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THE ACQUISITION OF INTONATION PATTERNS IN ENGLISH BY NATIVE SPEAKERS OF KOREAN AND MANDARIN

DISSERTATION

Presentented in Partial Fulfillment of the Requirements for

the Degree Doctor of Philosophy

in the Graduate School of The Ohio State Univeristy

By

Julia Tevis McGory, M.A.

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The Ohio State Univerisity

1997

Dissertation Committee:

Professor Robert A. Fox (Advisor)
Dept. of Speech and Hearing Sciences

Professor Mary E. Beckman
Dept. of Linguistics

Professor Marios Fourakis
Dept. of Linguistics

ABSTRACT

Dedicated to

John Richard McGory, Ethan James McGory, Jonathan Stone McGory, and

Elizabeth Tevis McGory,

to my mother Jamie Griggs Tevis and my brother William Thomas Tevis III

ACKNOWLEDGMENTS

I gratefully acknowledge the guidance and advice of my committe members, Robert A. Fox, Mary Beckman, and Marios Fourakis. I know that without them answering my unending questions, for supporting me, and believing in me, I would not have completed this dissertation. I give the my warmest thanks to my husband, John R. McGory who seems to have unending faith in me; to my children, Elizabeth McGory, Jonathan McGory, and Ethan McGory who have been growing and learning with me these past years; and to my mother who has always been proud of me. I would also like to thank Rebecca Herman, Stefanie Jannedy, and Jennifer Venditti for thier friendship and support and expertise in this enourmous effort.

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CHAPTER 1

INTRODUCTION

1.1 Overview

The type of English spoken by individuals who do not speak English with native-like competence is often called accented English. Different varieties of accented English are associated with different native languages. The origin of the accented speech of nonnative speakers is thought to be due primarily to a process called language transfer. Language transfer is a technical term that refers to the influence of a speaker's native language on the processes involved in the production and perception of a second language. Language transfer can have a positive effect; that is, it can enhance the acquisition of a second language when the same linguistic elements exist in both the first language (L1) and the second language (L2). However, it can produce a negative, interfering effect when there is a difference (at any level, including phonetic, phonological, or syntactic) between the two languages. Enhancement of second language learning occurs when a sound such as [p] or [b] exists within both the native language and the second language. The learner need only to substitute the native sound in a nonnative word. Interference, or negative transfer, occurs when a sound such as [θ] does not exist in the native language (a well-known difference between Mandarin Chinese and English). Similar sounds from the L1 are likely to be substituted for these sounds in the L2. For example, [s] may be substituted for [θ]. Many studies have examined the nature of interference in the production of individual vowels or consonants (Briere, 1966; Caramazza, Yeni-Komshian, Zurif, & Carbone, 1973; Flege & Port, 1981; Mack, 1982; Flege, 1987; Flege & Eefting, 1987; Hazan & Boulakian 1993; Flege, 1995), but very little research has been done on interference effects upon the prosodic elements of second language acquisition.

Previous research examining language interference in the acquisition of nonnative vowels and consonants has identified at least two important variables: First, the amount of exposure to the second language affects how proficient the speakers may be in using the L2 (Goto, 1971; Sheldon & Strange, 1982; Best and Strange, 1992; Flege, 1992). A nonnative speaker of English who has lived in the United States and has used English as her/his primary language for more than 10 years is likely to be more proficient than a person who has only been exposed to English for 2 months. Second, the differences between the phonetic segments in the L1 and the L2 may affect phonological development in the second language (Best, McRoberts, & Sithole, 1988; Flege, 1986). For example, the way that /t/ is produced in English is not quite the same as the /t/ produced in French. In English, /t/ is produced with the tip of the tongue contacting a region of the roof of the mouth behind the teeth. Aspiration follows the release of this stop closure at the beginning of a word. In French, /t/ is produced with the tongue contacting the teeth with significantly less aspiration following its release. These differences make acquisition of French /t/ difficult for English speakers (and vice versa).

Just as languages differ in their inventory of phonemically contrasted consonants and vowels, languages also differ in ways in which intonation serves to organize words into phrases, and differentiate less from more prominent words. To follow is a brief discussion of the role of intonation in English, Korean, and Mandarin.

In English, prominent words are produced with pitch accents. These pitch accents are associated with stressed syllables in English. Because of this relationship between stress and pitch accents, duration and intensity play an important role in English intonation. Stressed syllables have been found to be longer and more intense the stressed syllable (Fry, 1955; Lieberman, 1960; and Beckman, 1986). A group of words (or even one word) with at least one pitch accent are produced within an intermediate phrase. Low and high boundary tones mark the right edge of these phrases. Intermediate phrases are produced within a larger prosodic unit called an intonational phrase. These phrases are also marked with low and high boundary tones.

English Declarative

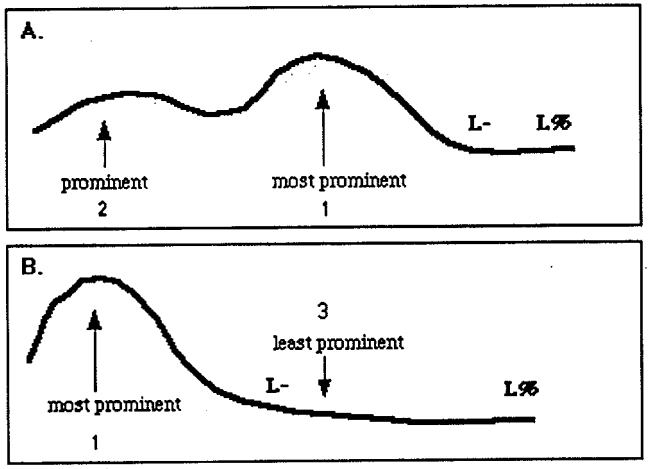


Figure 1.1 Schematized version of words produced with three levels of prominence in English. Most prominent words (1) are produced with a nuclear pitch accent, (2) less prominent words are produced with a prenuclear pitch accent and (3) least prominent words are unaccented.

The most prominent word in an intermediate phrase is produced with a "nuclear pitch accent" and is the last accented word in that phrase; pitch accented words that are produced before the nuclear accent are produced with a "prenuclear accent" and are less prominent that nuclear accented words; words that are produced after the nuclear pitch accent are "postnuclear unaccented" words and have the least amount of prominence (Pierrehumbert, 1980; Terken, 1991; Ayers, 1996).

Figures 1a and 1b are schematized illustrations of the f0 patterns in an English utterance. One intonational phrase consisting of one intermediate phrase is represented in each of these figures. Phrase final low boundary tones mark the ends of each utterance. The prominence shifts from a word produced at the end of the phrase in Figure 1a to an earlier word in Figure 1b. In each Figure, the most prominent word is produced with a nuclear pitch accent (1). These figures illustrate how the amount of f0 change is greatest in the most prominent nuclear pitch accented word. A prenuclear pitch accented word (2) is produced in Figure 1a. When the nuclear pitch accents shifts to an earlier position in Figure 1b, the following postnuclear words are not accented (3) and has no tonal shape associated with its production.

In Standard Korean (hereafter, Korean), the dialect spoken in Seoul Korea, tonal changes mark the edges of prosodically defined phrases, called "accentual phrases". These tonal changes serve to organize words into phrases in speech. Accentual phrases are produced within intonational phrases. Boundary tones are produced at the ends of intonational phrases. Boundary tones mark the ends of intonational phrases, on also serve to group accentual phrases together into larger units. A primary function of intonation in Korean is to group words into accentual phrases, and accentual phrases into intonational phrases. Figure 2a is schematized f0 pattern of a Korean utterance. Figure 2a represents an utterance produced with three accentual phrases. Rising tones in each phrase mark the boundaries of each accentual phrase. A final low boundary tone, illustrated by "L%" is produced at the end of the utterance.

Korean Declarative

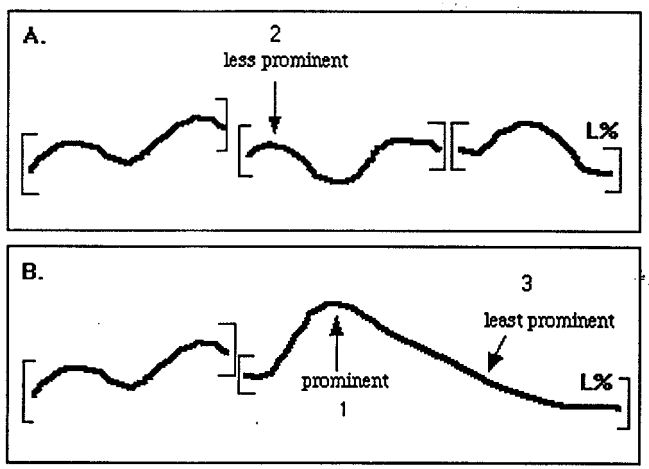


Figure 1.2. Schematized version of words produced with three levels of prominence in Seoul Korean. Most prominent words (1) are produced with an expanded pitch range, less prominent words (2) are produced without expanded pitch range, and least prominent words (3) are dephrased.

The rising tones of the accentual phrase in Korean are not bound to specific syllable, but are instead realized around the second syllable of the word. Tonal changes are not bound to a specified syllable, because stress is not part of Korean. This is unlike English, where pitch accents are anchored to stressed syllables. Because Korean does not have stress, duration and intensity changes are less likely to be associated with changes in prominence.

Prominence relationships among words in Korean is achieved by phrasing and dephrasing, and pitch range changes. Figure 2b illustrates how the tonal characteristics of one utterance change when one word is produced with great prominence, or narrow focus. A prominent word is produced first within the accentual phrase so that it will be produced with the rising tonal pattern associated with the accentual phrase. This rising pattern is be expanded to increase the acoustic saliency within the focussed word. When comparing the tonal rise in the second accentual phrase in Figures 2a and 2b, the rise is expanded in the latter utterance. In addition, the 3rd accentual phrase has become part of the 2nd accentual phrase in 2b. This is an example of "dephrasing". The tonal characteristics of the third accentual phrase no longer exist. The tonal pattern moves from a high tone associated with the accentual phrase, to a low tone associated with a final low boundary tone.

Mandarin is like English in that it is a stress language; but is unlike English in that prominent words are not pitch accented. Tones are part of the phonological makeup of syllables and words in Mandarin and this influences intonation. Pitch accents and boundary tones are not produced in Mandarin. Tonal changes associated with pitch accents and boundary tones would potentially change the f0 shape of tones, and so are not part of Mandarin intonation.

Stressed syllables in Mandarin are specified as having one of four tones. Unstressed syllables have no specified tones and are produced with a "neutral" tone. Prominence is associated with stressed syllables in Mandarin. Greater acoustic changes in pitch, duration, and perhaps intensity (Jin, 1996; Shih, 1988; Shen, 1990) occur within stressed syllables in prominent words. Tone-bearing syllables keep their characteristic movements, but the tonal shape of stressed syllables is expanded when in focus. In addition, words that follow the most prominent or focussed element are produced within a reduced or compressed pitch range. These post-focussed words are least prominent in the utterance. The different tonal shapes of Mandarin words produced with three levels of prominence are illustrated in Figure 3. Figure 3a is provided to illustrate an utterance where no word is produced with focus. Figure 3b is provided to illustrate how the same utterance is influenced by focus. The pitch range of the second syllable or word in Figure 3b is produced with more prominence than in 3a, and so the tone-bearing word is produced within an expanded pitch range. The post-focussed words in 3b are produced with f0 changes that are reduced in comparison to its tonal shape in 3a. The tonal shape of words is maintained no matter how prominent a word is, while the extent of tonal changes differs in prominent words.

Mandarin Declarative

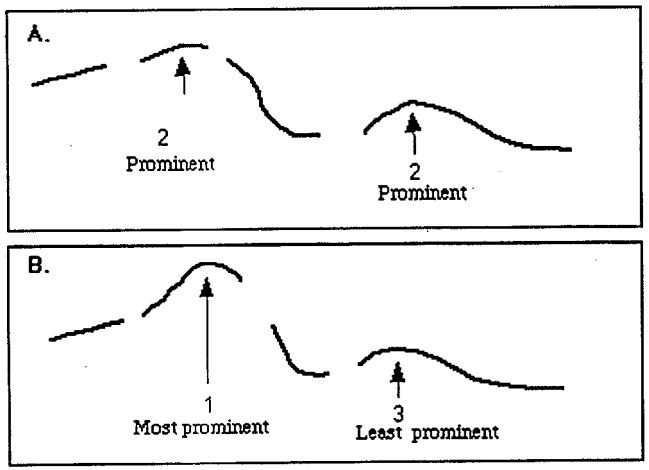


Figure 1.3. Schematized version of words produced with three levels of prominence in Mandarin. Most prominent words (1) are produced with an expanded pitch range, less prominent words (2) are produced without expanded pitch range, and least prominent words are produced with reduced pitch range.

In developing a set of hypothesis describing how prominence patterns in English might be acquired by native Mandarin and Korean speakers, Catherine Best's model of perceptual assimilation can be used to describe how acquisition of prosodic contours might occur. Within this model, contrasting phonemes existing in the L1 that are acoustically similar (but not identical) to a pair of contrasting phonemes in the L2 will be assimilated as two opposing categories in the target language. For example, if a /t/ - /d/ contrast in the L1 is acoustically similar to an L2 /t/ - /d/ contrast, then the L2 learner will perceive this contrast as being the same in both languages, even though they may not be acoustically identical.

Similarly, a prominence system within a language, is a system of contrasts. A word is produced with more acoustic salience, or prominence, in order to contrast that word from other less prominent words. Just as phonemes serve to distinguish one word from another word ("two" differs from "dew" in only the first phoneme) a system of prominence allows a speaker to contrast the relative importance of words. The utterance, "Did you WRITE "electrical?" differs in interpretation from "Did you write ELECTRICAL?" because of differences in prominence.

The intonation systems of English, Korean, and Mandarin are similar in that fundamental frequency is an acoustic parameter used to contrast prominent from less prominent words in all three languages. According to the perceptual assimilation model, it is likely that speakers of Korean and Mandarin will perceive the prominence system of English to be like that of their native language. Based on this perception, they will transfer their production patterns used within the prominence system from their native language to their productions in English. However, even though changes in f0 are used to convey prominence in each of these languages, their intonation systems do differ. Because English is a stress-language with pitch accents; Korean is a non-stress language with phrase accents; and Mandarin is a stress language with tones, the way that f0 is used within each intonation system differs. English uses an inventory of pitch accents associated with the heavy or stressed syllable of prominent words. Because of the association between stress and pitch accents, duration and intensity play an important role in English. In Korean intonation, particular tonal shapes are associated with boundary tones that are used to demark intonation phrases. Prominence relationships are revealed through changes in pitch range and phrasing. Because Korean is a nonstress language, duration and intensity play a lesser role in prominence that in English. Mandarin is a tone language, and so the tonal characteristics of words influence intonation. Prominence relationships are associated with stressed syllables and are revealed through expansion and compression in pitch range. Because of the relationship between stress and prominence in Mandarin, duration and intensity changes are also associated with changes in prominence.

It is the purpose of this study to observe the phonetic correlates of stressed syllables in productions of words produced with three levels of prominence: nuclear-accented, prenuclear accented and postnuclear unaccented in declaratives and yes-no questions in English by native English speakers, and by native Korean and native Mandarin Chinese speakers with differing amounts of exposure to English. It is hypothesized that speakers with less exposure to English will transfer patterns that occur within the L1 into English productions. Native Korean speakers will use f0 to convey differences in prominence to a greater degree than duration and intensity. In addition, they will use a rising tonal pattern like that associated with the Korean accentual phrase in prominent words regardless of pitch accent type. Native Mandarin speakers with less exposure to English will modify f0, duration and intensity to convey

different levels of prominence. Pitch changes will be produced in stressed syllables regardless of prominence level. Speakers of Korean and Mandarin who have more exposure to English, will produce intonation patterns in English more like those of native English speakers.

In order to motivate this experimental design, I will describe in more detail the factors that affect spoken language proficiency in a second language and differences between the intonation systems of English, Mandarin Chinese, and Standard Korean. These are the topics of Chapters 2 and 3. Chapter 4 then, describes the methodology used within a production experiment. Chapters 5, 6 and 7 includes the results and discussions of fundamental frequency, duration, and intensity comparisons. And finally, Chapter 8 includes the conclusions and discusses considerations in teaching intonation in a second language.

CHAPTER 2

FACTORS AFFECTING PROFICIENCY IN A SECOND LANGUAGE

2.1 Experience

In order to discuss the effects of experience and exposure to an L1, it is impossible to discount the affects of age upon acquisition. Previous studies in language production and perception have shown that the age at which L2 acquisition begins affects the extent to which the L2 will be acquired (Goto, 1971; Miyawaki et al, 1975; Mackain, Best, and Strange, 1981; Flege, 1984; Flege and Hillenbrand, 1986). This hypothesis follows from the work by Lenneberg (1967) on brain development and critical periods. This theory as it relates to second language acquisition, predicts that experience using a nonnative language will matter little if a critical age of learning has been passed. In order for acquisition of a second language to be possible, the learner must be exposed to the second language before brain lateralization has occurred and the brain becomes less plastic, thought to be somewhere between 7 and puberty. Adult learners, therefore, may never be able to develop native-like proficiency in the target language even with large amounts of exposure.

Perhaps accent free speech cannot develop after a certain critical age. This does not mean that experience in the L2 does not affect productions of L2, or target language, sounds. Experience may bring the productions within the target language closer and closer to the norms exhibited by native speakers. Production patterns within first language acquisition are acquired only after months or years of practice (Vihman, 1987). When a given production pattern has been acquired, a habit or routine has been developed for the implementation of a given sound. These routines are the foundations for further learning; new routines with new articulations will develop from previously acquired routines. It follows then, that acquisition of a second language sound system will develop out of previously learned productions in the L1. Continued exposure and experience should affect the productions of L2 target sounds. In the early stages of language acquisition, the routines used to implement target sounds will be those used in productions of L1 sounds but these routines may be modified in later stages of acquisition so that target productions become more native-like.

2.1.1. Acquisition of Segments

2.1.1.1. Acquisition of word-initial stops

The effects of experience were noticed in earlier experiments on second language production. Goto (1971) observed how well productions of words containing "r" and "l" by native Japanese were perceived by English speakers. Some of the Japanese subjects in this experiment were better in English conversation (as determined by Goto) than others. Goto noted that Japanese subjects who had more experience in English in his experiment produced words that were better identified by the native English speakers. Two of the Japanese subjects who performed best had lived and studied English in the United states for more than two years. More recent work in the production of nonnative phones has supported the result that experience within the

target language influences the production of nonnative sounds (Caramazza, Yeni-Komshian, Surif, & Carbone, 1973; Williams, 1980; Flege, 1987; Flege, Monroe, & Skelton, 1992, Flege, 1995)

Caramazza et al (1973) looked at the productions of initial voiced stops in bilingual French-English subjects and compared their performance to French and English monolingual speakers. In French, voiced stops are produced with prevoicing and voiceless stops are produced as short lag stops with short VOT values while for most speakers of American English, /b/ is produced as a short lag stop while /p/ is produced as a long lag stop. Subjects in the bilingual group had begun studying English before the age of 7. Bilingual proficiency was determined by self-report and by experimenter evaluation of read English. Subjects produced common stop initial words in French and in English. Voice onset time (VOT) measurements were made. The bilingual subjects produced VOT values in French that were like those of the monolingual French, produced VOT values in English words like similar to those of the monolingual English speakers. These productions, although not the same as those produced by monolingual English speakers, were more English-like than French-like; they approximated English norms.

Similar results were found in Williams (1980). Williams looked at the production of initial bilabial stops produced by monolingual Spanish, monolingual English, and Spanish-English bilinguals with different amounts of exposure to English. Like French, Spanish /b/ is produced with prevoicing and Spanish /p/ is produced as a short lag stop. Production patterns by the more experienced bilingual groups were more like those of native English speakers. VOT values of initial /p/ produced by bilinguals with 3-3.5 years of English exposure were similar to those of monolingual English speakers, however, initial /b/ was produced with more voicing lead than in English subjects. Prevoicing of initial stops does not interfere with communication in English because stop productions with voicing lead, (i.e., with a negative VOT boundary are still produced within the appropriate category, below +30 VOT). In other words, ambiguous productions will not result if /b/ is produced with 0 VOT or with -30 VOT. Although productions of these prevoiced stops may not be native-like, they do not interfere with communication. These speakers appeared to be using the same articulatory routines for productions of initial voiced stops established in the native language, while developing new routines approximating productions of voiceless stops.

Flege (1987) found that amount of L2 experience in French by native speakers of English influenced the productions of word-initial /t/. Native speakers of English who were proficient in French, (i.e., held proficient degrees in French and were teaching French or were living in France and using French as their primary language), produced /t/ in the French word "tous" with VOT values that approximated French norms. Less experienced French speakers-students who had spent 9 months studying French in Paris-produced word-initial /t/ in French with VOT values that were almost identical to the VOT values in English /t/.

More recent observations of productions of word-initial stops by native French speakers acquiring English, by Lauefer (1995) indicate that L2 learners do not globally acquire all the features of a linguistic construct together, but instead may master different articulatory gestures sequencially. Lauefer observed the acquisition of aspirated and voiced initial stops in English by native French speakers by measuring VOT and the voicing during the consonantal closure of initial voiced and voiceless stops. In English initial voiceless stops are produced with greater voicing

lag and less vocal fold vibration during the consonantal closure than in voiced stops, produced with short voicing lag. In French, voiceless stops are produced with short voicing lag and have longer closure durations than voiced stops, produced with voicing lead.

The results from this study indicate that native French speakers acquire greater aspiration of intial long lag stops before acquiring voicing patterns consistent with aspirated stops in English Measurements of VOT in the productions of [t] and [k] by less experienced French-English speakers fell within the long lag range of stops characteristic of English stops in stressed syllable-initial position. The VOT values for productions of [p] by most of the less experienced speakers were about midway between French norms and English norms. The VOT values in productions of [p] by the more experienced bilinguals were closer to French norms. Longer VOT values are produced with [t] and [k] in French, and so French speakers positively transfer these into productions of English. The labial [p], however, is produced with shorter VOT values in French. According to Laeuffer (1995), the French speakers with less exposure to English produced VOT values in [p] that were greater than those in French by generalizing what they knew about aspiration from L1 productions of [t] and [k]. Although aspirated [p] was a new L2 segment to French speakers, aspiration in itself was not a new L2 structure.

Productions of [b]. [d], and [g] were more difficult to acquired for native French speakers. French speakers need to reduce the amount of voicing during the closure of these word-initial segments (in comparison to voicing lead produced in French voiced stops), and also to produce short values in voicing lag. Initial voiced stops are produced with voicing lead in French. There was not a similar pattern in French to transfer. In addition, production of short lag stops may be physically more difficult and complext than producing long lag stops. These results indicate that the production of stops in English are not acquired as one unit, but that certain production patterns can be acquired before others. In addition, articulatory patterns that are the same in one context in the L1 and L2 (ie., aspirated [t] and [k] in French and English) can be extended to productions of a new L2 construct (ie., aspirated [p]). Finally, some productions may involve more complex articulatory gestures than other, and this will limit the production of new L2 sounds.

2.1.1.2. Acquisition of word-final stops

Differences in productions of word-final voiced stops have also been observed in production by nonnative speakers of English by Flege, McCutcheon, and Smith (1987). Articulatory measurements, including voicing during closure, closure duration, and measurements of supraglottal air pressure produced during the articulation of word-final /b/ and /p/ were taken from productions by experienced Mandarin Chinese speakers of English and monolingual English speakers. The Mandarin speakers had lived in the United States for an average of 13.4 years. Monolingual English subjects sustained voicing longer in final voiced /b/ with increased voicing during closure and longer closure durations. Analysis of air pressure waveforms indicated that the Chinese subjects were not actively expanding the oral cavity during productions of /b/ in order to allow for continued voicing during the voiced stop closure. In this case, productions of final stops without sustained voicing are likely to be perceived as voiceless stops by native speakers of English. Flege, Monro, Skelton (1992) found this to be the case. Productions of minimal pairs of words differing in the voicing status of the final consonant by experienced and

inexperienced Spanish and Mandarin speakers were recorded. Syllable-final voiced stops are not produced in either language. Although voiced stops exist phonemically in final position in Spanish, they are spirantized in production. Native English speakers were asked to identify the word member of the minimal pair in a listening task. Ninety-five percent of the words produced by native English speakers were correctly identified, as opposed to 71% and 73% of productions by the Inexperienced and Experienced Spanish speakers and 65% and 62% of the Inexperienced and Experienced Mandarin productions. These results indicate that it may be difficult to develop new articulatory routines when learning to produce nonnative sounds, however, the fact that the correct identification increased with language experience for both groups of nonnative English speakers indicates that development of L2 articulatory patterns may increase with amount of language experience.

Some sounds within a second language may be easier to acquire that other sounds. While voiceless aspirated stops were acquired by experienced Spanish-English bilinguals as reported by Williams (1980), word-final voiced stops posed difficulty for Mandarin speakers as reported by Flege et. al. (1984). The age of exposure and the amount of experience in a second language cannot be used to explain this discrepancy. Even the most experienced Mandarin subjects could not produce final voiced stops with English-like phonetic values. In order to understand why some sounds within a nonnative language might pose more difficulty than others, it is helpful to look at the phones that are shared between the L1 and the L2, phones that exist in one language but not the other, and phones in and L1 that are similar to L2 phones. This is accomplished through use of contrastive analysis.

2.2. Similarity between L1 and L2 sound systems: A contrastive analysis

Although it is an important variable influencing second language acquisition, experience alone cannot alone explain why some sounds are more difficult to acquire than others. Contrastive analysis has been used by linguists, grammarians, teachers, and others to make predictions about the linguistic structures a second language learner will have difficulty with when learning a second language. A contrastive analysis is made by comparing similar linguistic structures within the native language and the target language. According to this theory, those structures that are the same in both languages will be positively transferred into the second language and those that are different will be negatively transferred. Negative transfer has been used to explain why the speech of nonnative speakers sounds "accented." A native Spanish or French speaker learning English, for example, may substitute a long lag stop with a short lag stop when speaking English. This type of error is said to result from negative transfer of phones from the L1 that are different from those within the L2 phonological systems. Theories based on contrastive analysis also predict that negative transfer will be predominant in the early stages of language learning, but will subside as the learner becomes more experienced in the L2. If this is true, an experienced Spanish-English or French-English bilingual will eventually produce word-initial voiceless stops with VOT values characteristic of English.

Making predictions based on a contrastive analysis has proved to be far too simplistic in explaining the development of a phonological system in a second language. Productions of word-initial stops by the French-English bilinguals observed by Caramazza et. al. (1973), word-initial /p/ produced by the bilingual subjects in Lauefer (1995), and word-final voiced stops produced by the experienced Mandarin and

Spanish speakers in Flege et. al. (1987) were not similar to the monolingual English speakers' productions. On the other hand, productions of word-initial voiceless stops by the experienced Spanish speakers in Williams (1980) and productions of word-initial /t/ and /k/ in Laeufer (1995) were produced with VOT values that approached English norms. According to a contrastive analysis, all nonnative phones should be acquired in a similar fashion. If this were true, then the experienced speakers in the previous studies should have been able to acquire native-like production patterns for all nonnative phones. A contrastive analysis approach is too simplistic, it cannot explain why some nonnative phones are acquired and others are not. Because of this, theories of language acquisition have been developed to take into consideration other kinds of relatioships between L1 and L2 phones -other than presence or absence of phones- that explain why acquisition of some L2 phones are accomplished more readily than others.

2.3. Theories of second language acquisition

2.3.1. Speech Learning Model (SLM)

Contrastive analysis, despite its limited predictiveness, has been influential in current models of phonological acquisition. The Speech Learning Model (SLM) developed by James Flege and his colleges (Flege and Hillenbrand, 1984; Flege & Eefting, 1987; Flege, 1992) expands contrastive analysis by including three relationships that L1 and L2 phones can have. This model posits that a phone within the native language can have one of three relationships with a phone in the target language. An L1 phone can be the same as, similar to, or different from an L2 phone. According to the SLM, how a phone is perceived affects how it will be produced. In addition, experience in the target language will affect the accuracy of productions of new and similar phones. According to the SLM, similar phones will be more difficult to acquire than new phones that are not like any phone in the L1.

Flege includes the process of equivalence classification as important to understanding how phones are perceived and consequently produced. Equivalence classification, which enables us to perceive acoustically different sounds as belonging to the same category helps to explain why adults learning an L2 may never be able to produce authentic productions of similar phones (Flege, 1981, 1987). This process allows us to attend to language-relevant differences within phones while ignoring language-irrelevant differences. Instances of /t/ produced with a palato-alveolar place of articulation or dental place of articulation will be perceived as instances of one phoneme by native English speakers and instances of two phonemes by Hindi speakers. What is relevant in one language is irrelevant in another. If an English speaker cannot attend to these differences in Hindi, then native-like production of these Hindi sounds may not be possible. Equivalence classification processes, necessary for learning a first language, become more fixed with age. Once well-defined categories have been established, equivalence classification prevents new categories that are similar to previously developed categories from being formed. However, if a phone is different enough from all L1 phones and cannot be categorized as an exemplar of any L1 category, then a new category can be developed. This is the case of "new" phones.

"New phones" are those that are acoustically different from any phone within the native language. For example, French /y/ is unlike English /i/ and /u/. Although these three phonemes are realized with low first formant frequencies, the second formant

frequency values are quite different (F2 values being highest for /i/, lowest for /u/, and intermediate for /y/). The SLM makes the prediction that for the inexperienced French language learner with English as the native language, /y/ may first be perceived as belonging to the /i/ or /u/ phonemic category, and would thus be produced as [u] or perhaps [i]. With experience, the language learner will eventually recognize productions of [y] as belonging to the different French category /y/ thereby developing a set of articulatory patterns that result in productions of [y].

"Similar" phones, according to Flege (1987), are those which share some acoustic properties, but not all. As an illustration, French and English /u/ are similar phones in that both are high vowels with similar F1 values; however, French /u/ is produced with the tongue root further back in the vocal tract resulting in lower F2 values than English /u/. Because of the acoustic similarity between French and English /u/, they are perceived as being similar phones through equivalence classification. Equivalence classification results in similar phones being the most difficult to acquire. According to the SLM, similar phones may never be produced authentically in the L2 unless language learning begins before the end of a sensitive period.

Phones that are acoustically the same are described as "identical" phones. These phones will be positively transferred from the L1 to the L2, being implemented with the same articulatory patterns, and thus offering no problem to the L2 speaker. French and English both contain /i/ in their phonemic inventories with similar spectral and temporal characteristics. The L2 speaker need only to use the same articulatory routine acquired in the L1 when producing /i/ in the L2. Jun and Cowie (1994) found that productions of /i/ in Seoul Korean and American English were identical phones having the same formant structure within productions of Korean and English words. Korean-English bilinguals with differing amounts of exposure to English were able to produce authentic productions of /i/ in English words. Positive transfer of an identical phone from the L1 to the L2 resulted in native-like production patterns of this phone for even the least experienced Korean speakers.

The Speech Learning Model, in summary, makes predictions about productions in a target language based on a contrastive analysis between the L1 and the L2 phonemic systems; categorizes these contrasts based on acoustic parameters as identical, similar, or new; and takes into account a sensitive period after which equivalence classification makes it difficult if not impossible to produce similar L2 phones authentically. Then the SLM makes differing predictions about the three categories of relationships based on the amount of experience a person has in speaking the second language.

