER TWO

Literature Review and Background

As has been noted in the preceding chapter, the present study seeks to investigate the acquisition of the pharyngealized fricatives by American learners of Arabic from a perceptual perspective. In other words, the ability to discriminate the acoustic cues associated with pharyngealization will be considered as evidence of the acquisition of this feature. This study is also concerned with the relationship between the level of proficiency attained by American learners of Arabic and their ability to discriminate the pharyngealized fricatives. In addition, the perceptual strategies employed by native speakers of Arabic and those employed by English-speaking learners of Arabic will be investigated. It follows, then, that previous studies dealing with language acquisition, speech perception, acoustic properties of speech sounds, and pharyngealization in Arabic should be reviewed in order to provide background and perspective.

The production data obtained from the English-speaking subjects will not be made a crucial part of this study. However, the ability of the American subjects to distinguish between pharyngealized and plain fricatives will be compared with their perception thereof at different levels of proficiency (Following Barton (1978), the word *discriminate* will be used when making distinctions with reference to speech perception, and *distinguish* when referring to speech production.) Production data might yield interesting information, and it will be used to make some points that are relevant to the general argument of this study, particularly with regard to motor theory and the relationship between perception and production.

Language Acquisition and Perception

Listening in Second Language Acquisition: Krashen wrote that the Input Hypothesis "may be the single most important concept in second language acquisition theory today" (1982: 9). Its importance stems from its attempt to answer the crucial question of how one acquires a second or a foreign language. Described briefly, the Input Hypothesis, as advanced by Krashen, claims that "a necessary (but not sufficient) condition to move from stage *i* to stage *i + 1* is that the acquirer understand input that contains *i + 1*, where *understand* means that the acquirer is focussed on the meaning and not on the form of the message" (Krashen, 1982: 21).

The Input Hypothesis posits that linguistic input is a prerequisite to production, which emerges on its own over time, not as a direct consequence of teaching (Krashen, 1982). While it is not within the scope of this study to evaluate the latter part of this claim, it is interesting to note that comprehensible input is given precedence over production. Elsewhere, Krashen reiterates that "speaking skills emerge significantly later than listening skills" (1982: 7).

Similarly, findings in second language acquisition research support the hypothesis of a *silent period* that precedes production. Hatch (1972) reported the case of a five-year-old child acquiring English as a second language. Apart from a few set phrases learned as whole utterances, the child did not use *creative* language for the first few months of his learning. Krashen offers an explanation of this phenomenon within the framework of the Input hypothesis. He proposes that the child, during the silent period, "is building up competence in the second language via listening, by understanding the language around him" (1982: 27). Although Krashen does not elaborate on the components of this competence, one can safely assume that phonological competence must be an intrinsic part of it. During the initial stage of building up competence, the learner's first task, then, is necessarily the construction of an interim, target-language phonological system (this system is *interim* in the sense that it remains variable at least until maximum approximation of the target system is achieved). Overall competence could become possible once the phonological contrasts are established.

Ordering instruction of language skills so that they start with listening then speaking is not a unique characteristic of communicatively-oriented approaches to L2 teaching. The well-known minimal pair drills of the Audiolingual Method (and other methods, for that matter) are used as a tool to help the learners construct their individual phonological systems of the target language by providing them with the phonological oppositions necessary to build such a system. Implicit in the use of this technique is the conviction that helping the learners perceive the contrasts through exposure (and then repetition) would ultimately lead to the production of sounds that are roughly equivalent to the target sounds.

Perception and Production: The unanimity in the literature regarding the precedence of listening over production and, hence, the important role of perception in constructing a phonological system need not be pursued further (see "Introduction" for references). Nevertheless, the issue of whether perception shapes production or whether it is dependent on production is a long-standing controversy among researchers in speech perception.

The view that speech perception is dependent on speech production is called the *motor theory* of speech perception. The proponents of the motor theory hypothesize that people perceive speech by "matching the incoming signal against an internally generated signal" (Lieberman, 1977: 122). Ladefoged claims that people perceive sounds with reference to the way they produce them. He writes that "some aspects of speech are identified by reference to the acoustic properties of the stimulus, and others by reference to the articulatory activity which produced the sounds" (1967: 165). Elsewhere in the same work, he more explicitly states that "in general, people cannot hear differences between sounds until after they have learnt to make these differences" (p. 167). He further adds that "we no more 'speak in order to be heard, in order to be understood' (Jakobson & Halle, 1956) than we understand what we hear because we can speak" (1967: 167).

Ladefoged cites two experiments in support of "the hypothesis that the ability to produce differences between sounds often comes before the ability to hear these differences" (1967: 168). The first one of these was conducted on Filipino students learning English. They were asked to pronounce a list of

English words containing contrasting vowels and were scored according to the correctness of their pronunciation. The ability of the same learners to write down the same words was then tested. The experimenter found that the subjects always scored higher on the pronunciation test. It is not clear from the description given how the words were presented on the pronunciation test, for the method of presentation of stimuli would make much difference in the way they are reproduced. Besides, in the writing test the experimenter assumed high correlation between the listening task and spelling ability. There may be other factors responsible for the lag between the subjects' performance in pronunciation and their performance in writing.

Another experiment cited was reported by Brière (1966) where English-speaking American students were taught, on tape, words from Arabic, French, and Vietnamese containing contrasts not found in English and were asked to repeat them. He found that the subjects could produce these sounds without the ability to hear the differences among them. A possible explanation is offered by Hatch (1983) that the pronunciation ability could be a function of kinesthetic cue, or, in simple terms, a matter of imitation.

In a way, the motor theory of speech perception attempts to account for perception in the light of variation in production. More recently, Ladefoged has claimed that "speakers produce utterances sometimes in one way and sometimes in another but always in reference to what they hear, and what the utterances sound like" (1982: 235). He, however, accepts that children can sometimes hear the difference between two sounds without being able to produce them, but he suspects that this is not the usual pattern in language learning (1967). Liberman et al. (1967) hold a similar view and argue that speech perception is closely linked to speech production. In a later work, Liberman (1975) provides evidence that when subjects listen to stimuli, they recognize the movements involved in producing these stimuli in the vocal tract and that they take time. For instance, if two stimuli, [beg] and [be] are presented successively, a silent period must occur between the two syllables so that the listener can hear the final stop in the first syllable if the two syllables are uttered by the same voice. However, this requirement would not be needed if the two syllables were uttered by two different voices. In other words, the listener knows that the articulators take time to move from /g/ to /b/. If the stimuli do not contain a relatively long silent interval when uttered by the same speaker, the listener would not be able to perceive /g/ unless the two syllables are produced by two different voices. In this case, /g/ is perceived because this is possible.

On the other hand, there is evidence to support the opposite view, that perception is not dependent on production. Lenneberg (1962) reports the case of a child who could perceive and comprehend language without having the capacity to produce speech. It has been demonstrated (Molfese et al., 1975) that infants aged one to two months can perceive speech sound differences, which occur long before they show any ability or neuro-physiological capability to produce these sounds. These findings led to the belief that perception must precede production. Palermo (1978) indicates that speech production is mediated by processes involved in the perception of speech rather than the other way round. He cites seven kinds of data to support his claim, including the data from the infants and the child referred to above. Further, he argues that all cases of receptive aphasia result in productive impairment, while the reverse is not necessarily true. Léon (1966) claims that second language speech production of speech sounds cannot proceed until perceptual discrimination can be made. Barton (1978) further demonstrates this by noting that congenital deafness incapacitates speech production and that speech production deteriorates in people who become profoundly deaf. He also surveys evidence from previous research in children's speech production supporting the view that "children's knowledge of phonology is closer to the adult model than surface production alone would suggest " (p. 119). Barton provides evidence from his own experiments as well, showing that fairly young children (aged 1;8 to 2;0) "could generally make the discriminations that were tested even though most of them did not distinguish the minimal pairs in their speech production" (Barton, 1978: 118). He argues that even though children may appear to ignore some aspects of the speech signal while learning to speak, this does not mean that they cannot perceive them.

Anecdotal evidence from production errors made by young children can be cited to support the precedence of speech perception over production in first language acquisition. The "fis" phenomenon reported by Berko and Brown (1960) is an interesting example that clearly indicates that a child does discriminate /s/ and /sh/ perceptually, but fails to distinguish them in production. The experiment is replicated by Palermo (1978) and yields similar results. The delightful dialogue is quoted below:

"What do you have in your bag?"
"Candy fis. Would you like one?"
"Candy fis?"

"No, fis."
"I would love to have a fis."
"No, not fis, fis."
"Oh, fish."
"Yes, fis. Here is one for you."

In the light of the inadequacy of motor theory to explain the facts of speech perception, a number of researchers have developed a model of speech perception based on neural "property detectors" that respond to specific acoustic signals (Lieberman, 1977). Morse (1972), Eimas et al. (1973), and Cutting and Eimas (1975) found that people from the age of two months onwards seem to identify speech signals in a fashion suggesting that the human brain has a number of feature detectors that respond selectively to particular acoustic signals. Thus, instead of trying to generate an internal signal and match it with the incoming signal, people can utilize their feature detectors that respond to the acoustic signals of human speech.

The Role of Perception: Having established the non-dependence of perception on production, Barton (1978) points out its role in the process of acquisition of phonology. The task is one of setting up phonological categories, and then "working out a system which will reflect these phonological categories in production" (p. 125). The process is a dynamic one because it involves "making successive hypotheses about the system" (Barton, 1978: 125). These hypotheses are influenced by many factors: physiological and phonetic. One of them is the external constraints on what can be considered possible speech sounds. Another factor is the wide variation in the discriminability of sounds. This is based on many variables such as the position the sound takes in a phonological sequence and the vocalic environment (Barton, 1978). He argues that the interaction of the various variables creates a framework that influences the hypotheses tried by the acquirers of the phonological system. The active nature of hypothesis-testing by acquirers, according to Barton (1978), allows us to account for the broad range of variation in the phonological systems of different acquirers. The variability is thought to be the result of attending to some aspects of the linguistic input and ignoring others within the wide framework of the system.

The view concerning active hypothesis testing and the general nature of the phonological framework of the system can account for production errors by American learners of Arabic. Teachers of this language have observed that many learners at various stages of their progress tend to substitute, in their oral production, /aa/ for the voiced pharyngeal fricative ع /ʿ/ (see Appendix A for Arabic characters, the symbols used to represent them in this study, and their equivalent IPA symbols). The substitution may be brought about because the learners attend selectively to the feature of *backness* and ignore *frication*. In fact, this pharyngeal fricative is characterized as the backmost consonant in the Arabic sound system. This property may be an outstanding one to the ear of the nonnative speakers of Arabic who equate it with /aa/ (a low back vowel), which they appear to substitute instead. The same argument can also explain the *depharyngealization* of pharyngealized sounds such as /ṯ, d̲, s̲, dh/ as well as the pronunciation of the voiceless velar fricative /x/ خ as /k/ and the voiceless pharyngeal fricative /h̲/ ح as /h/. In both cases the constriction necessary to produce these Arabic fricatives is not produced, particularly by elementary level learners.

If spelling errors are influenced by perception, then they may reveal insight into the perception of second language learners. Spelling errors in the writing of American learners of Arabic reveal interesting information about perception. While attempting to transliterate a number of proper western names in Arabic , students have produced some interesting spelling errors. Two tokens have been particularly relevant for the argument concerning motor theory. The proper name *Michael* was transliterated as معقال [m^{c}qaal], using the voiced pharyngeal fricative ع [^{c}] as a substitute for the diphthong. A similar error was made in the transliteration of *Montreal*. The word was transliterated as منتريعل [mantrii^{c}l], where ع again replaced the back vowel in the last syllable (both students would have been categorized as *advanced* if they were to participate in the present experiment). Apparently, the two learners have developed at that point of their learning a phonological representation of ع [^{c}] that contained [+ back] and [+ syllabic], but [-fricative].

Distinctive Features

Jakobson argued that the phonemic analysis of language was inadequate to account for the acquisition of the phonological system of language. He suggested that the phoneme could further be analyzed into distinctive features and referred to phonemes as bundles of distinctive features (Jakobson & Halle, 1956). Distinctive features are characteristics of speech sounds that distinguish the sounds of a language according to their place and manner of articulation as well as their acoustic characteristics. These features are thought to be universal and occur in all human languages. Each particular language, however, uses a subset drawn from these features (Palermo, 1978) .

Jakobson proposed a theory of the acquisition of the phonological system based on the ability of children to make distinctions among features (Jakobson & Halle, 1956). His theory, however, applies only to speech sounds; that is, only when the child starts using meaningful words does a phonological system start to emerge. The child, according to Jakobson's theory, begins by dichotomizing all speech sounds on the basis of one feature: [+ / - consonant]. Then the child continues to refine the system by adding other features, like voicing, nasality, and so forth. This process of acquisition is not haphazard. The order of acquiring the segments of the language proceeds in the following manner: stops, nasals, fricatives, and then liquids and glides (Jakobson, 1968). Based on this order, he proposes also an implicational hierarchy, which holds that if a child has a fricative in his or her repertoire, for example, then he or she must necessarily have stops and nasals as well.

Nevertheless, what applies to children acquiring the sound system of their first language does not completely transfer to learners of a foreign language. Foreign language learners already have a developed system of phonological contrasts, which means that they know the effect of distinctive features on discriminating and distinguishing speech sounds. Therefore, the acquisition of the new system does not necessarily follow the same order. What they probably need to incorporate in the new system is shifting or modifying the application of certain features. For instance, the feature [+ round] does exist in English and applies meaningfully to high and mid, back vowels and to a glide. When English speakers learn French, they should learn to apply this feature to front vowels as well. Difficulty of acquisition of a new fearure is not an issue here, rather the process by which they succeed in shifting the application of this feature to the proper segment.

In like manner, English-speaking students learning Arabic, who do not yet have [+ pharyngeal] in their system, need to learn, among other things, to apply this feature. Although a similar feature is present in English (Delattre, 1971), it is redundant and consequently has no phonemic status. To illustrate, the English words *soft* and *sift* contrast only in the vowels. They may be transliterated into Arabic, however, as [s̱aft] and [sift] contrasting mainly in the consonant (pharyngealized [s̱] and its plain counterpart) and in the following short vowel, which is not represented orthographically. But since the feature [+ low] is associated with the vowel in English, it is automatically blocked when high vowels follow the consonant. This is not the case in Arabic; words still contrast while having the same vowel (phonemically speaking). The words [siin] (a letter of the alphabet) and [s̱iin] (China) contrast only in the consonants (see the argument regarding the influence of pharyngealization on [ii] below "The Effect of Pharyngealization on the Following Vowel"). Thus, American learners of Arabic apply the closest feature they have and perceive to be the counterpart of [+ pharyngeal], namely, [+ low]. In the literature on Arabic linguistics, several terms have been used to denote the process of pharyngealization. These will be reviewed and the process discussed in a following section.

Phonemic Status of Pharyngealization

As has been noted above, Arabic words may contrast only by the presence or absence of pharyngealization, which may affect the whole word rather than a single segment. The consonants and vowels affected by pharyngealization in a syllable or word are not automatically considered phonemically *pharyngealized*. Only the four pharyngealized consonants /t̲, d̲, s̲, dh̲/ are regarded as contrasts to the plain ones. For example, in the word [mabsuut] (happy; outstretched), pharyngealization is detectable over the whole word, yet only the final stop is considered to be the locus of this feature. Also, compare the words [masruur] (glad) and [masruur] (wrapped). Not only is the fricative pharyngealized, but also all the consonants and vowels in the word. Pharyngealization spreads both ways over the whole word. But in the minimal pair cited above [siin] (a letter of the alphabet) and [s̲iin] (China), pharyngealization is restricted to a single segment because of the following high, front vowel, which is not affected by pharyngealization (Card, 1983). It, therefore, blocks its spread to subsequent segments. Thus, whatever the scope of pharyngealization in a single word (whether limited to one segment or spread over one or more syllables), it serves as a distinctive feature in Arabic, like voicing, rounding, and the like in English.

The traditional phonemic analysis of Arabic, which assumed its final form in the eighth century, designated pharyngealization as a consonantal rather than a vocalic element. Ancient grammarians, when they refined and reformed the alphabet, set up four distinct letters to represent the pharyngealized consonants /t̲, d̲, s̲, d̲h̲/ (Al-Ani, 1970). However, western linguists in this century have attempted to provide different analyses.

Harris (1942) suggests that, instead of recognizing two sets of consonants (t, t̲, etc.) representing plain and pharyngealized sounds, and calling the vowels found in their vicinity variants, we might consider the vowels as distinct phonemes and the consonants as variants, or allophones. As we shall see later, this analysis has serious problems.

An alternative analysis is suggested by Ferguson (as reported by Harris, 1942). He posits that the most convenient analysis would be to designate a separate phoneme /'/ for back position and use it for pharyngealized consonants and to distinguish between /aa/ and /a̲a̲/.

Lehn (1963) rejects the traditional Arabic analysis that recognized separate graphemes for only four pharyngealized consonants, though he accepts that assigning these graphemes to the consonants is not without significance. His first alternative analysis is similar to the traditional one, but differs in that it recognizes more than four pharyngealized consonants. It considers pharyngealization as a distinctive feature for consonants and a redundant feature for vowels. One liability of this analysis is the increased number of phonemes resulting from creating additional phonological contrasts from all consonants that can show the effect of pharyngealization. In order to obviate this problem, he posits another analysis that comprises "a phoneme of emphasis" (1963), reminiscent of Ferguson's analysis.

Lehn suggests yet another alternative analysis that interprets pharyngealization as a distinctive feature of the vowel system and a redundant one for the consonant system, thus increasing the number of vowel phonemes. This is no different from Harris's analysis.

The last alternative presented by Lehn was first suggested by Ferguson (as reported by Harris, 1942) and later elaborated by Harrell (1960). This analysis considers pharyngealization a suprasegmental feature that "never occurs as a feature of a single segment" (Harrell, 1960). Lehn (1963), however, does not subscribe to this analysis because pharyngealization is sometimes used for expressive and stylistic purposes, which does not warrant its interpretation as suprasegmental because it is not phonemic.

Problems with Terminology

In the preceding chapter, pharyngealization has been defined with no discussion of the terminology associated with it, nor have its acoustical characteristics been adequately explained. Both these points will be discussed in this section along with illustrative examples from the stimuli used in the experiment of this study. Spectrograms and waveforms of a number of contrasting stimuli will be presented.

Arabic linguists have variably referred to the feature of pharyngealization as velarization (Obrecht, 1961; Cowell, 1964), emphasis (Harris, 1942; Lehn, 1963; Card, 1983), pharyngealization (Al-Ani, 1970; Norlin, 1985), and even as the Arabic term *mufaxxama* (Jakobson, 1957). There seems to be no agreement on which term best describes this feature. Although Cowell (1964) uses the term *velarization*, he is not completely satisfied with it. His reason is that the voiceless velar fricative [x], the voiced velar fricative [gh], and the voiceless uvular stop [q] are not inherently velarized, yet they can be either *plain* or *velarized*. In the first place, his classification of all three sounds as post-velar is incorrect. The fricatives /x/ and /gh/ are velar and the stop /q/ is uvular according to the Ladefoged (1982) and Al-Ani (1970). Second, velarization is characterized by raising the back of the tongue toward the velum (Ladefoged, 1982), which is not what takes place when we articulate a pharyngealized consonant.