To test the Speech Learning Model, Flege (1987) observed productions of new and similar phones in a second language. Productions of /u/, /t/, and /y/ by English-French bilinguals with varying degrees of language experience and monolingual speakers of English and French were compared. Acoustic measures of VOT and difference between formant values were made in order to assess these productions. Aspiration differences, measured in VOT were used to determine possible differences in productions of /t/, and formant values representing different oral tract shapes, were used to determine differences in productions of /u/ and /y/. Flege describes /t/ and /u/ as being similar phones in English and French, and French /y/ as a new phone for English speakers. The hypotheses made by the SLM were supported. Although the most experienced bilingual approached acoustic norms for French /t/ and /u/, these productions were not equal to monolingual French speakers. Productions of /y/ -a new phone-, however, were produced authentically by experienced bilinguals. Formant values for these phones were similar in productions by the experienced

English-French bilinguals and the monolingual French group. Less experienced bilinguals produced /y/ with formant values that were intermediate to French /y/ and English /u/. The new phone was produced authentically by the experienced bilinguals, but the similar phone was not. Even the most experienced subjects who had lived in Paris for 11.7 years, were not producing /t/ and French /u/ authentically. Flege concluded that acquisition of the target language must begin before a critical age, and then with enough experience, native-like production patterns can be established. Experience, age of onset of language learning, and similarity between phones all are variables influencing the degree of foreign accent in nonnative productions of phones.

2.3.2. Perceptual Assimilation Model (PAM)

Catherine Best and her colleagues (Best, McRoberts, & Sithole, 1988; Best and Strange, 1992) have developed what has been called an "assimilation model" based on contrasing sets of phones that exist within the native language and target language. How contrasting L2 phones are perceived will depend on how they are assimilated into the L1 phonological system. While the SLM makes predictions about how particular phonemes in the L2 are realized given the phonological organization of the L1, the assimilation model makes predictions about how a pair of phonemic contrasts in the L2 fits into the phonological system of the L1. Although there are fundamental differences in the descriptions of these two models, the predictions that the two make are in general, similar.

According to the assimilation model, contrasts within the target language may be assimilated into the perceptual system of the language learner in four ways, single category assimilation, opposing category assimilation, category goodness assimilation, and nonassimilation. Single category assimilation occurs when contrasting sounds in the L2 are perceived as being variants of a single category in the L1. These contrasts pose the most difficulty for language learners. For example, Thompson velar and uvular ejectives /k'/ and /q'/ are likely to be understood as variants of English /k/ by native English speakers. Opposing category assimilation results in the least difficulty in second language production. This occurs when two contrasting sounds are assimilated as two separate sounds as in the case of Thompson /k'/ and /t'/ assimilated into English /k/ and /t/ categories. Category goodness assimilation occurs when one member of an L2 contrast is a better exemplar of an L1 category than the other. For example, the realizations of Farsi /G/ may be perceived as a poor exemplar of English /g/, while realizations of Farsi /g/ may be perceived as good exemplars. Consequently, these phones may be contrasted by the language learner; a distinction made on perceptions of "good" and "bad", or perhaps "good" and "not so good." The "not so good" sound falls on the periphery of the perceptual space of the native language comparison phoneme. Nonassimilated contrasts are those which have no counterpart in the target language. The phonemic system in English contains no phones that are similar to Zulu clicks, for example. Best et. al. (1988) hypothesize that these sounds are perceived "acoustically" rather than "phonemically", and because phonemic categorization in the L1 does not influence perception of these contrasts as speech, the language learner is able to use psychoacoustic, or extralinguistic, information to make distinctions. The ability to distinguish between nonassimilated sounds is not lost by the non-native speaker because phonetic specifications for these phones fall outside any native language category. English speakers use acoustic information, not phonemic information, to distinguish between Zulu clicks differing in dental, lateral, and palatal places of articulation. The assimilation model thus makes predictions of the perception of L2 phones based on how phones are organized within a phonological system.

Like the SLM, experience within the second language is a variable within this model. With continued experience in the target language, the bilingual speaker may develop separate L2 categories that are no longer affected by assimilation processes (Best and Strange, 1992). Best and Strange (1992) tested the Assimilation Model by looking at the ability of experienced and inexperienced Japanese-English bilinguals to perceive nonnative English contrasts. Three types of contrasts were used. A two-category contrast, /w/-/j/ (similar phones exist within Japanese); a category goodness contrast, /w/-/ɹ/ (/w/ in English may be a better exemplar of Japanese /w/ than English /ɹ/); and a single category contrast, /ɹ/-/l/ (both phones are poor exemplars of a Japanese approximate). Subjects were asked to complete identification and discrimination tests of these three contrasts.

The results of perception tests confirmed the predictions based on the assimilation model. Less experienced Japanese speakers of English had greater difficulty discrimimating between /w/ and /ɹ/ and identified less tokens as being /ɹ/ than did native English speakers. The authors felt that this result was due to "category goodness" assimilation. The inexperienced Japanese subjects were basing their perception of these phones on what they perceived as being a good exemplar of /w/ and what they perceived as being a poor exemplar of /w/. The same stimuli that were perceived as being poor exemplars of Japanese /w/ to the inexperienced Japanese speakers were perceived as being exemplars of /ɹ/, a phoneme in English, to the experienced Japanese and English speakers. This suggests that with experience, a new category for /ɹ/ is established enabling the contrast of /w/ and /ɹ/ to be perceived as it is in English.

The experienced and inexperienced Japanese and the native English speakers performed similarly in perception of /w/ and /j/. These phones, according to the authors, were assimilated into two separate categories and therefore presented the least amount of difficulty to the Japanese speakers. So while /w/ and /j/ may have slightly different acoustic characteristics in Japanese, they are nonetheless perceived as belonging to two different phonemic categories in the L2.

The inexperienced Japanese performed at chance levels in identifying and discriminating between /ɹ/ and /l/, appearing to percieve variants of both of these English phonemic categories as belonging to one phonemic category. The experienced Japanese-English speakers performed more like the native English speakers suggesting that categories for /ɹ/ and /l/ had been established in these Japanese subjects' phonemic systems. Yet, while the more experienced native Japanese English speakers performed better than the less experienced speakers, their performance did not equal that of the native English speakers. Even though phonemic categories had been established by these experienced Japanese speakers of English for /ɹ/ and /l/, these categories were not as well-formed as they were for native English speakers.

Both the Speech Language Model and the Perceptual Assimilation Model make contrasts between the first language and the target language fundamental to their predictions of language acquisition. While the SLM compares individual phones in the target language to phones in the native language in order to make predictions about production of nonnative phones; the Assimilation Model compares contrasts in the target language with contrasts in the native language in order to evaluate the perception of nonnative phones. Both models are important to understanding second language acquisition in that the phonological system of the first language is fundamental to

understanding the development of the phonological system in the target language. In addition, experience is an important part of language acquisition in that it may determine the degree to which a bilingual speaker becomes proficient in a second language.

2.4. Acquisition of tonal patterns in a second language

There has been little work that addresses the possibility that similar types of interference processes occur when learning prosodic elements in another language. The difficulty that a person will have in acquiring a new phonemic contrast, according to the Speech Learning Model and the Perceptual Assimilation Model, is based on acoustic similarity between phonetic realizations of native phonemes and a target phonemes. Because phonetic realizations of /k/ and /q/; /ɹ/ and /l/; /s/ and /z/; and /i/ and /y/ are acoustically similar, these contrasts may be difficult to acquire for nonnative speakers whose native languages lack such contrasts. Similarly, the prosodic systems of may be similar in that fundamental frequency is a part of intonational prominence in most if not all languages. This acoustic similarity may affect the extent to which L2 intonation is acquired by nonnative speakers.

2.4.1 Experimental Evidence

Few investigations have observed the acquisition of intonation patterns in a second language. Two of these investigations have focused on perception of a nonnative contrast. The first study observed the acoustic cues used in the perception of lexical stress by French speakers of English (Fry, 1972). Again, because stress is a part of English intonation, the acquisition of stress in an L2 is relevant to this study. The second study observs the perception of the falling intonation pattern of English by native speakers of Japanese (Beckman, 1986). A third production experiment will also be reviewed; observations by Ueyama & Jun (1997) of the rising intonation contour of yes/no questions and the falling intonation pattern of declaratives.

The earliest of experiments addressing the acquisition of prosody in a second language is one by D.B. Fry (1972), who is well-known for his experiment in the perception of lexical stress in English (1955, 1958, 1964). In this latter 1972 experiment, Fry was interested in determining the acoustic information that native speakers of French perceive as being most salient in the perception of stress in English. In an earlier study (1955), word pairs differing in location of stress (e.g., sub'ject and 'subject) were synthesized so that the duration and intensity levels of the first and second syllables could be manipulated. The ratio of duration and intensity level between these syllables changed so that while one of these acoustic parameters increased within the first syllable, the same parameter decreased in the second. These tokens were either consistent with the stress pattern of the verb or the noun, or they were consistent for one acoustic feature but not the other. English subjects were presented with these tokens and judges whether they had heard a noun or a verbs (1955). Noun judgments changed from 19% to 90% as duration became greater in the first syllable, and from 46% to 75% as intensity became greater in the first syllable. Duration was a more salient cue to stress for English speakers. In 1972, Fry presented the same stimuli to two groups of French speakers of English differing in English proficiency. The less proficient speakers appeared to be equally sensitive to duration and intensity. The percentage of noun judgments grew from 32% to 75% as duration ratios increased in the first syllable and from 33% to 77% as the intensity level increased in the first syllable. The more proficient French speakers of English performed more like the native English speakers: The percentage of noun judgments grew from 13% to 90%

as duration ratios became more consistent with first syllable stress and from 48% to 78% as intensity ratios became more consistent with first syllable stress. These results suggest that duration plays a lesser role in intonational prominence in French than in English. The less proficient French-English speakers were not as sensitive to duration changes in stressed syllables as were the native Engish speakers. However, with experience in English, the more proficient French-English speakers became more sensitive to changes in duration. Perception of a nonnative prosodic contrast, stress, was acquired by the more proficient French speakers.

Beckman (1986) observed the duration, average intensity, f0 characteristics of syllables produced with falling tonal contours in English and in Japanese. Pitch accented syllables in productions by native English and Japanese speakers were observed. Pitch accents are part of English intonational prominence and are produced in stressed syllables; the location of pitch accents in Japanese are lexically specified and not part of intonational prominence. Comparisons of acoustic correlates in the first and second syllables in nuclear pitch accented words contrasting in stress placement in English, eg., 'subject and sub'ject; and Japanese words contrasting in accent location, (e.g., 'iken (differing view) and i'ken (opinion) were made). Although the prosodic structure of Japanese is different from the prosodic structure in English, the context in which these word pairs were observed is superficially similar. In Japanese, pitch accents are produced with a falling f0 contour. This is acoustically similar to the f0 contour of falling intonation contour in English.

The results were consistent with the hypothesis that accents are realized differently within stress and nonstress languages. While measurements of f0 peak were consistently higher in accented syllables than in nonaccented syllable in both Japanese and English, syllable duration and average amplitude measurements of the accented syllables were consistently greater in only productions of English words. Although some of the accent pairs were separated by differences in intensity and duration within the Japanese words, there was high variation among these productions with much overlap. F0 measures, on the other hand, were consistently higher in accented syllables in Japanese productions and there was little variance in their productions. Conversely, there was more variance within the f0 measures taken from English accent pairs than was exhibited in the Japanese pairs.

In sum, in English, a stress language, changes in duration, intensity, and fundamental frequency are attributes of intonationally prominent stressed syllables in English. In Japanese, a non-stress language, only changes in fundamental frequency are attributes of pitch accented syllables.

Beckman used a hybrid resynthesis process to investigate the perceptual salience of these acoustic correlates of accent in English and Japanese. Productions of Japanese and English accent pairs from the production experiment were used to create hybrid stimuli. F0, duration, amplitude, and spectral contours were taken from these tokens and recombined into all possible combinations so that one, some, or all of the acoustic cues were consistent with the a given accent pattern. Two groups of Japanese-speaking subjects differing in experience in English, and two groups of English-speaking subjects differing in experience in Japanese listened to hybrid forms of Japanese tokens and English tokens presented within separate testing sessions. Subjects circled the form of the word that they heard with accent on the first or second syllable.

First, observations of Japanese and English speakers listening to their native language were made. Native Japanese speakers were most sensitive to differences in fundamental frequency within accented and unaccented syllables in Japanese words regardless of the duration and intensity characteristics of target syllables. These subjects were not sensitive to intensity and duration patterns also consistent with accented morae in Japanese. This information appeared to be irrelevent in judgements of accent location. English speakers, in contrast, although most sensitive to differences in fundamental frequency, were also sensitive to duration, intensity, and spectral differences in English accent pairs. These results indicate that f0 is salient feature of pitch accents in a non-stress language (Japanese), and that f0, duration, intensity, and spectral characteristics are all acoustic properties of pitch accents in a stress language (English).

Beckman (1986) made additional observations on the effect of experience in a second language in using "similar" types of acoustic information (in Flege's terms) as perceptual cues to a nonnative phonological distinction. Based on the results of the hybrid synthesis experiment, Beckman concluded that although fundamental frequency is a salient cue in the perception of accent in English, duration, and intensity are also important. Conversely, only fundamental frequency is salient to perception of accent in Japanese. In terms of the SLM, these are similar phones in that fundamental frequency is a salient cue to accented syllables in both languages. English speakers need to ignore irrelevant differences in intensity and duration while attending only to fundamental frequency differences when learning Japanese. Japanese speakers, however, need to become sensitive to distinctions in duration, intensity, spectral changes, and to the fact that not all accents are pitch falls when learning English. As Beckman's results indicate, duration and intensity are not consistently reliable cues to accent in Japanese. According to the SLM, experienced L2 speakers will acquire new perceptual categories for native-like perception of similar phones. Thus, experienced bilingual Japanese and American English speakers should perceive accent in the target language in a native-like fashion.

Beckman observed how native Japanese and English speakers differing in L2 language proficiency performed when listening to nonnative productions. Both inexperienced and experienced English-Japanese were sensitive to f0 changes, but the experienced group performed most like native Japanese speakers. Exposure within the L2, facilitated the perception of pitch accent in Japanese. In contrast, experience within English did not affect perception of prominent accented syllables in English by Japanese subjects. Both less and more proficient English speaking Japanese subjects were in general most sensitive to changes in f0, an not sensitive to duration, intensity, and spectral information when listening to pitch accented stressed syllables in English.

Together, these studies illustrate how the intonation or tonal system of a native language can influence perception of intonation patterns in a second language. In a stress-accent language, such as English, changes in f0, duration and intensity are associated with intonational prominence, while in French and Japanese -both non stress languages- duration and intensity may play a lesser role.

A recent experiment, particularly relevant to the current investigation is one of these. Ueyama and Jun (1997) observe how certain aspects of intonation are acquired in a second language. Ueyama and Jun, (1997), observed productions of a rising intonation pattern and falling intonation pattern in English by native speakers of Korean and Japanese differing in amounts of language proficiency. The results of English and Korean speakers will be discussed here. Of interest, were the possible

effects of the native intonation system on productions of intonation patterns in English, in particular, the steepness of the rise in a rising intonation pattern and the ability to deaccent words that follow a rising or falling sentence accent. English declaratives, as discussed in Chapter 1, are often produced with a rising accent followed by a falling tonal pattern. English yes/no questions are produced with a falling accent followed by a rising tonal pattern. Words that follow these prominent accents are produced within a low tonal plateau in declaratives and a high tonal plateau in questions. In Korean, both statements and questions are produced with a rising/falling tonal pattern similar to declaratives in English. Korean does not have a falling focal accent as produced in English yes/no questions. A final fall is used within Korean declaratives and a final rise is used in declaratives in English. These patterns have been discussed and are illustrated in Figure 1.2a and 1.2b. In the phrase "I did it." with focus on "I", the words following "I" are not accented and are produced with a low tonal pattern; in the question "Did I do it?" with focus on "I", the words following "I" are not accented and produced within a high tonal pattern. A similar pattern occurs in Korean, however deaccented words are not produced within a high tonal pattern, but only within a low tonal pattern.

As predicted by the SLM, the slope of the rising accent pattern produced by beginning Korean speakers was steeper than the slope of the more experienced speakers. The steeper rise produced by the less proficient Korean speakers was more like that produced in phrase accents in Korean, while the rise produced by the more experienced Korean speakers was more like that of the rising intonation pattern in English. These results indicate that less proficient speakers of an L2 rely on the prosodic structure of the L1 when producing a similar prosodic contrast in the L2. Moreover, with experience in the target language, acquisition of a similar prosodic structure is acquired as indicated by productions of more proficient Korean speakers. Experience in English also affected production of the rising intonation pattern in English. While native English speakers produced all questions with a final high plateau, the more proficient Korean-English speakers produced this tonal pattern in about half of the utterances, while less proficient Korean-English speakers almost never produced this final high plateau.

Last, Ueyama and Jun (1997) observed productions of unaccented syllables by counting the number of accented nouns that follow the nuclear-accented word in English utterances produced by the native English and the two groups of Korean speakers. These results indicated that experience in English had an effect on the number of nouns produced without a pitch accent. For English speakers, no postnuclear nouns were accented; for nonnative speakers, the number of unaccented nouns related to the amount of experience. More proficient speakers accented fewer nouns than did beginning speakers. Experience in the L2 influenced the production of this similar contrast, producing post-focused unaccented words.

The results of this experiment indicate that experience in an L2 influences the production of intonation patterns in English. The shape of the rising intonation pattern in English, the production of unaccented words, and the production of a high plateau in yes/no questions were all influenced by the amount of English language experience. While productions by the more experienced Korean language speakers were not the same as productions by native English speakers, their productions were more similar to native productions. These prosodic contrasts in English and Korean discussed in Ueyama and Jun (1997) are similar prosodic forms. Because English intonation is similar to Korean intonation, English intonation patterns should be difficult to acquire for Korean speakers according to the SLM. This may explain why the more proficient

Korean-English speakers did not produced English intonation patterns that were the same as those by native English speakers.

CHAPTER 3

INTONATION SYSTEMS: ENGLISH, SEOUL KOREAN, MANDARIN CHINESE

3.1. English

3.1.1. Prominence relationships

English is a stress-accent language because of the relationship between stressed syllables and intonational prominence. Prominent words are produced with distinctive tonal patterns, called pitch accents. Pitch accents are associated with a stressed syllable in words. Words in English may consist of more than one syllable. The words "memorizes" and "memorial" for example, both consist of four syllables. Certain syllables within words are produced with a full vowel, and these are the stressed syllables in words. The first syllable and third syllables in "memorizes" are produced with a full vowel; the second syllable in "memorial" is produced with a full vowel. Syllables that are not produced with a full vowel are typcially produced with a schwa or a more central vowel. They are also shorter, and have less intensity. Multisyllabic words in English then are produced with a pattern of full and reduced syllables. The second and fourth syllables in "memorizes" are reduced; the first, third, and fourth syllables in "memorial" are reduced. Native speakers of English have a sense that these syllables with a full vowel are heavier or more prominent than other syllables within a word.

Similarly, single syllable words that have little content, referred to as "function words", are also typically produced with a reduced vowel. The vowels in the function words "a" and "the", for example, are produced with reduced vowels. Consequently, this patterning of full and reduced syllables occurs within phrases. In the phrase "he wrote the word", the words "he", "wrote" and "word" are produced with a full vowel while the vowel in "the" is reduced. This patterning of full and reduced syllables gives a rhythmic sense to English utterances.

Below is the word "memorial" in one of the experimental sentences, "He wrote the word "memorial" nine times." This phrase can be described using a "prominence grid", a modified version developed by Nespor and Vogel (19**). The lowest level of prominence is the syllable level where each syllable is assigned an asterisk (*). At this level there is no prominence contrast. Above this level, is the first level that discriminates between more and less prominent syllables. Because full vowels are more prominent than reduced vowels, they are assigned an asterisk (*).

```
full vowel:     *  *       *       *    *       *   *
syllable: *  *  *    *   *   *  * * * *  *    *
utterance:      I know he wrote the word memorial nine times.
```

Prominent words are produced with pitch accents. These pitch accents are associated with the stressed syllable in a word. The first syllable in "memorizes", and the second

syllable in "memorial" can be produced with a pitch accent. Pitch accents are a fundamental aspect of English prominence and need to be understood within a theory of intonation. A pitch accent theory of intonation developed by Pierrehumbert (1980) and Pierrehumbert & Beckman (1988) is adopted here to describe English intonation. Pitch accents are used to enhance the prominence of a word or phrase within discourse. They are realized on or around the stressed syllable within a word. If a word is one syllable, such as "wrote", then the pitch accent is realized on or near the word's vowel nucleus [o]. If a word has more than one syllable, as in "memorial", then the pitch accent is realized on the lexically stressed syllable, the second syllable [ɔr], in this case. This is the syllable with primary stress; it marks the location for a pitch accent. Pitch accented words are more prominent than words produced without a pitch accent. This adds another level to the prominence hierarchy presented earlier. In this next example, "know", "wrote" and "memorial" are prominent within the utterance and so are produced with a pitch accent.

```
accent          *                 *
full vowel:     *  *       *      *     *    *
syllable: *  *  *    *   *   *  * * * *  *    *
utterance:      I know he wrote the word memorial nine times.
```

A word need not be accented if it is not particularly salient to the discourse. In the example utterance above, only "know" and "memorial" are produced with pitch accents. The remaining words in this utterance are not pitch accented.

In English, different types of pitch accents are used within prominent words in order to communicate different types of intonational meanings (Pierrehumbert and Hirschberg, 1991). Pitch accents consist of low (L) and high (H) tonal targets. There are three "low" pitch accents: L*, L*+H, and H+L* and three "high" pitch accents: H*, H*+L, and L+H*. The starred (*) portion of each tonal target is aligned with the stressed syllable of the prominent word.

Figure 3.1 is a schematized illustration of the f0 contour within the utterance, "I know he wrote memorial nine times." "Know" is produced with a H* pitch accent, and "memorial" are produced with rising L+H* pitch accent. The different tonal pattern in these two pitch accents is illustrated here. While a high f0 associated with a H* pitch accent is realized within "know", a steep rising f0 contour characteristic of a L+H* pitch accent is realized within the stressed syllable in "memorizes".

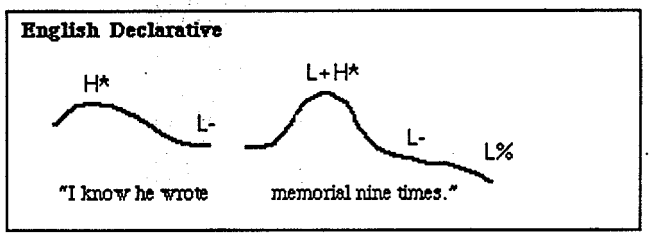


Figure 3.1 Schematized pitch track of an English utterance. "Know" is produced with a H* pitch accent and "memorial" is produced with a L+H* pitch accent.

3.1.2. Boundary tones

Tonal elements have not only a major role in intonational prominence in English, but also serve to mark the boundaries of prosodic phrases. A string of spoken words is organized into phrases, and the ends of these phrases are marked with tonal changes. An "intermediate phrase" is comprised of one or more pitch accented words. The right edge of the intermediate phrase is marked with a low or high boundary tone, and are symbolized with L- and H- in Pierrehumbert's system of intonation (1980). These boundary tones delimit the intermediate phrase. Two intermediate phrases are produced in Figure 3.1. Low phrase tones are produced at the ends of both of these phrases.

Intermediate phrases are produced within a larger prosodically defined unit, the intonational phrase. The edges of the intonational phrase are tonally marked with a low or high boundary tone. These tones are symbolized in Pierrehumbert's system as L% and H%. A L% boundary tone is produced at the end of Figure 3.1.

The location of pitch accents in intermediate phrases is important in English. If more than one word is pitch accented in an intermediate phrase, the last pitch accent is the most prominent. The final prominent word within an intermediate phrase carries the nuclear pitch accent and is typically perceived as the most prominent pitch accent in that phrase (Ayers, 1996). The nuclear pitch accent is the final level of prominence.

```
nuclear accent:                    *
accent:      *                 *
full vowel:        *     *     *   *     *   *
syllable:  *  *   *   *   *   *  * * * *  *   *
utterance:       I know he wrote the word memorial nine times.
```

Nuclear accented words are most prominent; pitch accented words produced in the same intermediate phrase, but before the nuclear accent are less prominent (Ayers, 1996; Pierrehumbert, 1980); and finally, words produced after the nuclear accented word are produced without a pitch accent and are least prominent. The words "nine" and "times" have no pitch accents in Figure 3.1. There is no prominent pitch change produced in either of these words. This analysis of prominence, then, can be discussed in terms of three levels or three degrees of prominence (see e.g., Beckman, 1986; Beckman & Edwards, 1994, deJong, 1995). It is possible for one word to be produced in different utterances with three different levels of prominence. The word "memorial" can be produced with three levels of prominence in the following examples (bold-faced words are nuclear-accented).

Nuclear: I know he wrote the word **memorial** nine times.
Prenuclear: He wrote memorial **eight** times.
Unaccented: He **typed** memorial nine times.

3.1.3. Intonation patterns

Pitch accents and boundary tones together form intonation patterns. Two common intonation patterns are produced in statements and in yes/no questions. A declarative intonation pattern can consist of a rising pitch accent (L+H*) followed by a L- intermediate boundary tone and a L% intonational boundary tone. The following three utterances are likely to be produced with this intonation pattern The bold-faced word is to be produced with the most emphasis, or prominence. The pitch accent is aligned

with the nuclear-accented word, and the boundary tones are aligned with the end of the intonational phrase.

1. "I know he wrote the word **electrical** nine times."
   L+H* L-L%
2. "He wrote electrical **eight** times."
   L+H* L-L%
3. "He **said** electrical eight times."
   L+H* L-L%

A yes/no question intonation pattern contour can consist of a L* accent followed by a H- intermediate boundary tone and a H% intonational boundary tone. The following three utterances are likely to be produced with this intonational pattern. Again, these utterances are produced in contexts where the bold-faced word receives and nuclear L* accent. The L* accents are associated with the stressed syllable in the prominent bold-faced words, and the boundary tones are produced after this nuclear accent.

1. "Did he write the word **electrical** nine times?"
   L* H- H%
2. "Did you say he wrote electrical **eight** times?"
   L* H-H%
3. "Did he **type** electrical eight times?"
   L* H-H%

A pitch accent theory of intonation allows us to understand how the intonational contour of an utterance, made up of tonal movements between a series of pitch accents and boundary tones, governs the realization of f0 within words in English. As has been illustrated, words can be produced with varying levels of prominence. The most prominent words are produced with a nuclear pitch accent, less prominent words with a prenuclear pitch accent, and words without a pitch accent are least prominent within discourse.

3.1.4. Acoustic Correlates of Stressed Syllables

Duration and intensity changes play a role in English intonation because pitch accents are bound to stressed syllables. If pitch accents were bound to a word, and not a particular stressed syllable, then pitch changes associated with these accents could be realized over the entirety of a word. Because, pitch accents are associated with stressed syllables, the tonal changes in pitch accents need to be produced within -or very near- the stressed syllable. The duration and intensity characteristics of stressed syllables are potentially affected by pitch accents, and must be considered when acquiring English intonation.

3.1.4.1 Fundamental Frequency

Changes in fundamental frequency within a syllable have been found to affect the perception of stressed syllables. Fry (1964), in the second of three related experiments, found that the level of fundamental frequency in a syllable affected the perception of stress location in a word. Both duration and direction of f0 movement in syllables within synthetically produced tokens of stress-contrasting disyllabic pairs (e.g., "'subject" and "sub'ject") were presented to subjects in a perception experiment. The ratio of duration between the first and second syllable varied in tokens as did the f0 levels. Subjects were more likely to hear a syllable as stressed if

the pitch was higher within that syllable regardless of the length of the syllable. The amount of difference in f0, so long as perceptible, had less of an effect. A word was perceived as a noun if the f0 contour was a higher in the first syllable; and a verb when the f0 contour was higher in the second syllable.

The pattern or movement in f0 within syllables also affects stress perception (Fry 1958). Fundamental frequency contours in both syllables of disyllabic stress pairs were varied so that syllables contained either a linear fall, a linear rise, a final fall, a final rise, or were level. Different combinations of these patterns were used within the first and second syllables of stimuli. Eighty percent of the tokens were heard as nouns (with first syllable stress) in cases where a linear fall occurred within the first syllable while the second syllable f0 remained low, and 79% were heard as nouns when a late fall in f0 occurred within the first syllable. This combination is consistent with a H* L-L% declarative intonation pattern where the high pitch is associated with the first syllable ('object) and the fall onto the second unstressed syllable is a result of movement to low boundary tones. Similarly, more tokens were judged as being verbs with stress in the second syllable when a linear fall occurred on the second syllable (76%) or a late fall occurred within the first syllable (76%). Again, this is consistent with the H*L-L% tonal pattern of declaratives, when the last syllable of the nuclear-accented word is stressed.

Lieberman (1960), also found that higher f0 levels existed in stressed syllables. Subjects read lists of sentences containing word pairs differing in stress placement, such as "'rebel" (noun) and "reb'el (verb)". Fundamental frequency levels were measured within the stressed and unstressed syllables. Lieberman found that when comparing measurements taken from the same syllable produced with and without stress (e.g., "re-" in "re'bel" and "re-" in "rebel'") the stressed syllables were consistently produced with higher fundamental frequency. Stressed syllables within the productions in this experiment had a higher f0 than unstressed comparison syllables in 72% of the tokens. This percentage is quite high given that tokens were produced in different sentential positions. Although it is impossible to know the intonational patterns produced in this study, we can conclude that comparison tokens were likely to have been produced within different intonational contexts. From the previous discussion on English intonation, we know that the type of pitch accent used (i.e., L* or L+H*) and the relative level of prominence (i.e., accented vs. unaccented) controls the f0 contour realized within a word. Surely, words produced with low accents or without an accent at all were included in this study. Taking this into account, we can conclude that f0 levels are an important aspect of accent in English.

A later experiment by Beckman (1986) observed the f0 characteristics of stressed and unstressed syllables in only nuclear-accented words. Native English speakers produced noun/verb word pairs produced with a nuclear H* pitch accent in statements. F0 measures were taken in the middle of stressed and unstressed target vowels and compared. A ratio measure was obtained for each word by dividing the second syllable by the first. These fundamental frequency values were greater in stressed than in unstressed syllables indicating that f0 separates accented stressed syllables from unstressed syllables. We can conclude that f0 height separates stressed syllables in pitch accented words produced with a H* accent. We cannot conclude that f0 height separates accented from unaccented syllables, given that low pitch accents also are used in English. Instead, these experiments indicate that f0 level and f0 movement are important in separating accented from unaccented syllables.

3.1.4.2 Duration and Intensity

Fry (1958) used synthesized versions of stress pairs to observe how duration and intensity differences affected the perception of stress judgments. Duration and intensity levels of syllables in these disyllabic words were varied so that as the first syllable became longer, the second syllable became shorter. Intensity levels varied between first and second syllables in the same manner. In some tokens, both duration and intensity were consistent with the stress pattern of a particular syllable, in others, the duration of a syllable was consistent with first syllable stress, while the intensity of the other syllable was consistent with second syllable stress. Subjects had to chose if they had heard a verb or a noun. The number of "noun" responses was the dependent measure. Subjects were more sensitive to changes in duration than to changes in intensity. In other words, duration appears to be a better perceptual cue to stress location than intensity. The percentage of subjects' responses to words as "nouns" with first syllable stress increased from 12% to 92% as the duration ratio shifted from the longer second syllable vowel to longer first syllable vowel. The percentage of responses increased from 40% to 82% as intensity increased within the first syllable of stimuli. Durational changes had a larger effect on the perception of stress placement than did intensity changes.

Nakatani and Aston (1978), measured the intensity levels and durations of stressed and unstressed syllables in words differing in sentence context (medial vs. final position). Reiterant speech was used in order to control for the intrinsic properties of different vowels and word frequency effects. Subjects in this experiment produced sentences containing non-word substitutes for the target words that differed in stress pattern: "The lawyer MAma /maMA the client" was produced by substituting "MAma" for "badgered" and "maMA" for "convinced". Although these measures are confounded by the lack of control over the *prosodic* context of words, the results are nonetheless indicative of the role of duration and intensity of stressed syllables. In all sentence contexts, duration separated first from second syllables in that the stressed syllable was longer than the first syllable. The ratio of stressed to unstressed syllable duration was not the same. The location of the stressed syllable had an affect on the length of that syllable. As a result, the stressed second syllable in maMA was much longer in comparison to the first stressed syllable in MAma, but the stressed syllable was longest in both stress types. Intensity levels consistently separated stressed from unstressed syllables in word-final contexts where stressed vowels were higher in intensity. In sentence medial contexts, the second syllable was louder regardless of stress location. The tonal pattern produced within words in medial position is impossible to know; although given that all sentences were produced as statements, it is likely that the sentence-final words were produced with a nuclear H* or L+H* pitch accent. In this context where words are produced with a prominent pitch accent, intensity separated stressed from unstressed syllables. In sum, duration consistently separated syllables in all sentence contexts, and intensity separated syllables in a nuclear accent context.

Beckman (1986) also observed the duration and the average intensity of stressed syllables produced in accented words. Beckman hypothesized that because English is a stress language, duration, intensity, and f0 are all used to separate stressed from unstressed syllables. As with f0 measures, ratio measures of duration and intensity levels between first and second syllables in each word were made. The stressed syllables in the five word pairs were consistently separated by duration and average intensity. In general, the stressed syllable was longer and louder than the unstressed syllable.

The role of duration and intensity in stressed unaccented syllables was observed in a recent experiment by Sluijter and van Heuven (1996). This is the only experiment where targets were produced in unaccented and accented contexts (or with less and greater amounts of prominence). Noun/verb pairs were produced in focus and out of focus (i.e., with a nuclear pitch accent and without a nuclear pitch accent) and intensity and duration measures were made within stressed and unstressed syllables. Sluijter and van Heuven found that average intensity, and syllable duration were consistently greater in stressed syllables and that this difference was greater in target words produced in focus.

The results from Sluijter and vanHeuvan (1996) confirm earlier results that duration and intensity separate unstressed and stressed syllables, but these results also indicate that as the intonational prominence of a word increases, so do differences in duration and intensity between unstressed and stressed syllables. This suggests that if there are three levels of accentual prominence in English (nuclear accented, prenuclear accented, and postnuclear unaccented), then there are three levels of separation between unstressed and stressed syllables.

3.2. KOREAN

The intonation system of the standard dialect of South Korea, the Seoul dialect, referred to here as Korean, differs from English in the role that intonation plays in marking prosodic boundaries and in prominence relatioships. Lexical stress and pitch accent do not exist in Korean as they do in English. Korean is a nonstress language. Although words may consist of more than one syllable, no one syllable is lexically specified as more prominent than others. Because of this lack of contrast between stressed and unstressed syllables, tonal changes used to indicate the relative prominence of words and phrases in Korean are not bound to a specific syllable.

3.2.1 Boundary tones

3.2.1.1 Accentual phrases

Words are produced within prosodically defined phrases called accentual phrases. The accentual phrase in similar to the intermediate phrase in English, but differs in that it is tonally defined with rising tonal patterns. These tonal movements serve to group words into phrases in Korean. An initial rising LH tone initiates accentual phrases, unless the first sound is a fortis or aspirated stop. In this latter case, the H tone initiates the accentual phrase. The initial H tone in the (L)H rise in accentual phrases is realized around the second syllable in that phrase (Jun, 1993). Figure 3.2 is provided to illustrate the tonal characteristics of accentual phrases. Three accentual phrases are produced within one intonational phrase in this example. Rising LH tonal patterns initiate the first and last accentual phrase. The second phrase illustrates the initial H boundary tone in a word beginning with an aspirated stop.

Korean Declarative

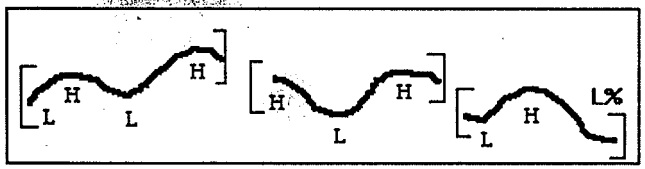


Figure 3.2 Schematized pitch tract of one intonational phrase in Korean produced with three accentual phrases. A final L% boundary tone is produced at the end of the intonational phrase.

The number of syllables in an accentual phrase affects the tonal pattern of that phrase. Shorter accentual phrases in Korean are produced with a (L)H or (L)HL pattern, and longer phrases are produced with (L)HLH tonal patterns (Jun, 1993). While the tonal pattern of an accentual phrase is LHLH, the length of the phrase affects the realization of this tonal pattern. The tonal pattern in accentual phrases then, is determined by the number of syllables in a phrase, and by the segmental characteristics of the words in these phrases (ie., a L tone does not initiate an accentual phrase when the first word in the accentual phrase is an aspirated stop).

Important to this study is the similarity between the rising tonal pattern of the accentual phrase in Korean and rising pitch accents in English. According to the Speech Learning Model, the LH rise in the accentual phrase is similar to the LH rise in a L+H* pitch accent. Also relevant is the association of an initial H tone in the Korean accentual phrase with the second syllable of that accentual phrase. While the L+H* pitch accent in English is associated with a stressed syllable, the H tone in a LH accentual phrase pattern is associated with the second syllable in that phrase.

3.2.1.2 Intonational Phrases

Accentual phrases are produced within a larger prosodic unit, referred to as the intonational phrase. Intonational boundary tones have two functions in Korean. They mark the right edges of these phrases and unlike accentual phrase tones, they have a pragmatic purpose in Korean. These tonal movements influence the interpretation of utterances. They are L, H, LH, HL, LHL, and HLH (Koo, 1986; Jun, 1993). Relevant to this study, a high boundary tone (H%) is typically used within questions and a low boundary tone (L%) is used in statements (The latter boundary tone is illustrated in Figure 3.2). Statements, for example, can be produced with an initial rise, characteristic of the accentual phrase, followed by a low boundary tone at the end of statements. Questions in Korean can be produced with the same initial rise and fall followed by a final high boundary tone at the end of the utterance. This final rise differentiates statements from questions. These patterns are illustrated in Figure 3.3. In this figure, one accentual phrase is produced with a LHL tonal shape.

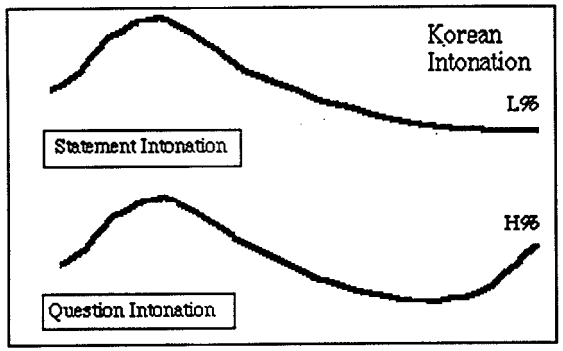


Figure 3.3 Schematized representation of two different boundary tones in Korean. A L% boundary tone marks the edge of a statement in this example, and a H% boundary tone marks the edge of a question.

3.2.2. Intonational Prominence

Focused words and phrases within a phrase are made more acoustically prominent through changes in pitch range, and through changes in intonation phrasing. Because Korean is a non-stress language, prominence is not associated with words and phrases and not with a particular syllable in a word.

Important to prominence in Korean is intonational phrasing. Jun (1993) reports that focused words begin accentual phrases in Korean. Subjects within her experiments were asked to produce an utterance with different words focused in each production. Jun (1993) and Ueyama & Jun (1996) report that the phrasing of utterances changes when the focused element changes within an utterance. As an illustration, an utterance in Korean might be produced with three accentual phrases. Each syllable in this utterance can be represented with an asterisk. Syllables are produced within three accentual phrases, and these accentual phrases -represented with brackets- are produced in one intonation phrase -represented with braces: {[***] [****] [**]}. If for some reason, a word in the second accentual phrase is produced with narrow focus, the following words in the intonational phrase are "dephrased" and become part of the second accentual phrase: {[***] [******]}. As a result, the same string of words is rephrased based on the relative prominence of a word. The most prominent focused word is first in the accentual phrase, and all words after it in the same intonational phrase are dephrased.

Results from Kang (1995) illustrate the importance of phrasing. Pairs of words were produced, in this experiment, in adjectival phrases so that the effects of phrasing could be observed. When these phrases were produced as "new" or more prominent to discourse, each word was more likely to be produced within its own accentual phrase. By producing two acentual phrases rather than one, the LH patterns of the accentual phrase could be realized within both prominent "new" words.

The tonal characteristics of an accentual phrase in Korean are used to make words more acoustically prominent. Focused words are always produced first within an accentual phrase and are always produced with a phrase initial rising tone LH or high H tone followed by a low (L) tone (Ueyama & Jun , 1997). The initial low tone is loosely associated with the first syllable, and the high tone with the second syllable, and the second low tone with the third syllable (Jun, 1993). This LHL tonal pattern within prominent words is linked to the tonal patterns of accentual phrases in Korean. Within a system such as this, an acoustic parameter that already exists (the rising pattern of the accentual phrase) is used to enhance the prominence of a word.

There may be changes in duration and intensity within prominent words, but because prominence is not associated with stress in Korean, these acoustic changes are likely to be less important than changes in pitch. Jun (1993) has noted that focused words are produced within a wider pitch range and are stronger in amplitude than they would be when not produced in focus (p. 190). Important to remember is that these changes in intensity and pitch are not associated with a particular syllable however, unlike in English where accent is associated with the stressed syllables of focused words.

Kang (1995), examined the phonetic characteristics used to distinguish between "new" and "given" information in discourse in Korean. New information within this experiment can be said to be information that is produced with more prominence than given information. The duration and the average intensity of phrases produced as new and given were measured. Peak f0 measurements within comparable H tones, associated with the accentual phrase, were compared. The results were consistent with Jun (1993). Words produced as new to discourse were longer than when produced as given in 75% of the phrases. These more prominent words were higher in average intensity in 64.4% of the phrases; and had higher peak f0 values in 67.1% of the phrases. These results suggest that duration, intensity, and f0 play a role in prominence in Korean. However, the extent to which duration and intensity are used within more prominent words in Korean (a nonstress language) may be less than that of English (a stress language). Kang made comparisons of possible acoustic correlates of prominent words. Comparisons of duration between phrases differing in prominence revealed that the average duration of less prominent phrases was between 93%-98% of the duration in more prominent phrases. Comparisons of the average intensity level (RMS.) of less prominent phrases on average were 96% of the intensity in more prominent phrases. These small changes between less prominent and more prominent phrases suggest that duration and intensity play a lesser role in prominence than they do in English.

3.2.3 A comparison of Korean and English intonation

Particularly relevant to the present experiment is the similarity in how tonal changes are associated with prominence in English and Korean. First, in Korean, prominent words are produced with expanded rising LH or high H tonal patterns. In English, prominent words are often produced with L+H* and H* pitch accents. These languages are also similar in that words produced after a focussed word are least prominent in an utterance. These post prominent words are dephrased in Korean and unaccented in English. Prominent changes in f0 are not associated with these words in either of these langauges.

Korean and English differ in that tonal changes of intonationally prominent words in English are linked to stressed syllables, but intonational prominence in Korean is linked to the accentual phrase. In addition, these languages also differ in that only a rising tonal pattern is used within prominent words in Korean, while a variety of pitch accents with different tonal shapes are used in Enlgish.

Based on these similarities and differences, hypothesis regarding the acquisition of intonation patterns in English by Korean speakers of English can be made.

1. Korean speakers will produce only rising tonal patterns in prominent words in English. **Korean speakers will appropriately use rising tonal patterns in prominent words in English statements, but will inappropriately also use rising tonal patterns in yes/no questions.**

2. Tonal changes in English are associated with stressed syllables, but not in Korean, a non-stress language. For this reason, changes in duration and intensity are not as important in Korean intonation, and so **duration and intensity will not differentiate productions of unstressed and stressed syllables in in English by Korean speakers.**

3. Because tonal changes are not associated with stressed syllables in Korean, **tonal changes in prominent words in Korean productions of English will not be bound to stressed syllables in prominent English words.**

4. Korean and English are similar in that specific tonal movements are not inherent to syllables in these languages. **Unaccented words are not produced with accents in these languages and so Korean speakers are likely to produce unaccented words without a prominent pitch protrusion.**

3.3 Mandarin Chinese

The following description of the prosodic system of Mandarin Chinese is based on the results of experimental observations reported by Jin (1996), Xiao-nan Shen (1990), Shih (1988), and Howie (1976) and subjective observations made by Kratochvil (1968). Intonation in tone languages is complex because of the multiple uses of pitch. Fundamental frequency is the primary acoustic correlate of lexical tones in Mandarin. That is to say that the specified f0 contours associated with most syllables in Mandarin are phonemic; a better descriptive term for tones is therefore "toneme." Because tones have a meaningful distinctive function, intonational changes are limited. A tone cannot be so distorted that its underlying form be difficult to retrieve. This makes the intonational system of Mandarin necessarily quite different from that of English. The tonal contours of Mandarin utterances are influenced by tones and intonation, while the tonal contours of English are influenced by intonation.

3.3.1 Tones in Mandarin

There are four tones in Mandarin and a fifth "neutral tone", that is, a syllable with no contrastive tonal specification. The f0 contours of four tones are provided in Figure 3.4. Tones are typically described as moving within a pitch range that varies from low, numerically denoted as 1, to high levels of pitch, numerically denoted as 5. Tone 1 is described as 55, Tone 2 as 35; Tone 3 as 214; and Tone 4 as 51. To make the description of f0 patterns consistent with discussions of intonation in Korean and English, these tonal patterns can also be described with (L), middle (M), and high (H) targets. Tone 1 is represented as HH; Tone 2 as MH; Tone 3 as MLH; Tone 4 as HL; and Tone 5 is without pitch specification. Pitch tracks of these four tones produced in isolation are provided in Figures 3.11. In citation form, Tone 1 is a high level tone that begins high in the speaker's pitch range and remains high. Tone 2, a rising tone, begins in the middle of the speaker's pitch range and rises to a high level in pitch at the end. Tone 3 is a low tone. It begins in the middle of a speaker's pitch range, drops to a low pitch level, and rises to a higher pitch level at the end of the vowel. Tone 4 is a falling tone that begins high in the pitch range and falls to a low level at the end of the vowel. (In this figure, Tone 4 begins lower in the pitch range and rises to a higher level before it falls. This initial low pitch may be due to the initial bilabial closure, [m] in "ma", resulting in a delay in realization of peak f0).

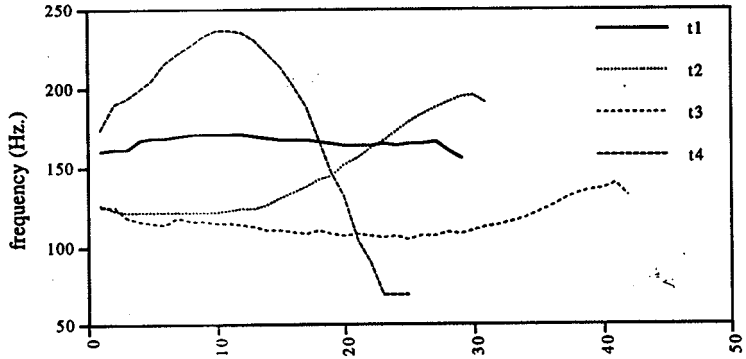


Figure 3.4. Pitch tracks of the Mandarin word "ma" produced with Tone 1(55), Tone 2(35), Tone 3(214), and Tone 4(51) by a male native Mandarin speaker. Each frame on the horizontal axis represents 10 ms (10 frames = 100 ms).

As well as a characteristic tonal pattern, each tone also has characteristic duration and intensity patterns first noticed by Krotachvil, 1968. The intensity patterns resemble the tonal patterns within each tone. According to Kratochvil, Tone 1 remains constant in intensity throughout, Tone 2 increases in intensity at the end of the vowel; Tone 3 has a slightly falling intensity; and Tone 4 drops sharply in intensity at the end of the vowel. The durations of tones also differ. The longest tone, in citation form, is tone 3. The shortest is tone 4. Tone 1 and Tone 2 are intermediate in duration in comparison. These four tones in Mandarin are overlaid in Figure 3.11 to illustrate differences in duration.

The tonal shapes of two tones in Mandarin, at least in isolaation, are similar to two common intonation patterns in English. The fall-rise tonal pattern (MLH) of tone 3 in Mandarin is similar to the question intonation pattern in English (L*H-H%); and falling tone 4 (HL) is similar to the English statement intonation pattern (L+H* L-L%). Figure 3.5a and 3.5b illustrate this similarity in these two languages. A native Mandarin speaker produced the Mandarin word "ma", meaning "horse" with Tone 3 and the word "ma" meaning "to scold" with Tone 4. A native English speaker produced the word "mom" as a question with a rising intonation pattern and as a statement with a falling intonation pattern. Even though the intonation systems are very different in these two languages, the tonal patterns are very similar in these examples. The pitch tracks in Figure 3.5a and 3.5b can be described with the same tonal patterns. In Figure 3.4a, both pitch tracks begin middle in pitch range, fall and then rise at the end of the utterances. In Figure 3.4b, both pitch tracks rise and then end with a steep fall.

Figure 3.4a. Pitch tracks of productions of he words "ma" [tone 3] meaning "horse" by a native Mandarin speaker and "Mom?" [question intonation] by a native English speaker to illustrate the similarity in f0 patterns.

Figure 3.4b. Pitch tracks of productions of he words "ma" [tone 4] meaning "to scold" by a native Mandarin speaker and "Mom." [statement intonation] by a native English speaker to illustrate the similarity in f0 patterns.

To more fully understand the nature of f0, duration, and intensity manipulations in Mandarin, it is necessary to understand how intonational meaning affects these acoustic parameters. The following section reviews how prominence influences the realization of tones in Mandarin.

3.3.2 Stress and prominence

Like English, lexical stress exists in Mandarin. Unstressed syllables and words are produced with the neutral tone 5; "neutral" because tone 5 has no intrinsic tonal properties. There are two types of categories of neutral or toneless syllables. The first category includes syllables or words with no underlying tonal specification. Prepositions and enclitics, for example, have no dictionary tonal specification. The particles "zi" and "ma" are examples of such forms. The tonal realization of the these morphemes is determined by the preceding syllable (Jin, 1996). The f0 pattern produced in the morpheme "zi" in the following example is influenced by the tone of the preceding syllable and is produced in five different ways.

1. zhuo55 zi2	"desk"
2. fang35 zi3	"house"
3. yi21 zi4	"chair"
4. deng51 zi1	"stool"

The second category of unstressed or toneless morphemes appears within noninitial syllables in polysyllable words. This category of unstressed morphemes is more like that of English unstressed syllables. In this category, an underlying tonal specification exists but is not realized within production. Pairs like "'ma214tou" (pier) and "ma214'tou214" (horse's head) differ in that the second syllable is not stressed and has no tonal specification in the word meaning "pier" while the second syllable is stressed in "horse's head" and produced with Tone 3. Unstressed syllables in this case lose their characteristic intrinsic fundamental frequency patterns and become toneless. This situation is similar to English in that stress can be used to contrast words, as in 'subject and sub'ject. However, there is an important difference. In English, the position of stressed and unstressed syllables is not confined to any particular pattern. For example, the first syllable in "'memorize" is stressed, the second in "me'morial", and the fourth in "memori'zation". In Mandarin, the first syllable must be stressed, but the second syllable need not be stressed. This is why the first syllable in the Mandarin pair above, "'ma214tou" and "ma214'tou214", remains stressed in both pairs and only the second syllable contrasts.

Unstressed syllables are not as common in Mandarin as they are in English. In English, at least one syllable in a multisyllabic word must be stressed. The majority of English multisyllabic words contain both stressed and unstressed syllables. This is not the case in Mandarin where the majority multisyllabic words do not have lexically unstressed syllables.

The realization of stressed syllables and words in Mandarin is affected by how salient a word is within an utterance. As in English, the acoustic properties of stressed syllables depends on that word's level of prominence. Previous researchers in Mandarin have observed changes in f0, duration, and intensity within more prominent syllables and words although there is disagreement as to the saliency of these

correlates (Chao, 1968; Garding, 1987; Shih, 1988). A word can be made more prominent in discourse in Mandarin, according to Shen (1990), by giving additional stress (acoustic prominence) to a stressable syllable in a polysyllabic phrase. The degree of stress within a syllable is related to the amount of relative prominence or importance that word has in a given context. Because fundamental frequency in Mandarin is the most salient feature of lexical tones, prominence or contrastive stress interacts with the production of lexical tones.

Shen has reported that prominent syllables within focused constituents are generally produced within a wider pitch range (1990). Shih (1988) has reached a similar conclusion, observing that low tones are produced with lower f0 values, and high tones are produced with higher f0 values. Shen also reports that prominent syllables are longer in duration, while tones that are not prominent are reduced: "On the one hand, a tone-carrier loses its underlying tone only when it is unstressed; inversely, a toneless neutral tone recovers its underlying tone when stressed" (p. 60). For example, the syllable "shen" in "baoshengong" (indentured laborer) is unstressed in connected speech and "shen" loses its characteristic tone and is produced with shorter duration.

Jin (1996) analyzed the acoustic characteristics of f0 change, syllable duration, and peak intensity in tokens produced with and without contrastive stress in Mandarin statements. He observed the effects of contrastive stress on the realization of tones. When observing the effects of stress on all tones, he found that words produced with contrastive stress were produced with twice the pitch range of the same words produced without contrastive stress. The target syllables "wu55", "wu35" and "lu214" and "lu51" were produced with an average pitch range of 46 Hz. in words produced without contrastive stress, and were produced in a pitch range of 86 Hz. in words produced with contrastive stress. The duration of these tokens also increased when they were produced with contrastive stress; duration increased by about 25%, from 150 ms. to 206 ms. Intensity measurements were less informative. No similar patterns could be observed within subjects. Jin concluded that while f0 and duration were characteristic of stressed syllables in Mandarin, intensity was not.

The realization of prominent stressed syllables in Mandarin and English appears to be similar. In both of these languages, prominent syllables are longer, may have greater amplitude, and are realized with a distinct tonal pattern. There is however, an important difference. While the tonal pattern of accented syllables in English is dependent on the choice of pitch accents, the tonal pattern of more prominent syllables in Mandarin is dependent on the tonal specification of that syllable or word in Mandarin. If a word is to be produced with more prominence, the inherent tonal characteristics of the stressed syllable control the direction of the f0 change. High tones are produced higher, and low tones are produced lower. The word is made more prominent by intensifying the intrinsic characteristics of the tone. The direction of the change in fundamental frequency is not a pragmatic choice, but instead a lexically or tonally bound modification in prominent syllables in Mandarin. In English, on the other hand, the choice of one of six pitch accents, is a pragmatic choice, bound to intonational meaning. Although the location of a pitch accent is bound to the lexically stressed syllable in English, the choice of pitch accent, and the contour of the pitch accent, depends on speaker intention (Ward and Hirschberg, 1990).

3.3.3 Intonational Tunes

Intonational meaning in Mandarin is distinguished through changes in overall pitch range, rather than through pitch shape (Shen, 1990). Questions and statements differ

in that they are produced in different parts of a speaker's pitch range. Shen (1990) makes experimental observations of questions and statements produced with what she calls the "intonational minimum" of Mandarin. These are utterances that have not been influenced by narrow focus. A tune, according to Shen (1980) is a description of the f0 contour over an entire utterance that can be said to have a characteristic meaning of its own. Statement intonation, is produced within a lower pitch range relative to question intonation patterns. Questions that have no grammatical question marker are produced in the upper half of a person's pitch range and end with a slight rise. This question pattern is syntactically similar to unmarked yes/no questions in English as might be produced in the following utterance questioning the validity of a person's age: "You're only 39?" Shen posits these changes in pitch range do not change the characteristic shape of tones. A schematized representation of these two tunes are provided in Figure 3.5. These have been adapted from Shen (1990, p34).

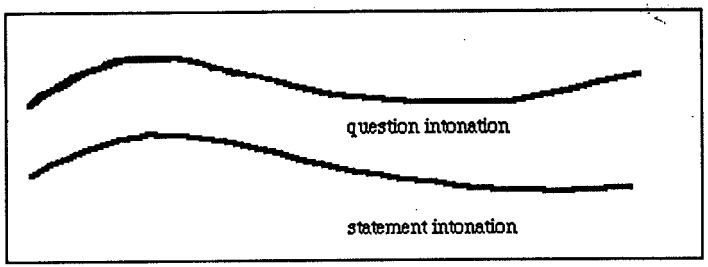


Figure 3.5 Two schematized intonation patterns in Mandarin produced in statements and in unmarked questions.

While pitch level over an entire utterance indicates differences between question and statement intonation in Mandarin, boundary tones aligned with the right edge of intermediate and intonational phrases are used to indicate these differences in English. Rising or falling intonation patterns at the ends of utterances in English are the result of a rise from a low pitch accent to a high boundary tone in questions, and a fall from a high pitch accent to a low boundary tone in English. These two patterns are schematized in Figure 3.6.

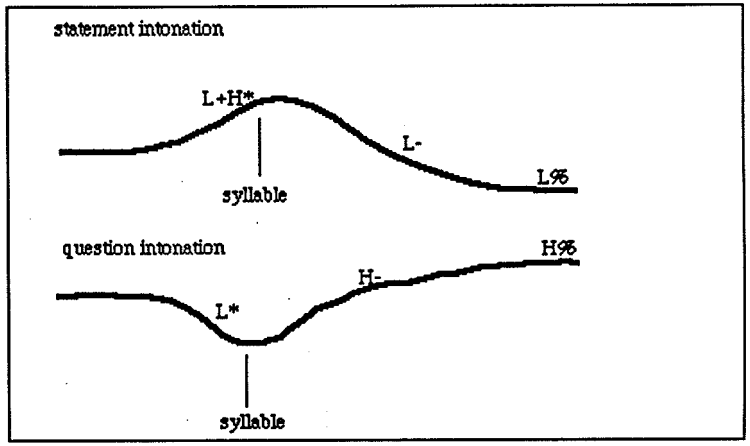


Figure 3.6 Two schematized intonation patterns in English used in statements and yes/no questions.

Intonation patterns in English are the result of tonal movements between tonal targets, these being pitch accents and phrase boundaries; while in Mandarin, intonation patterns are controlled by the tonal properties of words, their relative prominence in an utterance, and the choice of intonational tunes.

3.3.4 Comparisons of English and Mandarin intonation systems

Similarities and differences in Mandarin and English increase the likelihood of transfer of Mandarin intonation patterns into productions of English. The similarity in tonal patterns may be the primary reason why transfer might occur. Tone 3 and Tone 4 are superficially similar to the rising and falling intonation patterns of English. In addition, both are stress languages. Prominent stressed syllables are realized with increased duration and intensity and changes in f0 while unstressed syllables are shorter in duration, less intense, and are not produced with any specific salient tonal pattern. These similarities increase the likelihood of transfer of the acoustic properties of Mandarin intonation patterns into productions of English. **Mandarin speakers will positively transfer the tonal pattern of tone4 to statement intonation in English, and tone3 to question intonation.**

There are differences between these two languages, and this may be negatively transferred to productions in English by native Mandarin speakers. One of the most important differences is that in Mandarin, tones are associated with the meaning of words. In English, pitch accents are associated with intonational meaning. Pitch accents are used to enhance to prominence of a word, but are not a property of a stressed syllable as are tones in Mandarin. Because of this difference, **Mandarin speakers acquiring English will produce stressed syllables with tonal changes in both accented and unaccented words.**

Intonational prominence is linked to stressed syllables in both Mandarin and English and unstressed syllables are reduced, they are shorter, less intense, and are produced without tones. This suggests that **unstressed syllables in English will be reduced by Mandarin speakers acquiring English.**

Prominent words are distinguished from less prominent words in the extent of tonal changes, in duration, and in intensity. This suggests that **like native English speakers, Mandarin speakers acquiring English will produce stressed syllables in more prominent words with longer durations and greater intensities.**

In addition, the possible location of stressed syllables differs in that Mandarin words do not have an initial unstressed syllable while English words do. For this reason, **Mandarin speakers learning English will have difficulty producing initial unstressed syllables in the early stages of language acquisition.**

CHAPTER 4

METHODS

4.1 Subjects

The earlier discussion of the prosodic systems of English, Korean, and Mandarin Chinese, illustrated the unique differences and similarities between these three language. For this reason, native speakers of Korean and native speakers of Mandarin Chinese living in the United States who were using English as a second language were asked to participate in the current experiment. Because dialectal and language differences occur between varieties of Chinese and Korean, care was taken to chose groups of subjects whose native language was most similar. Subjects from Mainland China whose native language was similar to the Mandarin spoken in Beijing, China, and Korean speakers who spoke the Seoul dialect of Korean were asked to participate. These two groups of subjects were divided into groups based on English language proficiency. Mandarin speakers and Korean speakers of English with a higher level of proficiency (M2) and (K2) formed separate groups from less proficient speakers of English (M1 and K1). A test analyzing spoken fluency in English developed and administered by the experimenter was used to determine proficiency in English (Appendix A). This assessment was administered to each participant immediately prior to the experiment. In addition, information likely to affect spoken language fluency was obtained. This included the age when language instruction began (ALI), the amount of naturalistic exposure to English in an English speaking country (ANE), the hours of English spoken daily (HDU), (Appendix B.) The responses from this questionnaire and the proficiency test are listed below in Figure 4.1.

Sub #	Grp	Sex	Age	Birthday	ALI	ANE	HDU	Fluency
17	E	m	24	08.31.71				
20	E	f	23	11.24.72				
23	E	f	24	03.19.72				
31	E	m	31	05.08.68				
32	E	m	32	10.18.63				
39	E	f	43	08.09.52				
41	E	f	31	11.16.68				
mean			**29.7**					
5	K1	f	21	10.17.74	14 yrs	6 weeks	3-5 hrs	67
7	K1	m	26	07.29.69	13 yrs	6 weeks	3-5 hrs	65
19	K1	m	27	03.20.68	12 yrs	8 weeks	3-5 hrs	61
21	K1	f	20	02.04.75	13 yrs	5 weeks	3-5 hrs	62
34	K1	f	35	12.31.61	14 yrs	29 weeks	0-2 hrs	57
35	K1	m	23	11.29.72	14 yrs	3 weeks	0-2 hrs	60
50	K1	f	19	09.29.76	14 yrs	5 weeks	3-5 hrs	57
mean			**24.4**		**13.43**	**8.86 wks**	**3.86 hrs**	**61.3**
6	K2	m	22	12.29.73	13 yrs	2 yrs.2 mos	6 hrs	94
30	K2	m	36	02.08.59	13 yrs	6 yrs. 3 mos	3-5 hrs	87
36	K2	m	23	04.09.72	13 yrs	8 yrs. 5mos	3-5 hrs	99.5
38	K2	f	25	01.24.70	12 yrs	1 yr. 1mos	6 hrs	89
40	K2	m	25	05.03.70	13 yrs	7 yrs.5mos	0-2 hrs	99
42	K2	f	22	10.17.73	13 yrs	6yrs.5mos	0-2 hrs	91
47	K2	f	31	08.30.64	12 yrs	5 yrs. 6 mos	3-5 hrs	92
mean			**26.28**		**12.57**	**5.4 yrs.**	**4.29 hrs**	**93.07**
10	M1	m	22	02.17.73	12 yrs	4 mos	3-5 hrs	66
15	M1	f	31	04.07.64	14 yrs	5 mos	3-5 hrs	67
18	M1	m	29	07.17.66	14 yrs	2 mos	0-2 hrs	64
24	M1	m	25	10.08.70	14 yrs	5 mos	0-2 hrs	47
27	M1	f	31	10.04.64	13 yrs	6 mos	0-2 hrs	53
28	M1	m	26	09.29.69	12 yrs	4 mos	0-2 hrs	64
29	M1	f	24	06.09.71	15 yrs	9 mos	0-2 hrs	51
mean			**26.86**		**13.43**	**5 mos.**	**2.86 hrs**	**58.86**
13	M2	f	23	05.09.72	16 yrs	2 mos	3-5 hrs	84
14	M2	m	27	07.03.68	13 yrs	2 yrs.3 mos	0-2 hrs	81
44	M2	m	29	08.10.66	8 yrs	2.5 yrs	6 hrs	98
45	M2	m	41	03.28.55	21 yrs	9.5 yrs	6 hrs	86
48	M2	m	27	12.14.68	10 yrs	2 yrs.9mos	3-5 hrs	78
49	M2	f	38	08.15.58	18 yrs	8 yrs.	6 hrs	95
51	M2	f	32	09.01.65	13 yrs	13 yrs	3-5 hrs	89
mean			**31**		**14.14**	**4.45 yrs.**	**5 hrs**	**87.29**

Figure 4.1. Personal information for each participant. Mean time periods are given for each subject group. ALI: Age of Language Instruction; ANE: Amount of Naturalistic Exposure; HDU: Hours of Daily Use; Fluency: score derived from spoken proficiency test.