Pharyngealization involves tightening of the pharynx by backward movement of root of the tongue (Fant, 1968). Cowell (1964), however, thinks that the term *pharyngealization* is more misleading than *velarization* because "the pharyngeal spirants /h̲/ and /^{c}/ have still less in common with the velarized sounds than the post-velars have." Obviously, his use of *velarization* for *pharyngealization* has caused much of the confusion. Furthermore, findings by Ali and Daniloff (1972) confirm the appropriate use of *pharyngealization*. Their cinefluographic films showed pharyngeal constriction due to the retraction of the tongue root. Therefore, they reject the term *velarization* in favor of *pharyngealization*. Similar results have been obtained by Ghazeli (1977). Card (1983) concurs with these phoneticians, though she does not use the term herself.

The term *emphatic* is also misleading, since it gives the impression that these phonemes are articulated more forcefully or emphatically than their plain counterparts. Perhaps this term has originated from an imprecise or literal translation of the Arabic term *mufaxxama* (dignified, heavy, thick, dark, corpulent, etc.). What is probably meant by the Arabic term is that those sounds are produced at a deeper point than the plain ones. Two other Arabic terms are used to describe pharyngealization: *iṯbaaq* (spreading and raising of the tongue) and *isti*^{c}*laaʔ* (elevation of the dorsum) (Lehn, 1963). The first term can, in fact, be interpreted as constriction (effected either by backing or raising the back of the tongue), which makes it a plausible term.

Effect of Pharyngealization on the Following Vowel

Obrecht (1961) and Norlin (1985) have found that the difference in the frequencies within the noise segment of the pharyngealized and nonpharyngealized sibilant is insufficient and unreliable in differentiating between these consonants. They describe cases in which [s̱] is characterized by frequencies that are even higher than those of [s]. Both researchers agree that it is necessary to look at the effect of pharyngealization on an adjacent vowel.

As noted in Chapter One and in the preceding section, pharyngealization is not usually limited to the pharyngealized consonants. Rather, it may spread progressively and/or regressively to adjacent sounds. Spectrographic measurements have shown that a pharyngealized consonant has considerable influence on the following vowel, strongly affecting formant transitions and steady states of the vowel (Norlin, 1985). Obrecht (1961) claims that formant transitions are the most important cue for the perception of pharyngealization. However, not all vowels are affected similarly by pharyngealization. Norlin (1985), Card (1983), Al-Ani (1970), Obrecht (1961), and others agree that the second formants (F2) of [aa] and [<u>aa</u>] differ significantly as a result of the presence of a pharyngealized consonant in the vicinity of [<u>aa</u>]. Card (1983) claims, however, that [ii] is impervious to and, therefore, blocks pharyngealization from spreading to contiguous segments. But, being a high vowel, it shows a sharp transition when it is in the vicinity of a pharyngealized consonant. High back [uu] shows neither a drop in the frequency of F2 nor a distinctively different transition when it is adjacent to a pharyngealized consonant because both segments already have low F2s. Norlin (1985) advances a similar argument that [ii] and [<u>ii</u>] overlap considerably and that [uu] and [<u>uu</u>] overlap even to a greater extent. T-tests of mean frequencies show no significant difference.

Perceptually, the effect of pharyngealization on a following vowel is most pronounced in the case of [aa], which becomes [<u>aa</u>] following a pharyngealized consonant. Spectrograms of [dhaa] and [<u>dhaa</u>] (Figures 1 and 2) illustrate this point acoustically. Both syllables are produced by speaker B (see Chapter Three for a description) and are used as part of the stimuli. The second formant of [dhaa] is displayed at 1720 Hz, whereas F2 of [<u>dhaa</u>] is considerably lower (1245 Hz) with a difference of 475 Hz between them. This is congruent with Norlin's (1985), Card's (1983), and Obrecht's (1961) findings regarding variations in F2 frequency.

By contrast, the spectrograms of [sii] and [sii] (Figures 3 and 4) do not show significant lowering of F2s. The fricative is displayed as random noise followed by bands of energy, or vowel formants. A sharp rising transition of F2 characterizes [sii]. The tip of the transition starts at 755 Hz and rises to reach a steady state of about 2335 Hz. On the other hand, F2 of [sii] shows no transition at all and its steady state is roughly equivalent to that of the vowel in [sii]. The frequency of its steady state is only 65 Hz higher than that of the steady state of F2 in [sii]. This is also in total agreement with Norlin's (1985) and Card's (1983) argument that [ii] does not show the effect of pharyngealization in terms of the frequency of the second formant. However, as Obrecht (1961) claims, the most striking cue of pharyngealization is transitional variation in the vowel rather than steady state variation, implying that it can be considered an attribute of the consonant since he claims that phonetic and acoustic evidence suggest that pharyngealization is better analyzed as a consonantal feature. However, recent research (Hussein, 1987) has shown that F2 of [ii] drops 165 Hz after [s] and 100Hz after [dh] on the average, which is obviously at odds with Norlin's (1985), Card's (1983), and Obrecht's (1961) claims.

Looking at the two spectrograms of [suu] and [suu] (Figures 5 and 6) produced by speaker A reveals a clear lowering of F2 from about 1050 Hz in [suu] to about 650 Hz in [suu]. However, while [suu] shows a falling transition, the transition in [suu] is barely visible. A similar effect can be seen in the spectrograms of [suu] and [suu] (Figues 7 and 8) by speaker B. F2 drops from 1130 Hz in [suu] to 825 Hz in [suu], a difference of 305 Hz in frequency compared to about 400 Hz for the other speaker. These differences, however, are not dramatically less than the difference observed between F2s of [aa] and [aa]. These results run counter to the claim made by Obrecht (1961), Card (1983), and Norlin (1985) that front and back high vowels show no effect of pharyngealization. This finding is confirmed by Hussein (1987), who found that F2 of [uu] drops on the average 55 Hz following [s] and 124 Hz following [dh]. The lowering of F2 of [uu] following a pharyngealized consonant was found to be 80Hz over 119 tokens.

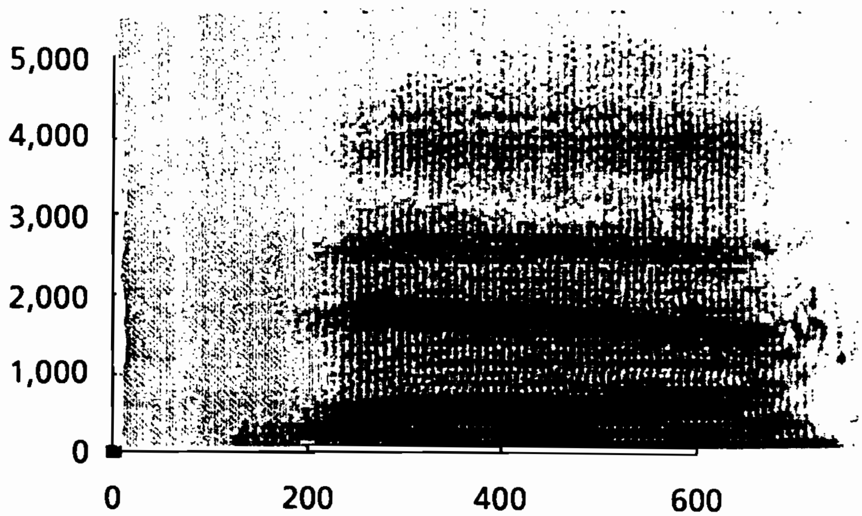

Figure 1. Spectrogram of [dhaa] by Speaker B

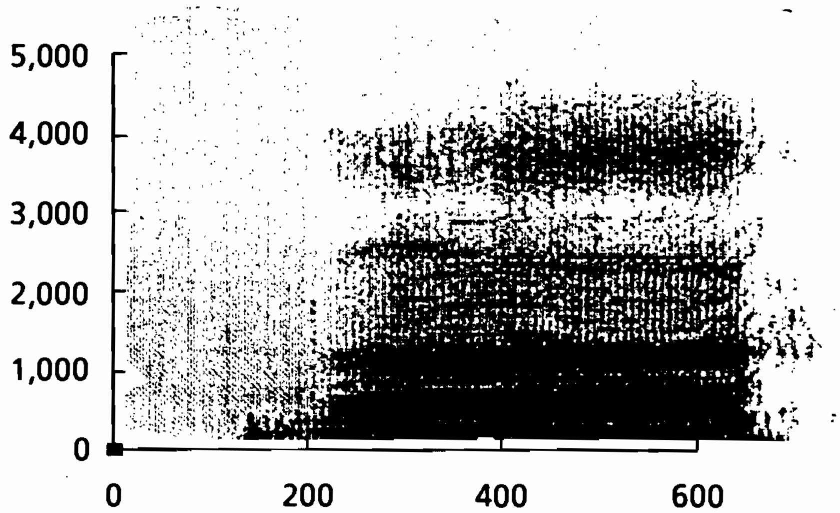

Figure 2. Spectrogram of [dhaa] by Speaker B

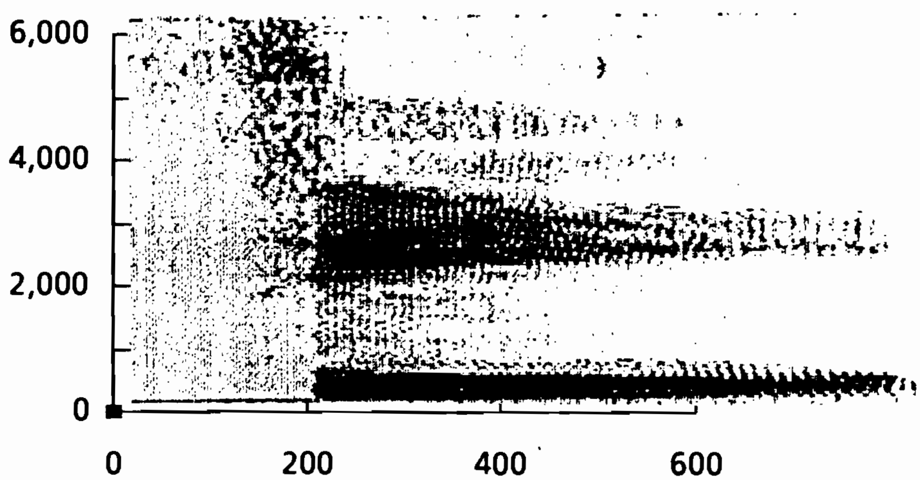

Figure 3. Spectrogram of [sii] by Speaker A

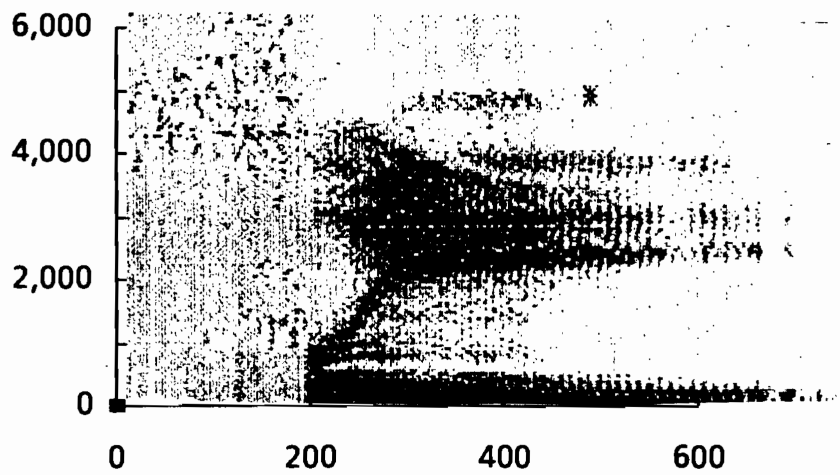

Figure 4. Spectrogram of [sii] by Speaker A

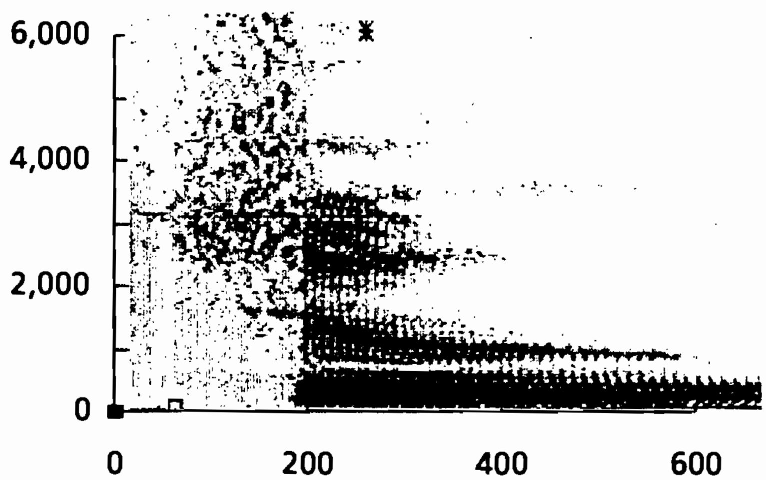

Figure 5. Spectrogram of [suu] by Speaker A

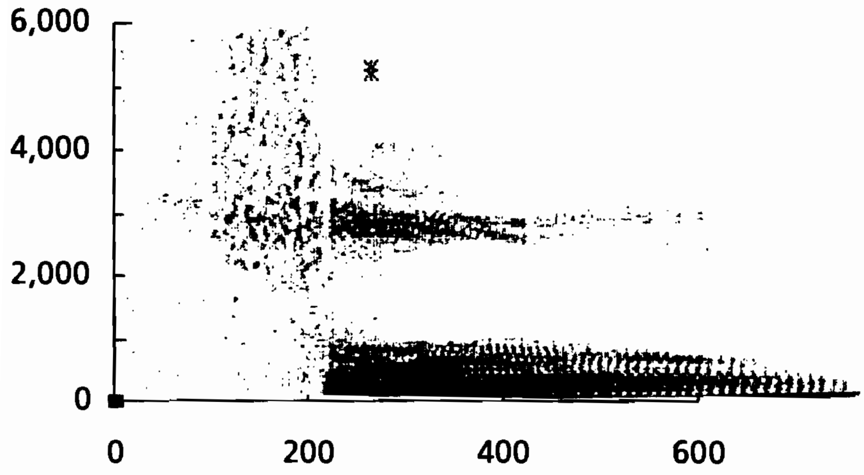

Figure 6. Spectrogram of [suu] by Speaker A

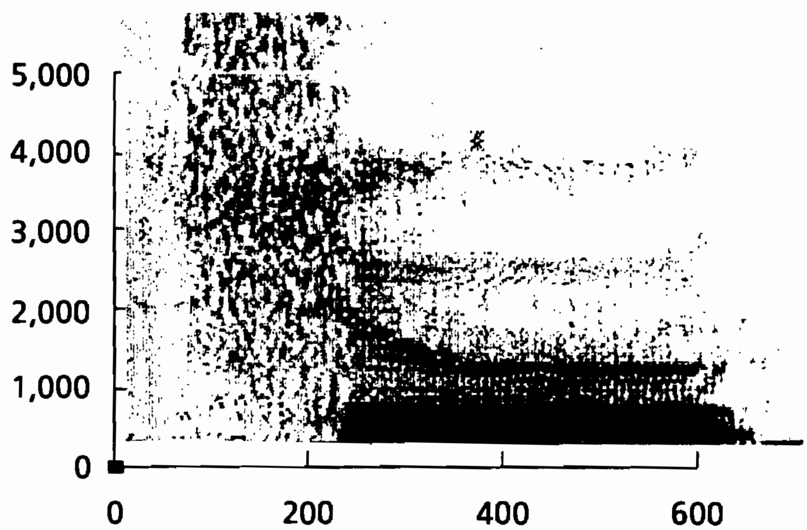

Figure 7. Spectrogram of [suu] by Speaker B

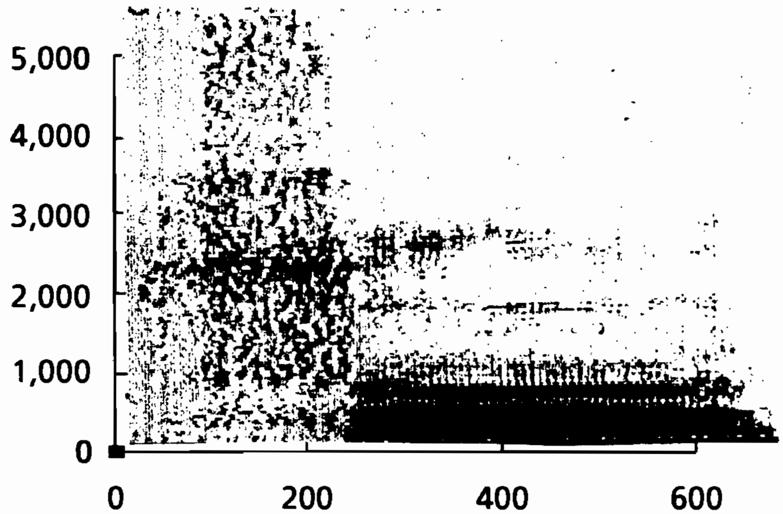

Figure 8. Spectrogram of [suu] by Speaker B

For the sake of comparison with spectrograms and for seeking additional information, waveform displays of the syllables [saa, saa; suu, suu; sii; sii] are presented. They are all produced by speaker B. Amplitude is shown on the ordinate and duration on the abscissa. The temporal envelope of each syllable describes the manner in which amplitude varies with respect to time. Looking at the temporal envelopes of the consonantal segments of the six

spectral displays below reveals a distinct difference in the shape of the envelopes between the pharyngealized and nonpharyngealized sibilants preceding [aa] and [ii], but not before [uu]. The temporal envelopes of the pharyngealized sibilants have noticeably smaller amplitudes than those of their plain counterparts, except before [uu]. Consonantal amplitude varies between +0.8 and -0.7 volts in [saa] (Figures 9), while it varies between +0.3 and -0.2 volts in [saa] (Figure 10). In [sii] (Figure 2.13), the temporal envelope fluctuates between +0.9 and -0.9 volts, whereas [sii] (Figure 14) shows a 0.2 volts drop in both directions. Both sibilants in [suu] and [suu] (Figures 11 and 12) are at +/- 0.3 volts, showing no perceptible variation.

While the pharyngealized consonants show a drop in amplitude, the vowels show an increase, particularly in the case of [aa] versus [aa] where amplitude varies between +3.2 and -2.1 volts and +3.5 and -3 volts, respectively. A modest increase in amplitude characterizes [ii]: +3.1; -2.2 versus +2.9; -1.9 for [ii]. These values represent the maximum amplitude reached by the sound waves. Another difference, however, is observable between [ii] and [ii] in the pattern of the sound waves. In [sii] there is a sharp decline at the point where the consonantal and vocalic segments meet, then there is a gradual rise. By contrast, [s] seems to merge into [aa] with an abrupt rise to about +3, which is maintained almost throughout the duration of the segment.

There is minimal variation between [uu] and [uu]. It remains to be seen whether perceptual data reflect these acoustical characteristics.