Scores from the spoken English test were the primary factor in determining assignment into groups. Productions of these nonnative speakers of English were compared to those produced by monolingual English speakers (E). These five experimental groups are listed below:

Experimental Groups:

E: Monolingual English speakers
K1: Less Experienced Korean speakers
K2: More Experienced Korean speakers
M1: Less Experienced Mandarin speakers
M2: More Experienced Mandarin speakers

4.2 Stimuli

4.2.1 Stress Type

The stimuli set consisted of three word pairs that differed in the location of primary stress. In each pair of target words, one member the pair had a stressed syllable that occurred early in the word and will be referred to as having *early stress*, and the other member of the pair had a stressed syllable occurring later in the word and will be refereed to as having *late stress*. The 3 stress pairs, 6 target words, with stressed syllables printed in boldface letters were as follows:

Early Stress:	Late Stress:
1. memorizes	2. memorial
3. photography	4. photographic
5. electrical	6. electrician

4.2.2 Intonation Type

Each stress pair was produced in frame sentences of two types: declarative statements and Yes/No questions. Different intonation types were used in order to elicit different types of pitch accents and phrase tones. Statements in English are typically produced with a rise over the last prominent word followed by a fall at the end of the utterance. This rise-fall pattern is [H* L- L%] or [L+H* L- L%]. Yes/no questions are typically produced with a falling tonal movement in the last prominent word followed by a rise at the end of the utterance. This rising intonation pattern is described as [L* H- H*]. Target words produced within sentences that were likely to be produced with these two different types of intonation patterns.

4.2.3 Prominence Type

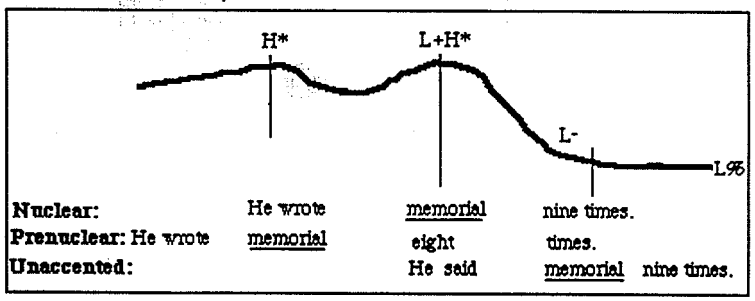
Three levels of prominence exist in English. Words produced with the sentence accent, nuclear-accented words, are most prominent; words produced with a *nuclear accent* before the sentence accent are less prominent, and words produced after the sentence accent are *unaccented* and least prominent. To observe the acoustic characteristics of words produced with differing degrees of prominence, target words were placed in these three different prominence contexts. In the following example, the target word "memorial" appears in three different prominence or accent contexts.

Capitalized words are those that should be produced with the focal or nuclear sentence accent.

Prominence Condition

1. nuclear position:	*He wrote the word MEMORIAL nine times.*
2. prenuclear position:	*He wrote memorial NINE times.*
3. unaccented position.	*He WROTE memorial nine times.*

In order to understand how the prosodic context influences the tonal shape within target words, schematic representations in Figure 4.2a and 4.2b are provided. Each target word appeared in each of three prosodic contexts in statements and in questions. Figure 4.4a illustrates the location of one of the target words, "memorial" in three prosodic contexts in the statement intonation pattern. Figure 4.4b illustrates the location of "memorial" in three prosodic conditions in statement and in yes/no question intonation patterns. These conditions are nuclear position, prenuclear position, and unaccented position.



FFigure 4.2a Target sentences in statement intonation patterns.

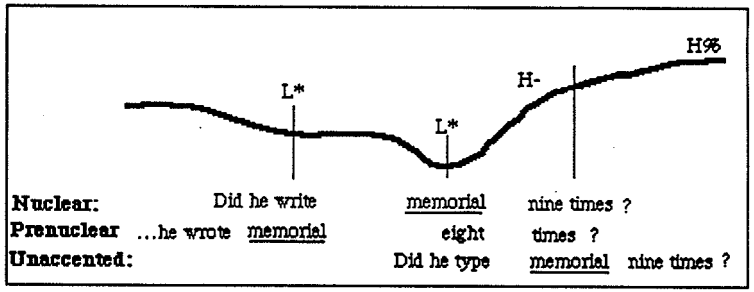


Figure 4.2b Target sentences in question intonation patterns.

As can be seen, the tonal realization of words within these different prosodic positions is affected by the type of intonation pattern used. In statements produced in English, nuclear-accented target words are typically realized with a H* or L+H* accent; prenuclear target words, with a H* accent; and unaccented words are realized within the tonal movement falling from the high pitch accent to the low phrase tones. In interrogatives, nuclear accented words are typically realized with a L* pitch accent; prenuclear targets words may be realized with a L* accent; and unaccented words are realized within the tonal movement rising from a low pitch accent to higher phrase tones. These differences in intonational condition are likely to affect the duration, intensity, and tonal patterns of target words.

Target words were placed in contexts where each of these three levels of prominence were likely to be produced. Each target word was produced in 6 prosodic conditions (2 intonation types X 3 levels of prominence):

Statement Forms:	**Question Forms:**
Nuclear Accented	Nuclear Accented
Prenuclear Accented	Prenuclear Accented
Unaccented	Unaccented

4.3 Procedure

Each of the 6 accent types were placed within 6 frame sentences that appeared in a dialogue provided in Table 4.6. Each dialogue was printed on an 8X10 piece of paper. Target words were repeated six times in each accent type. The first five repetitions were analyzed when possible. If one of these repetitions was of poor quality due to unintentional noise, the 6th repetition was analyzed. A total of 216 target productions (6 target words X 6 repetitions X 6 accent types) were produced in 36 dialogues. The presentation of dialogues was randomized. Each subject read dialogues in the same randomized order. Subjects were offered a 5-10 minute break in the middle of the test session, after recording 108 test sentences in 18 dialogues.

Figure 4.3 Frame Sentences. Words printed in bold faced letters were to be read with the most prominence:

Nuclear
statement: I know he wrote the word X nine times.
question: Did he write the word Y nine times?

Prenuclear
statement: No, he read Y EIGHT times.
question: Did you say he wrote Y EIGHT times?

Postnuclear
statement: He didn't actually WRITE Y eight times.
question: Well then, did he TYPE Y eight times?

Prior to the experimental recordings, subjects were presented with a list of the target words in isolation with the stressed syllable in bold face and were asked to practice saying each word until they became comfortable with the pronunciation of each target

word. This was done to assure that subjects knew which syllable to stress. To facilitate each subject's memory of the stressed syllable, target words were printed with their appropriate stressed syllable typed in bold-face letters and underlined at the top of each test dialogue. In addition, prominent words within each of utterance were typed in capital letters within the experiment (as in the frame sentences above). Subjects were made aware within the instructions that the words in bold faced letters were the most important words within each utterance. A sample dialogue page used within the experiment is provided in Appendix C.

Subjects were recorded in a sound attenuated booth within a laboratory at the Department of Speech and Hearing Sciences at The Ohio State University. Each subject wore a microphone attached to a headset in order to reduced intensity fluctuations. The headset was connected to a JVC stereo cassette deck (model KD-V6J) outside the sound booth. Each subject was asked to count to 25 while the experimenter adjusted to input levels. Input levels were not changed after the experiment began. Subjects were asked to speak at a normal rate throughout the experiment. If a subject clearly produced the wrong stress pattern within a word (i.e., "pho'tographic" instead of "photo'graphic"). The experimenter interrupted and requested the subject to repeat the entire dialogue. This was a difficult task. The experimenter used her native English perception of stress and accent to decide if a nonnative speaker produced the correct stress pattern, therefore, only when subjects produced target words differently from productions in the pre-experimental session, were they asked to repeat a dialogue.

4.4 Data Analysis

4.4.1 Segmentation

The utterances were analyzed using XWaves (a speech analysis program developed by Entropic Research Laboratory). Target utterances were digitized at 16 kHz with 16 bit amplitude resolution. The first five repetitions were analyzed unless one of these was affected by hesitation, mispronunciation, or incorrect focus placement. In this case, the sixth repetition was analyzed. Oscillograms and wideband spectrograms were used to locate syllable boundaries. The vocalic portion of each target syllable marked by regular periodic voicing was delineated for comparison purposes. Syntagmatic comparisons of two target syllables in each word were made. This comparison controlled for possible durational changes that are likely to have occurred within each dialogue and throughout the entire experimental session.

The first and second syllables were compared in "memorizes" and "memorial", and the second and third syllables were compared in the word pairs "photographic" and "photography" and "electrical" and "electrician". Guidelines used by Peterson and Lehiste (1960) were used to determine segmental boundaries.

Figure 4.7 provides the waveforms, a wideband spectrograms, and pitch tracks (the f0 contours) used to aid in segmentation of the targets "memorizes" and "memorial". Three time points used to delineate the beginning of the first syllable, the end of the first syllable-and the beginning of the second syllable, and the end of the second syllable. The vertical lines in Figure 4.7 represent these times: Time1, Time2 and Time 3. The first syllable included the segments "me-", the second syllable included the segments "-mor-" in "memorizes" and in memorial. Spectrograms were primarily used to locate the three time points. The damping or decrease in spectral energy seen in the spectrograms and the decrease in intensity seen within the waveforms at the onset of the nasal [m] in both the first and second syllables of these target words were used to determine both Time1 and Time 2. The place where a rise in the second

formant met a fall in the third formant was determined as the end of the [r], Time 3. In addition, these productions were listened to for auditory confirmation.

Figure 4.4 Waveform, spectrogram, and pitch track, used to delineate syllable boundaries in "memorizes" and memorial.

Figure 4.8 provides a waveforms, spectrograms, and a pitch tracks of the target words "photography" and "photographic" to illustrate how the second and third target syllables were segmented. Four time points were used to delineate the target syllables in this word pair. The first target syllable occurred between Time 1 and Time 2 and included the vocalic portion of the second syllable "-to-"; the second target syllable between Time 3 and Time 4 included the sonorant portion of the third syllables. Waveforms were used in determining these time points. The onset of regular periodic voicing was a reliable cue in determining Time 1 and Time 3. The cessation of periodic voicing or the obvious decrease in waveform energy was used in determining Time 2 and Time 4.

Figure 4.5 Waveform, spectrogram, and pitch track, used to delineate syllable boundaries in "photography" and photographic.

Figure 4.9 provides a waveforms, spectrograms, and a pitch tracks of the target words "electrical" and "electrician" to illustrate how the second and third target syllables were segmented. Four time points were used to delineate the target syllables. It was difficult of identify the offset or end of the [l] in these words, so this liquid was included within the first target syllable. The second target syllable included both the liquid and vowel "-ri-". Time 1 and Time 2 encompassed the first target syllable; Time 3 and Time 4 encompassed the second target syllable. Spectrograms and waveforms were used to determine these time points. Time 1 was identified where periodic voicing began after glottalization of the word-initial vowel, and the time when energy at the third formant ended when alveolar contact was made for [l]. The end of periodic voicing visible in waveforms and spectrograms were a strong cue for delineating Time 2. The onset of periodic voicing after aspiration of the [t] visible in waveforms and in the appearance of the voice bar in spectrograms marked Time 3. The end of periodic voicing as seen by the decrease in amplitude in waveforms and in spectrograms marked Time 4.

Figure 4.6 Waveform, spectrogram, and pitch track, used to delineate syllable boundaries in "electrical" and "electrician".

4.4.4.1 Duration

The word pairs memorizes/memorial, electrical/electrician, and photography/photographic were analyzed for duration differences. The duration of the early target syllables in each word were compared, as were the later target syllables. For example, the early syllables "me-" in each word were compared; reduced syllable "me-" in "memorial" was compared stressed syllable "me-" in "memorizes", as were the later syllables "-mor-", unstressed in "memorizes" and stressed in "memorial". The duration of the sonorant portion of each target syllable was obtained by subtracting the time of the onset of the syllable by the end of that syllable. These time points have been described previously in Section 4.4.

4.4.1.2 Intensity

The word pair memorizes/memorial was analyzed for average intensity differences. The average intensity was obtained by calculating the total intensity, in RMS, within target syllables, and then dividing this total RMS value by the duration of the syllable. This average amplitude in RMS was transferred into decibel values (dB.) and this value was used as the dependent measure in statistical observations. Similar to duration measures, the average intensities of the early target syllables in each word were compared, as were the average intensities of later target syllables.

4.4.1.3 Fundamental Frequency

F0 comparisons in the word pair "memorial" and "memorizes" were observed. Four different types of comparisons were made invoving one or more types of analysis.

First, an analysis of tonal patterns used within target utterances was made in order to understand the distribution of different accent types produced by each group of subjects so that appropriate comparisons could be made. Tonal patterns were described as rising (LH), rising/falling (LHL), falling (HL), and unaccented (UN).

Based on these results, three different types of measures were taken in order to isolate the possible differences in tonal patterns produced in questions and in statements.

F0 minimum: The location of the f0 minimum relative to the onset of the stressed syllable in target words was used to isolate the location of the initial rise in LH and LHL pitch accents. The lowest f0 value before the onset of a tonal rise was determined as the f0 minimum. This time point is illustrated in Figure 4.10. The onset of the stressed syllable was determined by a set of criteria described in the durations section of this section 4.4.4.1. The dependent measure was the difference between these two values obtained by subtracting the location of the f0 minimum from the time of the end of the stressed syllable. Positive measures indicate the rise began within the stressed syllable and negative measures indicate the rise began before the stressed syllable.

F0 maximum: The location of the f0 maximum was identified in productions of target words relative to the end of target words, "memorial" and "memorizes". The

dependent measure was the difference between the f0 maximum and the end of the target word, obtained by subtracting the time of the f0 peak from the time of the end of the word. The f0 peak was identified as the highest f0 value within the target word. In most productions by E, an f0 peak did not exist. Instead, an f0 shoulder or bend occured. This was realized as a steep rise that tapered off into a less steep rise. This value is illustrated in Yes/No questions in Figure 10. This location was determined by isolating the point in time where an increment in f0 was less than the previous increment. As an illustration, if f0 was continually rising 4 Hz. every 20 ms. (f0 is calculated every 20 ms. in XWaves) over a period of 200 ms, and then tapered off to a 2 Hz increment, the time when the step size (in Hz.) decreased was determined as the f0 maximum (f0 bend, in this case).

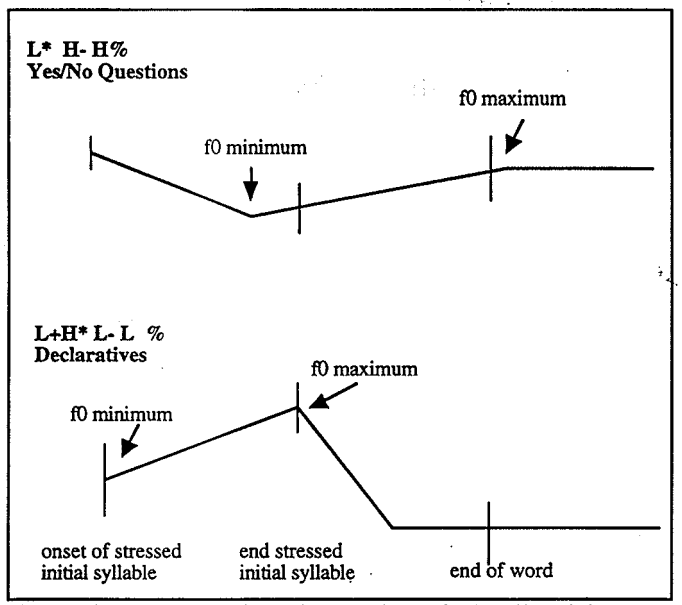


Figure 4.7. Schematized illustration of the f0 minimum and f0 maximum.

F0 excursion: The distance in Hz. of the initial LH rise in nuclear accented targets was obtained by subtracting the f0 minimum from the f0 maximum.

In addition to these measures, the timing of the f0 maximum in productions of targets produced with LHL tonal patterns was observed to capture the timing of pitch accents in productions of nuclear accented words produced only in statements. The highest f0 value following a word initial low tone was determined as the f0 minimum. This value is illustrated in declaratives in Figure 4.10. The end of the stressed syllable was determined by the criterea described in Section 4.4.1.1 of this chapter. The dependent measure was obtained by subtracting the location of the f0 maximum from the time of the stressed syllable end. Resulting negative values indicate the f0 peak ocurred within the stressed syllable, and positive values indicate theat the peak ocurred after the stressed syllable.

All of the above measures were used as the dependent measure in separate ANOVAs. In each ANOVA, language group was treated as a repeated measure, and stress type, intonation type, and repetition were treated as within subjects variables.

CHAPTER 5

RESULTS OF FUNDAMENTAL FREQUENCY COMPARISONS

5.1 Intonation Patterns Within Target Words and Utterances

In order to devise measures that can capture phonetic differences in the intonation patterns used by native and nonnative speakers of English in target words, it is necessary to first describe the tonal patterns used. That is, unless we know what tonal patterns were being produced by subjects in each language group, we cannot know what aspects of the f0 contour to use in appropriate statistical comparisons.

This section describes the intonational characteristics of describing the tonal patterns occurring within five repetitions of the word "memorial" and "memorizes" produced in differing prosodic conditions by each of seven subjects in each language group. The intonation patterns in target words are described as having one of tonal patterns that move between low (L) and high (H) tonal targets. A rising tonal pattern that continued throughout the word, for example, was described as having a LH contour; a falling pattern, HL; and a rising tonal pattern followed by a fall, LHL. These patterns will be described in more detail and illustrated as they become relevant to the results.

Five repetitions of "memorizes" with first syllable stress and "memorial" with second syllable stress were analyzed in each of six prosodic conditions. Each prosodic condition will be separately described. These words were produced within a nuclear-accented condition, a prenuclear condition, and a postnuclear unaccented condition. Each of these three conditions were produced in a statement and in a question. Targets produced in nuclear-accented conditions will be discussed first, followed by targets produced in prenuclear and postnuclear unaccented conditions.

5.1.1 Nuclear accented condition

5.1.1.1. Statements

"Memorizes" and "memorial" were placed in sentences where they should be read (produced) with the most prominence, in a nuclear accented condition, in the following utterance:

"I know he wrote the word MEMORIZES/MEMORIAL nine times."

Capitalized words are those that subjects were told to produce with the most importance, or prominence.

Native English Speakers.

Native English speaking subjects produced a steep rising tonal pattern consistent with a L+H* pitch accent, followed by a L- phrase tone in their productions of "memorizes" and "memorial". All five repetitions of these words produced by each of the seven native English speakers were produced with this pattern. Representative utterances of "memorizes" and "memorial" produced with a nuclear accent by a native

English speaker are provided in Figure 5.1. Vertical lines delineate the beginning and end of each target word.

A. "I know he wrote the word MEMORIZES nine times."

B. "I know he wrote the word MEMORIAL nine times."

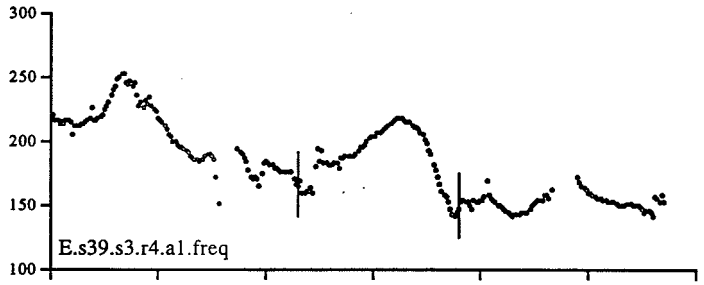


Figure 5.1 The words "memorizes" and "memorial produced with a LHL tonal pattern by a native English speaker, Subject 39, with a statement nuclear accent. Vertical lines mark the beginning and end of target words.

The intonation contours of the phrases in Figures 5.1a and 5.1b are the same. The words "know" and "memorizes (memorial)" were produced with tonal patterns characterized by a L+H* pitch accent. The high f0 peak in each target word is lower than the peak in "know" because of declination, the gradual decrease in f0 throughout the utterance. These pitch accents realized as prominent steep f0 movements are clearly visible in these pitch tracks. Characteristic of this type of pitch accent is a steep rise in f0 within the stressed syllable of the prominent word. A prominent f0 rise occurs within the stressed syllable in "memorizes" in 5.1a and in "memorial" in 5.1b. The f0 peak in "memorial" with a later stressed syllable is delayed relative to the word onset in comparison to the f0 peak in "memorizes". This is seen as a shift in the f0 rise to the right. Both targets are produced with the same intonation pattern.

The difference between the f0 contours provided in Figures 5.1a and 5.1b is not the tonal pattern; both utterances are produced with the same pitch accents and boundary tones. What differs between them is the timing of the initial tonal rise in the different target words. Because a pitch accent is associated with a stressed syllable in English, a steep rise begins early in "memorizes" with initial stress, and later in "memorial" with a later stressed syllable. This difference is evident in these utterances where a tonal rise begins at the onset of the target word in Figure 5.1a and is delayed in Figure 5.1b. Both target words are followed by steep a tonal fall as f0 moves to a low L-phrase tone. This low tonal phrasal target is reached well after the end of the stressed syllable in "memorizes" and "memorial" and closer to the ends of these target words. Both utterances also end with a L% intonational boundary tone. The postnuclear words "nine" and "times" are produced without prominent tonal movements by this subject within these low boundary tones.

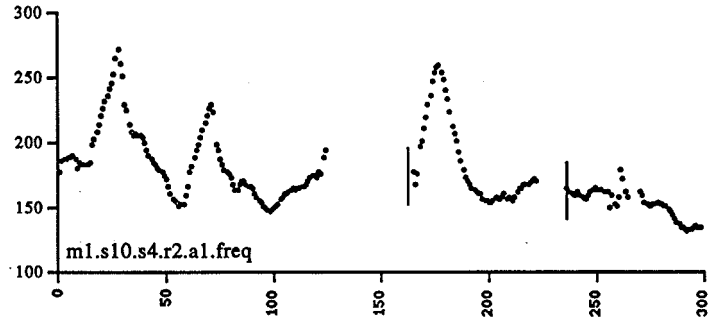
The phrasing of utterances produced by E speakers was also observed. Target utterances containing the word "memorial" were analyzed for this purpose. Two subjects produced target utterances in one intonational phrase. This phrasing is examplified in Figure 5.1. The words "know" and "memorial/memorizes" are produced with pitch accents. This phrasing can be described as: [(I know he wrote the word memorial nine times)]. Brackets encompass an intonational phrase, and parenthesis encompass intermediate phrases. The underlined words in this and following examples are produced with prominent changes in f0, associated with pitch accents by native speakers of English. The remaining subjects in E produced three intermediate phrases within one intonational phrase: [(I know he wrote the word)(memorial)(nine times)]. These subjects spoke at a slower rate of speech and appeared to careful in producing every content word with clarity. In the first phrase, these subjects produced "know", "wrote", and "word" with a pitch accent in a downstep pattern. Downstepped, in that these words were produced within progressively compressed pitch ranges, creating a stepping pattern within the intermediate phrase. "Memorial" was produced with a prominent L+H* pitch accent within its own intermediate phrase, and "nine" was produced with a pitch accent followed by an unaccented "times". The following is a summary of the intonational phrasing of E productions:

Intonational phrasing by E subjects:
A. [(I know he wrote the word)(memorial)(nine times)]
(Speakers: S20, S23, S31, S32, S41)
B. [(I know he wrote the word memorial nine times)]
(Speakers: S17, S39)

M1 Speakers

Less experienced English speaking Mandarin subjects in M1 produced intonation patterns similar to E in "memorial". Most M1 subjects also produced a similar pattern in "memorizes". Representative utterances by an M1 speaker are provided in Figure 5.2a and 5.2b.

A. I know he wrote the word MEMORIZES nine times."



B. I know he wrote the word MEMORIAL nine times."

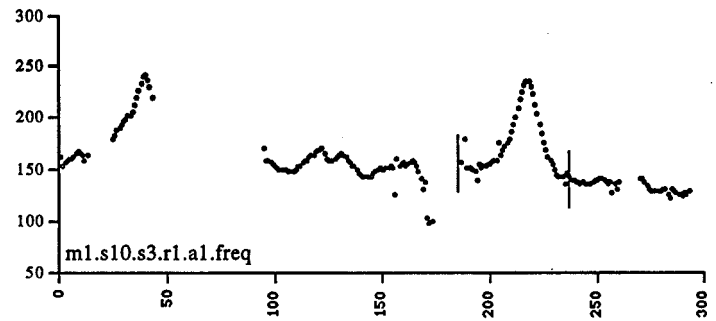


Figure 5.2 The utterances, "I know he wrote the word "memorizes"("memorial") nine times." with target words produced with a LHL tonal pattern by an M1 speaker, Subject 10. Vertical lines mark the beginning and end of target words.

These intonation patterns in Figure 5.2 are similar to those produced by E. The words "know" and "memorial" are produced with LHL tonal patterns that are similar to the tonal movements in productions by native English speakers. A rising tone occurs within the stressed syllable of each target word. The rise begins early in "memorizes" with initial stress and is delayed in "memorial" with second syllable stress. A fall in f0 is realized after this rise and is completed within the target word. The f0 level remains low until the end of the utterance. "Nine times" is produced within this utterance final low pitch range. The tonal patterns produced in target words are very similar to those produced by E.

An important aspect of these results is the number of speakers who produced the same tonal pattern in the different target words. Five of the seven M1 speakers produced the same LHL tonal pattern target words having different stressed syllables. Two M1 speakers did not. These two speakers produced rising LHL pattern in "memorial" with an intitial steep slope, but a (L)HL pattern in "memorizes" with a very reduced initial rise. A representative example of these productions is provided in Figure 5.3a and 5.3b. The intonation patterns of these two utterances are not the same, unlike those produced by most M1 subjects and all E subjects.

A. I know he wrote the word MEMORIZES nine times."

B. I know he wrote the word MEMORIAL nine times."

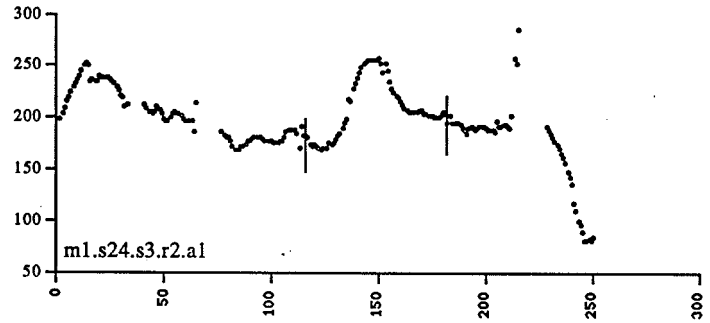


Figure 5.3 The, "I know he wrote the word "memorizes" ("memorial") nine times." with "memorizes" produced with a LH tonal pattern and "memorial" produced with a LHL tonal pattern by M1 speaker 24. Vertical lines mark the beginning and end of target words.

In this same subject's productions of "memorial", on the other hand, a LHL tonal movement similar to productions of this word by all M1 speakers and all E speakers. So while the intonation contexts are the same in these two utterance, the intonation patterns in them differ. It appears that for these two M1 speakers, a different tonal pattern is associated with words that differ in stress patterns.

For native English speakers, the stress pattern of target words does not control the intonation pattern. The location of a stressed syllable in a word does not control the choice of pitch accents and boundary tones in English; instead, the choice of pitch accents and boundary tones controls the tonal pattern of English utterances. However, the location of a stressed syllable, controls the timing of tonal movements. As was pointed out in Figure 5.1a and 5.1b, the rise in a L+H* pitch accent begins at the onset of the word "memorizes" and is delayed in "memorial".

Another important difference between productions by M1 speakers is the tonal contour produced after each target word. In productions by the M1 speaker in Figure 5.2, the f0 pattern moves to a low level after each target word, and remains level until the end of the utterance. "Nine" and "times" are produced within these low tones. This is similar to the intonation patterns produced by two E speakers. A very prominent steep f0 fall is produced within the final portion of the target words produced in this nuclear accented condition. Productions in Figure 5.3., have a different intonation pattern. The word "nine" is produced with another prominent rise, and so a steep fall does not occur at the end of target words, this fall is interrupted by the rise in "nine".

The phrasing, and location of tonally prominent words were analyzed in utterances including the target word "memorial". In these descriptions of M1 productions, and all nonnative speakers in this experiment, the terms "intermediate phrase" and "intonation phrase" are used to describe the phrasing of utterances. These terms refer to two levels of prosodic phrasing, where intonational phrases consist of one intermediate phrase. These terms are not meant to suggest that nonnative speakers are using an English system of phrasing.

Four M1 subjects produced intonation patterns like those illustrated in Figure 5.2. The phrasing of these utterances is described here as: [(I know he wrote the word memorial nine times)]. "Know" and "memorial" are produced with prominent f0 movements. "Memorial" is the last tonally prominent word in the phrase. It is produced with steep initial f0 rise, followed by a steep f0 fall. One M1 subject produced "memorial" and "nine times" in separate phrases. In this case, a steep fall was produced after the intial LH rise in "memorial", followed by another tonal rise in the next phrase in the word "nine". The phrasing of these utterances are described as [(I know)(he wrote)(the word)(memorial)(nine times). These five subjects produced the target word "memorial" with a steep LH rise followed by a steep L fall.

Two subjects produced intonation patterns like those exemplified in Figure 5.3. In these productions, target words were followed by another accented word within the same phrase. The phrasing of these utterances is described here as [(I know he wrote the word)(memorial nine times)]. Like all M1 speakers, these two speakers produced a steep LH rise in the beginning of the word "memorial"; unlike the majority of M1 speakers, these two speakers produced another LH rise within the neighboring word "nine" and an f0 fall in the word "times." A steep word-final tonal fall was not produced by these two M1 speakers. A scematic representation of this tonal pattern is used to illustrate differences in these two M1 speakers and two E speakers in Figure

5.4. Producing an additional rise and fall at the ends of statements, potentially changes the prominence of target words. The last pitch accented word in an intermediate phrase is the most prominent in English. The utterances produced by E illustrate how very prominent tonal changes are produced within nuclear accented words. A sharp f0 rise is followed by a sharp f0 fall in all of E productions and these tonal changes potentially enhance the acoustic prominence of nuclear accented words.

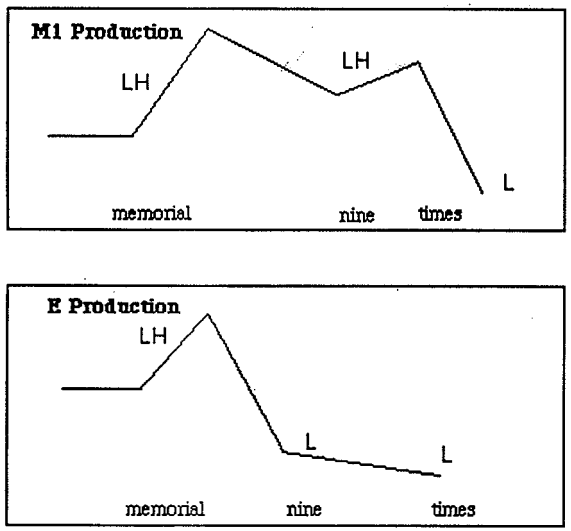


Figure 5.4 Schematized representations of f0 contours produced within targets produced in a statements in a nuclear accented condition.

The phrasing of M1 utterances are summarized as being:

A. [(I know he wrote the word memorial nine times)]
(S10, S18, S27, S28)
B. [(I know)(he wrote)(the word)(memorial)(nine times)
(S29)
C. [(I know he wrote the word)(memorial nine times)]
(S15,S24)

There are two important results to consider . First is that five speakers in M1 produced consistent steep rising tonal patterns in both target words, while two M1 speakers produced different tonal patterns in each target word. These two subjects produced different intonation patterns in words differing in the location of the stressed syllable. "Memorizes" initiated with a stressed syllable followed by an unstressed syllable was produced with a tonal fall, and "memorial" initiated with an unstressed syllable followed by a stressed syllables was produced with a prominent steep initial rise. Because these words were produced in identical contexts, the stress patterns of words must influence these productions. Second, two M1 subjects produced a falling f0 pattern at the ends of "memorial" that were different from those of E. These speakers did not produce a word-final steep f0 fall in target words, potentially decreasing the acoustic prominence of these targets.

M2 speakers
The more experienced Mandarin speakers, M2, produced rising tonal patterns in targets like those subjects in M1. All productions of "memorial" were produced within a steep initial LH rise, and six of the seven M2 subjects also produced a steep tonal LH rise in "memorizes". One subject produced a falling HL tonal pattern in "memorizes" like those produced by two subjects in M1.

The phrasing of these utterances in these more proficient Mandarin-English speakers was more like those of E. Three M2 subjects produced each utterance with one intonational phrase consisting of three intermediate phrases. These can be described as [(I know he wrote the word)(memorial)(nine times)]. Three M2 subjects produced one intonational phrase consisting of one intermediate phrase: [(I know he wrote the word memorial nine times)]. One subject produced one intonational phrase consisting of three intermediate phrases: [(I know)(he wrote the word)(memorial nine times)]. In each production by all M2 speakers, "memorial" was the last word in the intermediate phrase. In each production, a steep fall in f0 following the intial steep f0 rise. The tonal patterns in targets words and the phrasing of utterances were similar in productions by E and M2. One difference between E and M2 productions was in the number of tonally prominent words in each utterance. M2 speakers were less likely to produce "wrote" and "word" with acoustically prominent tonal changes (as determined by this experimenter).

A. [(I know he wrote the word)(memorial)(nine times)]
(S48, S49, S51)
B. [(I know he wrote the word memorial nine times)]
(S14, S13, S44)
C. [(I know)(he wrote the word)(memorial nine times)]
(S45)

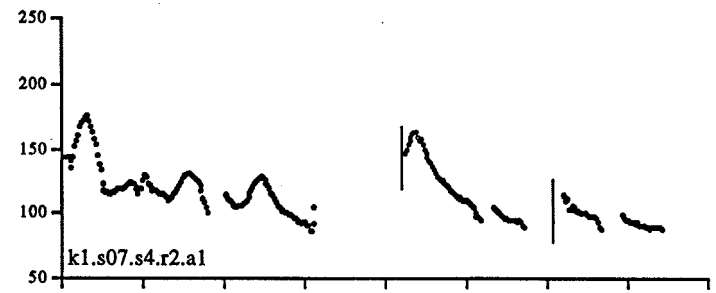
To summarize these results, all productions of the target word with a stressed second syllable, "memorial" were produced with a similar word-initial steep tonal rise by all

subjects in M1 and M2 groups. In addition, most subjects in both M1 and M2 produced this same tonal pattern with this steep initial rise in "memorizes" with first syllable stress. Two subjects in M1 and only one subject in M2 produced a different tonal pattern in "memorizes" with a shallow initial rise suggesting that for these three subjects, the stress pattern of target words influenced the tonal patterns produced in these words. The phrasing of utterances in M2 productions were more like those of E, where target words were produced last in an intermediate phrase, and were produced with a steep word-final steep tonal fall.

K1 subjects

The less experienced English speaking Korean subjects, K1, performed most like the Mandarin subjects. These native Korean speakers, however, were as a group influenced to a greater extent than were the native Mandarin speakers by the stress pattern of target words. The f0 contour realized in "memorizes" differed from the contour in "memorial". While all K1 productions of "memorial" were produced with a steep initial rising LH tonal pattern, the majority of K1 subjects, five of seven subjects, produced a shorter initial rise followed by a f0 fall in "memorizes". A steep f0 fall followed the peak in all productions of both targets. A LHL describes patterns in "memorial", and a HL pattern describes patterns in "memorizes". Representative productions of "memorizes" and "memorial" by a K1 speaker are provided in Figures 5.5a and 5.5b. While the f0 rise in "memorial" is long and steep, the f0 rise at the onset of "memorizes" is shorter and shallower in comparison. The location of the stressed syllable in target words seems to influence the shape of the intonation contour in these productions.

A. I know he wrote the word MEMORIZES nine times.



B. I know he wrote the word MEMORIAL nine times.

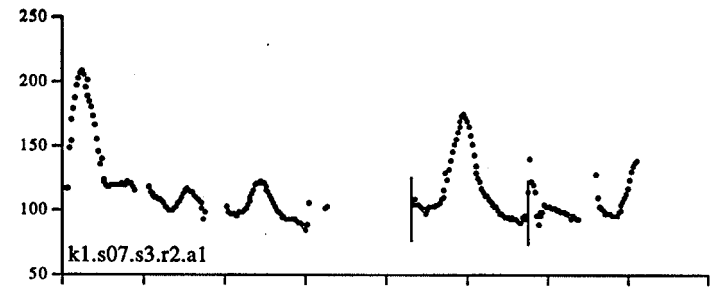


Figure 5.5 The utterances, "I know he wrote the word "memorizes"("memorial") nine times." with "memorizes" produced with a HL tonal pattern, and "memorial" produced with a LHL tonal pattern by a speaker in K1, Subject 07. Vertical lines mark the beginning and end of target words.

F0 moves to a lower target after the prominent high peak in target words. Like native M2 and English speakers, target words in this most prominent context are produced with a steep word final tonal fall. In the productions in Figure 5.5, "nine times" is produced without prominent tonal changes within the lower part of this person's pitch range.

While these intonation patterns are similar in that the same words are tonally distinct and the final phrase tones are the same, they differ in that the tonal shape realized within target words differ. In short, the majority of K1 speakers produced a tonal pattern in "memorizes" that was different from the tonal pattern produced in "memorial". Similar to teh minority of M1 and M2 speakers who did the same, the stress pattern of the target word appears to have influenced the intonation pattern produced within the utterance.

Flege's Speech Learning Model can be used to explain why these different tonal patterns might be produced in "memorizes" and "memorial". K1 speakers may be producing target utterances with the tonal characteristics of Korean accentual phrases. There are noticable tonal rises and falls within the words "know", "wrote", "word", "memorizes" in Figures 5.5a. There are no tonal rises produced within "nine" and "times." The phrasing of this utterance can be described in Korean as consisting of two intonational phrases; the first comprised of three accentual phrases and the second comprised of one accentual phrase. "Memorizes" is produced with narrow focus:

[(I know)(he wrote)(theword)] pause [(memorizes nine times)]

In terms of Korean intonation, LHL tonal patterns consistent with accentual phrases are produced within each of these phrases. Dephrasing has occured within the last accentual phrase. The pitch range at the beginning of the word "memorizes" is expanded, and the words following this focussed word are produced within the same accentual phrase as the prominent word "memorizes". This is a clear example of intonational phrasing and prominence through expanded pitch range in Korean. "Memorizes" with a first stressed syllable is produced with an expanded H tone realized in the beginning of this word. This tonal pattern is similar to Korean intonation.

In terms of the SLM, the tonal pattern produced in the utterance with "memorial" is a new intonation pattern for Korean speakers. This is because the location of the later stressed syllable is unlike any pattern in Korean. Prominent rises are associated with the beginnings of words in Korean, and so a tonal rise produced in the first syllable of "memorizes" conforms to this pattern. A non-initial stressed syllable in "memorial" associated with a later tonal rise, is a "new" linguistic structure for native Korean speakers.

The majority of K1 speakers may have transferred the tonal shape of prominent accentual phrases in their L1 to productions of "memorizes" in the L2. These speakers were producing this focussed word in English with the same tonal pattern produced in Korean. On the other hand, K1 speakers could not transfer this pattern to productions of "memorial"; this word is not prosodically similar to a word in Korean. In this case, five out of seven K1 speakers in this study produced a steep rising tonal pattern in "memorial" that was like that of E. These speakers acquired a "new" tonal pattern for "memorial" but did not acquire a "similar" pattern for "memorizes."

The phrasing of all K1 productions of utterances containing the word "memorial" was observed. Here the terms "intermediate phrase" and "intonational phrase" are used to describe the prosodic constituents in these utternces. All K1 speakers produced utterances with two or three intonational phrases, and all K1 speakers produced either "memorial" as the only tonally prominent word in an intermediate phrase or at the beginning of an intermediate phrase. Two speakers produced utterances with the following phrasing: [(I know)(he wrote)(the word)][(memorial nine times)]. This pattern was produced by S07 in Figure 5.5. These are the only two subjects to produce "nine" and "times" within the same intermediate phrase. Four subjects produced [(I know)(he wrote)(the word)][(memorial][(nine times)], and one speaker produced [(I know)(he wrote)(the word)(memorial)][(nine times)]. In the first pattern described here, "nine times" was produced without prominent tonal changes, and in the latter two pattens, "nine times" was produced with tonally distinct movements within a separate phrase. In these latter cases, "nine" was produced with a tonal rise and "times" was produced with a tonal fall. These utterances, in comparison to the similarly less proficient M1 speakers, were produced with many more tonally distinct movements realized within almost every content word.

The intonational phrasing of utterances produced by K1 speakers are:

[(I know)(he wrote)(the word)][(memorial nine times)]
(S05. S07, S19, 50)
[(I know)(he wrote)(the word)][(memorial][(nine times)]
(S34, S35)
[(I know)(he wrote)(the word)(memorial)][(nine times)]
(S21)

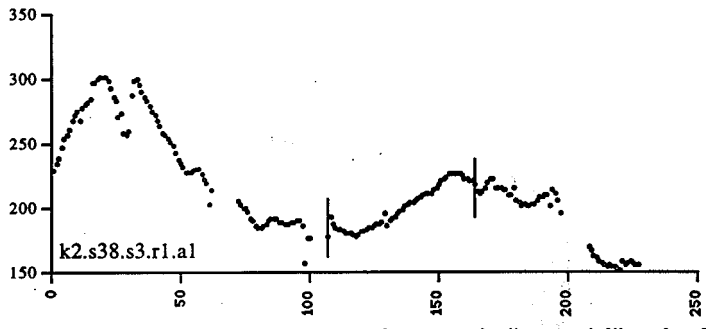
K2 speakers

K2 speakers produced two different tonal patterns in "memorial": a LHL tonal pattern was produced by five K2 subjects, and a LH tonal pattern was produced in only this target word by the remaining two subjects. In addition, like the K1 speakers, subjects in K2 produced two different types of intonation patterns, a LHL and a HL pattern, in "memorizes". K2 productions of this "memorizes" with were similar to those produced by K1 speakers and will therefore not be illustrated. In short, three different types of intonation patterns were produced by speakers in K2. A LHL contour was produced in both target words; in addition, a falling contour was also used in "memorizes", and a rising contour was also used in "memorial".

The two tonal patterns produced in "memorial", representative of two K2 speakers, are provided in Figure 5.6a and 5.6b. Both utterances are produced with "know" and "memorizes (memorial)" with LHL rising tones. In addition, "nine" and "times" are produced after the focussed word within the low part of this person's pitch range. The tonal patterns in target words are quite different, however. While a LHL pattern is produced in "memorizes", a clearly different LH pattern is produced in "memorial". A LH rise begins at the beginning of each target word. How they differ is that a f0 fall occurs within "memorial" followed by a gradual rise throughout the entirety of the word. In contrast to this, a sharp (LH) rise begins within the initial syllable of "memorizes", ends in the middle of the word, and then falls (L) to a low f0 reached before the end of this word. Similar to other native speaking Korean subjects who produced different intonation contours in target words produced in the same condition, the stress pattern of the target word affects the intonation pattern produced in these utterances.

A. I know he wrote the word MEMORIZES nine times.

B. I know he wrote the word MEMORIAL nine times.



igure 5.6 Production of a LHL tonal pattern in "memorial" and a LH tonal pattern in "memorizes" within the utterance "I know he wrote the word "memorial(memorizes) nine times." by one K1 speaker, Subject 38.

K2 speakers produced utterances with phrasing patterns different from those in K1 utterances. The phrasing of utterances containing the target word "memorial" were analyzed in this nuclear accented condition. A production by a K2 speaker is illustrated in Figure 5.6. Two K2 subjects produced this phrasing in their productions. "Know" and "memorial" were produced with prominent pitch changes within one intermediate phrase: [(I know he wrote the word)(memorial nine times).

Five K2 subjects produced utterances with two intonational phrases, and produced more tonally distinct changes in content words: [(I know he wrote the word)][(memorial nine times)]. Two words in these utterances were produced with the greatest tonal changes,these were the words "know" and "memorial". In addition, "wrote" and "word" are produced with reduced pitch ranges relative to "know", and "nine times" was produced with a reduced pitch range relative to "memorial". These speakers, like many E speakers wer producing downstep patterns in each intonational phrase. In all utterances, "memorial" was produced with a steep f0 rise followed by a steep f0 fall. The phrasing of K2 utterances, and the LHL tonal pattern produced in target words were similar to productions by E:

A. [(I know he wrote the word)(memorial nine times)
(S30, S38)
B. [(I know he wrote the word)][(memorial nine times)]
(S06, S36, S40, S42, S47)

K2 productions are unlike K1 productions in that almost every content word in K1 utterances was produced with a very distinct rising tonal pattern. K2 speakers did not produced such distinct tonal changes in each phrase. Instead, the phrasing of K2 utterances was more like that of native English speakers. While, K1 produced target utterances with four or five tonally prominent words, K2 speakers produced only two. In the following descriptions, underlines words are produced with very distinct tonal changes.

K1: [(I know)(he wrote)(theword)][(memorial nine times)]
K2: [(I know he wrote the word)(memorial nine times)]

In summary, the majority of K2 subjects did not in produce the same tonal patterns in both target words, (e.g., subjects only produced a steep LH rise in "memorial" and a very shallow rise in "memorizes"). Only two speakers in K2 produced the same a steep f0 fall realized within "memorial" after a LH rise in both "memorial" and "memorizes." Similar to K1 productions, only two subjects in K1 produced the same tonal pattern in target words. In addition, K1 speakers produced four and five phrases within each utterance. Each phrase was produced with a LHL tonal pattern characteristic of accentual phrases in Korean. Target words were produced with the greatest tonal change. K2 productions were more like those of E. K2 speakers grouped words into fewer phrases with only two words -including the target word- were produced with prominent rising tonal patterns.

5.1.1.2. Questions

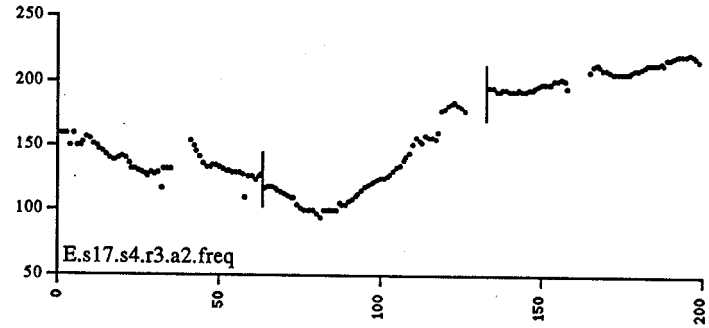
Target words were also produced in nuclear accented conditions in yes/no questions. "Memorial" and "memorizes" were produced in the following utterance:

"Did he write the word "MEMORIAL" ("MEMORIZES") nine times?

Native English speaking subjects produced "memorial" and "memorizes" with a LH tonal pattern consistent with a L* pitch accent followed by a sequence of H- H% boundary tones. Productions of these target words produced with a nuclear accent are provided in Figure 5.7. Because pitch accents are associated with the stressed syllable, a falling f0 pattern characteristic of a L* pitch accent falls onto the stressed syllable. Productions of L* pitch accents representative of E speakers are provided in Figures 5.7a and 5.7b. A L* pitch accent is realized on the first syllable of "memorizes" and on the second syllable of "memorial". There is a delay in the location of the f0 minimum in "memorial" with a later stressed syllable. A rise begins after this fall, and continues to rise to a H- phrase boundary tone occurring around the end of the word. At this point, the tonal rise tapers off and continues to the final H% intonational boundary tone reached at the end of the phrase. The words "nine" and "times" are produced within a plateau between these high boundary tones.

To appreciate the difference between the tonal pattern in a L+H* pitch accent and a L* pitch accent followed by a H- phrase tone, compare the utterances of "memorizes" in 5.1a and 5.6a. In the question, the target word is produced with a L* pitch accent and so the f0 level falls to a lower level; in the statement, the target is produced with a rising L+H* pitch accent and so a sharp rise begins at the onset of the target word. Thus, a L* pitch accent is realized as a falling accent, and a L+H* pitch accent is realized as a rising pitch accent. The rise that occurs after a L* pitch accent in Figure 5.7a is the result of a H-phrase boundary. This target is reached around the end of the nuclear accented word. The end of target words is marked with a final vertical line. The fall that occurs after a L+H* pitch accent in Figure 5.1a is the result of a L- phrase boundary, also reached at the end of the word.

A. "Did he write the word MEMORIZES nine times?"



B "Did he write the word MEMORIAL nine times?"

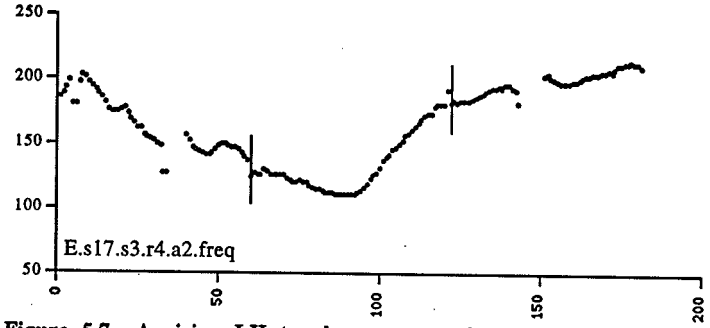
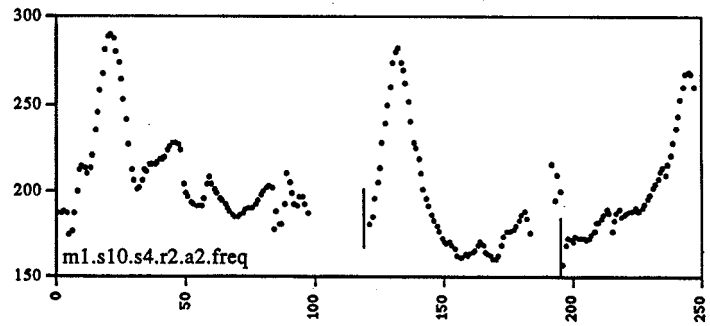


Figure 5.7 A rising LH tonal pattern produced in nuclear accented "memorizes" and "memorial" by a native English speaker, Subject 17 in the utterance, "Did he write the word "memorizes/memorial" nine times?.

None of the M1 speakers produced LH tonal rsing patterns like those of E speakers' productions in any of the nuclear accented targets in questions. A LHL tonal pattern similar to the LHL pattern used in statements was produced in both "memorial" and "memorizes" by 5 of the M1 speakers who produced this LHL pattern in statements, and a HL tonal pattern was used by the 2 M1 speakers who produced a HL in statements. In other words, all speakers used the same tonal pattern in target words in both statements and questions. Representative utterances of the target words produced with a LHL intonation contour by an M1 speaker are illustrated in Figure 5.8. The intonation patterns in Figure 5.8 are similar to the statement intonation patterns produced by M1 speakers illustrated in Figure 5.2. They are the same until the ends of utterances. The tones produced at the ends of these utterances differ in questions and statements produced by M1 speakers. While statements end with a final tonal fall, questions end with a sharp final rise. Questions end with steep tonal rise. This final rise in questions is tonally distinct from the final tonal fall in statements.

A. "Did he write the word MEMORIZES nine times?"



B. Did he write the word MEMORIAL nine times?

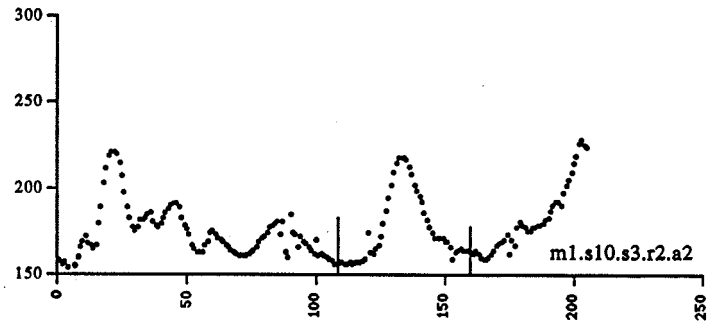


Figure 5.8 The utterance "Did he write the word memorial(memorizes) nine times" produced by an M1 speaker, Subject 10. "Memorial is produced in a nuclear accented condition and is delineated with vertical lines.

The final boundary tones produced in questions by E and M1 speakers differ. These differences are illustrated in Figure 5.9. In productions by the English speakers, an f0 rise begins within the stressed syllable of the last prominent (nuclear accented) word "memorizes/memorial". This rise continues until it reaches a H- phrase tone at the end of the word. This rise tapers off but continues until the end of the phrase until a H% boundary tone is reached. This rising tonal pattern is different from M1 productions. In M1 productions, a LH rise is produced in target words, and another LH rise is produced at the ends of questions. In M1 utterances, this second rise -an utterance final rise- begins at the end of "memorizes/memorial". This second L tone, realized at the end of target words, is followed by a final f0 rise reached at the end of the utterance. The final tonal rise in productions by M1 is produced at the ends of questions, and does not seem to be at associated with the last prominent word in the utterance.

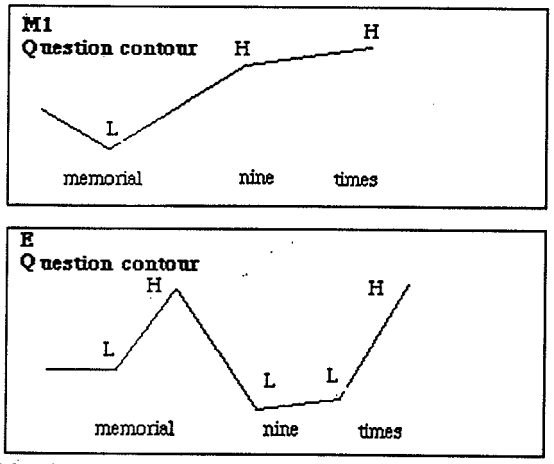


Figure 5.9. Schematic Representation of the tonal contour in questions by E and M1 and M2 speakers.

The majority of M2 productions of nuclear accented targets were produced with a LHL pattern. Only one subject in this group produced a LH tonal pattern within the word "memorial". No M2 speaker produced a rising tonal pattern in the word "memorizes"; this word was produced with LHL tonal pattern. The atypical LH tonal pattern consistently produced in an utterance by M2 Subject 48 is exemplified in Figure 5.10.

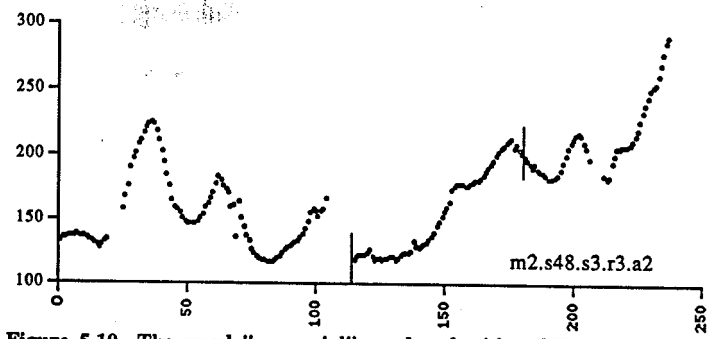


Figure 5.10 The word "memorial" produced with a LH tonal pattern in the utterance, "Did he write the word "memorial" nine times?" by M2 speaker, Subject 48. Vertical lines delineate "memorial".

The tonal pattern within the target word is similar to E productions of L* pitch accents followed by H- H% phrase boundaries, however, the tonal movements produced after "memorizes" are different. A LH rise similar to E productions can be seen to continue through the production of this target word with first syllable stress. Unlike E productions, f0 does not continue to rise after this word. Fundamental frequency begins to fall around the end of "memorizes" into the following word, "nine". "Nine" is then produced with a LH tonal pattern. "Times" is also produced with a LH pattern, and this final rise is like that of f0 change in a L- H% boundary tone. So while this intonation pattern is similar to E productions, a smooth f0 transition between a tonal movement in the most prominent word, "memorizes", and a phrase tone at the end of the utterance is not made.

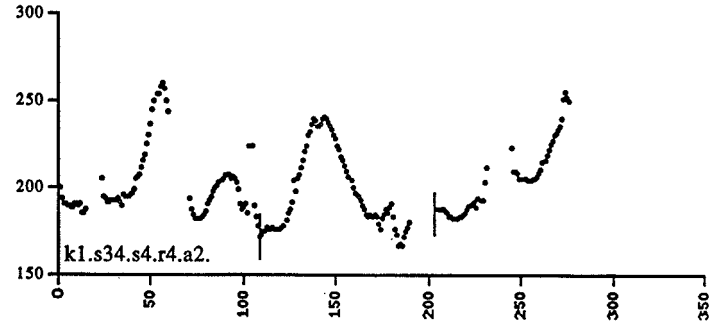
The tonal movements after both target words in M2 productions were similar to those of M1. The schematic representation in the lower half of Figure 5.9 represents the tonal patterns produced by all M1 speakers and the majority of productions by M2. No native Mandarin speaker produced a gradual rise between target words and the ends of utterances. Instead, an utterance final tonal rise was produced within the final word, "times".

To summarize, only one subject in M2 produced a rising LH tonal pattern, and in only one word, "memorial". The majority of M2 subjects produced the same LHL tonal patterns in target words in statements that they had produced in questions. The way that questions and statements differ in M1 and M2 productions is in the final boundary tones. Rising phrase tones are produced at the ends of questions and falling boundary tones are produced at the ends of statements.

A LH tonal pattern like those produced by E, was not produced in any of the productions of "memorial" or "memorizes" by K1. All productions of "memorial", like those produced in statements by K1, were produced with a LHL tonal pattern. Also like K1 productions of target words in statements, a HL tonal pattern with a considerably smaller initial rise was produced in "memorizes" by five subjects. A LHL pattern produced in both target words is illustrated in Figure 5.12. This subject produced the same tonal pattern in both target words similar to the LHL patterns produced in target words by two K1 subjects in statements. A LH rise is realized

around the stressed syllable in both target words, followed by a fall completed at end of target words. Two K1 subjects produced a LHL rise in both target words in both statements and questions, and the remaining subjects produced a HL fall in "memorizes" and a LHL rise in "memorial" in both statements and in questions. The stress pattern of target words for these five subjects influenced the pitch accent used in otherwise identical utterances.

A. "Did you say he wrote the word MEMORIZES nine times?"



B. "Did you say he wrote the word MEMORIAL nine times?"

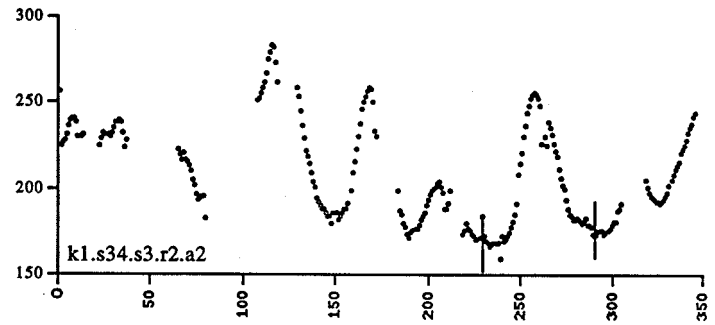


Figure 5.10 A rising/falling LHL tonal pattern produced in nuclear accented "memorial" by a K1 speaker, Subject 34, in the utterance, "Did he write the word "memorial" nine times?.

Like native Mandarin speakers, a tonal contrast was not used to distinguish between nuclear accented words in statements and in questions in productions by K1 speakers, a tonal movement at the end of utterances distinguished statements from questions. This is illustrated in Figures 5.3 and 5.11. Although the tonal pattern within target words in similar in nuclear accented conditions in both questions and statements, the final phrase boundaries within these intonation patterns of these utterances differ. These phrase boundaries are similarly produced by M1 and M2 speakers. A final tonal rise is produced at the end of questions; while a final tonal fall occurs at the end of statements.

The question and statement intonation patterns used by these K1 speakers are similar to the intonation patterns typical of Korean. Prominent words are realized with a rising tonal pattern within utterances, regardless of whether the utterance is a question or a statement. Questions end with a final rise due to a H% intonational boundary tone, while statements end with a fall due to L% intonational boundary tone. These K1 speakers with less exposure to English, seem to be producing intonation patterns consistent with the tonal patterns in their L1. Native English speakers produced a prominent rise within the nuclear accented word in statements. Following a LH rise is a prominent fall to a L- phrase tone. The turning point, the f0 maximum is linked to the stressed syllable in the nuclear accented word. A prominent tonal fall associated with a L* pitch accent is produced within the nuclear accented word in yes/no questions. Following this fall is a prominent rise to the high boundary tones. Again, the turning point, the f0 minimum, is linked to the stressed syllable. K1 speakers do not make the association between a final nuclear accent and a prominent rise or fall continuing from this pitch accent, instead a rise in questions and a fall in statements is realized at the end of the utterance. These pitch movements do not fall or rise from a the f0 maximum or minimum realized in the stressed syllable.

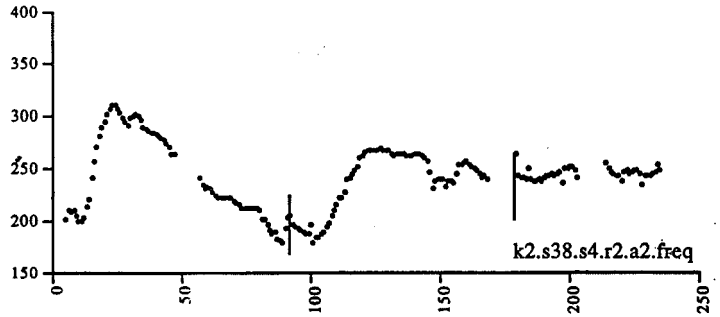
Some of the productions of nuclear accented targets in questions by the more proficient Korean speakers, K2, are more like those of E, and produced with a LH tonal pattern. The majority of productions of "memorial" with a noninitial stressed syllable, were produced with this rising tonal pattern by five speakers in this group. Of these five subjects, two also produced this rising pattern in productions of "memorial" in statements. This suggests that these two subjects did not use this rising LH tone differentially in statements and in questions; but used a LH tone in "memorial" with a later stressed syllable. A LH tonal pattern produced in "memorial" and representative of those produced by five K2 speakers is provided in Figure 5.12b. The remaining two subjects produced a LHL tonal pattern similar to their productions of nuclear accented targets in statements.