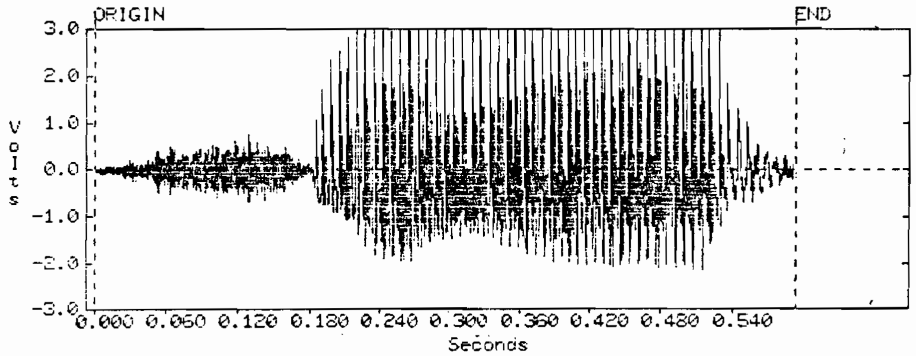

Figure 9. Waveform Display of [saa] by Speaker B.

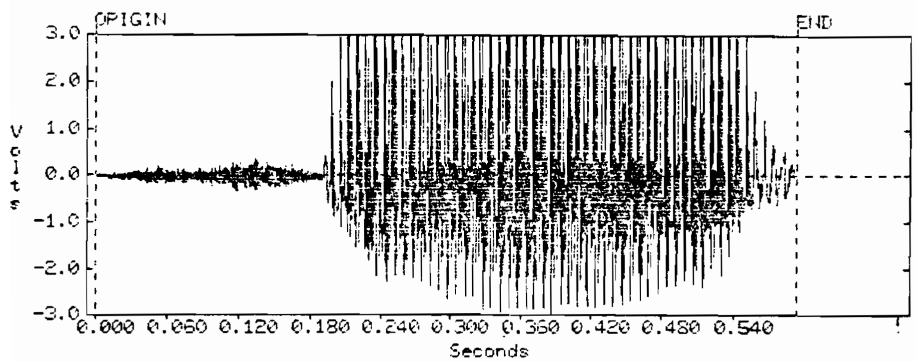

Figure 10. Waveform Display of [saa] by Speaker B.

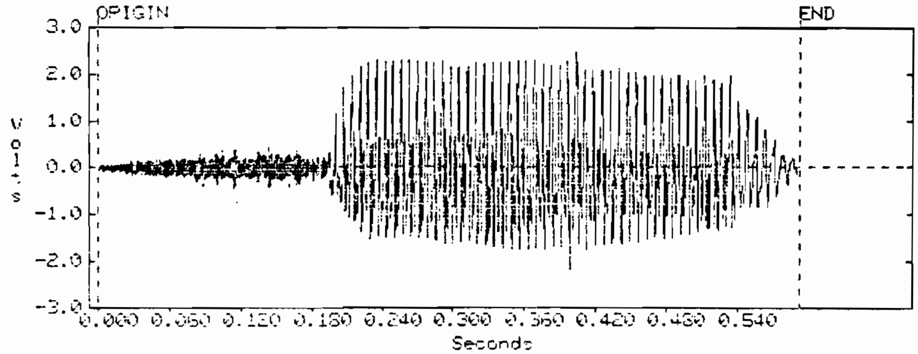

Figure 11. Waveform Display of [suu] by Speaker B.

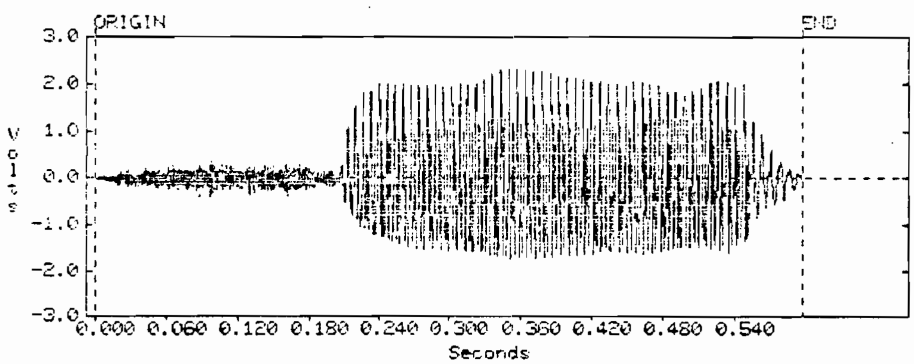

Figure 12. Waveform Display of [suu] by Speaker B.

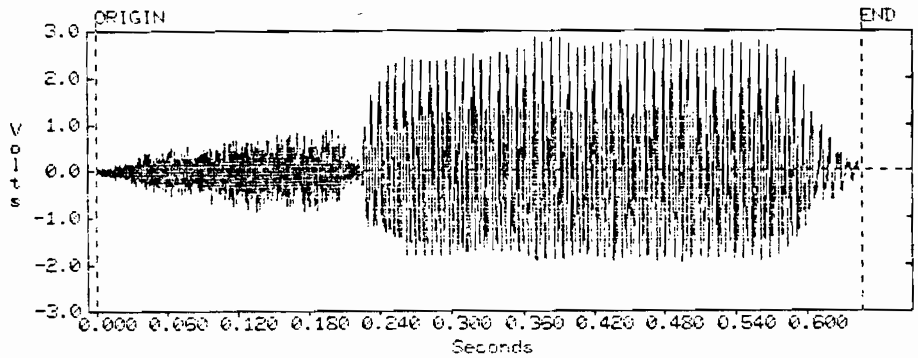

Figure 13. Waveform Display of [sii] by Speaker B.

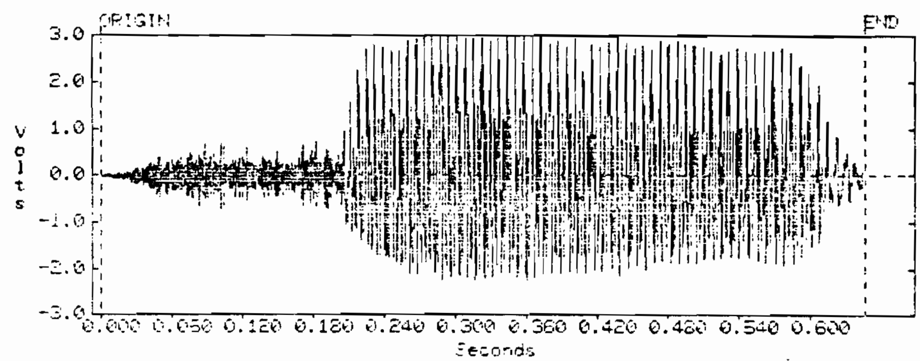

Figure 14. Waveform Display of [s̲i̲i̲] by Speaker B.

In short, variations observed between [aa] and [aa] in spectrograms and waveforms are compatible in the sense that there is distinct differentiation. However, [ii] and [uu] tend to show little influence caused by an adjacent pharyngealized consonant, especially in waveforms. Waveforms of pharyngealized and nonpharyngealized sibilants in the sequences under consideration reveal a difference between [s] and [s] preceding [aa] and [ii], which may suggest that the feature of pharyngealization may be neither a property of the consonant nor one of the vowel, but rather a supra-gegmental feature as Ferguson (see Harris, 1942) proposed earlier. At any rate, matching the acoustical data at hand with perceptual data obtained from the present experiment may yield a clearer picture of this feature.

In the following chapter, the subjects who participated in the experiment and the preparation of the stimuli used will be described as well as the way in which the perception and production experiments were conducted. Also, the experimental design of this research will be described and discussed in detail.

CHAPTER THREE

Methodology of the Study

Subjects

Selection of the subjects has been dictated by the hypotheses stipulated in this study. The developmental hypothesis proposing that there is a relationship between degree of exposure to the target language and the ability to discriminate and distinguish pharyngealized consonants entails dividing the nonnative subjects into three levels of proficiency. And the question that native speakers of Arabic and American learners of Arabic might use different perceptual strategies in discriminating pharyngealized and plain consonants calls for the use of both native speakers of Arabic and American learners of Arabic. The group of native speakers of Arabic is made up of 10 undergraduate and graduate Arab students pursuing their higher education at The Ohio State University. All these subjects have completed at least their secondary school education in an Arab country. They are, thus, assumed to be representative of the population of native speakers of Arabic.

The American subjects are divided into three levels of proficiency based on the length of exposure to Arabic measured by the number of credit hours in the quarter system accumulated up to the date the experiment is conducted. Level I consists of 10 subjects who have had between three and 10 credit hours of Arabic. The 11 subjects who constitute Level II have had between 11 and 30 credit hours of Arabic. The highest level of proficiency, Level III, is made up of 15 subjects who have accumulated 31 credit hours of Arabic and above. Some of them have spent up to a year in an Arab country. The American subjects, as a group, may not be a highly representative sample of the population of learners of Arabic in the United States because the pool of students from which they were selected was not large enough to allow for adequate randomization.

Speakers

The Arabic syllables used in the experiment are tape recorded by two native speakers of Arabic who have completed their university education in an Arab country. Speaker A speaks the dialect of Damascus and Speaker B speaks that of Jerusalem. Thus, both of them speak a colloquial variety known as Levantine, or Syrian Arabic. Although they do not have the fricatives /dh/ and /d̲h̲/ in their colloquial speech, they are able to produce them according to the norms of Modern Standard Arabic, the variety the American subjects are studying. (These sounds are usually replaced by /d/ and /z/ for /dh/, and /z̲/ for /d̲h̲/.)

Instrumentation

Stimuli: The tokens used in the experiment are made from 12 different syllable types of Arabic, each one recurring twice, recorded in random order by the two speakers. Thus, each speaker actually produced 24 syllables with a total of 48 syllables btween the two speakers (12 x 2 x 2). The twelve syllable types are: [saa, suu, sii, saa, suu, sii, dhaa, dhuu, dhii, dhaa, dhuu, dhii]. The decision to use nonsense syllables instead of meaningful words was made in order to avoid semantic pressure which might interfere with or override perception. Besides, Level I subjects may be unfamiliar with some of the words, which may give advantage to higher level subjects.

The choice of using fricatives rather than stops for this study is determined purely by technical constraints. Stops are not amenable to electronic manipulation since they are acoustically represented as silence. Thus, there is little point in spilicing these silent segments because they carry no acoustical information that might influence perception of pharyngealization.

The syllables were not presented to the subjects in their "raw" form. Rather, they were processed by feeding them into the computer and digitalizing them for two reasons. First, in order to test the hypothesis that American learners of Arabic and native speakers of Arabic perceive pharyngealization differently, *i. e.*, that the former group perceive pharyngealization on the vowel and the latter group on the consonant, a set of cross-spliced syllables needs to be prepared. To illustrate this point, the plain syllable [saa] and its pharyngealized counterpart [saa] are spliced into their component segments producing /s, aa, s, aa/. Then they are cross-spliced yielding a new set of syllables: [saa] and [saa], which do not occur in normal speech. As noted above, the reason for this procedure is to test the perceptual strategies used by the two groups. This procedure controls for the quality of the segments. Since pharyngealization usually spreads to contiguous segments, it would be difficult, if not impossible, to determine perceptually where the locus of this feature is in case of utterances with two or more segments. For this reason the segments are first isolated and then recombined in order to test perception based on the properties of a specific segment. If it is true that American learners of Arabic do perceive pharyngealization on the vowel, then the cross-spliced sequence [sa̲a̲] would be perceived as pharyngealized. Conversely, Arabic-speaking subjects would perceive the sequence [s̲aa] as pharyngealized. Cross-splicing has doubled the number of tokens to an overall total of 96 sequences (12 x 2 x 2 x 2), half of them normal sequences and the other half cross-spliced sequences. The second reason for digitalizing the syllables is to facilitate randomization of the 96 tokens.

Procedure: Each speaker recorded 24 syllables randomly ordered. The recording took place in a sound-treated, anechoic recording chamber in the Linguistics Laboratory of the Department of Linguistics at The Ohio State University. A reel-to-reel TEAC 40-4 Tascam Series 4-channel recorder reproducer was used. It is placed outside the recording chamber and connected to a microphone and a control panel inside the chamber. The recorded material was then transferred to an audio cassette using a Sony cassette deck (TC-FX 25). Another identical machine was hooked up to a Digital VT100 Synclavier II computer with a Winchester (hard) disk drive. This is used to feed the information recorded on tape into the computer through two sound filters. The software used to operate the sample-to-disk system is called Signal File Management (SFM), which gives access to the system in order to make sound files. The sound files convert the information recorded by powerful 16-bit data converters into a form that the computer can use, which is a series of digital samples. And then the converted information is stored on the computer's Winchester disk. The sounds can be exactly recorded on the disk where they are available for display, manipulation, or analysis.

The process of preparing the stimuli begins with creating a file of a certain length (in seconds) and recording data on it. It must be noted that data are recorded at a particular sampling rate, which is usually set at 50 KHz to avoid noise that can be heard when the sound is resynthesized. It is the rule that the higher the sampling rate the less the sampling error. However, although the human ear is sensitive to sounds between 15 Hz and 20 KHz, it is recommended by the manufacturer (see *A Musician's Guide to the Sample-to-Disk System*, 1982) that the sampling rate should be at least twice the highest frequency in the recorded data. In the present experiment the sampling rate is set at 15KHz because sound files take an enormous amount of memory space at higher rates. Since the highest frequency in the stimuli is that of /s/ ranging between 6 and 8 KHz, the rate was set at 15 KHz to make enough room in the memory for the numerous sound files required for the stimuli and to avoid excessive noise and sound distortion at the same time.

Once the data are on the sound file, it is possible to produce a spectral display through the waveform editor of all or a part of the file depending on how much detail is needed. The sampled waveforms stored on the disk can be displayed on the monitor in order to examine and measure their specific properties. This display is used to isolate the points in the sound needing closer examination. The necessary segments are isolated by labelling the beginning and ending of the portion by moving the curser (a vertical thin line) to particular points on the abscissa. In the process of preparing the stimuli, the beginning and ending of the vowels and consonants are labelled and then the segments are extracted and saved in separate files. In addition to visual observation, the extracted segments are listened to through headphones for further checking of the accuracy of splicing. After extracting all the segments, an editing program is used to splice and combine the sound files in the manner described above producing normal as well as cross-spliced sequences (see Appendix B for a list of the spliced tokens in order of presentation on tape).

The finished sequences are recorded back on tape in random order with an interval pause of three seconds between tokens using the Sony cassette deck. The tokens are presented in blocks of three tokens each. The blocks are separated by a beep in order to minimize the chance of error on the part of the subjects while marking their responses on the answer sheet. The subjects are informed orally and in writing at the top of the answer sheet that a beep signals the end of a block and the beginning of another.

In addition to the 96 experimental tokens, twelve practice tokens are also created from the pool of sound files. They are all produced by speaker A and they represent normal sequences. They are intended to familiarize the subjects with the process.

Answer Sheet: The subjects marked their responses to the stimuli on an answer sheet prepared specifically for this experiment. The first page has a set of instructions in English pertinent to the task at hand. Then, on the following line, the twelve Arabic syllable types are printed clearly in 18-point characters in Arabic script (see Appendix C for a sample answer sheet). These are followed by 12 blank lines numbered in Arabic numerals on the left margin. The twelve Arabic syllables are separated by vertical lines, thus creating cells in which the subjects mark their responses to the practice and experimental tokens with an (X). Pages two through eight have a similar design.

Discrimination Experiment

The subjects participating in the experiment took the forced-choice test individually under identical conditions. Subjects sat in the anechoic chamber in the Linguistic Laboratory on the same chair at the same table with the answer sheet in front of them. They first read the instructions in English and then the experimenter explained the procedure orally. They listened to the stimuli through headphones connected to the Sony cassette deck located outside the chamber. The subjects listened first to the 12 practice items and marked their responses, then they listened to the 96 experimental tokens. They had to judge each token as one of the 12 Arabic syllables printed at the top of each page of the answer sheet (see Appendix C). They marked (X) under the syllable corresponding to the token they think they heard. When the listening task was completed, the answer sheet was removed and the American subjects were given a sheet of paper on which the 12 original syllables are printed in 18-point fonts. They were asked to read the syllables aloud into the microphone. The production task provides the data for the second part of the experiment that is intended to test the relationship between production and perception on the one hand, and the relationship between production and level of proficiency on the other.

Experimental Design

The data derived from the discrimination experiment were analyzed in terms of the four properties of each stimulus and the response of each subject to it. The four properties of the tokens are (1) the type of fricative (sibilant, nonsibilant), (2) the following vowel (/i, a, u/), (3) whether or not the consonant is pharyngealized, and (4) whether or not the vowel is pharyngealized. The properties are coded as (1) or (2) for the consonant, (1, 2, 3) for the vowels, and (0, 1) for pharyngealization.

The data are tabulated according to the properties of each stimulus, first language of the listener, and level of proficiency. Native speakers of Arabic are grouped together (10 subjects) and the American learners are divided into three groups, each representing one level of proficiency (15, 11, and 10 subjects representing Levels, III, II, and I). Thus, the four properties of each stimulus, the native language, and level of proficiency constitute the independent variables, and subject reponses are the dependent variable.

Table 1 is a sample representation of the way the data are tabulated and fed into the computer for statistical analysis.

Table 1. Tabulation of the Discrimination Data with Sample Stimuli and Responses

Consonant		Vowel	Pharyngealization		Native	Nonnative		
Stimulus Number	/s/ /dh/ 1 2	/a, i, u/ 1, 2, 3	Consonant 0/1	Vowel 0/1		Level of Prof. III	II	I
01	1	3	0	0	0	0	0	0
18	2	1	0	1	0	0	0	1

The actual table represented by Table 1 includes all 96 stimuli, and the subject columns (Native and Nonnative) extend horizontally to include the responses of all the subjects in each group. Each subject response is recorded as 0 or 1 depending on whether the stimulus is perceived as plain or pharyngealized. The properties of the first stimulus, for example, indicate that it is [suu] and is perceived to be unpharyngealized by all four subjects listed in Table 1. However, stimulus number 18, [dhaa], is not perceived similarly by the same subjects. The Level I subject perceives the stimulus to be pharyngealized; the other three subjects perceive it to be plain (see Appendix D for tabulation of discrimination data). By tabulating the data in this manner, each column of the 51 columns represents an independent variable. However, in the statistical program, these variables are reduced to only nine variables, the first five of which are stimulus properties and the last four are the groups of subjects. The nine variables are: (1) stimulus number (column 1), (2) the consonant being a sibilant or not (/s/ vs. /dh/) (column 2), (3) the vowel being /ii/, /aa/, or/uu/ (column 3), (4) the consonant being pharyngealized or plain (column 4), (5) the vowel being pharyngealized or plain (column 5), (6) native speakers of Arabic (columns 6-15), (7) Level III subjects (columns 16-30), (8) Level II subjects (columns 31-41), and finally (9) Level I subjects (columns 42-51).

Some statistical models have been developed in light of the research questions this study is seeking to answer. In order to test the perceptual hypothesis, the variables of "consonant" and "vowel" are crossed with each other, each consisting of two levels: "plain" (0) and "pharyngealized" (1). Nested within either one is the variable of language background, which is also composed of two levels: native speakers of Arabic (NS) and nonnative speakers (NNS). This independent variable is actually a moderator variable, which cannot be controlled or manipulated. Whereas, the other two variables are amenable to manipulation. The consonant can be presented as a sibilant (/s/) or a non-sibilant (/dh/), and the vowel can be /ii/, /aa/, or /uu/. Further, both of these variables, consonant and vowel, can be either pharyngealized or plain. Figure 15 is a schematic representation of this model. It is a 2 x 2 x 2 factorial design, which can be further expanded to include the additional variables relevant to the consonant and to the vowel. This is a general model that can reveal the effect of any one or a combination of these variables on perception.