A LH tonal pattern was produced in the majority of productions of "memorizes" by K2 speakers. This is fewer than the five K2 subjects who produced LH contours produced in "memorial". K2 speakers were more likely to produce a LH accent in this target word with a later stressed syllable. In addition, one subject produced a HL contour within "memorizes. The remaining four subjects primarily produced a LHL tonal contour in productions of "memorizes."

The LH tonal patterns produced by two K2 subjects are similar to E speakers productions, but not the same. K2 Subject 38 produced a LH tonal pattern in both target words. These productions are illustrated in Figures 5.12a and 5.12b. The primary difference between these productions and those of E is in the location of an f0 minimum (or trough) and the f0 peak (or bend) in the target words. In productions of

"memorizes" by this K2 speaker, a fall occurs within the initial stressed syllable of this target word, like that of a L* pitch accent. The f0 rise that follows, peaks in the middle of the word, perhaps around the end of the stressed syllable. In "memorial", a f0 fall also occurs within the initial part of the word followed by an f0 rise. Here, the timing of the f0 minimum in "memorial" is similar to that produced in "memorizes", whereas in E productions the timing of the f0 minimum is later in "memorial". In addition, the peak f0 is realized earlier in target words, and not at the end of the word, as it is in E. So, while the LH tonal patterns produced by this K2 speaker and E may be similar, the timing of the L* accent and later H tone differ. In English, a L* pitch accent is realized in a stressed syllable, and a H- phrase tone is reached at the end of the word. In productions by this K2 speaker, a L target is reached early in the word, and a H target is realized before the end of the word. The timing of tonal movements in nuclear accented productions will help to reveal these possible differences.

A. "Did he write the word MEMORIZES nine times?"



B. "Did he write the word MEMORIAL nine times?"

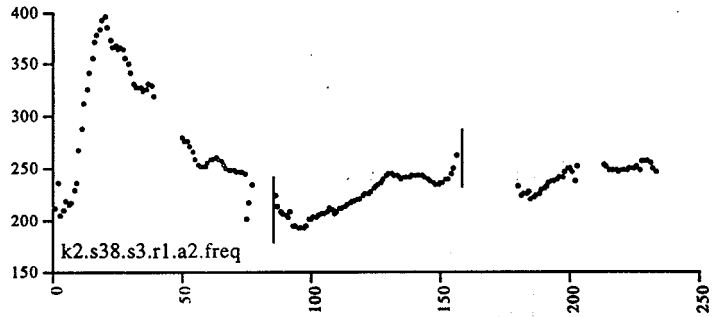


Figure 5.12 A rising LH tonal pattern produced in nuclear accented "memorizes" and "memorial" by K2 speaker, Subject 38, in the utterance "Did he write the word "memorizes (memorial)" nine times?

5.1.2 Prenuclear accented condition

"Memorizes" and "memorial" were produced before the nuclear accented word in the statements and in questions:

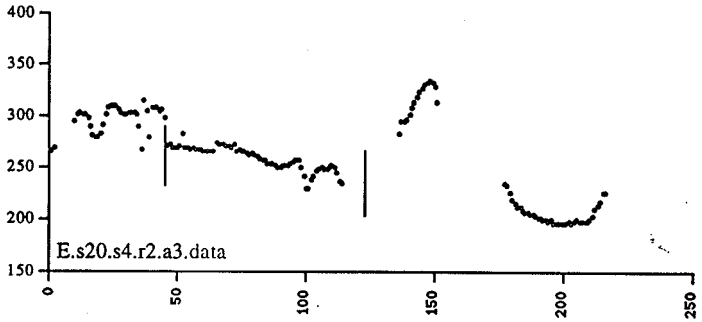
"No, he wrote the word memorizes/memorial EIGHT times."
"Did you say he wrote memorizes/memorial EIGHT times?"

5.1.2.1 Statements and questions

Productions of these prenuclear targets by all subject groups were similar in questions and in statements and so these results will be presented together in this section.

Subjects in E consistently produced targets without an accent. Only one subject produced each target word with a H* accent. The location of the stressed syllable did not affect the intonation pattern in E productions. Productions of both "memorizes" and "memorial" produced in statements are provided in Figure 5.11. In these productions, "wrote" and "eight" are produced with pitch accents. "Wrote" is produced with a H* pitch accent, and "eight" is produced with a L+H* pitch accent. Target words are produced between these two pitch accented words, after a H tone and before a L tone . The tonal pattern within both "memorizes" and "memorial" interpolates between these high and low targets, and is as a result produced with a falling tonal pattern. This tonal pattern in unaffected by the stressed syllable in target words.

A. "He wrote memorizes EIGHT times."



B. "He wrote memorial EIGHT times."

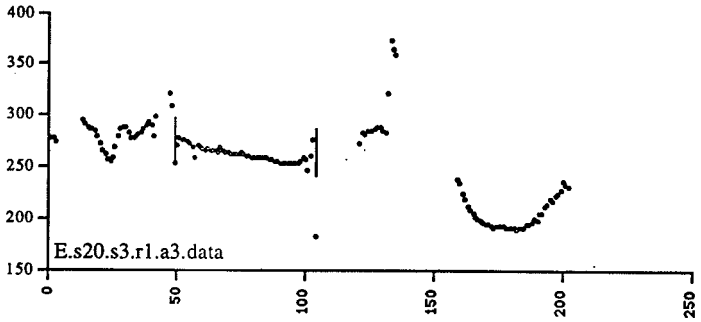
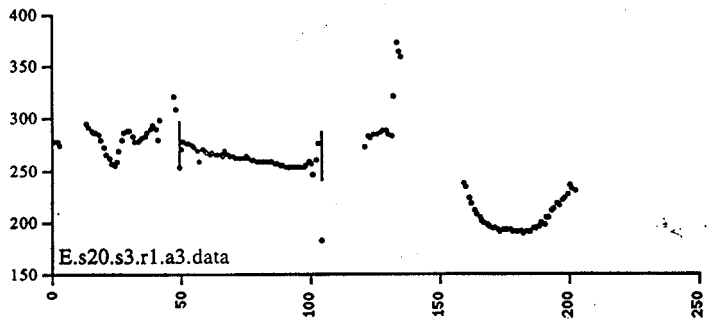


Figure 5.13 "Memorizes" and "memorial" produced in postnuclear unaccented condition in statements by an English speaker. Vertical lines delineate the beginning and end of target words.

The intonation pattern produced in statements was the same as the intonation pattern produced in questions for each E speaker. "Memorial" produced in a statement and in a question by another E speaker is provided in Figure 5.14. In 5.14a, a falling tonal pattern similar to those just described occurs in "memorial" when produced in a statement. The falling tonal pattern in "memorial" in Figure 5.14b is steeper in questions. In this utterance, a L* pitch accent follows "memorial". This target is even lower than that of a L in a L+H* pitch accent. (The L* target is not visible in Figure 5.12b. This speaker speaks with creaky voice normal in low frequencies, affecting the f0 tracking ability of the computer analysis.) The tonal pattern within the target word is steeper because the following L* tonal target is lower. These examples illustrate how the f0 shape of an unaccented word is controlled by surrounding tones in the utterance.

A. "He wrote memorial EIGHT times."



B. "Did you say he wrote memorial EIGHT times?"

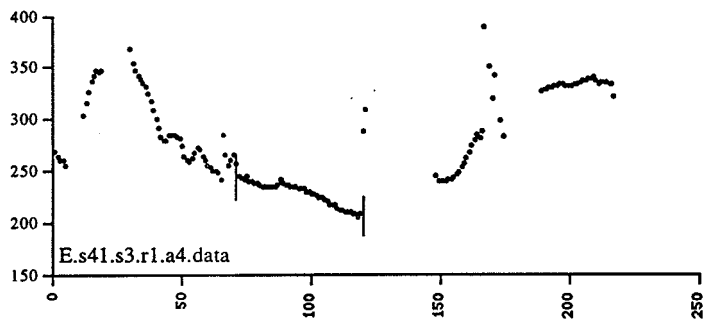
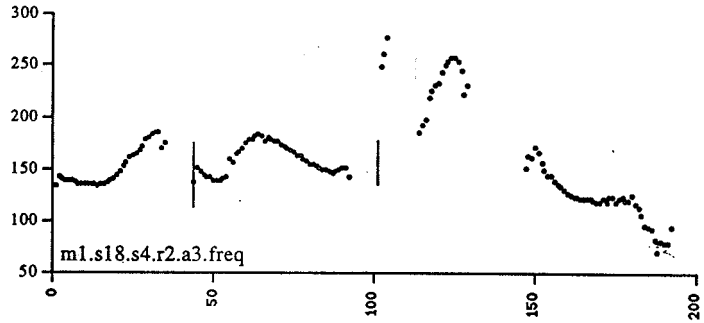


Figure 5.14. "Memorizes" and "memorial" produced without an accent in a prenuclear condition by E subject 41 in a question. Vertical lines delineate the beginning and end of each target word.

To summarize, native English speaking subjects produced falling tonal patterns within words produced in prenuclear conditions. These target words were not produced with pitch accents and were produced between H and L tonal targets within statements and in questions.

The majority of speakers in M1 produced pitch accents in target words in prenuclear conditions in statements and in questions that were similar to those they produced in nuclear accented conditions. LHL tonal patterns were produced in "memorial", and LHL and HL tonal patterns with a reduced initial rise were produced in "memorizes". The tonal patterns in prenuclear conditions differed from those in nuclear conditions in the extent of f0 changes in target words. M1 productions of target words in a prenuclear condition in statements are provided in Figure 5.15. A rise and fall in f0 occurs with the target words, however, the extent of the f0 rise is not as great as those produced in nuclear conditions, nor is the f0 peak realized in these target words as high as the f0 peak produced in the nuclear accented word "eight" in the same utterance.

A. "He wrote memorizes EIGHT times."



B. "He wrote memorial EIGHT times."

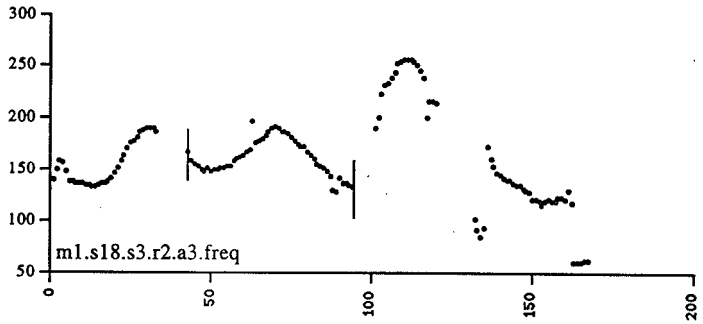
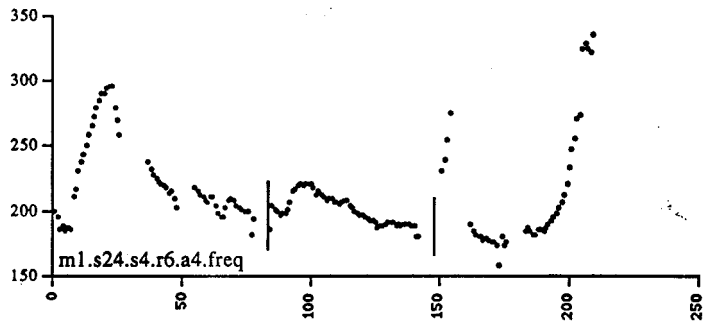


Figure 5.15. "Memorizes" and "memorial" produced in prenuclear conditions in statements by M1 Subject 18. Vertical lines delineate the beginning and end of target words.

Four M1 subjects produced this LHL pattern in target words in statements and in questions. Production of "memorizes" and "memorial" in questions produced by one of these subjects is provided in Figure 5.16. Figures 5.15 and 5.16 differ in phrase tones. Questions end with a sharp final rise due to a sequence of L- and H% phrase tones, while statements end with a final rise due to a sequence of L- and L% phrase tones. These phrase tones may affect the tonal pattern in the nuclear accented word "eight". "Eight" was produced with a very high pitch accent in statements (Figure 5.15) followed by "times" produced with a very low tone. In questions (Fig. 5.16), "eight" was produced with a low pitch accent followed by "times" produced with a high tone. These subjects did not produce nuclear accented target words with a low pitch accent in questions ("Did he write the word MEMORIAL nine times?"), although they were able to produce a low pitch accent in "eight". These subjects may associate low tones with phrase boundaries and not with pitch accents. The closer the word is to the end of an utterance, where boundary tones occur, the more likely a phrase final word be produced with a low tone. Nuclear accented target words were followed by two words, and were not produced close to the edge of the utterance. The boundary tones, perhaps associated with the edge of the utterance by M1 speakers, may have been too far from target words to influence the f0 pattern produced within them. As a result, a low pitch accent was not produced in nuclear accented target words.

A. "Did you say he wrote the word memorizes EIGHT times?"



B. "Did you say he wrote the word memorial EIGHT times?"

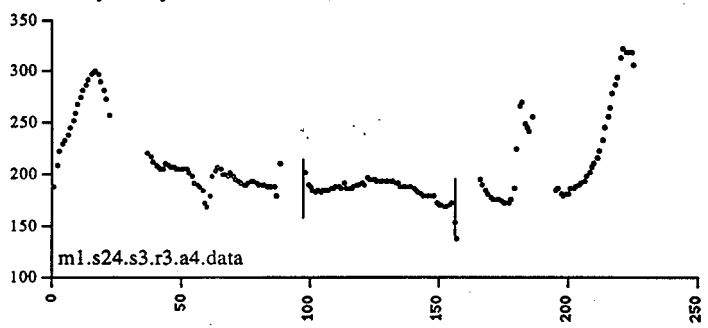


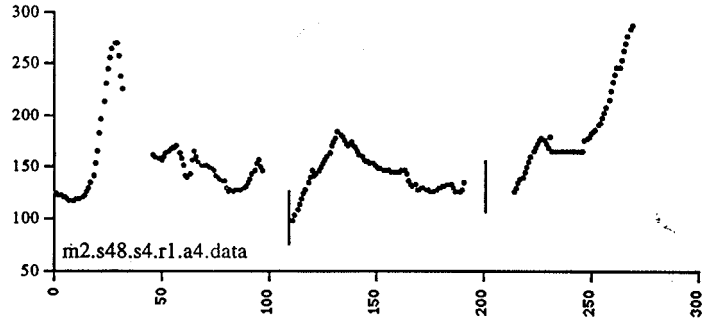
Figure 5.16. "Memorizes" and "memorial" produced in a prenuclear accent condition in a question by M1 Subject 24. Vertical lines delineate the beginning and end of target words.

Three subjects in M1 produced different tonal patterns in target words. These subjects produced a rising LH accent in "memorial" and a LHL tonal pattern similar to the remaining subjects in "memorizes". The rising pattern used by these subjects, were used in both questions and in statements.

To summarize the results of M1, target words were produced with distinct tonal patterns in prenuclear conditions, unlike speakers of E who produced target words without an accent in this context. Four subjects in this group produced similar LHL tonal patterns in "memorizes" and "memorial" in both questions and in statements. Three subjects produced rising LH pattern in only "memorial" in both statements and questions; these different tonal patterns were produced in target words regardless of the intonation context. This indicates that the stress pattern of words, not the intonation context, influenced the accent pattern for these three subjects. M1 subjects produced "memorial" with a [weak-strong] initial rhythmic structure with a LH or a LHL accent pattern, while "memorizes" with a [strong-weak] syllable structure was produced with a HL or a LHL tonal pattern.

The more proficient English speaking Mandarin subjects, M2, produced tonal patterns that were like those of M1. In statements, "memorial" was produced with a LHL pattern and "memorizes" was produced with a LHL or HL pattern. These patterns are similar to those produced by these subjects in nuclear accented target words. In questions, M2 speakers produced a LHL pattern or a LH tonal pattern in "memorial", and a LHL or HL tonal pattern in "memorizes". M2 subjects differ from those of M1 in that a LH rising pattern was only used in questions, and not in statements. Example utterances of a LH and LHL pattern produced in questions by one M2 subject are provided in Figure 5.17.

A. "Did you say he wrote the word memorizes EIGHT times?"



B. "Did you say he wrote the word memorial EIGHT times?"

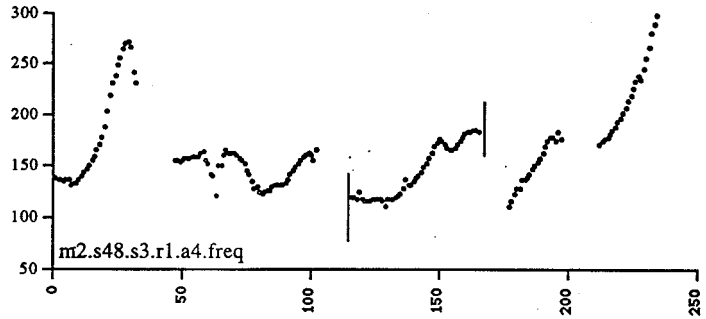
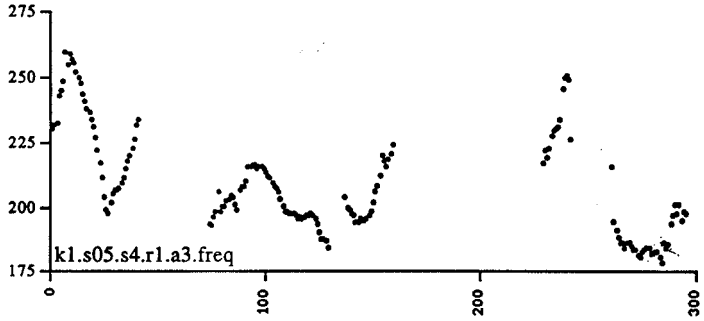


Figure 5.17. "Memorizes" and "memorial" are produced with two different tonal patterns by M2 Subject 48. Vertical lines delineate the beginning and end of target words.

Subjects in K1 produced LHL and LH tonal patterns in "memorial" consistent with L+H* L- and L* H- intonation patterns, and produced LHL and HL tonal patterns in "memorizes" consistent with L+H* L- and H* L- intonation patterns in both statements and in questions. Representative utterances of the LHL tonal patterns produced in both targets in statements are provided in Figure 5.18. The nuclear accented word "eight" is produced with the highest level of f0, the target words, "memorizes" and "memorial", produced before this nuclear accented word, are produced with f0 peaks that are shallower in comparison. These target words are produced with tonal characteristics of prenuclear pitch accents. A final fall in f0 occurs at the ends of these utterances onto the final word, "times". This utterance-final fall is the result of L- L% phrase tones, like those characteristic of statements discussed so far.

A. "He wrote memorizes EIGHT times."



A. "He wrote memorial EIGHT times."

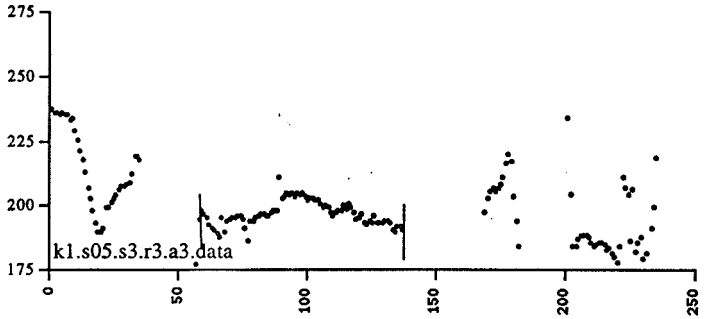
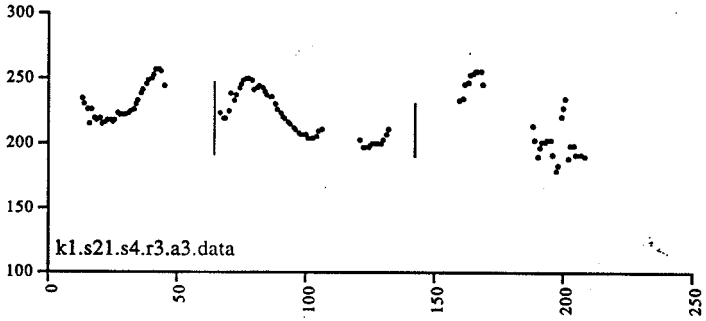


Figure 5.18 "Memorizes" and "memorial" produced with LHL tonal patterns by K1 speaker 05 in a prenuclear accent target in statements. Vertical lines delineate the beginning and end of target words.

K1 speakers, like M1 and M2 speakers, produced targets words with a shallower f0 rise in comparison to nuclear accented targets. So while the shape of the LHL tonal pattern in target words produced in a prenuclear condition is similar to those produced with a nuclear accent, differences in these levels of prominence appear to be conveyed through the extent of f0 change within the accented target words. The same LHL tonal patterns produced in statements were also produced in questions. A rise begins at the beginning of each target word, reaches a high target within the word, and then falls to a low f0 target at the end of the word. Statements differ from questions not in pitch accent types, but in the final boundary tones. A rising L- H% occurs at the ends of questions.

The great majority of K1 speakers produced a LHL pattern in "memorial" in both statements and in questions. Six subjects produced this pattern in statements, and five produced this in questions. "Memorial" was also produced with a LH tonal pattern, by one K1 speaker in statements, and by two K1 speakers in questions. "Memorizes" was produced with a LHL pattern by about half of the subjects. Three subjects produced this pattern in statements, and two subjects in questions. A HL tonal pattern was also used in productions of "memorizes", by four speakers in statements, and by two subjects in questions. "Memorizes" was also not accented in two productions by three speakers. Representative productions of "memorizes" produced with a HL tonal pattern and "memorial produced with a LH tonal pattern are provided in Figure 5.19.

A. "He wrote memorizes EIGHT times."



B. "He wrote memorial EIGHT times."

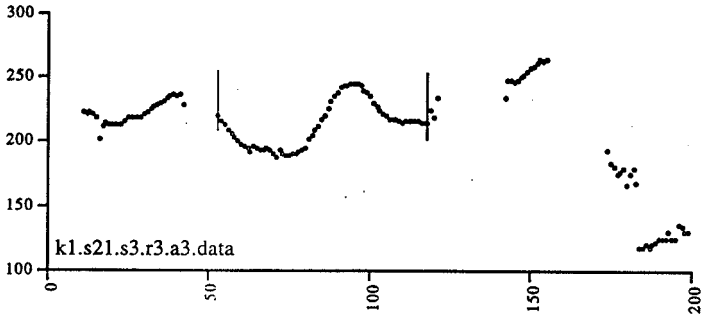
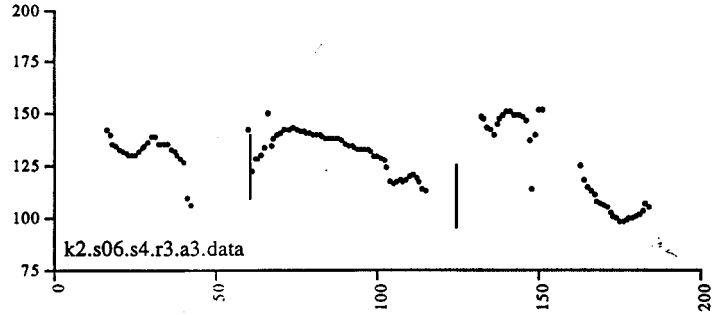


Figure 5.19 "Memorizes" produced with a HL accent pattern and "memorial" produced with LH accent pattern by K1 speaker 21 in a prenuclear accent target in statements. A vertical line marks the beginning of the stressed syllable.

These patterns produced in target words by the same K1 speaker are different in that a f0 fall occurs onto the stressed syllable of "memorial", and a rise in f0 occurs within the stressed syllable of "memorizes." The vertical lines in Figure 5.19 mark the beginning of the stressed syllable in "memorizes" and "memorial". The fall is consistent with a L* pitch accent, and the rise is consistent with a L+H* pitch accent. These tonal patterns in productions of prenuclear accented targets are similar to those produced in nuclear accented targets. While the majority of targets are produced with LHL tonal patterns, "memorizes" may be produced with a falling HL tonal pattern, and "memorial" may be produced with a LH tonal pattern. Prenuclear productions differ from nuclear productions in the extent of f0 changes within them. Nuclear accented words are produced with higher f0 targets than are prenuclear accented words.

The more English proficient K2 speakers produced intonation patterns that were like those of K1 speakers. K2 speakers, however, were more likely to produce a LH tonal pattern in "memorial", and a HL tonal pattern in "memorizes". To summarize their results, in statements, "memorial" was produced with a LHL tonal pattern by six of the seven K2 speakers, and a LH tonal pattern was produced by one speaker. In questions, five subjects produced a LH rise in "memorial" and two produced a LHL pattern. "Memorizes" was typically produced with a falling HL tone in by all K2 subjects in statements, and by six subjects in questions. "Memorizes" was also produced with no accent (UN) by one K2 subject. Representative productions of "memorizes" produced with a typical HL tonal pattern, and "memorial" produced with a typical LHL tonal pattern are provided in Figure 5.20.

A. "He wrote memorizes EIGHT times."



B. "He wrote memorial EIGHT times."

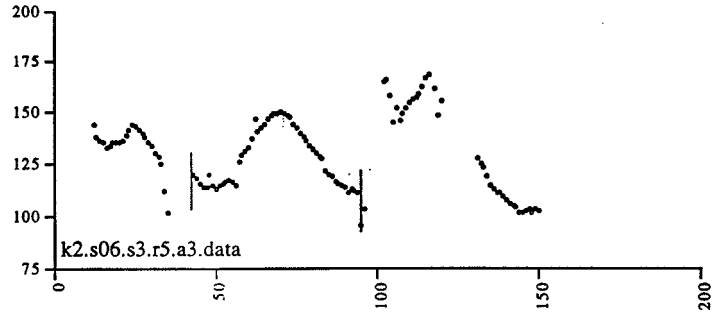


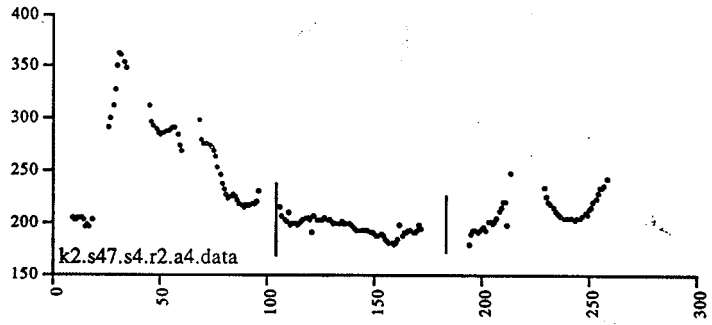
Figure 5.20 "Memorizes" and produced with a falling HL tonal pattern and "memorial" produced with a LHL tonal pattern in statements in a prenuclear condition by K2 Subjects 06. Vertical lines delineate the beginning and end of "memorizes".

The same K2 speaker produced these two different tonal patterns in linguistically identical utterances. "Memorizes" with an initial stressed syllable is produced with a falling accent, and "memorial" with an initial unstressed syllable is produced with a rising-falling accent.

Target words produced in questions are provided in Figure 5.21. These pitch tracks exemplify the differences in boundary tones in statements and in questions. In questions, "eight" is produced with a prominent rise since it is in a nuclear accented context. A L- H% tone is produced in "times". A short f0 fall occurs within the middle of the word as a L- phrase tone is reached, and a rise follows to the end of the utterance reaching a H% boundary tone. In target words, this K2 speaker produced a falling HL tonal pattern in "memorizes" and a rising-falling pattern in "memorial". One might argue that the target words in these utterances are not accented, and so are produced without an f0 protrusion. However, the same f0 pattern is not produced in these target words. F0 falls within "memorizes" and rises within "memorial". If these words were produced without a pitch accent (or without a particular f0 pattern) then the f0 realized within these two words should be an interpolation between tonal targets. The intonation context is the same in these two utterances as can be seen by the almost identical tonal shape before and after the target words. Only the f0 pattern in target words is different, and this suggests again that the stress pattern in words is affecting the intonation pattern of the utterances.

K1 and K2 differ in that subjects in K2 more consistently produced tonal patterns that are influenced by the stress pattern of words. In statements, "memorial" is produced with a LHL pattern by all K2 subjects and "memorizes" is produced with a HL tonal pattern by all K2 subjects. In questions, five subjects produced a LH tonal pattern in the majority of their productions of "memorial", and all subjects produced a HL pattern in "memorizes".

A. "Did you say he wrote memorizes EIGHT times?"



B. "Did you say he wrote memorial EIGHT times?"

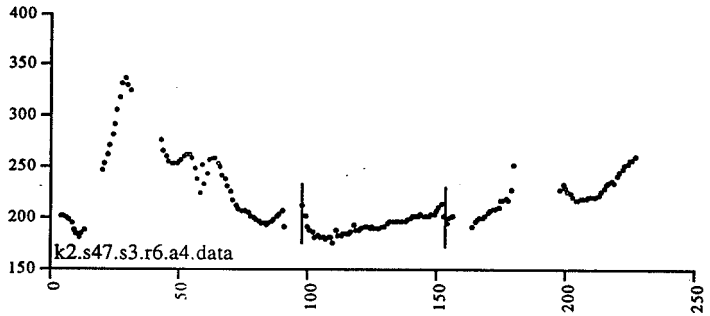


Figure 5.21 "Memorizes" produced with a falling HL tonal pattern in a statement and "memorial" produced with a rising LH tonal pattern in a question in a prenuclear condition by K2 Subject 47. Vertical lines delineate the beginning and end of target words.

An important aspect of these results is the finding that there are differences in the tonal patterns produced in "memorial" in statements and in questions by the majority of K2 speakers. A LHL pattern was used in statements and a LH pattern was produced in questions. This difference in tonal patterns between statement and question are not different in productions of "memorizes", however. This suggests that while these more proficient English speakers may be producing different accents in target words produced in different intonational contexts, that this ability to produce a different accent pattern is limited by the stress pattern of the word. K2 speakers were able to produced an f0 fall onto a later stressed syllable in "memorial", but not onto an initial stressed syllable in "memorizes." If they had not been affected by the stress pattern of the word, then a LH pattern would have been produced in "memorizes".

5.1.3. Postnuclear unaccented conditions

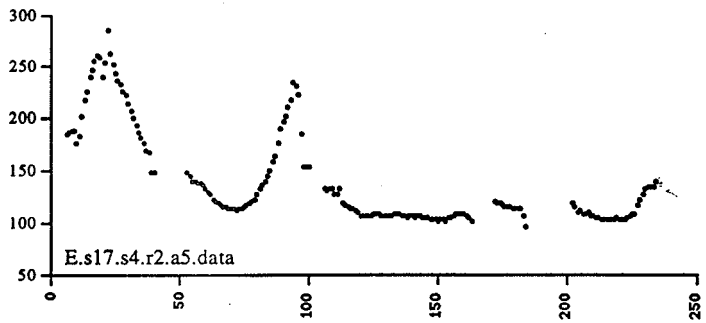
5.1.3.1 Statements and questions

"Memorizes" and "memorial" were produced after a nuclear accented word in statements and in questions:

"Well, he didn't actually WRITE memorial eight times."
"Did he TYPE memorial eight times?"

All Native English speakers in E produced both target words without an accent when they were produced after a nuclear accented word. These targets were unaccented in statements (Figure 5.22) and in questions (Figure 5.23).