		Consonant			
		0		1	
		NS	NNS	NS	NNS
Vowel	0				
	1				

Figure 15. Factorial Design of the Effect of Phonetic Context and Language Background on Perception.

Cell 1, for example, can show the perception of native speakers when the stimulus is composed of of a plain vowel and a plain consonant. Obviously, other variables are disregarded in this design, like level of proficiency, type of vowel, and type of consonant. The design may be further refined by building these variables into it. Also partial models can be designed to answer specific questions.

For the analysis of data in this study, several designs are constructed. One is identical to the factorial design above, which would yield information about the effect of pharyngealization on perception by native speakers and American learners of Arabic.

Language Background				
			NS	NNS
Consonant	0	/s/		
		/dh/		
	1	/s/		
		/dh/		

Figure 16. The Effect of Fricative Type on Perception of Pharyngealization

Nevertheless, in order to answer the question whether pharyngealization is ascribed to the consonant and by whom, particular features of the consonant (sibilant, nonsibilant, pharyngealized, nonpharyngealized) are incorporated. The vowel is left out as a variable, but language background is of course retained. This design can provide information whether perception of pharyngealization is sensitive to these properties. Figure 16 illustrates this design graphically.

Variations of these designs, where other variables relevant to this study, like type of vowel (a, i, u) and level of proficiency (I, II, III), may be included and can yield the information required to answer the research questions generated by the hypotheses advanced in this study. The research questions that are answered by statistical analyses are whether there is a difference among the subjects in the perception of pharyngealization attributable to

(1) first language
(2) level of proficiency
(3) the consonant
(4) the sibilant
(5) the vowel
(6) low back vowel
(7) high back vowel
(8) high front vowel.

The statistical test appropriate for these data is the analysis of variance. It investigates the relationship between one or more independent variables and a dependent variable. The BMDP statistical software package available at the linguistics laboratory is used for this purpose.

Production Data

The syllables produced by the American subjects following the discrimination task are digitalized for splicing and randomization (excluding the data obtained from one Level III subject). Then they are transformed back to tape for four native speaker raters to evaluate the syllables as plain or pharyngealized. The total number of the tokens is then 420 (35 x 12). They are saved on sound files at a rate of 15 KHz using a process similar to that followed for preparing the stimuli. However, the production data are spliced as whole syllables without tampering with the component segments. Each syllable is isolated by labelling its beginning and end, then it is extracted and saved in a separate file. The spliced syllables are transferred back to tape in random order (see Appendix E for a list of production data in order of presentation on tape by subject and syllable).

The data obtained from the rater evaluation sheets are tabulated according to subject, level, and token (see Table 2 and Appendix F for tabulation of ratings according to subjects, levels, and tokens). The specifications concerning subject serial number, level of proficiency, token code are entered. Originally, the ratings of the four judges were recorded in terms of 0 and 1 for each one of the 12 syllables produced by a particular subject as in Table 2 below. However, for statistical manipulation, the tokens are coded 1-12. That is, /saa/ = 1, /suu/ = 2, and so forth (See Appendix F for coding). The entered data are subjected to statistical analysis to find out whether there is significant difference among the groups representing the three levels of proficiency in their production ability. Also, the production data of groups are compared with the perception data of each group to find out the degree of correlation between these two processes. The data are ordered in the manner shown in Table 2.

Table 2. Tabulation of Production Data.

Token	Level	Subject	Pharyngealization	Vowel	Rater1	R2	R3	R4
1	1	1	0	3	1	1	0	1

Token numbers 1 through 12 are repeated for each subject. Level number (1-3) remains constant throughout a particular level of proficiency. The subjects are ordered from 1 through 35 starting with Level 1. Under Pharyngealization, there is either 1 or 0 indicating whether the syllable in question is judged by the rater to be pharyngealized or plain. Vowels are coded 1, 2, or 3 for /a, i/, and /u/. In the following four columns, the raters' judgments are listed as either 0 or 1 depending on whether the rater judged a particular sequence as plain or pharyngealized.

In short, the questions that the study seeks to answer at this point are whether there is a relationship between level of proficiency in Arabic and the ability to produce sounds having the feature of pharyngealization, and whether there is a relationship between the ability to discriminate and to distinguish sounds that have the feature of pharyngealization. For the first question, a simple one-way ANOVA is used, where the single independent variable is the level of proficiency, which has three levels I, II, and III. At each level, two means are to be compared; the production mean and the perception mean. The purpose is to examine the differences between perception and production data and decide whether these differences are significant. The design is schematically represented in Table 3.

Table 3. Comparing Perception and Production on Level of Proficiency

Level of Proficiency					
I		II		III	
Perc	Prod	Perc	Prod	Perc	Prod

The second question concerning the relationship between the ability to discriminate and distinguish pharyngealization is tested by computing the score for each American subject on the production task and the score on the perception of the normal sequences. Then, an average score for both tasks is calculated representing the percentage of items perceived and produced correctly. A mean score is calculated across subjects for each level of proficiency in order to compare the proportion of the tokens correctly produced with the proportion of similar tokens correctly perceived. A one-way ANOVA is used to compare the means for each level.

In the next chapter, the results of the statistical analyses concerning the perception and production experiments will be presented and discussed with reference to each of the variables under consideration. Some conclusions will be made with respect to the motor theory of speech perception and the subjects' performance both in perception and production across language background and levels of proficiency.

CHAPTER FOUR

Presentation of Statistical Analysis and Discussion of Results

In this chapter, the results of the discrimination and production experiments will be described and discussed. Findings for each null hypothesis will be presented along with the relationship among the variables. As noted in the preceding chapter, the experiments were conducted under extremely controlled and similar conditions to institute control over extraneous factors. This may make it safe to assume that variability among the subjects due to setting and procedure might be maximally inappreciable. Variability, then, can be ascribed, for the most part, to factors related to the variables under consideration, namely, language background, level of proficiency, and the phonetic properties of the stimuli.

Results of the Discrimination Experiment

Perceptual Hypothesis: With regard to the perceptual hypothesis posited in Chapter One that native speakers of Arabic (NSs) and American learners of Arabic (NNSs) utilize different strategies in perceiving pharyngealization, that is, the former group ascribe it to the consonant and the latter group to the vowel, it appears that statistical analysis of the data supports the greater part of this hypothesis. Looking specifically at the means associated with the perception of the cross-spliced sequences (CV, CV) reveals that, overall, native speakers of Arabic are more sensitive to any cue of pharyngealization either on the vowel or on the consonant than American learners of Arabic. However, the proportion of stimuli with a pharyngealized consonant perceived by the Arab subjects (0.5038) is substantially larger than the proportion perceived by the other group (0.3670). Means and standard deviations of both groups are shown in Table 4 (Underscored C and V stand for pharyngealized consonants and vowels).

Table 4. Means and Standard Deviations of Perception of Pharyngealized Segments by Arab and American Subjects

	Group	CV	CV	CV	CV
Means	NSs	.0500	.7041	.5038	.9727
	NNSs	.1750	.6643	.3670	.7299
SDs	NSs	.0722	.3028	.3243	.0456
	NNSs	.1033	.2742	.2029	.1836

These percentages representing perception of pharyngealized segments in cross-spliced sequences can be captured more clearly by a bar graph that shows the differences between Arab and American subjects in discriminating the consonantal and vocalic segments as well as the differences observed in the perception of consonants and vowels. As the analysis of variance indicates (Table 5), these differences, across language background and segments, are statistically significant.

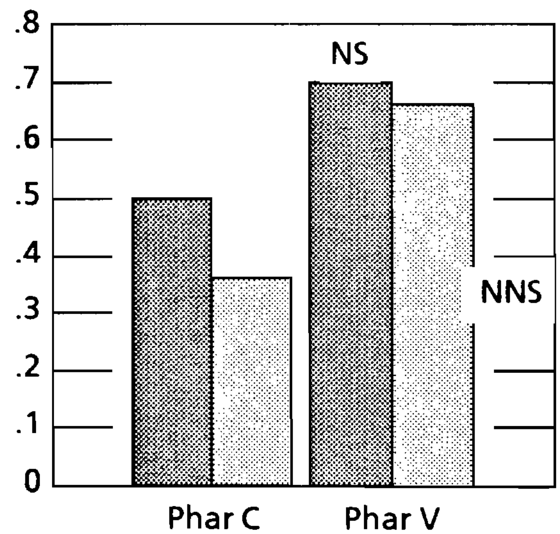

Figure 17. Perception of Consonants and Vowels

Obviously, the effect of pharyngealization on perception when it is localized on a single segment of a sequence, as is the case with the cross-spliced sequences, allows us to determine unequivocally the locus for the cue of this feature with respect to the two groups. These sequences are included in the experiment in the first place to avoid coarticulation, which would affect perception one way or another. Thus, the means of the cross-spliced sequences (the two middle columns in Table 4) are particularly informative in this regard because the observed outcome of the experiment would be directly linked to experimental manipulations. A cell means graph (Figure 18) illustrates the relationship between the perception of the subjects and pharyngealization in the consonant.

The graph indicates that the ability of native speakers of Arabic to discriminate pharyngealized consonants is greater than that of the other groups. Also, the ANOVA shows that there is a strong interaction between language background and the consonantal segment with an impressive *F*-ratio of 45.60 ($p < 0.0000$). This means that while pharyngealization on the consonant is important for perceiving a segment as such, the ability to discriminate pharyngealized segments may be due to language background of the subjects (factor A), which affirms the claim made in Chapter One that the first language of the subjects is a crucial factor in associating pharyngealization with the consonant. This result allows us to reject the null hypothesis of no difference in perception due to language background.

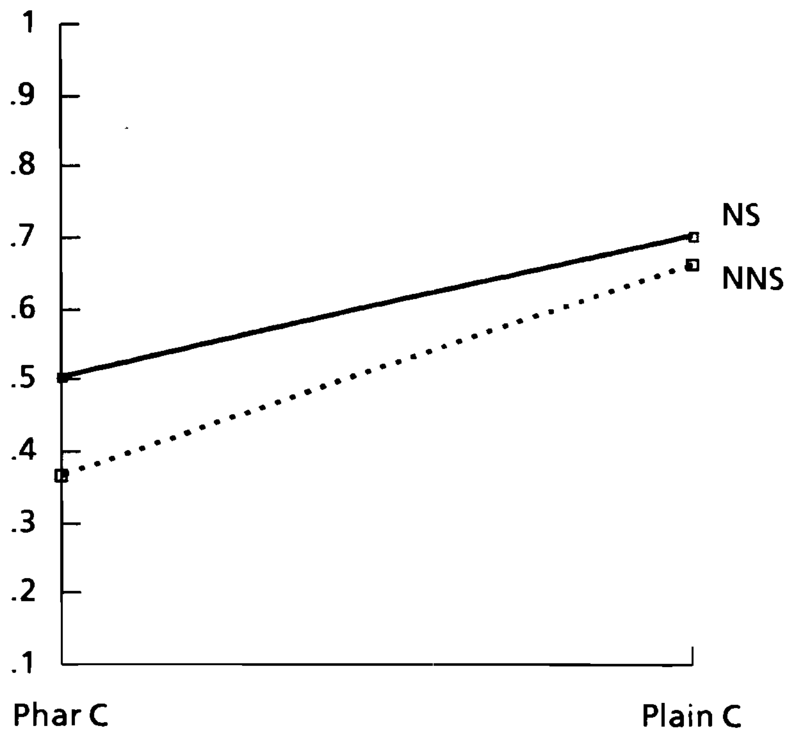

Figure 18. Cell Means Graph of Cross-Spliced Sequences

Similarly, the percentage of American learners of Arabic who perceived pharyngealization on the vocalic segment (0.6642) is much higher than when the segment was plain (0.3670). This is further confirmed by the *F* statistics in Table 5.

Table 5. ANOVA for Perception of Pharyngealization Over Language Background and Type of Segment

Factors	SS	d.f.	MS	*F*	Probability
Language (A)	0.2594	1	0.2594	18.31	0.0000
Consonant (B)	2.8713	1	2.8713	36.12	0.0000
Vowel (C)	11.6631	1	11.6631	146.74	0.0000
A X B	0.6458	1	0.6458	45.60	0.0000
A X C	0.2194	1	0.2194	15.49	0.0002
A X B X C	0.0103	1	0.0103	0.73	0.3949

The table shows that language as an independent factor is highly significant, so is the effect of vowels and consonants. The table also indicates that the interaction between language background and the vocalic segment of the sequence is highly significant ($p < 0.0002$), which makes it possible to reject the null hypothesis of no difference between the subjects due to the following vowel. One may conclude from the statistical analysis listed bove that while the presence or absence of pharyngealization in a particular segment is statistically highly significant by itself, one cannot dismiss the interaction between language background with pharyngealization on the consonant and with pharyngealization on the vowel. Since these interactions are significant, there is little information in the present data to determine which factor is responsible for this significant effect, although a substantially large *F*-ratio tells us that the pharyngealized vowels may be the source of the observed differences. This interpretation lends support to the perceptual hypothesis advanced earlier. Nevertheless, the three-way interaction among the three factors is not significant at all, which means that the main effects can be safely attributed to their respective factors.

The significant difference in the proportion of pharyngealized consonants perceived as pharyngealized by Arab and American subjects might be due to a particular attribute of the consonant. In order to find out the source of difference, analysis of variance was conducted on the data with the consonantal part divided into two levels: sibilant and non-sibilant. The results of the analysis indicate that there is no significant difference between the two groups in the perception of the fricatives based on whether they are sibilant or not (see Table 7). The top two lines in Table 6 show the proportion of stimuli perceived by the subjects to be pharyngealized or plain, and sibilant or non-sibilant.

Table 6. Means and Standard Deviations of Perception of Sibilants and Non-sibilants by Arab and American Subjects

	Group	/s/	/dh/	/s̱/	/d̲h̲/
Means	NSs	0.3833	0.3708	0.6667	0.7708
	NNSs	0.4274	0.4119	0.5191	0.5476
DSs	NSs	0.4341	0.3629	0.3761	0.2881
	NNSs	0.3555	0.2903	0.3103	0.2169

It is interesting to note that the differences are minimal between the two groups when the consonant is plain regardless of whether it is sibilant or not. However, the difference is much greater when the consonant is pharyngealized. The ANOVA for the independent variable 'language background' (Table 7) indicates, as has been established earlier, that the *F*-ratios of the language factor and pharyngealization are significant, so is the interaction between language and the consonantal segment. The *F*-ratio, however, for the sibilant factor is not significant (at $p < 0.05$), which means that the difference between the two groups in their perception of the fricatives is not due to whether a particular segment contained a sibilant.

Table 7. ANOVA for the Perception of Fricatives as Sibilant or Non-sibilant

Factors	SS	d.f.	MS	*F*	Probability
Language (A)	0.2450	1	0.2450	15.03	0.0002
Consonant (B)	2.4882	1	2.4882	11.94	0.0008
Sibilant (C)	0.0329	1	0.0329	0.16	0.6919
A X B	0.6237	1	0.6237	38.29	0.0000
A X C	0.0185	1	0.0185	1.14	0.2891
A X B X C	0.0158	1	0.0158	0.97	0.3270
B X C	0.0775	1	0.0775	0.37	0.5435

It must be noted, however, that this result runs counter to expectations based on the acoustic properties of sibilants. Pharyngealized and plain sibilants should be easier to discriminate because they tend to be acoustically more prominant for being characterized by higher formant frequencies than non-sibilants, specifically /dh/ in this case. The reason for non-difference may be attributable to the fact that the analysis is run on all the experimental sequences, including normal ones, that is, those that were not cross-spliced.

Therefore, another ANOVA was run where only the cross-spliced sequences were specified. This arrangement would exclude the effect of normal sequences on perception and focus on those sequences that were designed to test the effect of pharyngealization on a single segment of a sequence. The results point again to the significance of pharyngealization as an independent factor in discriminating vowels ($F\,(1, 48) = 228.65$, $p < 0.0000$) and the importance of language as a factor ($F\,(1, 48) = 10.00$, $p < 0.0027$). They also indicate that the interaction of language background and individual vowels is not significant, thus emphasizing the significance of the effect of pharyngealization on the perception of vowels and the effect of language background.

Further comparisons were needed to find out whether the differences observed between native speakers of Arabic and American learners were significant. In the case of the perception of pharyngealized vowels, the difference between these two groups is not significant ($F\,(1, 23) = 1.63$, $p < 0.214$). However, the difference between the percentage of pharyngealized consonants perceived by NSs as such (0.5039) and the percentage perceived by NNSs (0.3670) is significant ($F\,(1, 25) = 9.13$, $p < 0.0057$). This last statistic leads to the rejection of the null hypothesis of no difference between the two groups due to the consonant.

With respect to the perception of pharyngealized vowels, the results reveal, as noted in the preceding paragraph, that the difference between native speakers of Arabic and American learners of Arabic is not statistically significant. However, pharyngealization on the vowel is, overall, a powerful cue to the perception of pharyngealization by both NSs and NNSs. A closer look at the pharyngealized vowel to which the subjects were most sensitive reveals that /aa/ is the most powerful cue to pharyngealization with NSs discriminating it about 93% of the time and NNSs about 78%. The subjects seem to be less sensitive to this feature in the other two vowels, /ii/ and /uu/. These results are graphically represented in Figure 19.

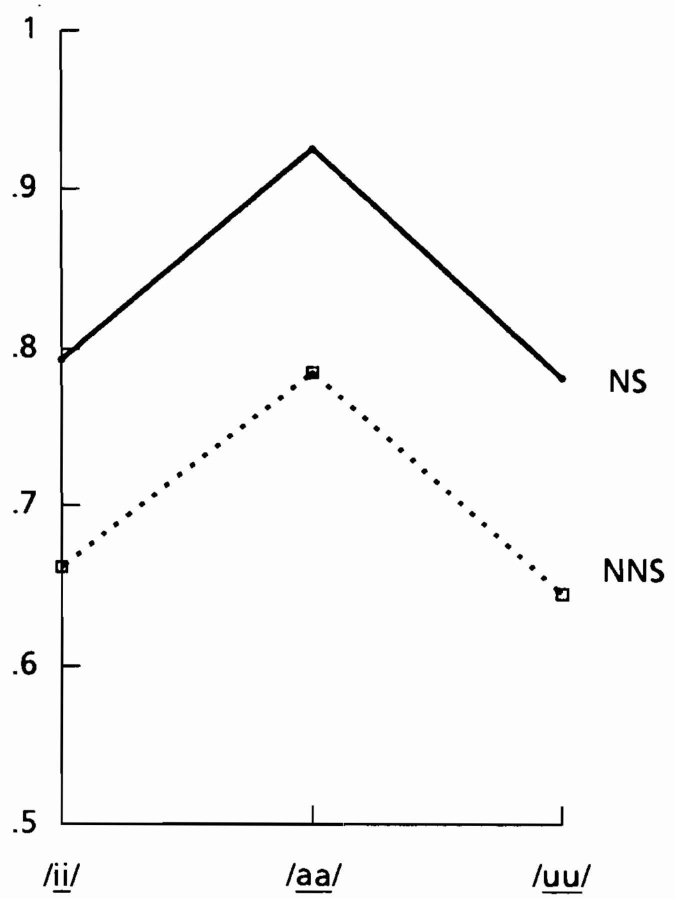

Figure 19. Cell Means Graph of Perception of Pharyngealized Vowels

It is interesting to note that these results are in agreement with the analysis of the spectrographic representations of these vowels (see Figures 1-8). The amount of the drop of second formant (F2) steady states and the perception of these vowels by both groups have similar patterns. The percentage of pharyngealized vowels perceived by Arab subjects as pharyngealized is higher than that of American subjects (Table 8). The values of the decline of F2 steady states of these vowels (Table 9) correspond to the percentages of perception of these vowels. These differences can be seen visually in Figure 19 above and in Figure 20, which represents the drop in F2 steady states as a result of pharyngealization.