A. "He didn't actually WRITE memorizes eight times."



B. "He didn't actually WRITE memorial eight times."

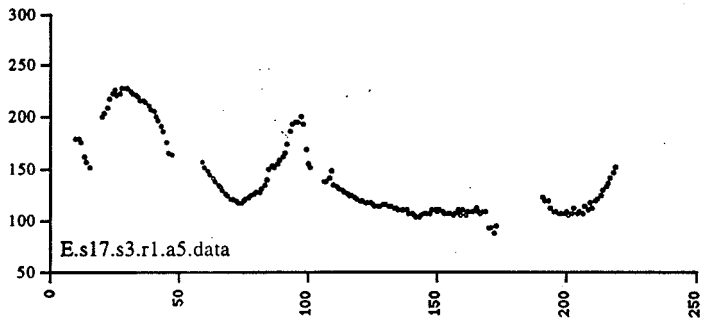
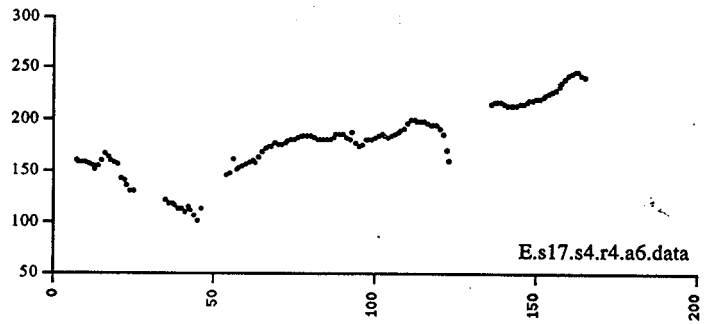


Figure 5.22 "Memorizes" and "memorial" produced in statements in a postnuclear condition by E Subject 17. Target words are delineated with vertical lines.

Similar to unaccented productions of target words in prenuclear conditions, the tonal characteristics of target words is controlled by the surrounding tones. In these utterances, "write" is produced with a L+H* accent, and so a high tone (H*) precedes the target words. No accent is produced after this nuclear accented word, instead a L- phrase target is reached around the end of each target word. This pitch accent and phrase tone control the f0 pattern in these utterances. A falling tonal pattern is produced within target words as a result. This f0 pattern is not influenced by the stressed syllable in "memorizes" and "memorial", and so these tonal patterns in target words are the same in both utterances.

Target words are produced without a pitch accent in Figure 5.23.

A. "Did he TYPE memorizes eight times?"



B. "Did he TYPE memorial eight times?"

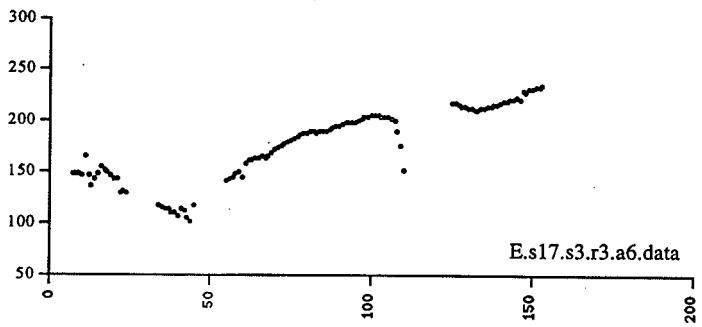
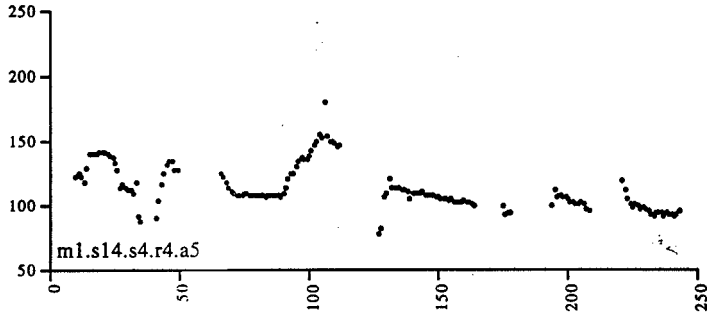


Figure 5.23 "Memorizes" and "memorial" produced in questions in a postnuclear condition by E Subject 17. Target words are delineated with vertical lines.

In questions, the word "type" produced before target words is produced with a L* pitch accent, and a H- phrase tone follows target words. As a result, a rising tonal pattern is produced within target words. Again, the stress pattern in target words does not affect this tonal pattern in these unaccented words, the surrounding tonal context does. As a result, the intonation patterns in these utterances are identical.

The intonation patterns produced by all but one M1 speakers were influenced by the location of the stressed syllable in target words. Although the tonal patterns within target words were reduced in this postnuclear condition, each target word was produced with an identifiable intonation pattern. In both statements and questions, a rising accent was produced in all produced by these six speakers in "memorial", and a falling stress pattern was produced in "memorizes". Unlike productions in nuclear and prenuclear conditions, these tonal patterns were consistently evident in productions by these speakers. Representative productions of each target word in statements produced by one M1 speaker are illustrated in Figure 5.24. Target words produced in questions by this speaker are illustrated in Figure 5.25.

A. "He didn't actually WRITE memorizes eight times."



B. "He didn't actually WRITE memorial eight times."

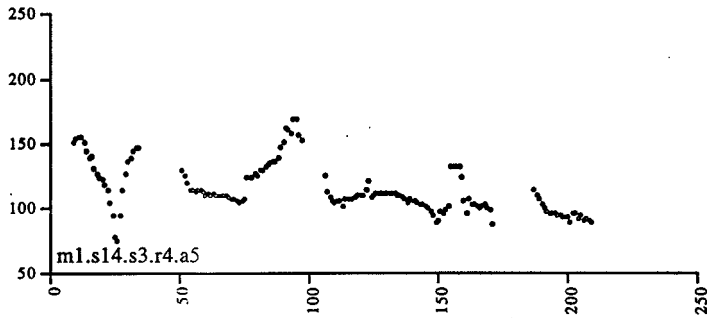
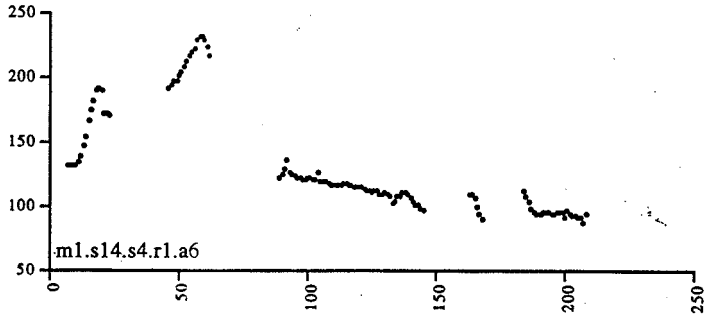


Figure 5.24. "Memorizes" produced with a falling HL tonal pattern and "memorial" produced with a rising LHL tonal pattern in statements in a postnuclear condition." Vertical lines delineate the beginning and end of target words.

Target words are produced between "write" produced with a L+H* pitch accent and a L- phrase tone realized around the end of each target word. "Memorizes" is produced with a falling HL tone as similar to those produced by E speakers. This word appears to be unaccented. However, "memorial" is produced with a slight f0 rise and fall and is tonally distinct from productions of "memorizes", and is clearly not accented. In fact, is was difficult to determine if "memorizes" was accented or not in these productions by M1, but because of the tonal distinction between this word and "memorial" it can be concluded that the location of the stressed syllable is influencing the intonation pattern. Because "memorizes" was likely to be produced with a falling tonal pattern in previous accented productions, and "memorial" was produced with a rise, these results suggest that these native Mandarin speakers are producing pitch accents in their productions.

This tonal difference between target words is maintained in questions (see Figure 5.25)

B. "Did he TYPE memorizes nine times?"



B. "Did he TYPE memorial nine times?"

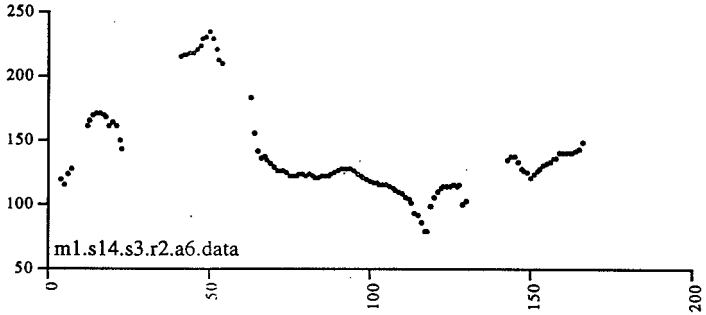


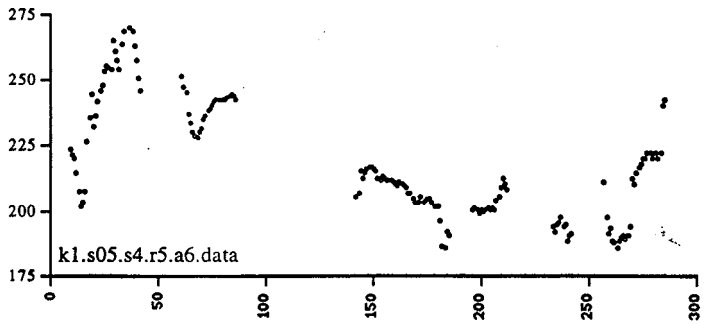
Figure 5.25 "Memorizes" produced with a falling HL pattern, and "memorial" produced with a rising LHL pattern by M1 Subject 14 in a postnuclear condition in questions.

The differences in tonal patterns in these target words in this speaker's utterance are more evident. While a HL fall occurs within "memorizes", a small, but obvious rise is produced within "memorial". To restate, the intonational context in which these utterances are produced are identical. There is nothing to suggest that the utterance with "memorial" should be produced with a different intonation contour - with a different intention - than the utterance with "memorizes". Because of this identical context, these utterances like those produced by E, should be intonationally identical. They are not. The stress paten in target words must be affecting the intonation pattern of these M1 productions.

Productions of M2 are the same as those from M1. Six subjects in this group produced intonationally different patterns in target words. "Memorizes" was produced with a falling intonation pattern, and "memorial" was produced with a rising pattern in both statements and in questions. One subject produced no pitch accent in target words. This subject's productions were more like those of E.

Productions by native Korean speakers were similar to those produced by native Mandarin speakers. Six K1 subjects produced different tonal patterns in target words in both statements and questions. The only difference in statements and questions was the final tonal pattern. Statements ended in a tonal fall, questions ended in a final rise. Representative utterances of target words produced in questions are provided in Figure 5.26.

A. "Did he TYPE memorizes nine times?"



B. "Did he TYPE memorial nine times?"

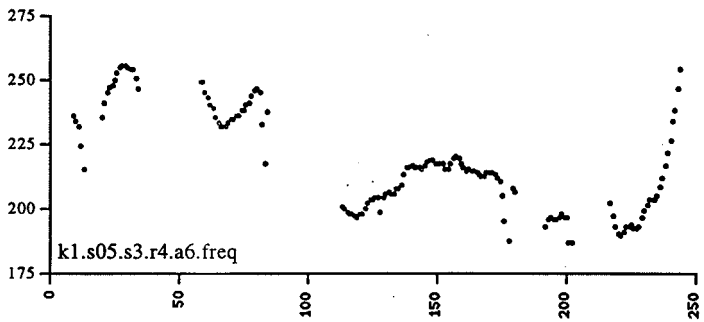


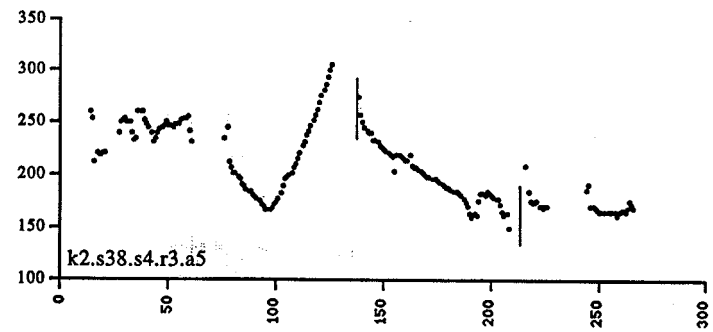
Figure 5.26 "Memorizes" produced with a falling HL pattern, and "memorial" produced with a rising LHL pattern by K1 Subject 05 in a postnuclear condition in questions.

Similar to productions by M1 and M2, each target word has a distinct tonal pattern. The extent of f0 change within target words was not as great as those produced in nuclear accented conditions indicating that the intonational context affects the extent of f0 change. All but one K1 subjects produced a shallow rising pattern within "memorial" and a falling tonal pattern in "memorizes". This pattern was unaffected by the intonation condition. "Memorizes" is produced with a falling tonal pattern in both statements and questions (Figures 5.26a and 5.27a), and "memorial" is produced with the same rising pattern in statements and in questions (Figures 5.26b and 5.27b). One K1 subject produced unaccented productions of both targets. Like E speakers, the tonal patterns in both target words were similar.

The majority of K2 speakers produced tonal patterns in target words that were like those they produced in prenuclear and nuclear conditions. Like all nonnative English speaking groups, the extent of f0 change within target words was reduced in comparison to other more prominent conditions. Two subjects produced LHL tonal patterns in both target words in statements and in questions, two subjects produced LHL tonal patterns in "memorial" and a HL tonal pattern in "memorizes"; and one subject produce a rising LH pattern in "memorial" and a LHL pattern in "memorizes". These patterns are similar to those produced by K1 and K2 speakers in prenuclear and nuclear conditions.

Two subjects in K2 produced no accent in either target word. Representative productions of utterances containing unaccented target words produced in statements is provided in Figure 5.27.

A. "He didn't actually WRITE memorizes nine times."



B. "He didn't actually WRITE memorial nine times."

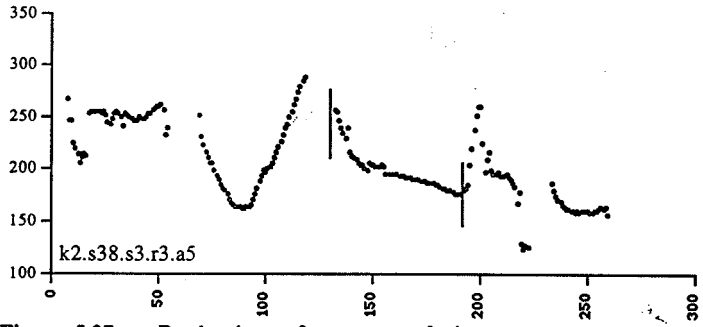


Figure 5.27 Productions of target words in an unaccented condition in statments by K2 Subject 38 in questions.

The same falling tonal pattern is produced within "memorizes" and "memorial". The f0 pattern interpolates between the surrounding tones. "Write" is produced with a L+H* nuclear accent and so a H tone is produced before each target word. L-L% boundary tones are produced at the ends of the utterance. Each target word is produced between a L+H* pitch accent and a L- phrase tone. These target words do not have a pitch accent, and so their tonal pattern is controlled by the surrounding tonal context. Consequently, a falling HL tonal pattern is produced within the target words. The stress pattern of target words did not affect the tonal pattern produced in these targets.

5.2. Analysis of tonal patterns in the nuclear accent condition

Productions of nuclear accent types were observed in order to isolate differences in productions of nuclear accents produced in yes/no questions and declarative statements. Schematized versions of these two intonation patterns are illustrated in Figure 5.28. In productions by native English speakers in E, the nuclear accented word was always produced with a L* pitch accent followed by high phrase boundary in questions, while the nuclear accented word in declaratives was produced with a L+H* pitch accent followed by a low phrase boundary.

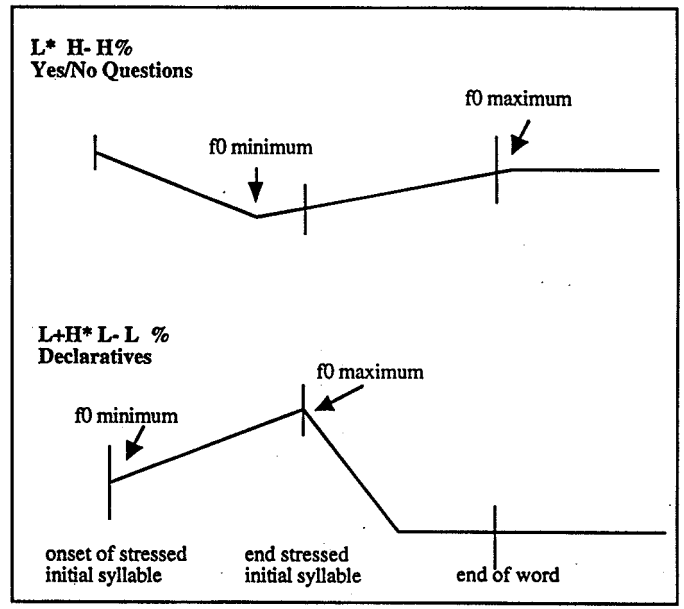


Figure 5.28 The tonal patterns of L* and L+H* accents and the location of low and high tonal targets.

A L* pitch accent, when produced in yes/no questions in English are produced with a fall in f0 onto the stressed syllable. This fall is realized well after the onset of the stressed syllable. Following this low tonal target is a rise to a H- phrase boundary. This H- tonal target is typically reached around the end of a word in English. In yes/no questions, a final H% boundary occurs at the end of the phrase. The end of questions is realized with a high plateau between the H- phrase accent at the end of the nuclear accented word, and the H% boundary occurring at the end of the utterance. A L* accent followed by high phrase boundaries is a very different pattern from a L+H* accent followed by low phrase boundaries, typically produced in declarative utterances. In this case, a rise in f0 is realized within the stressed syllable of the nuclear accented word. This rise begins around the beginning of the stressed syllable. The high tonal target of this pitch accent is realized at the end or shortly after the end of the stressed syllable (Silverman & Pierrehumbert, 1990). After the H* tonal target is reached, a fall occurs due to a L- phrase boundary. A L* accent then is realized as a fall, and a L+H* accent is realized as a rise within a stressed syllable.

The tonal pattern occurring in nuclear accented target words in statements and in questions were observed in all speakers. In this condition, all native speakers of English, E, produced a long rise within nuclear accented words followed by a fall. All speakers in M1 and M2, six speakers in K1 and six speakers in K2 produced either a shallow initial rise or a steep initial rise in targets. One subject from each group of Korean speakers, K1 and K2, produced a falling accent within the word "memorizes" in this context with no initial rise. These two subjects productions were not included in this statistical analysis. Productions of all subjects who produced rising tonal patterns in nuclear accented were observed in order to discern whether subjects were producing falling L* accents followed by a H- phrase tone typically used in English interrogatives, or a if subjects were producing a L+H* pitch accent typically produced in English declaratives.

Two different types of measures were taken in order to isolate the differences in LH tonal patterns produced in questions and in statements by all subjects in E, M1, and M2, and by six subjects in K1 and K2. First, the location of an f0 minimum was identified relative to the onset of the stressed syllable in order to isolate the location of the rise in L* H- and L+H* tonal patterns. The lowest f0 value before the onset of a tonal rise in target words was determined as the f0 minimum. The onset of the stressed syllable was determined by a set of criteria described in the methods chapter, Section 4.4.1. This location is illustrated in Figure 5.28. The dependent measure was obtained by subtracting the onset of the stressed syllable in "memorial" and "memorizes" from the f0 minimum. Positive measures indicate the rise began within the stressed syllable and negative measures indicate the rise began before the stressed syllable. Second, the location of the f0 maximum was identified in productions of target words relative to the end of the stressed syllable in "memorial" and "memorizes". In English, the f0 maximum is realized well after the stressed syllable in L* H- H% intonation patterns, and near the end of the stressed syllable in L+H* L- L% intonation patterns. The H- phrase tone is not typically realized as a peak by native English speakers, and so "f0 maximum" is not the best term for describing this value. Nonetheless, "f0 maximum" will be a term used here to describe both an f0 bend or a maximum productions by all language groups.

5.2.1 The timing of f0 minimum

A four-way ANOVA was used to analyze the location of the f0 minimum in nuclear accented targets produced in statements and in yes/no questions. Accent type (statement vs. question), stress type (memorizes vs. memorial) and repetition (repetition 1-5) were within-subject variables, and language group was a between-subjects variable. The dependent measure was the location of the f0 trough relative to the time of the onset of the stressed syllable; this was the beginning of the first syllable in "memorizes", and the beginning of the second syllable in "memorial". The f0 trough time delay was obtained by subtracting the time of the stressed syllable onset from the time of the f0 trough. Resulting negative values indicate that the f0 trough occurred before the stressed syllable, and positive values indicate that the trough was produced within the stressed syllable.

There was a significant main effect of word [$F(1,28)=74.4$; $p<.001$]. The location of the f0 minimum occurred before the beginning of the stressed syllable (mean = -.002 seconds) in "memorial" and after the onset of the stressed syllables in "memorizes" (mean = .041 seconds). The f0 minimum was later in productions of targets produced in questions than in statements, indicated by a significant main effect of intonation type [$F(1,28)=31.0$; $p<.002$]. There was no main effect of repetition [$F(4,112)=1.27$; $p>.28$].

The mean location of the f0 minimum was significantly different in productions by each language group [$F(4,28)=12.6$; $p<.001$]. A Tukey-Kramer Post hoc analysis indicated that the mean f0 trough location was significantly later in the stressed syllable of target words in productions by E in comparison to all other language groups ($p<.01$).

There was a significant interaction of stress type and language group [$F(4,28)$; $p<.029$]. The average f0 minimum in both "memorizes" and "memorial" occurred after the onset of the stressed syllable in productions by E; while the f0 minimum occurred before the stressed syllable in "memorial", and after the stressed syllable in "memorizes".

Relevant to this study, is the significant interaction between language group and intonation type [$F(4,28)=17.3$; $p<.001$]. The location of the f0 trough in E productions was significantly later in target words produced in questions by E as revealed by a means comparison ($p<.01$), while the f0 trough in M1, M2, K1, and K2 was not significantly different in statements and questions ($p>.05$). This is illustrated in Figure 5.29. In this graph, zero on the horizontal axis represents the beginning of the stressed syllable. Negative means indicate that the f0 minimum occurred before the onset of the stressed syllable, and positive means indicate that the f0 minimum occurred after the stressed syllable onset. The location of an f0 minimum in statements and questions in productions by English subjects are different. The f0 minimum is about .100 seconds after the onset of the stressed syllable in questions, and about .01 seconds after the onset of the stressed syllable in statements. The f0 minimum represents the time when a tonal rise begins. These results indicate that an f0 rise begins early in the stressed syllable in target words produced in statements, and a rise begins much later in stressed syllables in target words produced in questions.

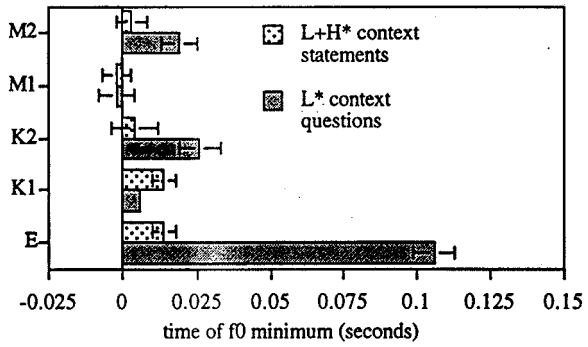


Figure 5.29 The location of the f0 minimum relative to the onset of the stressed syllable in target words produced in statements and in questions. Standard error bars are provided.

Less English proficient M1 and K1 speakers produced a mean f0 minimum that was similar in statements and in questions. The means derived from M1 productions are the same, and occur before the stressed syllable. The means derived from K1 productions are similar, and both occur right after the onset of the stressed syllable. The more English proficient K2 and M2 performed more like E. The mean f0 minimum is different in productions of statements and questions, indicating that different tonal patterns are being used in targets in statements and questions, and that a later rise is produced in questions. These results are more like those of E.

A later location of the f0 trough in the stressed syllable of nuclear accented targets produced in questions reflects the realization of a L* accent followed by a H- phrase tone. To understand where this f0 minimum occurs within the stressed syllable, it is necessary to know how long the stressed syllable is. The mean duration of the stressed syllables in "memorizes" and "memorial" in productions of nuclear accented targets by English speakers is .235 seconds. The mean location of the f0 trough is .104 seconds after the onset of the stressed syllable in this L* condition, or about in the middle of the syllable. This result is consistent with an f0 fall that occurs within the initial portion of the stressed vowel in a L* pitch accent, and an f0 rise beginning later in the stressed vowel. While K2 and M2 productions are more like those of E, the difference in the mean location of the f0 trough in these intonational contexts is not nearly as different as in productions by E. This pattern is not found in productions of nuclear-accented stressed syllables produced in statements by the nonnative English speaker groups.

The location of the f0 minimum is similar in productions of statements and questions by K1, K2, M1, and M2 as was indicated in the lack of significant differences between question (L*) and statement (L+H*) accent contexts in productions by each language group. The location of the f0 minimum is around the onset of the stressed syllable in nuclear accented words produced in statements and in questions. The mean durations of nuclear stressed syllables in productions by K1, K2, M1, and M2 are .249, .230, .262, and .247 seconds respectively. The latest location of the f0

minimum in productions of these groups is .026 seconds in K2 productions of target syllables produced in questions. This location is very early in the stressed syllable and illustrates that even this latest f0 trough is at the onset of the stressed syllable. This indicates that a rise begins early within the stressed syllable regardless of accent type in productions by each group of Korean and Mandarin speakers. These results indicate that nonnative speakers are producing H* or L+H* pitch accents. A shallow rise in a H* pitch accent and a steep rise in a L+H* pitch accent begin early within stressed syllables, or before the stressed syllable.

The similarity in results between language groups differing in English language proficiency also indicates that experience in the L2 has little effect on productions of L* accents. There was no significant difference between any two nonnative language groups. Moreover, a means comparison indicated that productions of nuclear accents produced in nuclear accented words did not differ in statements and in English. This lack of significant differences indicates that English language experience is not affecting productions in M2 and K2 speakers.

The mean location of the f0 minimum derived from each language groups' productions of "memorizes" and "memorial" in statements and questions was significantly different indicated by a significant interaction between language group, intonation type, and stress type [$F(4,28)=2.99$; $p<.036$]. These results are provided in Figure 5.30. The primary difference in the pattern of results is in the negative means derived from productions of "memorial" by all groups but E. Negative values indicate that the location of the f0 minimum occurred in the unstressed first syllable in "memorial", before the stressed syllable. In other words, an f0 rise begins before the stressed syllable. This pattern is more typical of a L+H* pitch accent. The means derived from all nonnative English speaking language groups occur before or immediately after the onset of the stressed syllable. On the other hand, a L* pitch accent begins much later in the stressed syllable. Only the mean location of the f0 minimum derived from E productions of target words produced in questions are consistent with a L* pitch accent. Also, the difference in means derived from target words occurring in statements and in questions is greatest in E in productions in both "memorizes" and "memorial". The f0 trough is about .100 seconds later in both targets in a the L* condition. There is not such a great separation in any other language group. These differences between E and the remaining language groups again indicate that English speakers are producing different pitch accents in different intonation conditions, while nonnative speakers are producing the same pitch accent in different intonation conditions.

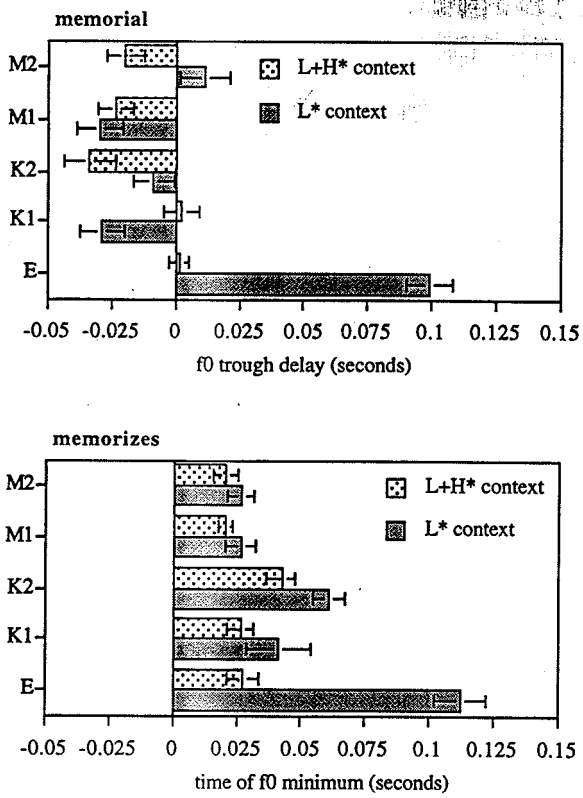


Figure 5.30 The location of the f0 minimum in productions of "memorial" and "memorizes" in statements and in questions.

5.2.2 The timing of f0 maximum

The location of an f0 maximum (or f0 bend) relative to the end of the word was observed to determine if the following H tone after the initial L tone was realized closer to the stressed syllable in targets words indicating that a L+H* pitch accent was used, or if the H tone was realized closer to the end of target words indicating that a H- phrase accent was used. Target words produced in nuclear accented targets in statements and in questions were observed. This f0 peak relative to the end of target words was used as the dependent measure in a four-way ANOVA. Language group was treated as a between subjects variable, and intonation type, stress type and repetition were treated as within subjects variables. Means derived from these measures are negative numbers indicating that the f0 maximum occurred before the end of target words. The larger the negative mean, the earlier in the target word the f0 peak occurred.

There was a significant effect of language group [$F(4,30)=9.42$; $p<.001$]. A Tukey-Kramer post-hoc test of significance revealed that English speakers performed differently from the less experienced native Mandarin speakers, M1, and the less experienced native Korean speakers, K1 ($p<.01$). The location of an f0 peak was significantly earlier in "memorizes" (mean =-.568 seconds) than in "memorial" (mean = -.263 seconds) [$F(1,30)=645$; $p<.001$]. Also, the f0 maximum was significantly earlier in words produced in questions (mean =.464) than in statements (mean =.367) [$F(1,30)=105$; $p<.001$]. Repetition was also significant [$F(4,120)=2.951$; $p<.023$]. The f0 peak was produced progressively closer to the end of the stressed syllable with each repetition. This effect of repetition may have been due to an increase in speech rate. In general, syllables are shorter with faster speech rate, and so the distance between the end of the stressed syllable and the f0 peak will be closer in faster speech. There were no significant interactions involving repetition and language group ($p>.05$).

There was no interaction of stress type and intonation type [$F(1,30)=1.82$; $p>.180$]. There was an interaction of stress type and language group [$F(4,30)=5.40$; $p<.003$]. Means from all language groups derived from measures taken from "memorizes" were greater than those derived from "memorial". The dependent measure was the f0 peak relative to the end of the word in this experiment. The f0 peak was typically produced at the end of the stressed syllable in productions of both statements and questions by all nonnative English speaking groups, and in only statements by E. The distance between the stressed syllable and the word end is greater in "memorizes" with a first stressed syllable than in "memorial" with a second stressed syllable. There was not a significant interaction between stress type and intonation type [$F(1,30)=1.82$; $p>.18$].

Of particular relevance to this experiment is the significant interaction between language group and intonation type [$F(4,30)=58.1$; $p<.001$]. These results are illustrated in Figure 5.31. The location of the f0 peak is well before the end of target words in productions of both statements and questions as illustrated by the greater negative means. Negative means indicate that the f0 peak is before the end of the word. Zero within the horizontal axis represents the location of the end of the target word. The mean f0 location for E speakers is well before the word end, about 500 ms in statements. This is more typical of L+H* accents followed by a L- phrase boundary where the peak H* is realized in or close to the stressed syllable. The peak f0, as illustrated in Figure 5.28 is at the end of the stressed syllable. In both "memorial" and "memorizes", the stressed syllable is followed by two or more syllables. The f0 peak thus occurs well before the end of the word.