Table 8. Means and Standard Deviations of Perception of Pharyngealized Vowels by Arab and American Subjects

	Group	/ii/	/aa/	/uu/
Means	NSs	0.7933	0.9267	0.7813
	NNSs	0.6610	0.7850	0.6450
SDs	NSs	0.3220	0.1280	0.2713
	NNSs	0.3200	0.1670	0.1819

Table 9. Lower Steady State of F2 in Sample Pharyngealized Vowels

/ii/	/ii/	/aa/	/aa/	/uu/	/uu/
2335	2270	1720	1245	1050	650

The data obtained from the analysis of variance for this variable (vowel type) indicate that the differences in the perception of the different vowel types are not statistically significant as cues to pharyngealization (see Table 10). Furthermore, the ANOVA indicates that language background is a significant factor in the perception of pharyngealized vowels either as a class or as individual vowels (Table 10). Pharyngealization of the vowel (factor B), in general, is shown to be significant in determining the differences in perception among the groups. The ANOVA table below shows significant interactions between language and pharyngealized vowels as a class, between language and individual vowels, and between language and these two factors. In the light of these significant interactions, one cannot make a strong claim regarding which factor is responsible for the observed effect. The large size of the *F*-ratio of the pharyngealized vowels, however, suggests that when pharyngealization is present in the vowel, it serves as a strong cue.

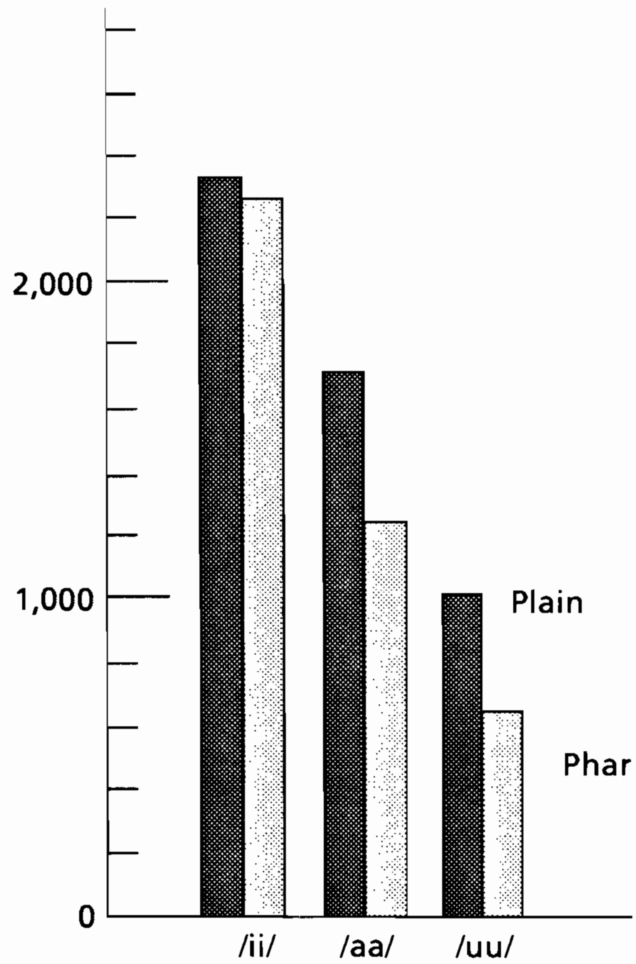

Figure 20. Drop in Second Formant Frequencies in Sample Vowels

The bar graph clearly shows that /aa/ is most sensitive to pharyngealization and that /ii/ is the least affected by it. This is in agreement with Hussein's data (1987) regarding average steady state values computed over two speakers and 960 tokens. His results show that, on the average, the steady state for /ii/

drops from about 2350 Hz to 2250 Hz, that for /aa/ from 1420 Hz to 1150 Hz, and for /uu/ from 880 Hz to 800 Hz.

Table 10. ANOVA for Perception of Vowels

Factors	SS	d.f.	MS	*F*	Probability
Language (A)	0.2610	1	0.2610	13.94	0.0003
Phar V (B)	11.2060	1	11.2060	102.61	0.0000
Vowel Type (C)	0.0017	2	0.0009	0.01	0.9921
A X B	0.1911	1	0.1911	10.22	0.0019
A X C	0.1241	2	0.0620	3.22	0.0407
A X B X C	0.1432	2	0.0716	3.83	0.0254
B X C	0.7271	2	0.3636	3.33	0.405

Developmental Hypothesis: In addition to the perceptual hypothesis, it is also hypothesized in this study that American learners of Arabic differ in their perception of pharyngealization according to their level of proficiency. In order to test this hypothesis, perception data from American learners of

Arabic were analyzed with the subjects divided into three levels of proficiency. The tests and their variations are similar to those run to test the perceptual hypothesis.

With respect to the effect of pharyngealization on the consonant, difference can be observed in the percentage of pharyngealized consonants correctly perceived by the three groups as Table 11 clearly shows.

Table 11. Means and Standard Deviations of Perception of Pharyngealized Consonants by American Learners of Arabic

	Group	C
Means	Level I	0.4646
	Level II	0.5210
	Level III	0.5528
SDs	Level I	0.2589
	Level II	0.2892
	Level III	0.2740

Analysis of variance, however, indicates that differences among the subjects due to pharyngealization on the consonant are not statistically significant ($F\ (1, 94) = 3.64, p < 0.0593$), which calls for the retention of the null hypothesis of no difference among the subjects due to pharyngealization on the consonant. But the differences between the subjects attributable to their level of proficiency are highly significant. This result is further consolidated by the absence of a significant interaction between level of proficiency and pharyngealization in the consonant. Thus, it can be safely and strongly claimed that subjects do differ in their perception of pharyngealized consonants due to their level of proficiency as the ANOVA table shows.

Table 12. ANOVA for the Perception of Consonants by American Subjects

Factors	SS	d.f.	MS	*F*	Probability
Phar. Cons. (A)	0.8899	1	0.8899	3.64	0.0595
Level of Prof. (B)	0.3404	2	0.1702	11.60	0.0000
A X B	0.0399	2	0.0199	1.36	0.2589

Although pharyngealization on the consonant was found not to be a significant factor in differentiating the subjects, further analysis of data was conducted on a particular feature of the consonant, namely, sibilant vs. non-sibilant. The analysis reveals that this feature, in combination with the level of proficiency of the subjects, does have a significant effect despite the fact that a consonant being sibilant or non-sibilant is not a significant factor by itself. The interaction between level of proficiency and this feature is demonstrated graphically in Figure 21, where only pharyngealized segments are plotted. The interaction means that while Level I and Level II subjects seem to discriminate pharyngealization on /dh/ more than they do on /s/, Level III subjects perceive this feature equally well on both fricatives. This result contradicts an acoustic fact as noted above. A sibilant should be more easily perceived than a non-sibilant due to the higher frequency that characterizes it.

Table 13. Means of Perception of Consonants by American Subjects

	Group	/s/	/dh/	/s̲/	/d̲h̲/
Means	Level I	0.3792	0.3708	0.4500	0.4792
	Level II	0.3561	0.3977	0.4849	0.5568
	Level III	0.4833	0.4222	0.5556	0.5500

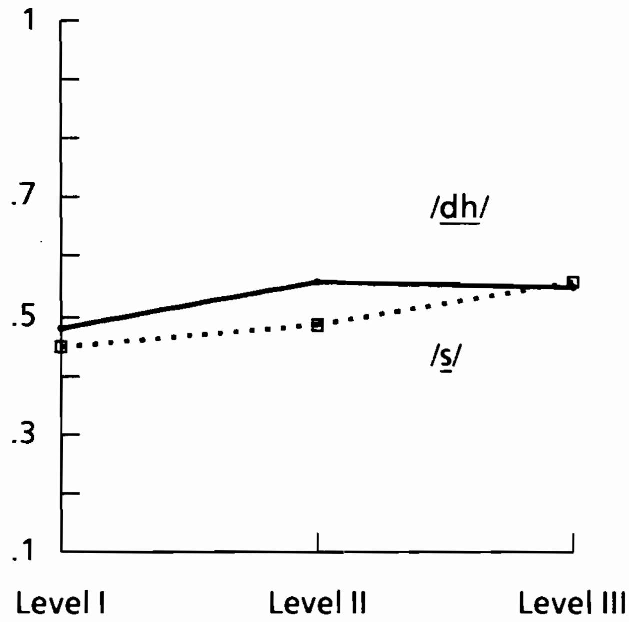

Figure 21. Means of Sibilants and non-Sibilants

In summary, the analysis concerning the consonant reveals that pharyngealization on the consonant is not a significant factor in separating the subjects based on their perception of this feature as can be seen in Table 14. However, the level of proficieny is a crucial factor in the ability of learners of Arabic to perceive pharyngealization on the consonant because of the size of the *F*-ratio. Also, the interaction between level of proficiency and the sibilant feature of the consonant produces a significant effect, the source of which might well be the level of proficiency of the subjects in the light of the insignificant effect of the sibilant feature by itself on perception.

Table 14. ANOVA for the Perception of Pharyngealized Consonants by American Subjects

Factors	SS	d.f.	MS	*F*	Probability
Level (A)	0.3404	2	0.1702	11.78	0.0000
Phar. Cons. (B)	0.8899	1	0.8899	3.57	0.0619
Sibilant (C)	0.0092	1	0.0092	0.04	0.8481
A X B	0.0399	2	0.0199	1.38	0.2537
A X C	0.0976	2	0.4878	3.37	0.0364
A X B X C	0.0020	2	0.0010	0.07	0.9322
B X C	0.0304	1	0.0304	0.12	0.7275

With regard to the effect of pharyngealized vowels on perception, it was found that it was highly significant, but so is the interaction between level of proficiency and the vowel, which overrides the main effect of pharyngealized vowels. This means that the observed variability could be attributable either to the effect of the level of proficiency or to the effect of pharyngealization on the vowel. The diagram representing the means of perceived vowels (Figure 22) shows that the ability to discriminate pharyngealized vowels increases with the level of proficiency and, at the same time, is much higher than the ability to discriminate plain vowels.

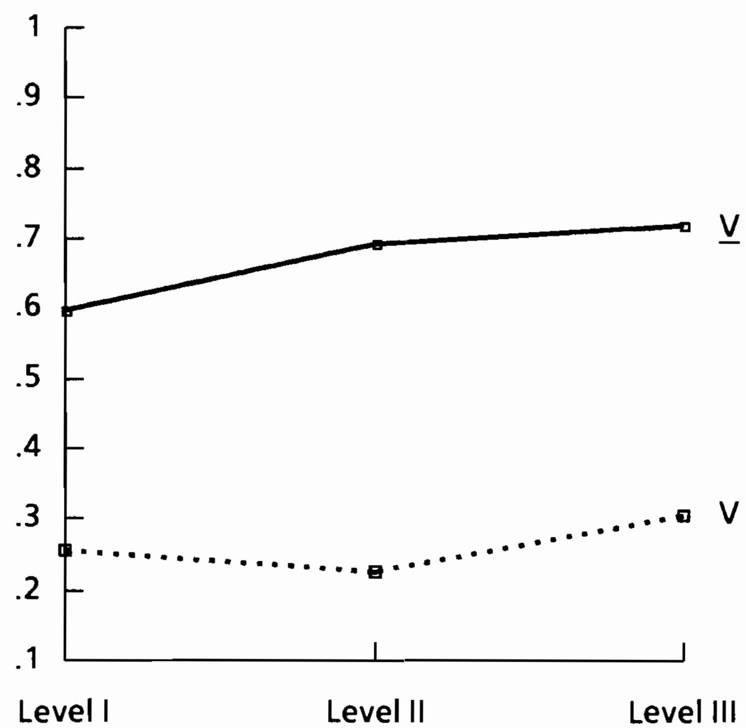

Figure 22. Cell Means Graph of Perception of Vowels by American Subjects

Table 15. Means and Standard Deviations of Perception of Vowels

	Group	V	$\underline{V}$
Means	Level I	0.2560	0.5978
	Level II	0.2255	0.6917
	Level III	0.3053	0.7174
SDs	Level I	0.1786	0.2680
	Level II	0.2198	0.2473
	Level III	0.2043	0.2411

The vowel is apparently a more powerful cue of pharyngealization to the American subjects than the consonant is. The following diagram shows this relationship, and the ANOVA table for the perception of pharyngealized vowels (Table 16) shows the significant effect of level of proficiency and pharyngealization on the vowel as well as a significant interaction between them.

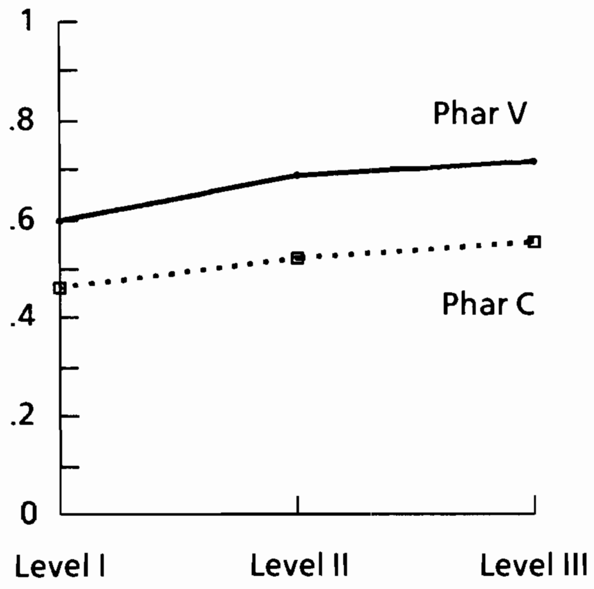

Figure 23. Cell Means Graph of Perception of Pharyngealized Vowels and Consonants by American Subjects

Table 16. ANOVA for Perception of Pharyngealized Vowels

Factors	SS	d.f.	MS	*F*	Probability
Level (A)	0.3488	1	0.1744	12.55	0.0000
Pharyn. V (B)	11.8890	2	11.8890	93.44	0.0000
A X B	0.1865	2	0.0932	6.71	0.0015

A more detailed examination of the vowel reveals that /aa/ is the most prominent cue to pharyngealization. Sequences that contain this vowel are perceived more often than those that contain /ii/ or /uu/. Figure 24 is a schematic representation of the perception of the three vowels by the American subjects across the three levels of proficieny.

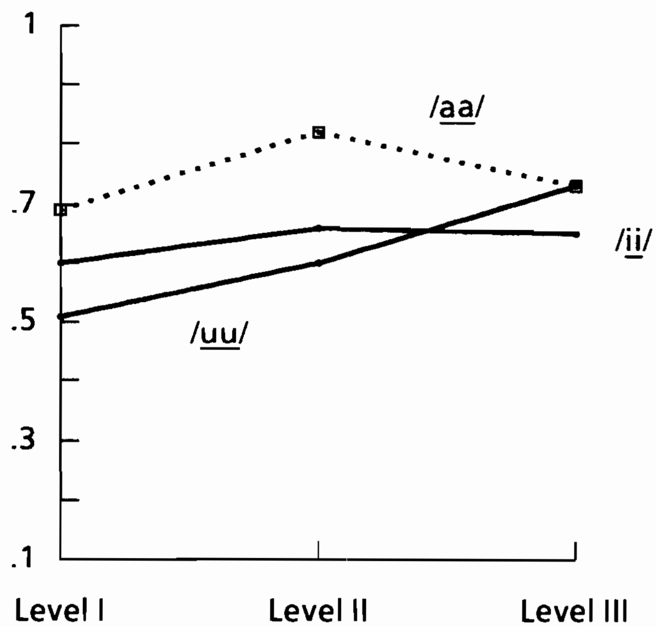

Figure 24. Perception of the Three Vowels by American Subjects

This result is not surprising in terms of acoustical fact as has been demonstrated in an earlier section of this chapter. The vowel /aa/ emerges as the most sensitive vowel to pharyngealization because of the size of the decline of F2 frequency when pharyngealization is superimposed on it. Whereas, the other two vowels are not as much influenced by this feature. (Refer to the bar graph in Figure20 constructed from the steady states of the sample vowels.)

The statistics concerning the effect of pharyngealization on the perception of vowels by the American subjects indicate that there are differences in the means representing the vowels perceived as pharyngealized (Table 17). Analysis of variance, however, shows that the observed differences among the means of perceived vowels are not significant (Table 18), though the interaction between the level of proficiency and the vowels is. This means that the proficiency level of the subjects is a stronger factor in the perception of pharyngealized vowel than the differences among the means of the three vowels perceived as pharyngealized by the subjects. In the ANOVA table, the level of proficiency and pharyngealization on the vowel stand out as the two most important factors in the perception of pharyngealization. However, this strong claim is tempered by the significant interaction between these two factors (refer back to Figure 22). It is difficult to ascribe the effect to either factor, but the large size of the *F*-ratio of pharyngealized vowels leads one to assume that it is the factor responsible for perceiving the vowels as pharyngealized.

Table 17. Means and Standard Deviations of Perception of Pharyngealized Vowels by American Subjects

	Group	/ii/	/aa/	/uu/
Means	Level I	0.6000	0.6933	0.5102
	Level II	0.6606	0.8242	0.5966
	Level III	0.6578	0.7244	0.7292
SDs	Level I	0.3162	0.2404	0.2335
	Level II	0.3005	0.1261	0.2370
	Level III	0.3370	0.1761	0.1829

Table 18. ANOVA for the Perception of the Three Pharyngealized Vowels

Factors	SS	d.f.	MS	*F*	Probability
Level (A)	0.3420	2	0.1710	12.96	0.0000
Phar. V (B)	11.8844	1	11.8844	96.26	0.0000
Vowel Type (C)	0.2152	2	0.1076	0.87	0.4219
A X B	0.1854	2	0.0823	7.02	0.0012
A X B X C	0.0726	4	0.0181	1.38	0.2442
B X C	0.6534	2	0.3267	2.65	0.0764

To recapitulate, the results of the statistical analyses of the perception data indicate that native speakers of Arabic are generally more sensitive to any cue of pharyngealization than American learners of Arabic. Also, it was found that the vowel /aa/ is most susceptible to the effect of pharyngealization, thus, constituting the most powerful cue to pharyngealization for all the subjects in this study. Although there is a difference between native speakers of Arabic and American learners of Arabic in the perception of pharyngealized vowels, the difference turned out to be statistically insignificant. The interaction, however, between language background and pharyngealized vowels is significant, suggesting that it may be the first language of the subjects that is responsible for the observed variability.

The difference in the perception of pharyngealized consonants is statistically significant, which supports the perceptual hypothesis that claims that Arabs are more sensitive to pharyngealization on the consonant than nonnative speakers of Arabic are. Nevertheless, no significant difference was found associated with the consonant being a sibilant.

Results of the Production Experiment

This study is partly concerned with how much correlation there is between perception and production of pharyngealized tokens. A second question to be answered by this study is whether there is a difference among the three groups due to the level of proficiency of the subjects. The data used for this analysis consist of the scores for correct perception of normal sequences (excluding the cross-spliced ones) and correct production of the 12 basic experimental syllables.

The analysis of variance of production and perception data reveals that there is no significant difference between perception and production for each level of proficiency. Although this study is limited to two fricatives only, it can be said that the results do not support the claims made by the proponents of the motor theory of speech perception, which claims that perception is dependent on production. Ladefoged's claim (1967, 1982) that the ability to distinguish, or produce, differences between sounds comes before the ability to discriminate these sounds is not supported by the results of this experiment. If his claim were true, the production mean scores should have been significantly higher than the perception mean scores. The means and *F* values in Table 19 do not even show a tendency toward this claim.

Table 19. Means and ANOVA for Production and Perception Scores

Group		Means	*F*-ratio	Probability
Level I	Prod	0.79	1.67	0.21200
	Perc	0.73		
Level II	Prod	0.82	0.00	0.9704
	Perc	0.82		
Level III	Prod	0.81	1.06	0.3117
	Perc	0.77		

The mean scores of Level II subjects are particularly interesting because production and perception mean scores for these subjects are exactly the same, resulting in a zero *F* value. Although the mean scores for the other two levels are not equivalent, they are close enough to retain the null hypothesis of no difference between perception and production.

The other question regarding the differences in the ability to produce the sounds in question across the three levels is partially answered by the data listed in Table 19 above. The production mean scores for the three levels are close enough to one another. However, another ANOVA is needed to find out whether these differences between perception and production warrant the rejection of the null hypothesis. The results are displayed in Table 20 which shows clearly that there are no significant differences among the subjects attributable to the level of proficiency. This leads to the retention of the null hypothesis of no difference among the levels.

Table 20. ANOVA and Productions Means Over Raters

Group	N	Mean	*F*-ratio	Probability
Level I	10	9.52	0.15	0.8593
Level II	11	9.86		
Level III	14	9.71		

In the light of the extreme closeness of these means, one can make two interpretations of the data; one that contradicts the claims of the proponents of the motor theory as has been argued above, and the other can, interestingly, partly support their position. If perception progressively proceeds along levels of proficiency, as has been established by the perception data, why should production not proceed in a similar fashion? Does the absence of differences in production ability across levels mean that once the learners have established the ability to produce the phonological contrasts of the target language, a stable production system is established independent of the perceptual ability? It appears that if there is such an independent production system, it does not develop in tandem with the perceptual ability because perception is equal to production or lags slightly behind. The developmental hypothesis advanced in this study may, then, be limited to perception since no development in production can be detected. The lack of a developmental process in the production ability may be due to the fact that the production ability might develop at a fairly early stage of learninig, but is not captured by the sampling and experimental procedures employed in this study.

Conclusion

The results of the statistical analyses of the perception data reveal significant differences between Arab and American subjects with respect to language background, pharyngealization on the vowel, and pharyngealization on the consonant. They, however, do not show significant differences due to the consonant being sibilant or not, or due to the type of vowel (/ii/, /aa/, or /uu/).

The analyses also indicate that American subjects can be differentiated according to their level of proficiency and to the presence of pharyngealization on the vowel. The results show no differences attributable either to pharyngealization on the consonant, to the consonant being a sibilant, or to the vowels /ii/, /aa/, and /uu/.

The analysis of production data, on the other hand, indicates the absence of significant differences in the ability to produce the syllables under consideration among the three levels of proficiency. This may suggest that the production ability may not be a developmental process, or that it is simply not captured by the experimental procedures used in this study.

Furthermore, comparing the American subjects' mean scores for the perception of unmanipulated tokens and the production of the twelve basic syllables used in this study shows no significant difference between these two abilities lending support to the view that perception of speech sounds is not dependent on the ability to produce them.

The next chapter will look at the results from two perspectives; a theoretical one that has to do with the theory of foreign language learning and the phonological analysis of Arabic, and an applied one concerning pedagogical practices based on the results of this study. The main thrust will be linking linguistic and learning theories with the field of foreign language education.

CHAPTER FIVE

Discussion and Conclusion

Linguistic and Pedagogical Implications

The present experiments yielded interesting results that have pedagogical and linguistic implications. This research, however, was not conducted in order to favor one linguistic analysis over another or to endorse a particular pedagogical approach. Rather, the major goal was to answer some well-defined questions based on the observation of the linguistic behavior of American learners of Arabic. Although the study is rooted in the theory of foreign language learning, it draws on linguistics and phonetics to investigate the processes of perception and production of particular sounds. Foreign language learning is, after all, an interdisciplinary field that has close affinity with linguistics, psychology, sociology, anthropology, and other disciplines. Thus, the results can be viewed from two perspectives: a theoretical one that might contribute to better understanding of the phonological analysis of Arabic and the theory of foreign language learning, particularly speech perception and production; and a pedagogical one that is concerned with the application of the new insights gained from this investigation to foreign language instruction, specifically to teaching Arabic phonology.

Theories of Speech Perception and Production

As has been argued in the preceding chapter, the results obtained from this experiment do not support the claims made by the proponents of the motor theory of speech perception. They claim that perception of speech sounds is based and dependent on the capacity to produce these sounds. Since the results show high correlation between the two processes of perception and production for each level of proficiency, it is argued that perception cannot be entirely dependent on production because if this was true, the mean scores for perception should have been significantly lower than those for production.

Nevertheless, the data in this study concerning the differences among the three levels of proficiency suggest an intermediate position with regard to the motor theory. Production mean scores indicate no difference that can be attributed to the level of proficiency of the subjects (Table 20), while differences across levels in the perception of pharyngealized segments of the experimental sequences by the American subjects are significant. The line graph below (Figure 25) illustrates variability in perception and production across levels of proficiency.

The slope and direction of the lines in the graph are indicators of the presence of differences or lack of them. It must be noted that the values for perception are the proportions of pharyngealized sequences correctly perceived, and for production, they represent the proportions of pharyngealized sequences correctly produced by each group as evaluated by

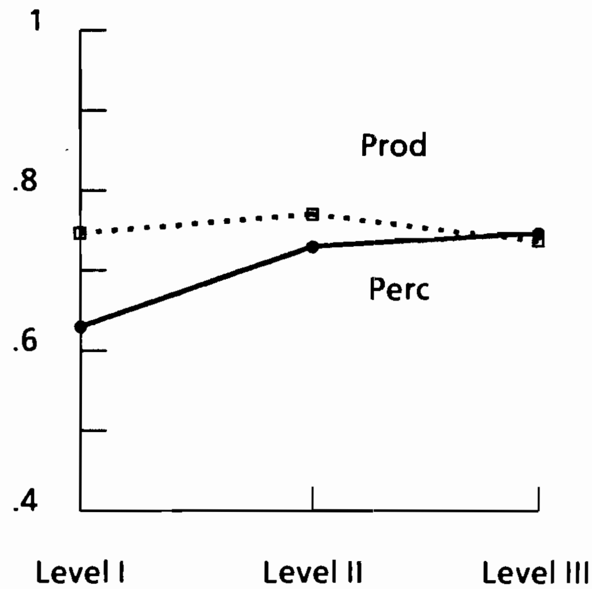

Figure 25. Representation of Perception and Production Means

four Arab raters. From these data, two important implications can be gleaned. First, the fact that there is no significant difference between the two processes suggests that the role of perception is to help the learners construct phonological categories which they utilize in producing the target sounds. Second, the ability of the subjects to produce pharyngealized segments almost equally well at all three levels of proficiency means that they can perceive these phonological contrasts as demostrated by the data.

This leads to proposing a weak version of the motor theory where perception is considered as the basis for production. However, production proceeds independently of perception. That is to say, improved perception due to increased exposure to the language is not necessarily reflected in production. Furthermore, production may develop much faster than perception so that it reaches an acceptable level quite early in the learning process even before perception has reached a "peak" level.

One is also tempted to propose a hypothesis claiming the existence of two independent systems; a perceptual system based on feature detectors (Cutting and Eimas, 1975) that respond selectively to particular stimuli and a production system that is propelled by kinesthetic cue (Hatch, 1983). That is, production may be a function of the ability to imitate incoming sounds, or it may be the ability to reproduce these sounds that have been originally produced in this fashion. This hypothesis, far fetched as it may seem, conforms nicely to the findings from the present experiment. The processes of perception and production appear to proceed in a manner incompatible with each other, thus suggesting two different underlying processes.

Phonological Analysis of Arabic Revisited

Generally, the phonological analyses concerning pharyngealized consonants of Arabic can be divided into two categories: The traditional analysis originally proposed by ancient Arab grammarians (Al-Ani, 1976) and the modern analysis suggested mostly by western scholars of Arabic (Harris, 1942). The traditional one assigns the feature of pharyngealization to the consonant, and the western analysis ascribes it to the vowel. Within the latter category, there is also the analysis that considers pharyngealization as a suprasegmental feature (Ferguson in Harris, 1942).

The results of this study reflect to a great extent the intuitive insight of both Arab and western linguists. These two groups of linguists seem to have trusted their respective personal perception and native intuitions in arriving at their analyses. Their analyses were obviously intuitive rather than demonstrated by empirical evidence. The data clearly show that native speakers of Arabic are far more sensitive to pharyngealization on the consonant than nonnative speakers are. This finding supports the traditional analysis advanced by Arab linguists (see Table 4). On the other hand, the alternative analysis proposed by western scholars is also justified. The data reveal that pharyngealization is mostly vocalic to the western ear. The American subjects correctly discriminated about 66% of pharyngealized vowels compared to only 37% of pharyngealized consonants correctly discriminated. It appears that western scholars were misguided by their own perceptual strategies that, naturally, differed from native ones.

Further examination of the data, however, lends greater support to the traditional Arab view considering the increasing ability of the American subjects to discriminate pharyngealization on the consonant as their proficiency level rises. This means that as the learners proceed in the learning process, their perceptual strategies tend to approximate those of the native speakers, suggesting that pharyngealization as a consonantal attribute is the norm. Table 21 represents the perception of pharyngealization in the four types of the experimental tokens by the American subjects. The sequence $\underline{C}V$ is particularly relevant to this argument.

Table 21. Means of Perception of Pharyngealization

Group		CV	$C\underline{V}$	$\underline{C}V$	$\underline{CV}$
Means	Level I	0.1792	0.5708	0.3269	0.6273
	Level II	0.0985	0.6553	0.3427	0.7314
	Level III	0.2167	0.6889	0.3872	0.7485

The observed differences in the proportion of pharyngealized segments correctly perceived are significant for each one of the independent variables, namely, the level of proficiency, pharyngealization on the consonant, and pharyngealization on the vowel. However, the interaction between level of proficiency and pharyngealization on the consonant is not significant, which suggests that the level of proficiency is a more powerful factor than pharyngealization on the consonant. Table 22 below displays the analysis of variance.

To sum up, the results of data analysis strongly support the traditional analysis of Arabic phonology which considers pharyngealization as an attribute of the consonant rather than of the vowel. They also explain the western hypotheses regarding pharyngealization in terms of intuition based on nonnative perceptual strategies.

Table 22. ANOVA for Perception of pharyngealization on Consonants and Vowels Across Levels of Proficiency

Factors	SS	d.f.	MS	*F*	Probability
Phar. C (A)	1.1349	1	1.1349	9.94	0.0022
Phar. V (B)	12.1702	1	12.1702	106.61	0.0000
Level (C)	0.3476	2	0.1738	12.56	0.0000
a X B	0.2733	1	0.2733	2.39	0.1252
A X C	0.0444	2	0.0022	1.60	0.2039
A X B X C	0.0190	2	0.0095	0.69	0.5044
B X C	0.1931	2	0.0965	6.97	0.0012

Pedagogical Implications and Observations

This research was first conceived in an instructional setting and carried out on learners of Arabic. Some of the research questions it sought to answer were related to the learning/teaching process. Thus, the results should yield some insights that may have pedagogical application and implications relevant to foreign language learning theory.

The most salient observation is the phenomenon of hypercorrection among the Level III subjects. The percentage of plain sequences perceived as pharyngealized by the subjects of this level is the highest among the American subjects (see Table 21), suggesting that as the learners became increasingly exposed to the target language, their awareness of certain features increases as well, and they tend to perceive it in sounds from which it is actually absent. Interestingly, the Level II subjects perform according to expectations. Their error factor is lower than the subjects of the first level. (The percentages in the first column in Table 21 represent error of perception. Correct perception of plain sequences is calculated by subtracting these values from one.) It is possible that the Level III subjects somehow became aware that the pharyngealized consonants were the object of the experiment and started listening for them, while the other two groups were more naive in this respect.

Hypercorrection, however, is not uncommon in foreign language learning. Weinreich (1968) reports the case of Spanish-speaking learners of English who misperceived English final /n/ as /n/ (the experiment was originally conducted by Marckwardt, 1946). Weinreich explains this phenomenon by the learners' excessive caution against under-differentiating /n/ and /n/, a phonemic distinction which Spanish does not possess. He claims that under-differentiation occurs when the learners confuse two sounds of the target language with their counterparts that are undistinguished in their native language. Likewise, the American subjects in the present experiment misheard plain fricatives as pharyngealized because this distinction is not present in English, phonemically at least.

The results of the discrimination experiment emphasize the importance of exposure to the target language. The more exposure there is, the greater the ability to perceive the sounds correctly. This is, obviously, not a new revelation in foreign language research. But in the case of the less commonly taught languages, like Arabic, it serves as a reminder that even in teaching these languages, the learners should have adequate and meaningful exposure to the spoken form of the language being taught. It is the rule rather than the exception that the learners almost never get any exposure to it outside the classroom.

If we accept that comprehension is analogous to perception, then the results of this study will be in accordance with the principles of many communicative approaches to foreign language teaching. Terrell's Natural Approach (1982), Asher's Total Physical Response (1974), and Lozanov's Suggestopedia (Stevick, 1980) all emphasize a prespeaking silent period during which the learners are exposed to large doses of oral language without having to produce much themselves. During this period they are building their own systems of phonological contrasts and morphological and syntactic patterns. The longer the period, the more mature these systems are. Based on the data of this study and on observation, some contrasts, like pharyngealization, do develop early, probably before five credit hours are accumulated. However, it is hard to tell when the ability to perceive and produce pharyngeals, for example, because, first, they are not within the scope of this study, and, secondly, this depends on several factors, like the proximity of the native and target sound systems, and on personal and contextual variables.

An important question arises in the light of the production data. Is a silent period really necessary? If production ability develops faster than perception and reaches an acceptable standard at a fairly early stage, then it will be perfectly acceptable for learners to start producing target language forms early in the learning process. Excluding the effect of affective variables, these forms should not suffer due to a deficient or incomplete production ability for it has been proven by the results of this experiment that the capacity to produce at various levels of proficiency is about the same. Nonetheless, this broad generalization should be viewed with caution. As in all forms of human behavior, performance in one area can hardly be generalizable to another. The results, then, may be generalizable only to the area of phonology.

Teaching Arabic Phonology

Teaching Arabic phonology should not be any different from teaching other phonologies. Foreign language teaching methodologists have produced over the years a plethora of invaluable books and articles in this field (see Allen & Valette , 1972; Paulston & Bruder, 1976; Rivers & Temperley, 1978, Wilkins, 1976; MacCarthy, 1978; and many others). However, in this section, the aim is not to replicate what has already been done or propose a set of techniques to teach pronunciation in Arabic, but rather to focus on aspects of phonetic training that are compatible with foreign language learning theory and with the findings of this experiment.

First of all, a distinction must be made between *speaking* and *pronouncing*. The former is concerned with *what* is being said, and the latter with *how* it is said. The concern here is with the latter. Therefore, it is the mechanics of speech production in relation to the distinctive features of the target sound system that are of interest. The teacher as well as the learner should be convinced of the need for proper pronunciation. In view of today's emphasis on the pivotal role of communication in language learning, including oral interaction, most approaches acknowledge the importance of the speaking skill, which involves pronunciation. Needless to say, the content of the oral message is of primary importance, but so is its oral form, which constitutes an intrinsic aspect of overall competence in the target language.

Pronunciation, like any other language skill, has to be taught because achieving an acceptable standard simply never occurs automatically (except when the target language is acquired rather than learned by young children). Some facts need to be laid out in front of the students and then translated into actual drills. These drills, however, should conform to certain principles that are relevant to the findings of this study and to the communicative approach of language learning:

(1) Knowledge of the features of particular phonemes and their influence on other phonemes. Referring to the narrow area being investigated in this study, i.e., pharyngealized fricatives, one finds that pharyngealization affects neighboring sounds to varying degrees. Thus, drilling phonemes in isolation would be a mindless, unproductive activity. The context and distribution of a particular phoneme are of paramount importance to the acquisition of phonological contrasts.

(2) Since learners cannot produce sounds they are unable to perceive, as has been empirically demonstrated, then discrimination drills should precede those drills where the learners need to distinguish sounds. In other words, the listening ability should be developed first, and then the production ability.

(3) When two languages come into contact, one important point emerges: allophonic variation. This point becomes important if allophonic variation in the native language is distinctive in the target language. For instance, pharyngealization on the consonant in English (Delattre, 1971) is allophonic with no phonemic status, while in Arabic it is a distinctive feature of consonants. Apparently, mishearing and mispronouncing pharyngealized segments by American learners of Arabic can be due to

associating it with the vowel as the case is in English. Words like *ma'am* [maam] and *mom* [maam] contrast in the vowel, but at the same time, pharyngealization can be detected in the adjacent segments. It might be a good approach to design listening drills that contain English minimal pairs contrasting in a similar fashion. They serve as a means of increasing the awareness of the learners of the significance of this feature.

Linguistic analysis at the phonological level is helpful primarily to the teacher because it promotes understanding of the phonetic features that the learners must acquire in order to make the phonological distinctions in the target language. It must be reiterated here that the effect of particular features on neighboring sounds cannot be captured when the sounds are presented in isolation. Pronunciation drills should, therefore, operate at least at the syllable level.

From the foregoing, one should conclude that the objective of pronuciation drills is to teach phonetic features, not in isolation, but in new combinations congruent with the phonological system of the target language. If the acquisition process of the phonology of a foreign language is similar to that of children acquiring their first language, then phonetic features should be viewed as the building blocks of the phonological system (see Jakobson's hierarchy of the aquisition of the phonological system, 1968). Further, Ervin-Tripp claims that "the hardest aspect of the acquisition of a new sound system is the articulation of new feature combinations" (1973: 107).

(4) The function of pronunciation drills is to train the learners not to test them (MacCarthy, 1978). The content of each drill should be well within the capacity of all the learners. Moreover, the number of contrasts in each drill should be reasonable. There is little point in overwhelming the learners with a large number of contrasts, particularly in production drills.

The above principles should be viewed as guidelines for constructing pronunciation drills. And since time is a crucial factor, such drills should not be indiscriminate, but rather selective and focussed. Problem areas should first be identified and then appropriate drills be designed for remedial purposes. Types of drills and techniques for conducting them can be found in various sources on foreign language teaching methodology and there is no need to review them here. However, certain types stand out as more appropriate than others for a particular approach. For instance, using meaningless syllables, or even words out of context, in discrimination drills would seem out of place in a communicative approach. A design of that sort would violate an important principle of the communicative approach because it will focus the attention on the linguistic form rather than on its meaning and communicative function. A possible alternative is the use of greetings, formulaic utterances, and exchanges in short dialogues with which the learners are already familiar as the content of the discrimination exercise. The task would be providing the frequency of occurrence of the sound, or sounds, in question. This is a subclass of discrimination exercises because it involves only the identification of the number of instances of that sound in the exercise. However, if the exercise contained contrasts, such as plain /s/ and its pharyngealized counterpart /s̱/, then it can be considered a truly discrimination exercise.

Each exercise should focus on a single phonetic feature, particularly those features that are distinctively different between the two sound systems. In addition to pharyngealization in Arabic, for example, vowel length constitutes a major stumbling block for learners of Arabic. In English, vowel length alone is not distinctive, while in Arabic, especially in /a/ vs. /aa/, vowel length is a distinctive feature. Identification and discrimination drills may contain English and Arabic words or phrases. The learners' task will include one or more of the following activities: Isolating the sound that does not belong (Odd-Man-Out), counting the number of occurrences, indicating whether the target feature is present or absent in an utterance, deciding whether the sound containing the feature in question is in word initial or final position, and whether the utterances contain the same or different sounds.

The responses to discrimination exercises can be made orally by stating the position of the sound, whether or not it is present, or saying the number of occurrences. Alternatively, the responses can also be recorded by circling numbers on an answer sheet indicating the above variations.

Discrimination exercises need not be conducted entirely in the classroom. This type of exercise is amenable to use outside the classroom, thus, saving valuable class time. Besides, it does not require neither sophisticated equipment nor immediate supervision by the teacher.

With respect to production exercises, the design should follow the same guidelines for discrimination exercises. The only difference is the task to be performed, which involves repetition of utterances, listening to utterances and recording them on tape then checking their accuracy, and responding to phrases, like greetings and questions. Progression from mechanical to meaningful responses will ensure compatibility with the communicative approach. Ultimately, discrimination drills will culminate in listening for comprehension, and production drills in meaningful exercises.

In short, the function of phonetic training is fourfold. First, it exposes the learners from the very beginning of the learning process to correct forms of the target language. Second, the pronunciation exercises put the learners in contact with the language outside the classroom in a meaningful context as much as possible. Third, they train the learners to *listen* to the target language and then to *produce* it. And last, these drills will help the learners acquire new feature combinations on which the new phonological system operates.

Conclusion

This study sought to espouse theory and application by the very nature of the research itself. The hypotheses advanced herein and the research questions that were formulated to operationalize them emanated from both linguistic and learning theory as well as from pedagogical practice and observation. The results answered some important questions that have long been the subject of conjecture and subjective opinion, like the controversy over phonological analysis of Arabic. The results also shed light on the similarities and differences between native and nonnative speakers of Arabic with regard to perceptual strategies. It was found that these strategies were distinctively different, thus alerting the Arabic teaching profession to take into account certain areas of language training that have been largely neglected, like phonetic training based on empirical evidence and informed opinion.

The study also yielded interesting information about differences across levels of proficiency. Many concepts in this respect are based on personal observation and subjective opinion. This study sought to quantify some of these differences and show and interpret the interactions between the variables built into the experimental design. Although extreme control was exercised in preparing the stimuli, conducting the experiment, and running the statistical tests, the answers gleaned from the results cannot be definitive and final.

It is recommended that, if further research should be conducted in this area, it should look at other aspects of acquisition beyond the feature level in order to capture the differences in production among the learners. It goes without saying that morphological and syntactic patterns are harder to acquire because, more often than not, their learning involves a measure of intellectual reasoning that renders the process of learning a conscious one, thus hampering acquisition and spontaneous use. The differences in this case, however, might be due to learning style, presentation of material, and a host of other factors. Nonetheless, even if research is confined to the area of phonetics, it might well be true that phonetic features other than pharyngealization are acquired later or that acquistion of these features is more related to the level of proficiency than pharyngealization is. Also, it is recommended that sampling procedures must be designed in a way to ensure better randomization and larger samples so that finer distinctions at the beginning level can be made. Further, it is suggested that should the subjects in the present discrimination experiment have been required to respond to the set of stimuli twice, idiosyncratic variation would have been reduced and, consequently, greater interlevel variability would have been captured (personal communication with Professor Sara Garnes, 1987).

From a purely linguistic point of view, there seems to be good evidence that pharyngealization can be a suprasegmental feature as was originally suggested by Ferguson (Harris, 1942). The domain of pharyngealization is usually the syllable, or the word, because of the spread effect associated with it. An experiment similar to the present one may be conducted using minimal pairs of the type [masruur/masruur]. The fricatives [s, s̱] can be switched around in order to find out whether discrimination data would reveal a significant effect attributable to the segments. Otherwise, it might be concluded that this feature is a suprasegmental one.

There remain, of course, many questions to which the foreign language teaching profession wants answers. It is hoped that this study has contributed some answers relevant to the research undertaken and that it will stimulate further research that brings together the disciplines of foreign language instruction and linguistics, specifically phonetics, more often than the current practice is .

APPENDIX A

Key to the Arabic Sound System

Key to the Arabic Sound System

The symbols used in representing the Arabic sounds are primarily selected because of their convenience to the word processing system used in preparing this docu-ment. However, every effort has been made to make them as close to the IPA symbols as possible. The sequence of the symbols follows the Arabic alphabetical order.

Symbol Used	Arabic Character	IPA Symbol	
Vowels			
aa	ا	a:	long, front, low
<u>aa</u>	ا	a:	long, back, low
uu	و	u:	long, back, high, rounded
ii	ي	i:	long, front, high
a	ـَ	a	short, front, low
<u>a</u>	ـَ	a	short, back, low
u	ـُ	u	short, back, high, rounded
i	ـِ	i	short, front, high
Consonants			
b	ب	b	voiced bilabial stop
t	ت	t	voiceless dental stop

th	ث	θ	voiceless interdental fricative
j	ج	z	voiced palato-alveolar fricative
x	خ	x	voiceless velar fricative
d	د	d	voiced alveolar stop
dh	ذ	ð	voiced interdental fricative
r	ر	r	voiced alveolar trill
z	ز	z	voiced alveolar fricative
s	س	s	voiceless alveolar fricative as
sh	ش	ʃ	voiceless palato-alveolar fricative
s̲	ص	s̲	pharyngealized voiceless alveolar fricative
d̲	ض	d̲	pharyngealized voiced alveolar stop
t̲	ط	t̲	pharyngealized voiceless alveolar stop
d̲h̲	ظ	ð̲	pharyngealized voiced interdental fricative
c	ع	ʕ	voiced pharyngeal fricative
gh	غ	ɣ	voiced uvular trill
f	ف	f	voiceless labiodental fricative
q	ق	q	voiceless uvular stop
k	ك	k	voiceless velar stop
l	ل	l	voiced alveolar liquid
m	م	m	voiced bilabial nasal
n	ن	n	voiced alveolar nasal
h	ه	h	voiceless glottal fricative
w	و	w	voiced labio-velar approximant
y	ي	j	voiced palatal approximant
ʔ	ء	ʔ	glottal stop

APPENDIX B

List of Stimuli in Order of Presentation on Tape

LIST OF STIMULI IN ORDER OF PRESENTATION ON TAPE

The following is a list of the practice and experimental tokens. They appear in the order in which they are presented on tape. Each syllable is represented by the two file names used to create it from its component segments. Also, the length in milliseconds of each segment is indicated.

Sound	File	Length (msec.)		File	Length (msec.)
A. Practice items:					
1. /saa/	RXY	248	+	XYZ	500
2. /suu/	HIT	194	+	TIH	552
3. /sii/	ORN	208	+	ONK	500
4. /saa/	EGN	224	+	NOG	496
5. /suu/	WON	204	+	WOS	572
6. /sii/	KRN	200	+	NRK	430
7. /dhaa/	ERI	192	+	ERE	532
8. /dhuu/	GAM	120	+	GMG	478
9. /dhii/	NUS	146	+	NUC	512
10. /dhaa/	DAR	174	+	DAF	442
11. /dhuu/	GET	146	+	GTU	512
12. /dhii/	GAV	142	+	GVO	382

B. Experimental items:

1. /suu/	HIT	194	+	TIH	552
2. /dhii/	NUS	146	+	GVO	382
3. /sii/	DYM	190	+	MDM	586
4. /saa/	RXY	248	+	XYZ	500
5. /dhaa/	TYK	122	+	TFK	384
6. /dhii/	RES	148	+	TST	444
7. /sii/	ORN	208	+	ONK	500
8. /suu/	MOMT	222	+	MTAN	426
9. /sii/	LERN	228	+	RNER	418
10. /sii/	DYM	190	+	NRK	430
11. /dhii/	MAKE	158	+	RKPT	390
12. /suu/	TDN	160	+	TNB	368
13. /suu/	ARDS	212	+	DSNT	386
14. /saa/	AGHW	184	+	BRVN	404
15. /sii/	PQPA	244	+	LJMJ	414
16. /suu/	WON	204	+	WOS	572
17. /dhuu/	CST	136	+	CTZ	452
18. /dhaa/	FTRL	140	+	URMY	432
19. /sii/	KRN	200	+	NRK	430
20. /dhuu/	ASND	148	+	NDTF	312
21. /dhuu/	EXPM	109	+	MPPL	433
22. /dhii/	NUS	146	+	NUC	512
23. /dhii/	MAKE	158	+	KERM	420
24. /dhii/	TFS	124	+	REC	402

25. /dhuu/	GAM	120	+	GTU	444
26. /dhaa/	ECHV	105	+	SKIN	514
27. /dhaa/	TYK	122	+	BBB	476
28. /dhii/	LIVL	160	+	VLAS	402
29. /dhaa/	BBL	164	+	BBB	476
30. /saa/	PSBL	180	+	BLOS	432
31. /dhaa/	DAR	164	+	DAF	442
32. /suu/	THNK	208	+	NKBM	390
33. /dhii/	CLRK	130	+	RKPT	390
34. /suu/	WON	204	+	TIH	552
35. /dhii/	CLRK	130	+	KERM	420
36. /suu/	TDN	160	+	JVC	644
37. /suu/	ARDS	212	+	MTAN	426
38. /saa/	HIBR	190	+	HWPR	408
39. /dhaa/	ERI	192	+	ERE	532
40. /saa/	QUST	184	+	STRV	414
41. /dhaa/	BBL	164	+	TKF	384
42. /dhaa/	TASK	102	+	SKIN	514
43. /saa/	ALN	182	+	ELN	598
44. /dhuu/	EXMP	109	+	CHAR	429
45. /dhii/	TFS	124	+	TST	444
46. /dhuu/	ASND	148	+	JSDL	376
47. /suu/	THNK	208	+	DNSS	393
48. /dhuu/	GET	146	+	GMG	478
49. /dhaa/	DAR	174	+	ERE	532

50. /dhaa/	TASK	102	+	HVSF	481
51. /dhii/	RES	148	+	REC	402
52. /dhaa/	FTRL	140	+	RLGU	438
53. /dhii/	GAV	142	+	GVO	382
54. /dhaa/	YOUR	102	+	RLGU	438
55. /dhuu/	GAM	120	+	GMG	478
56. /dhuu/	TICH	157	+	MPPL	433
57. /sii/	NOLJ	220	+	LJMJ	414
58. /suu/	JRV	184	+	TNB	368
59. /saa/	QUST	184	+	BLOS	432
60. /sii/	BUBL	208	+	BLAK	439
61. /suu/	MOMT	222	+	DSNT	386
62. /dhuu/	CST	136	+	SKM	326
63. /dhaa/	ECHV	105	+	HVSF	481
64. /saa/	RXY	248	+	NOG	496
65. /dhii/	LIVL	160	+	VTTV	417
66. /suu/	JRV	184	+	JVC	644
67. /dhuu/	MEJS	146	+	NDTF	312
68. /saa/	HIBR	190	+	BRVN	404
69. /sii/	KRN	200	+	ONK	500
70. /suu/	STDN	198	+	NKBM	390
71. /saa/	RBH	180	+	ELN	598
72. /sii/	NOLJ	220	+	PASN	398
73. /dhaa/	ERI	192	+	DAF	442
74. /dhaa/	YOUR	102	+	URMY	432

75. /saa/	AGHW	184	+	HWPR	408
76. /dhii/	GAV	142	+	NUC	512
77. /sii/	LERN	228	+	BLAK	439
78. /sii/	KRN	200	+	NRK	430
79. /suu/	HIT	194	+	WOS	572
80. /sii/	PQPA	244	+	PASN	398
81. /dhii/	CAVT	131	+	VTTV	417
82. /saa/	HRB	154	+	XYZ	500
83. /saa/	PSBL	180	+	STRV	414
84. /dhuu/	SUK	128	+	CTZ	452
85. /saa/	ALN	182	+	HRJ	538
86. /dhii/	CAVT	131	+	VLAS	402
87. /dhuu/	TICH	157	+	CHAR	429
88. /sii/	ORN	208	+	NRK	430
89. /sii/	BUBL	208	+	RNER	418
90. /sii/	KRN	200	+	MDM	586
91. /dhuu/	MEJS	146	+	JSDL	376
92. /dhuu/	SUK	128	+	SKM	326
93. /saa/	RBH	180	+	HRJ	538
94. /dhuu/	GET	146	+	GTU	444
95. /suu/	STDN	198	+	DNSS	393
96. /saa/	HRB	154	+	NOG	496

APPENDIX C

Sample Answer Sheet

Name: ....

First language: Arabic ....   English ....

Number of credit hours in Arabic accumulated so far: ....

Rank: Undergraduate ....   Graduate ....

Please read the following carefully:

For this experiment, you will be listening to 96 tokens of Arabic syllables representing 12 different types of syllables. These 12 syllables are written in Arabic at the top of each page of your answer sheet. Please mark (X) in the blank space below the syllable you hear in the headphones (one mark per line). The syllables are presented in blocks of three syllables each, separated by a beep on tape and a blank line on the answer sheet. If you make a mistake or miss a syllable, please wait for the beep and resume the task at the top of the next block.

The first block is made up of 12 **practice** items to familiarize you with the process.

	ظي	ظو	ظا	ذي	ذو	ذا	صي	صو	صا	سي	سو	سا
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												

	ظي	ظو	ظا	ذي	ذو	ذا	صي	صو	صا	سي	سو	سا
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												
24												

APPENDIX D

Tabulation of Perception Data

The following codes are used for the various variables. They appear in the same order in which they are listed in the table. The number in parentheses on the left represents column number or numbers:

(1) Token Number: 01 - 96

(2-5) Token Properties:

(2) Sibilant/Nonsibilant = 1/2

(3) Vowel Type: 1 = /ii/; 2 = /aa/; 3 = /uu/

(4) Pharyngealized/Nonpharyngealized Consonant = 0/1

(5) Pharyngealized/Nonpharyngealized Vowel = 0/1

(6-15) Native speakers

(16-30) Level III subjects

(31-41) Level II subjects

(42-51) Level I subjects

Response data are ordered in the following manner: Line 1 (native speakers), Lines 2 and 3 (Level III), Line 4 (Level II), Line 5 (Level I).

Token number	Token Specifications	Subject Responses
01	1300	0000000000 10100010100 0100 00000000000 0000000100
02	2101	1101111111 01111011111 1111 11101111000 1011100000
03	1100	0000000000 00000000100 0000 00000000000 0000001100
04	1200	0000000000 10000010010 0000 00000000000 0000000100
05	2211	1111111111 11011001111 1000 10111111111 1100111101
06	2110	1100101110 00000001001 1100 10000110000 1110011000

Token Number	Token specifications	Subject Responses
07	1100	0000000000 10100100010 0000 00000000000 0010000000
08	1300	0000000000 10100111000 0110 01000000000 0101000100
09	1100	0000000000 00000000000 0000 00000000000 0000000000
10	1101	1111111111 11111111111 1111 11111111011 1111100111
11	2101	0100000000 00000000000 0000 00000110100 0000001000
12	1311	1111111111 11111111111 1111 11111111000 0011111101

Token Number	Token Specifications	Subject Responses
13	1311	1111111111 10101111111 1110 10101110000 0111110000
14	1311	1111111111 11101111111 1110 10110111011 0110110100
15	1101	0000111110 00001110100 0001 10000001010 0001110100
16	1311	1111111111 11111011111 1111 10111011111 1011101000
17	2300	0100000000 10000011000 1100 00001010101 0001000100
18	2201	0101111110 11100111101 1010 01010110111 0101000100

Token Number	Token Specifications	Subject Responses
19	1111	1111111111 11111111111 1011 11111111111 1110111111
20	2300	0100000000 10100000000 1010 00000110100 0001000101
21	2311	1011111111 10101011000 1110 11111111110 0101100000
22	2100	0000100000 00000010000 1000 00000010000 0000001100
23	2100	0100000000 00000000000 0100 00000000000 0000000000
24	2101	1111111111 11011111111 1011 11101111111 1111101111

Token Number	Token Specifications	Subject Responses
25	2301	0111001110 11110110001 1110 11001110111 0001100100
26	2210	0101100101 01001111110 1011 01100011110 0110100110
27	2210	0000000000 00100000000 0100 00001100000 0000001001
28	2110	1111111111 01110101111 1011 11001111010 0010111101
29	2200	0000000000 11010110000 0000 00000100000 0000010000
30	1211	1111111111 10111111100 1101 10010110111 1110001100

Token Number	Token Specifications	Subject Responses
31	2210	1111111111 11011111111 1011 11011111111 1111110110
32	1311	1111111011 10100011100 1110 10011010100 0000000100
33	2111	1111111111 00011010111 1011 11001011011 1010110101
34	1310	0110000101 11000000110 0010 00010010000 0010001100
35	2110	1011111111 00001101111 1010 11110011001 0010100100
36	1310	0000000000 10000010000 0100 00000010100 0001001000

Token Number	Token Specifications	Subject Responses
37	1310	1110100011 10100011110 0110 00011110000 0100000000
38	1210	0000000001 11000011100 0000 00001000000 0100000100
39	2200	0000000100 00000010000 1100 00000000000 0100000100
40	1200	0000000000 01000010010 0000 00000000100 0100000100
41	2201	1111111111 11011011111 1111 01111111111 1110111111
42	2200	0000000000 00100000000 0000 00000000000 0001000000

Token Number	Token Specifications	Subject Responses
43	1200	0000000000 00000010000 0000 00000000110 0000001000
44	2310	1011110111 10001110001 1110 10011110101 0000010101
45	2100	0000000000 10100000000 1000 00000100100 0000010100
46	2301	1111110111 11011101100 1011 11001010110 0001000101
47	1310	1111111011 10101111000 1110 10011110100 0101010100
48	2310	1010001101 10111010011 1111 01010100101 1110111000

Token Number	Token Specifications	Subject Responses
49	2210	0100000001 10000010001 1111 00000000110 0000001100
50	2201	0001111110 11101001110 0000 01111111011 0110110010
51	2111	1111111111 01111111111 1011 01101111011 1111111001
52	2200	0000000000 11100000000 0000 00001000100 0100001100
53	2111	1111111111 11011111111 1011 11111111011 1011111101
54	2210	0000100101 10000000000 0000 00001000100 0100001100

Token Number	Token Specifications	Subject Responses
55	2300	0000000100 10000001000 1000 00001000000 0100011101
56	2301	0110111011 11101110111 0111 11011111111 1110110110
57	1111	1111111111 11011110110 0011 10011101011 1010101000
58	1301	1111111111 11111101111 1111 11011111110 1111111111
59	1201	1111111111 01101011111 0101 10111111011 1101101100
60	1111	1111111110 01101011111 0001 10010011011 1010101100

Token Number	Token Specifications	Subject Responses
61	1301	0000010011 11101111100 1010 00010010100 1000001100
62	2301	0000010010 11101001000 0111 10010100001 1001001101
63	2211	1111111111 11001011111 0001 11110011011 1101101100
64	1201	1111111111 11111111111 1111 11111111111 1111111110
65	2110	1011101111 00000010110 0010 00010010101 0000000100
66	1300	0000000000 00000010000 0000 00000000100 0000001000

Token Number	Token Specifications	Subject Responses
67	2310	0010111111 00000111000 1001 11110010101 0000011001
68	1211	1111111111 10101111111 1111 11111010111 1111111111
69	1110	1111110010 10010000101 0001 00000101001 1010101000
70	1301	0110010010 00011011110 0111 00010000100 1001001110
71	1210	0000000000 10000010000 0000 00000000010 0001000100
72	1110	1110110001 00100001000 0011 00010001011 0100001000

Token Number	Token Specifications	Subject Responses
73	2201	0111111011 11111111111 1011 11111111111 1111100111
74	2211	1011111111 00001001101 1101 11101100011 0001110000
75	1200	0000000000 00000110010 0001 00000000100 0000000100
76	2110	1110111111 00001011111 1011 01001011001 1010101001
77	1101	0010010000 00011000000 0001 00000001000 0000000000
78	1111	1111111111 01111111111 1111 11111111111 1111111111

Token Number	Token Specifications	Subject Responses
79	1301	0011111011 11111111110 1111 10011110101 1101011100
80	1100	0000100000 00000010100 0000 00000010000 0000000100
81	2100	0000100000 10000010010 0000 00000000000 0000001000
82	1210	0000000100 00101110000 1100 00110010110 1001101100
83	1210	1100000000 00000001000 0000 00000000000 0100000010
84	2310	1110001101 10000011000 1011 01000000000 0001011100

Token Number	Token Specifications	Subject Responses
85	1201	1111111111 01111110111 1111 11111111011 1111111111
86	2101	1100100010 00000000000 1001 10001011000 1000011100
87	2300	0100000101 00100011000 1111 10000010000 1100011110
88	1101	1011111111 11111111111 1111 11111111111 1111111111
89	1110	1100100000 00000001000 0000 00000000000 0000000001
90	1110	0100100110 00100010000 0100 00000000101 0100000000

Token Number	Token Specifications	Subject Responses
91	2311	1111111111 11101111100 1011 11111110001 0111100111
92	2311	1011111111 00001000011 0111 01001100000 1001011000
93	1211	1111111111 10111111111 1111 11111111011 1111111110
94	2311	1111111111 11111111110 1111 11011110011 1111011100
95	1300	0100000000 00011101100 1100 00010010010 0100000000
96	1211	0111111111 01111111111 1111 11111111011 1111111110

APPENDIX E

Production Data in Order of Presentation on Tape by Subject and Token

Subject	Level	Token	Syllable
1	3	01	/dhii/
1	3	02	/suu/
1	3	03	/saa/
1	3	04	/dhii/
1	3	05	/suu/
1	3	06	/dhaa/
1	3	07	/sii/
1	3	08	/dhaa/
1	3	09	/dhuu/
1	3	10	/saa/
1	3	11	/sii/
1	3	12	/dhuu/
2	3	01	/dhii/
2	3	02	/suu/
2	3	03	/dhii/
2	3	04	/saa/
2	3	05	/dhaa/
2	3	06	/saa/
2	3	07	/dhuu/
2	3	08	/suu/
2	3	09	/sii/
2	3	10	/dhuu/
2	3	11	/sii/
2	3	12	/dhaa/

Subject	Level	Token	Syllable
3	3	01	/suu/
3	3	02	/dhaa/
3	3	03	/suu/
3	3	04	/dhaa/
3	3	05	/dhii/
3	3	06	/sii/
3	3	07	/dhuu/
3	3	8	/sii/
3	3	09	/dhuu/
3	3	10	/saa/
3	3	11	/dhii/
3	3	12	/saa/
4	1	01	/suu/
4	1	02	/saa/
4	1	03	/dhuu/
4	1	04	/dhii/
4	1	05	/dhuu/
4	1	06	/suu/
4	1	07	/saa/
4	1	08	/dhaa/
4	1	09	/sii/
4	1	10	/sii/
4	1	11	/dhaa/
4	1	12	/dhii/

Subject	Level	Token	Syllable
5	2	01	/dhii/
5	2	02	/sii/
5	2	03	/dhuu/
5	2	04	/dhii/
5	2	05	/saa/
5	2	06	/dhuu/
5	2	07	/suu/
5	2	08	/dhaa/
5	2	09	/suu/
5	2	10	/dhaa/
5	2	11	/sii/
5	2	12	/saa/
6	2	01	/dhii/
6	2	02	/suu/
6	2	03	/dhaa/
6	2	04	/dhaa/
6	2	05	/saa/
6	2	06	/suu/
6	2	07	/sii/
6	2	08	/sii/
6	2	09	/dhuu/
6	2	10	/dhii/
6	2	11	/saa/
6	2	12	/dhuu/

Subject	Level	Token	Syllable
7	1	01	/sii/
7	1	02	/dhaa/
7	1	03	/dhii/
7	1	04	/dhaa/
7	1	05	/saa/
7	1	06	/dhii/
7	1	07	/suu/
7	1	08	/sii/
7	1	09	/saa/
7	1	10	/suu/
7	1	11	/dhuu/
7	1	12	/dhuu/
8	1	01	/dhii/
8	1	02	/saa/
8	1	03	/suu/
8	1	04	/dhii/
8	1	05	/suu/
8	1	06	/dhaa/
8	1	07	/sii/
8	1	08	/saa/
8	1	09	/dhuu/
8	1	10	/sii/
8	1	11	/dhuu/
8	1	12	/dhaa/

Subject	Level	Token	Syllable
9	1	01	/saa/
9	1	02	/sii/
9	1	03	/saa/
9	1	04	/dhii/
9	1	05	/dhaa/
9	1	06	/suu/
9	1	07	/dhii/
9	1	08	/sii/
9	1	09	/dhuu/
9	1	10	/dhaa/
9	1	11	/dhuu/
9	1	12	/suu/
10	1	01	/suu/
10	1	02	/saa/
10	1	03	/dhuu/
10	1	04	/dhii/
10	1	05	/dhuu/
10	1	06	/suu/
10	1	07	/saa/
10	1	08	/dhaa/
10	1	09	/sii/
10	1	10	/sii/
10	1	11	/dhaa/
10	1	12	/dhii/

Subject	Level	Token	Syllable
11	2	01	/sii/
11	2	02	/saa/
11	2	03	/dhaa/
11	2	04	/suu/
11	2	05	/dhuu/
11	2	06	/dhaa/
11	2	07	/dhuu/
11	2	08	/saa/
11	2	09	/sii/
11	2	10	/suu/
11	2	11	/dhii/
11	2	12	/dhii/
12	2	01	/sii/
12	2	02	/sii/
12	2	03	/dhaa/
12	2	04	/suu/
12	2	05	/dhuu/
12	2	06	/dhaa/
12	2	07	/dhuu/
12	2	08	/saa/
12	2	09	/saa/
12	2	10	/suu/
12	2	11	/dhii/
12	2	12	/dhii/

Subject	Level	Token	Syllable
13	2	01	/dhii/
13	2	02	/suu/
13	2	03	/dhaa/
13	2	04	/dhaa/
13	2	05	/saa/
13	2	06	/suu/
13	2	07	/sii/
13	2	08	/sii/
13	2	09	/dhu/
13	2	10	/dhii/
13	2	11	/saa/
13	2	12	/dhuu/
14	2	01	/dhaa/
14	2	02	/sii/
14	2	03	/saa/
14	2	04	/dhaa/
14	2	05	/dhii/
14	2	06	/suu/
14	2	07	/sii/
14	2	08	/dhii/
14	2	09	/saa/
14	2	10	/dhuu/
14	2	11	/dhuu/
14	2	12	/suu/

Subject	Level	Token	Syllable
15	2	01	/dhaa/
15	2	02	/sii/
15	2	03	/dhuu/
15	2	04	/saa/
15	2	05	/suu/
15	2	06	/dhii/
15	2	07	/dhaa/
15	2	08	/dhii/
15	2	09	/suu/
15	2	10	/saa/
15	2	11	/sii/
15	2	12	/dhuu/
16	2	01	/sii/
16	2	02	/sii/
16	2	03	/dhaa/
16	2	04	/suu/
16	2	05	/dhuu/
16	2	06	/dhaa/
16	2	07	/dhuu/
16	2	08	/saa/
16	2	09	/saa/
15	2	10	/suu/
16	2	11	/dhii/
16	2	12	/dhii/

Subject	Level	Token	Syllable
17	2	01	/sii/
17	2	02	/saa/
17	2	03	/dhaa/
17	2	04	/suu/
17	2	05	/dhuu/
17	2	06	/dhaa/
17	2	07	/dhuu/
17	2	08	/saa/
17	2	09	/sii/
17	2	10	/suu/
17	2	11	/dhii/
17	2	12	/dhii/
18	2	01	/dhuu/
18	2	02	/saa/
18	2	03	/suu/
18	2	04	/dhii/
18	2	05	/dhaa/
18	2	06	/saa/
18	2	07	/sii/
18	2	08	/dhaa/
18	2	09	/dhii/
18	2	10	/sii/
18	2	11	/suu/
18	2	12	/dhuu/

Subject	Level	Token	Syllable
19	2	01	/suu/
19	2	02	/sii/
19	2	03	/dhaa/
19	2	04	/saa/
19	2	05	/sii/
19	2	06	/suu/
19	2	07	/saa/
19	2	08	/dhii/
19	2	09	/dhaa/
19	2	10	/dhuu/
19	2	11	/dhii/
19	2	12	/dhuu/
20	2	01	/dhii/
20	2	02	/sii/
20	2	03	/dhuu/
20	2	04	/dhii/
20	2	05	/saa/
20	2	06	/dhuu/
20	2	07	/suu/
20	2	08	/dhaa/
20	2	09	/suu/
20	2	10	/dhaa/
20	2	11	/sii/
20	2	12	/saa/

Subject	Level	Token	Syllable
21	2	01	/ssu/
21	2	02	/saa/
21	2	03	/dhuu/
21	2	04	/sii/
21	2	05	/dhaa/
21	2	06	/suu/
21	2	07	/saa/
21	2	08	/dhii/
21	2	09	/dhuu/
21	2	10	/sii/
21	2	11	/dhaa/
21	2	12	/dhii/
22	3	01	/sii/
22	3	02	/saa/
22	3	03	/dhaa/
22	3	04	/suu/
22	3	05	/dhuu/
22	3	06	/dhaa/
22	3	07	/dhii/
22	3	08	/saa/
22	3	09	/sii/
22	3	10	/suu/
22	3	11	/dhii/
22	3	12	/dhuu/

Subject	Level	Token	Syllable
23	3	01	/sii/
23	3	02	/saa/
23	3	03	/dhaa/
23	3	04	/suu/
23	3	05	/dhuu/
23	3	06	/dhaa/
23	3	07	/dhuu/
23	3	08	/saa/
23	3	09	/sii/
23	3	10	/suu/
23	3	11	/dhii/
23	3	12	/dhii/
24	3	01	/dhuu/
24	3	02	/saa/
24	3	03	/suu/
24	3	04	/dhii/
24	3	05	/dhaa/
24	3	06	/dhaa/
24	3	07	/sii/
24	3	08	/saa/
24	3	09	/dhii/
24	3	10	/sii/
24	3	11	/suu/
24	3	12	/dhuu/

Subject	Level	Token	Syllable
25	3	01	/dhuu/
25	3	02	/saa/
25	3	03	/suu/
25	3	04	/dhii/
25	3	05	/dhaa/
25	3	06	/dhaa/
25	3	07	/sii/
25	3	08	/saa/
25	3	09	/dhii/
25	3	10	/sii/
25	3	11	/suu/
25	3	12	/dhuu/
26	3	01	/saa/
26	3	02	/suu/
26	3	03	/sii/
26	3	04	/saa/
26	3	05	/dhii/
26	3	06	/suu/
26	3	07	/sii/
26	3	08	/dhuu/
26	3	09	/dhaa/
26	3	10	/dhaa/
26	3	11	/dhii/
26	3	12	/dhuu/

Subject	Level	Token	Syllable
27	3	01	/saa/
27	3	02	/suu/
27	3	03	/sii/
27	3	04	/suu/
27	3	05	/sii/
27	3	06	/dhii/
27	3	07	/dhuu/
27	3	08	/dhaa/
27	3	09	/dhaa/
27	3	10	/dhii/
27	3	11	/dhuu/
27	3	12	/saa/
28	3	01	/dhuu/
28	3	02	/saa/
28	3	03	/suu/
28	3	04	/dhaa/
28	3	05	/dhuu/
28	3	06	/dhii/
28	3	07	/sii/
28	3	08	/dhii/
28	3	09	/sii/
28	3	10	/saa/
28	3	11	/suu/
28	3	12	/dhaa/

Subject	Level	Token	Syllable
29	3	01	/dhii/
29	3	02	/suu/
29	3	03	/dhii/
29	3	04	/saa/
29	3	05	/dhaa/
29	3	06	/saa/
29	3	07	/dhuu/
29	3	08	/suu/
29	3	09	/sii/
29	3	10	/dhuu/
29	3	11	/sii/
29	3	12	/dhaa/
30	3	01	/suu/
30	3	02	/dhaa/
30	3	03	/suu/
30	3	04	/dhaa/
30	3	05	/dhii/
30	3	06	/sii/
30	3	07	/dhuu/
30	3	08	/sii/
30	3	09	/dhuu/
30	3	10	/saa/
30	3	11	/dhii/
30	3	12	/saa/

Subject	Level	Token	Syllable
31	3	01	/dhii/
31	3	02	/suu/
31	3	03	/saa/
31	3	04	/dhii/
31	3	05	/suu/
31	3	06	/dhaa/
31	3	07	/sii/
31	3	08	/dhaa/
31	3	09	/dhuu/
31	3	10	/saa/
31	3	11	/sii/
31	3	12	/dhuu/
32	3	01	/sii/
32	3	02	/saa/
32	3	03	/dhaa/
32	3	04	/suu/
32	3	05	/dhuu/
32	3	06	/dhaa/
32	3	07	/dhii/
32	3	08	/saa/
32	3	09	/sii/
32	3	10	/suu/
32	3	11	/dhii/
32	3	12	/dhuu/

Subject	Level	Token	Syllable
33	3	01	/sii/
33	3	02	/saa/
33	3	03	/dhaa/
33	3	04	/suu/
33	3	05	/dhuu/
33	3	06	/dhaa/
33	3	07	/dhii/
33	3	08	/saa/
33	3	09	/sii/
33	3	10	/suu/
33	3	11	/dhii/
33	3	12	/dhuu/
34	3	01	/sii/
34	3	02	/saa/
34	3	03	/dhaa/
34	3	04	/suu/
34	3	05	/dhuu/
34	3	06	/dhaa/
34	3	07	/dhii/
34	3	08	/saa/
34	3	09	/sii/
24	3	10	/suu/
34	3	11	/dhii/
34	3	12	/dhuu/

Subject	Level	Token	Syllable
35	3	01	/sii/
35	3	02	/saa/
35	3	03	/dhaa/
35	3	04	/suu/
35	3	05	/dhuu/
35	3	06	/dhaa/
35	3	07	/dhii/
35	3	08	/saa/
35	3	09	/sii/
35	3	10	/suu/
35	3	11	/dhii/
35	3	12	/dhuu/

APPENDIX F

PRODUCTION DATA

Tabulation of Production Data across Subjects, Levels, and Tokens

The tokens in the following tables are coded as follows:

/saa/ = 1

/suu/ = 2

/sii/ = 3

/saa/ = 4

/suu/ = 5

/sii/ = 6

/dhaa/ = 7

/dhuu/ = 8

/dhii/ = 9

/dhaa/ = 10

/dhuu/ = 11

/dhii/ = 12

Subject and Level	Token 1 - 2 - 3	Token 4 - 5 - 6	Token 7 - 8 - 9	Token 10 - 11 - 12
01-1	4-4-0	4-4-0	4-0-4	4-1-4
02-1	3-1-4	4-2-4	4-2-3	4-1-3
03-1	4-4-4	4-3-4	4-4-4	4-3-4
04-1	4-4-4	4-3-4	4-4-4	4-4-3
05-1	4-4-4	4-3-4	4-4-3	4-2-2
06-1	4-3-4	4-4-4	4-4-0	4-4-4
07-1	4-4-3	4-4-1	4-4-4	0-0-0
08-1	4-3-4	4-1-2	4-4-4	2-2-0
09-1	1-4-4	4-3-1	0-3-4	4-3-4
10-1	4-3-4	4-4-1	4-0-4	4-3-4
11-2	3-3-4	4-4-2	4-3-3	3-3-4
12-2	4-3-4	4-4-4	4-4-4	4-3-4
13-2	4-4-3	4-4-1	4-3-3	3-3-4
14-2	4-4-4	4-3-3	4-2-3	4-2-2
15-2	4-4-4	4-2-4	4-3-3	4-3-3
16-2	4-3-4	4-3-4	4-4-4	4-4-2
17-2	4-1-2	4-3-4	4-4-4	4-0-0
18-2	4-4-4	4-4-4	4-4-4	4-4-4
19-2	3-3-4	0-1-0	4-4-3	2-0-1
20-2	4-4-3	4-4-4	4-3-4	4-4-4
21-2	4-4-3	4-4-2	4-4-4	4-0-1
22-3	3-4-4	4-0-1	4-4-4	4-0-1
23-3	3-3-4	4-4-4	4-2-4	4-4-4
24-3	4-3-2	4-3-1	4-0-3	3-4-4
25-3	0-4-3	4-4-4	1-3-3	4-1-3

Subject and Level	Token 1 - 2 - 3	Token 4 - 5 - 6	Token 7 - 8 - 9	Token 10 - 11 - 12
26-3	4-4-3	1-0-3	4-0-4	4-3-4
27-3	0-4-4	4-4-4	4-0-4	4-2-4
28-3	2-1-3	3-4-3	3-0-4	4-4-3
29-3	3-4-4	4-4-4	4-3-3	4-4-4
30-3	0-0-2	4-4-0	4-4-4	4-4-0
31-3	4-4-4	4-3-4	3-4-4	4-4-2
32-3	3-4-4	4-3-3	2-4-4	4-3-0
33-3	4-4-4	4-4-4	4-4-4	4-1-4
34-3	4-4-4	4-3-4	4-2-4	4-4-4
35-3	0-4-3	4-2-0	2-2-4	4-4-0

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