The f0 peak in productions of the nuclear accented words in questions, however, is right around the end of the word. The mean location of this peak is 100 ms before the end of target words. This is consistent with a H- phrase accent. A H- phrase accent is not realized until the edge of the pitch accented word (Silverman & Pierrehumbert, 1990).

These results confirm that native English speakers are producing two different types of tonal patterns in statements and in questions consistent with L+H* pitch accents and L* pitch accents, respectively. The difference in f0 peak realization confirms this difference.

Nonnative English language groups perform differently. K1, K2, M1, and M2 are producing a f0 peak that occurs within the same location in target words in both statements and in questions. The similar location of the f0 peak in Figure 5.31 illustrates this similarity. While the f0 peak is most different in M2 in comparison to all other nonnative English speaking groups, this difference is little in comparison to E.

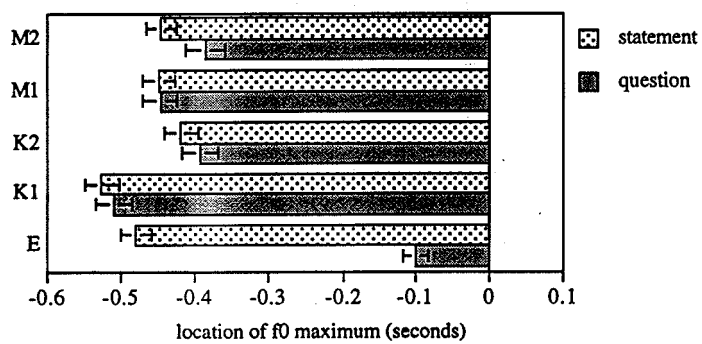
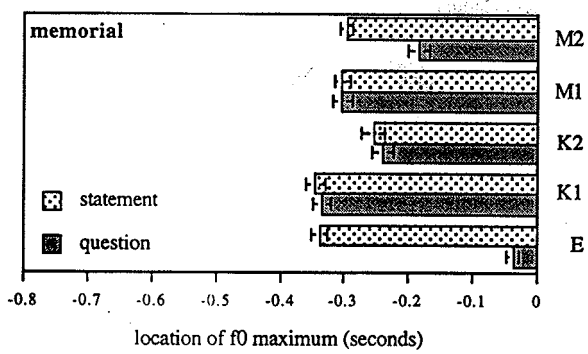


Figure 5.31 The location of the f0 maximum relative to the end of the word in productions of statements and questions by each language group. Standard error bars are provided.

Also relevant is the significant interaction of stress type, intonation type, and language group [$F(4,30)= 9.42$; $p<.001$]. These results are illustrated in Figure 5.32. In productions by E, the location of the f0 peak lies close to zero in questions in both "memorial" and "memorizes" indicating that the f0 bend occurs right before the end of target words, consistent with a H- phrase accent. The f0 peak in productions in statements is much earlier in both targets. The location of this peak is about 350 ms before the end of "memorial" and about 625 ms in "memorizes." This result suggests that the f0 peak in statements is realized closer to the stressed syllable, consistent with the location of the peak in a L+H* pitch accent. The greater difference in the location of the f0 peak in productions of "memorial" and "memorizes" in statements indicates that this is indeed the case. The greater distance between the location of the stressed syllable in "memorizes" and the end of this word compared to location of the stressed

syllable in "memorial" and the end of this word can explain why the f0 peak is so much further from the end of "memorizes" with an initial stressed syllable.

There is almost no difference between the location of an f0 peak in statements and questions in both target words in productions by M1, K1, and K2. This indicates that speakers in these groups were not producing different pitch accents in statements and in questions. A difference in the mean location of the f0 peak in productions of "memorial" by M2 suggest that these more proficient English speakers are producing different accent patterns in statements and in questions. But not in "memorizes". The means derived from productions of this word by M2 are almost the same. M2 speakers are more likely to produce a later peak in "memorial" and may be producing a H- phrase accent and not a L+H* pitch accent in this target word. This taken together with the results displayed in Figure 5.32 suggest that M2 speakers are producing a rising LH tonal pattern similar to a L* H- produced by E. In Figure 5.32, the location of the f0 trough in productions of "memorial" produced in questions is after the onset of the stressed syllable, and contrasts to the location of the f0 trough produced before the stressed syllable in statements. This pattern was of all nonnative English speaking groups, more like productions by E. Only M2 speakers, not the more proficient K2 speakers, are producing L* pitch accent patterns that are closer to productions by native English speakers.



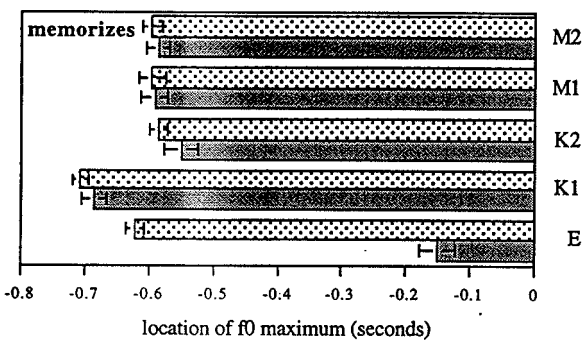


Figure 5.32 The location of the f0 peak relative to the end of the word "memorial" and "memorizes" in productions of questions and statements by each language group.

To shed light on the possible association of an f0 peak with the stressed syllable in target words, the f0 peak relative to the end of the stressed syllable was determined. The results of this comparison are illustrated in Figure 5.33. In this graph, zero represents the location of the end of the stressed syllable. Negative means indicate that the f0 peak is before the end of the stressed syllable, and positive means indicate the peak is after the end of the stressed syllable.

In productions by E, the location of the f0 peak is right before the end of the stressed syllable in productions of target words only in statements. This location is consistent with the location of an f0 peak in a L+H* pitch accent. The pitch accent is associated with the word and not the intermediate phrase. The f0 peak location in productions of questions by E, is well-after the stressed syllable edge as illustrated by a large positive mean. This is consistent with a later H- phrase accent that is realized around the end of nuclear accented words in English. In contrast, the location of the f0 peak is around the edge of the stressed syllable end in productions of both statements and questions in the remaining language groups. This is illustrated by positive and negative means that lie close to zero. This result confirms that the F0 peak in productions of nuclear accents in both statements and questions by nonnative speakers of English is realized at the edge of the stressed syllable.

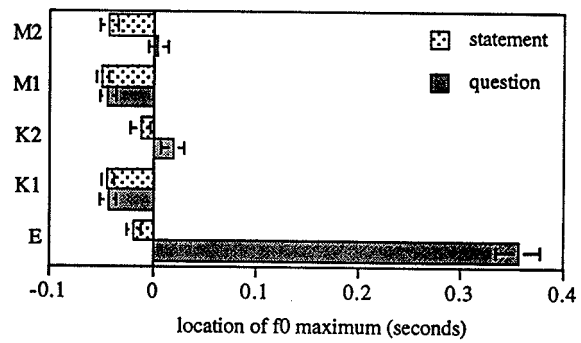


Figure 5.33 The location of the f0 maximum relative to the end of the stressed syllable in target words, in productions of statements and questions by each language group. Standard error bars are provided.

Possible differences in productions of different stress types were also observed, in order to observe if M2 speakers were producing a peak in "memorial" that corresponded to a H- phrase accent as was suggested earlier. M2 subjects produced a peak that was later in "memorial" produced in questions than in statements, and this indicated that these subjects might be producing a L* pitch accent followed by a H- phrase accent. The results found here suggest that the M2 speakers, like the remaining nonnative English speakers were producing a H tone that was associated with a stressed syllable, and so were producing a L+H* pitch accent and not a H- phrase accent. The location of the f0 peak in productions of "memorial" was -.016 ms in questions and -.104 ms in statements. A H tone was reached at the very end of the stressed syllable in questions, and well before the end of the stressed syllable in statements. So while an f0 maximum was reached within the stressed syllable of

"memorial" produced in both statements and questions, there is a difference in timing between accents produced in "memorial" in these two intonational conditions.

5.3 The association of H tones in LH f0 patterns

Productions of nuclear accented words produced in declarative statements were observed in order to analyze the timing of the f0 peak in targets that were produced with a rising tonal pattern. English speakers produced a LHL tonal pattern within target words in only this condition, while most nonnative speakers produced this type of pitch accent in prominent targets in both questions and statements as discussed previously in section 5.1 of this chapter. Because a LHL tonal pattern was produced in nuclear accented words in statements by most subjects, this accent condition was observed for possible differences in the timing of the f0 peak.

In English, a pitch accent is associated with a stressed syllable; however, the peaks of L+H* accents are not always realized in the stressed syllable, and are often realized in the following syllable (Silverman & Pierrehumbert, 1990). This is illustrated in Figure 5.5. The prominent rise in L+H* pitch accents is realized within the stressed syllable, however, the f0 maximum associated with the starred portion of this accent may not be realized until later. **If the stressed syllable is first in a word, as in "memorizes", the L+H* peak may be realized in the second syllable by English speakers, but if the stressed syllable is later in a word, as in "memorial", the L+H* peak may be realized in the stressed syllable.**

All Mandarin speakers (in both M1 and M2 groups) produced a LHL tonal pattern in nuclear accented target words in productions of "memorizes" and "memorial". Of interest here, is the location of the H tone relative to the accented stressed syllable. It is hypothesized that Mandarin speakers associate tone in Mandarin with stress in English because tone and stress are similar prosodic constructs. In Mandarin, the high tone in tone4 is realized within the syllable (Shih, 1988). If Mandarin speakers associate stress with a tone-bearing syllable, then the peak f0 in English accented words will be realized within the stressed syllable. **The high f0 target in "memorizes" will be realized within the first syllable, and the high target in "memorial" will be realized within the second syllable in productions by M1 speakers who are less proficient in English, while the timing of the high peak in productions by M2 speakers is expected to be more like that of E.**

In Korean, the f0 maximum associated with the initial high tone of the accentual phrase is loosely associated with the second syllable, according to Jun (1993). Korean speakers produced H tonal peaks within the stressed syllables of nuclear accented words, as was indicated by a chi-square analysis. All subjects in K1 produced LHL tonal patterns in the nuclear accented condition, while five subjects in K2 produced a LHL pattern. Productions by these 12 subjects were analyzed. In Korean, the second syllable of a prominent word is typically produced with a high tone. It is hypothesized, that if Korean speakers transfer the tonal pattern of the accentual phrase to productions of accented words in English, then the f0 maximum will be realized within the second syllable of multisyllabic words regardless of the location of the stressed syllable in their productions of English. **The high target will be realized in the stressed syllable in "memorial" and the unstressed second syllable of "memorizes". This realization of the high tonal peak is similar in Korean and English, and so productions by both K1 and K2 are expected be like those of E.**

In order to observe these possible differences, the time of f0 maximum in nuclear accented words produced with a LHL tonal pattern was observed relative to the end of the stressed syllable within "memorial" and "memorizes". The location of the f0 peak was identified as being the point in time where the maximum f0 value occurred following an initial low tone within nuclear accented targets produced in statements. The time of the f0 peak was then subtracted from the end of the stressed syllable. These values are illustrated in Figure 5.34.

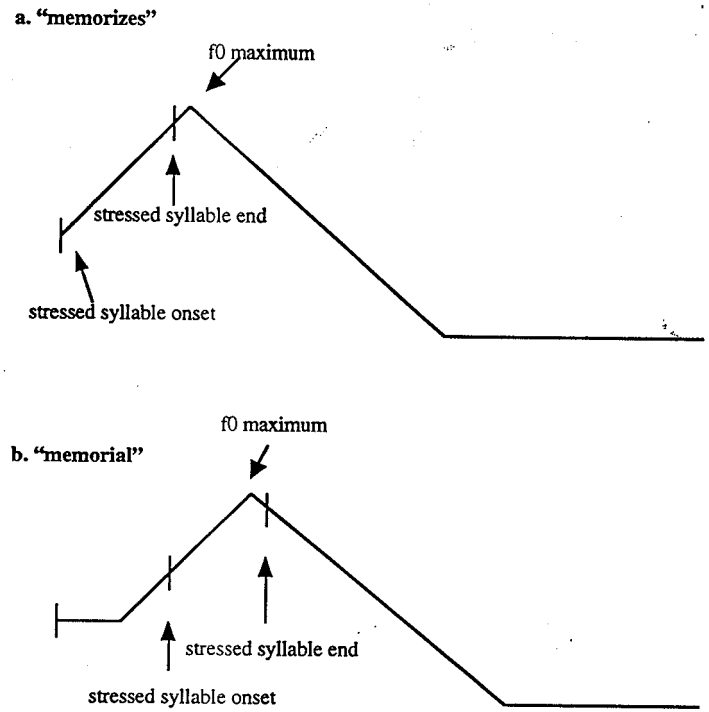


Figure 5.34 Illustration of f0 maximum in L+H* pitch accents in "memorizes" within first syllable stress, and "memorial" with second syllable stress.

A three-way ANOVA was used to determine if the location of the peak accent in declarative nuclear accented words was significantly affected by the location of the stressed syllable in each language group. The dependent measure was the time of the maximum f0 relative to the onset of the stressed syllable. Language group was a between group variable, stress type and repetition were treated as repeated variables.

The results of the ANOVA revealed that language groups did not perform significantly different from one another overall [$F(4,28)=2.44$; $p>.089$], nor was there a main effect of repetition [$F(4,112)=.829$; $p>.509$]. The location of the f0 peak was significantly later in productions of "memorial" than in productions of "memorizes" as revealed by a main effect of stress type [$F(1,28)=162$; $p<.001$].

There was not a significant interaction of stress type and language group [$F(4,28)=.805$; $p>.532$], however, the pattern of results suggests that E, and the more proficient English language speakers, K2 and M2, performed differently from the less proficient English language speakers, K1 and M1. Figure 5.35 provides the mean location of the f0 peak in "memorial" and "memorizes" relative to the end of the stressed syllable, obtained from each language group. Positive means are derived from f0 peaks that occur within the stressed syllable, negative means are derived from f0 peaks that occur after the stressed syllable. The greater the positive means, the earlier the f0 peak within the stressed syllable. The greater the negative means, the later the peak occurred after the stressed syllable.

In productions by E, the f0 maximum was produced early within the stressed syllable in "memorial", but not until the after the stressed syllable in "memorizes." This same pattern existed in productions by K2 and M2. The timing of the pitch accent peak realized within the accented word was affected by the location of the stressed syllable. The location of the f0 peak in productions by less experienced K1 and M1 occurred within the stressed syllable in target words, regardless of the location of the stressed syllable. The pattern was predicted for M1. Their productions appear to be influenced by Mandarin, their first language, where tones are a property of a syllable and not a property of an accented word. As a result, the location of the peak accent occurs within the stressed syllable of target words. Less proficient K1 speakers, however, did not perform as predicted. They too produced peak accents within the stressed syllable in targets.

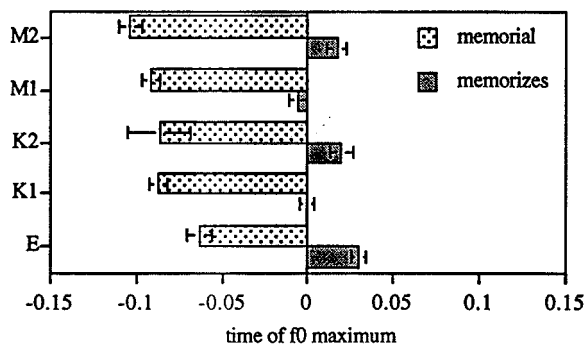


Figure 5.35 The location of the f0 peak relative to the end of the stressed syllable in "memorial" and "memorizes". Negative numbers indicate the peak is within the stressed syllable, positive numbers indicate the peak is after the stressed syllable.

5.4 F0 excursion in nuclear accent condition

The analysis of f0 contours in section 5.1 of this chapter indicated that many nonnative speakers of English were producing different tonal patterns in "memorial" and "memorizes" within one intonation condition, while native English speakers were producing one intonation pattern in one intonational condition in both targets. While a few subjects in M1 and M2 produced different tonal patterns in target words, the majority of K1 speakers produced rising accent patterns in "memorial" and falling tonal patterns in "memorizes". In order to discern if this analysis was correct, the f0 excursion within nuclear accented targets produced in statements was analyzed. Some speakers in all nonnative English speaking groups, but especially native Korean speakers were producing a falling accent pattern in "memorizes" characterized be a shallow initial rise in the initial stressed syllable and a rising intonation pattern in "memorizes" characterized by a longer rise within the stressed syllable. If speakers within these groups were producing different accent patterns in "memorizes" and "memorial", then the f0 excursion within the accented target words should differ. The excursion should be short in "memorizes", and longer in "memorial".

In order to determine if these different pitch accent patterns existed in productions by the nonnative English speaking groups, the initial f0 rise in target words was examined. The f0 excursion was determined by subtracting in Hz., the f0 minimum from the f0 maximum. This measure was used as the dependent measure in a 3-way ANOVA. Language group was treated as a between subjects variable, and stress type and repetition were treated as within subject variables.

There was not a significant effect of stress type [$F(1,30)=1.80$; $p>.189$]. The f0 excursion was slightly longer in productions of "memorial" (56 Hz.) than in "memorizes" (52 Hz.) There was no main effect of repetition [$F(4,120)=.958$; $p>.05$]. There was however, an interaction between repetition and stress type [$F(4,120)= p<.001$]. Because there was no interaction between repetition and stress type and language group [$F(16,120)=1.03$; $p>.428$], the influence of repetition will not be discussed further.

There was a significant effect of language group [$F(4,30)=3.78$; $p<.014$]. These results are displayed in Figure 5.36. A Tukey-Kramer post hoc test of significance revealed that the f0 excursion derived from K2 productions was significantly longer than the f0 excursion derived from M1 productions ($p<.01$).

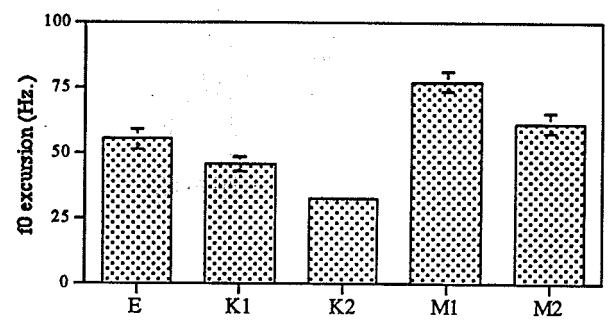


Figure 5.36 The f0 excursion within the initial rise of target words produced by each language group. Standard error bars are provided.

The average amount of f0 change within target words produced by E was around 50 Hz. All productions by E were characterized as having a L+H* pitch accent. The timing of the F0 minimum and maximum values determined earlier in this chapter were consistent with a L+H* pitch accent. This 50 Hz. rise in E productions, represents the mean f0 rise in a L+H* accent produced by these native English speakers. M1 and M2 groups also produced long initial rises in target words, the difference in these two groups being that the rise was less for the more proficient M2 speakers and more like those of E. These three groups were producing an initial rise consistent with a L+H* pitch accent. The means derived from productions from K1 and K2, however, were shorter than those produced by E, M1, and M2. This suggests that these native Korean speakers were producing shallower rises in target words that could be consistent with a H* pitch accent.

Most relevant to this discussion is a significant difference between language group and stress type [F(4,30)=2.89; p<.039]. It has been suggested that native Korean speakers may be using different tonal patterns in words differing in the location of a stressed syllable. This significant interaction suggests that this is indeed the case. These results are provided in Figure 5.37.

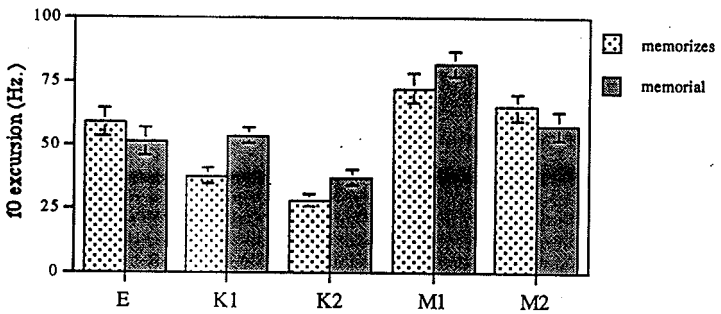


Figure 5.37 The f0 excursion within the initial rise in "memorizes" and "memorial" produced by each language group. Standard error bars are provided.

English speakers produced a slightly greater LH rise in production of "memorizes" than in "memorial". Although these means are similar indicated by overlapping standard error bars. Productions by M2 were most like those of E. The only difference between these two groups, is that productions by M2 were longer. Nonetheless, the mean LH rise in "memorizes" is slightly longer than in "memorial". And like E, the error bars overlap indicating that these extent of the f0 rise in target words is virtually the same. The means derived from productions of target words by M1 were also similar. The difference between M1 and M2 being that the LH rise in "memorial" was slightly greater than that of "memorizes". Because the results in productions of both target words are similar in E, M1, and M2, it can be concluded that a similar tonal pattern consistent with a L+H* pitch accent was being produced by these speakers.

Native Korean speakers produced a LH rise in both target words that were shorter than any other group. This is of relevance because any difference between the rise in "memorizes" and "memorial" will be greater had the mean excursions been longer. A percentage of the shorter excursion in relationship to the longer will reveal this significance. In E, the excursion in "memorizes" was 87% that of "memorial", and in M2, 88%. In M2, the excursion in "memorial" was 88% that of "memorizes", in K1, 70% , and in K2, 75%. These percentages indicate native Korean speakers were producing greater differences in a LH rise in target words than were other language groups, and that the less English proficient K1 groups were producing the greatest difference. These results suggest that native Korean speakers were producing different accent types in target words even though the intonational context in these utterances was identical.

5.5 Discussion

5.5. Comparisons of different tonal patterns in target words

The first section of this chapter, Section 5.1 was devoted to describing the intonation patterns produced by subjects in each language group. Several observations were made that initiated statistical comparisons between target words produced in various intonational contexts.

First, for native English speakers, the differences in primary stress in the words "memorizes" with an initial stressed syllable and "memorial" with a later stressed syllable did not influence the intonation pattern in utterances.

The intonational context influenced the tonal pattern produced in target words. Different pitch accents were produced by E in statements and in questions. When targets were produced in a nuclear accented condition in statements, E speakers produced a LHL tonal pattern consistent with a L+H* pitch accent followed by a L- intermediate phrase boundary in both "memorizes" and "memorial". When targets were produced in a nuclear accented condition in questions, E speakers produced a LH tonal pattern consistent with a L* pitch accent followed by a H- phrase tone. In other words, E speakers produced two different pitch accents in target words, depending on whether the utterance was a statement or a question.

Native Mandarin speakers and native Korean speakers produced predominantly LHL tonal patterns in both nuclear accented "memorizes" and "memorial" in both statements and in questions. These tonal patterns were similar to L+H* pitch accents produced by E in only statements, and were not like L* pitch accents produced in questions by E. These speakers did not use two different pitch accents in these two different intonation conditions.

To experimentally support this observation, two measures were compared to capture differences in the different L* H- and L+H* tonal patterns produced by E and the L+H* tonal pattern produced by the nonnative English speaking groups. The timing of the L tone (the f0 minimum) and the H tone (the f0 maximum) in target words produced by all language groups were compared.

The timing of the LH tonal pattern in productions by E were consistently different in statements and questions indicating that two pitch accents were being used. In questions, the L tone was realized well after the beginning of the stressed syllable in "memorizes" and "memorial", while the L tone was realized at the beginning of the

stressed syllable. The late L tone is consistent with a L* pitch accent, and the early L tone is consistent with a L+H* pitch accent. In questions, the H tone was realized around the end of each target word, while in statements, the H tone was realized around the end of the stressed syllable. The later H tone is consistent with the timing of a H- phrase accent, while the early H tone is consistent with the timing of the H tone in a L+H* pitch accent.

Nonnative speakers did not use different pitch accents to convey different intonational meanings in statements and in questions. In both statements and questions, the L tone was realized at the onset of the stressed syllable, and the H tone was realized around the end of the stressed syllable. The LH tonal rise, in other words, was realized in the stressed syllable of target words. The timing of this rise is consistent with a L+H* pitch accent. This results confirmed that nonnative English speakers were producing the same pitch accent in nuclear accented targets in both statements and in questions

The second observation made was that nonnative speakers were producing pitch accents in target words, where E speakers produced none.

All E speakers produced no pitch accent in target words produced in a post nuclear unaccented condition, and the majority of E speakers produced no pitch accent in target words produced in a prenuclear accented condition. The tonal pattern in these unaccented target words was controlled by the tonal characteristics of surrounding accents. In the postnuclear statement condition, both "memorizes" and "memorial" were produced with a falling tonal pattern resulting from an earlier H* pitch accent and a following L- phrase tone. In questions, a rising tonal pattern was produced in both of these target words resulting from an earlier L* pitch accent and a following H- intermediate phrase boundary tone.

In these two conditions, where targets were not produced with a nuclear accent, nonnative speakers produced pitch accents in both "memorizes" and "memorial". The tonal patterns in these accents were not as prominent as those produced in nuclear accented words. The extent of the f0 rise in target words was reduced in these prenuclear and postnuclear contexts.

This result indicates that nonnative speakers associate a tonal movement with stress, while E speakers associate tonal movements with intonation patterns. Only a pitch accented stressed syllable is produced with a particular f0 pattern consistent with a particular pitch accent. Unaccented stressed syllables are produced with the tonal characteristics of the surrounding accents and do not have a particular tonal shape associated with them. There is no lexically specified tonal shape that a stressed syllable must be produced with. Most native Mandarin and native Korean speakers were in general unable to produce unaccented target words. In addition, the amount of English experience did not affect these results. Only one speaker from M1 and M2, and only one K1 speaker, and two K2 speakers produced unaccented target words in the postnuclear unaccented condition.

This result was expected for Mandarin speakers but not for Korean speakers. It was hypothesized for M1 speakers, that stressed syllables would be produced with a particular tonal change in "memorizes" and "memorial". These tonal changes would be reduced in less prominent contexts. This hypothesis was made because stressed syllables in Mandarin have a particular tonal shape associated with their structure. And, the more prominent a word is, the greater the extent -and the more fully realized-

stressed syllables become. However, because tone is lexical in Mandarin, the tonal shape of target syllables is maintained even when words are not prominent. These results supported these conclusions. M1 speakers did not produced unaccented forms of "memorizes" and "memorial". It was also hypothesized that M2 speakers, with more exposure to spoken English would learn to produce unaccented targets. They, as a group, did not. Although their speech was rated as being more fluent than that of M1, they nonetheless produced noticeable pitch changes in target words produced in unaccented contexts. English experience did not facilitate their ability, and so they performed like M1 speakers.

This result was not expected for Korean speakers. In Korean, prominent words are produced with an accent, a LH tonal pattern of a phrase accent. This Korean accent is not an attribute of a word, but is only produced in prominent words. Less prominent words produced following an accented word in that phrase, are produced without a particular tonal pattern. Because of this, it was hypothesized that K1 and K2 speakers would be able to produce words without a particular tonal pattern in a postnuclear unaccented context. Only two of the seven K2 speakers produced no accent in target words. The remaining K2 subjects and six of the K1 subjects produced very small, but recognizable, f0 changes in target words. Korean speakers productions, in other words, were like those of Mandarin speakers. Even though these language differ in their respective intonational systems, their productions were nonetheless similar.

The third observation was that many nonnative speakers produced different tonal patterns in "memorizes" and "memorial" produced in the same intonation conditions. "Memorizes" was produced with a falling HL tonal pattern, and "memorial" was produced with a rising LHL tonal pattern.

Productions of "memorizes" by many nonnative speakers was produced with a falling HL tonal pattern. There was only a short initial rise within this target word followed by a tonal fall that ended around the end of the word. This pitch pattern is consistent with a H* pitch accent followed by a L- phrase boundary. "Memorial", on the other hand, was consistently produced with a steep initial rise consistent with a L+H* pitch accent. While E speakers produced a steep rise in both targets consistent with a L+H* pitch accent, the nonnative speakers appeared to be producing a L+H* pitch accent only in "memorial". These tonal patterns were most evident in prenuclear and postnuclear contexts.

This analysis suggests that native Mandarin and Korean speakers are associating a particular word with a particular tonal pattern. A falling tonal pattern is associated with "memorizes", a word with an initial "strong-weak" syllable structure, and a rising tonal pattern is associated with "memorial", a word with an initial "weak-strong" syllable structure.

To confirm this observation, statistical analysis of the initial f0 excursion was observed in productions of nuclear accented targets produced in only statements by all language groups. This context is not the one where nonnative speakers were most likely to produced these differences, but it was the only context where E speakers produced a pitch accent, and it was the best context for identifying reliable changes in f0. There were more effects of creaky voice in postnuclear and prenuclear conditions.

The f0 excursion in productions by E was similar in both "memorial" and "memorizes". This confirmed the observation that the same rising L+H* pitch accent

was produced in both "memorizes" and "memorial". K1 speakers productions were significantly different from those by E. "Memorial" was produced with a longer initial rise than was "memorizes" by all nonnative English speaking subjects. This indicated that a H* pitch accent was produced in "memorizes" and a L+H* pitch accent was produced in "memorial". Moreover, these differences in f0 excursions were most different in productions by K1. These nonnative speakers of English, as a group, were producing different tonal patterns in words differing in stress patterns.

5.5.2 The alignment of pitch accents

Not only were statistical analyses made based on observations made in Section 5.1 of this chapter, but one other statistical comparison was made based on differences between the intonation systems in the three languages observed in this study. The timing of pitch accents was observed. In English, the high tonal peak of a L+H* and a H* pitch accent is reached around the end of a stressed syllable. However, if the stressed syllable is first in a word, such as "memorizes", the f0 peak is not reached until the second syllable. In word with later stressed syllables, such as "memorial", the f0 peak is typically realized in the stressed syllable. With regards to this study, the peak would be realized early in the second syllable of "memorizes" and later in the second syllable of "memorial". In contrast to English, in Mandarin, tones are part of the syllable's structure, and so they are realized within a syllable. Because of this, it was hypothesized that Mandarin speakers would produce a f0 peak within the stressed syllable of target words. These speakers would produce a peak in the first syllable of "memorizes" and the second syllable of "memorial". In Korean, the H target in a LH accent produced in prominent words, is typically realized around the second syllable. If this pattern is transferred into productions of English, then this suggests that the H* peak of a L+H* pitch accent or a H* pitch accent will be realized within the second syllable of "memorizes" with an initial stressed syllable and "memorial" with a later stressed syllable.

The location of the H* tonal peak was compared in productions of nuclear accented target words produced in statements. There were no statistically significant differences, however, the pattern of results was as expected for less experienced Mandarin speakers (M1), but not for less experienced Korean speakers (K1).

The location of the H tone in L+H* pitch accented words was as predicted for E speakers. A H target was reached in just after the stressed syllable in "memorizes", or in the neighboring unstressed syllable; and a H target was reached late within the stressed syllable in "memorial". The rise of a L+H* pitch accent may be the most important aspect of this pitch accent, the fact that the H* peak is not realized until after the stressed syllable in "memorizes" suggests that the rise, not the f0 maximum is the most important. As predicted, M1 speakers produced a peak accent that was realized completely within the stressed syllable. K1 speakers also produced a peak accent that was realized in the stressed syllable. This latter result was not expected. Both of these less experienced English speaking groups produced a LH rise in the stressed syllable suggesting that for these speakers, a rise in f0 may not be as important as the location of the H* peak. These speakers may associate high f0 with a stressed syllable.

M2 and K2 speakers performed more like E speakers. The mean f0 maximum was located in the neighboring unstressed syllable in "memorizes". These more fluent speakers were producing rising accents that were similar to those produced by the native English speakers.

All of the f0 comparisons made in this study indicate that nonnative speakers of English do not produce intonation patterns like those of native English speakers. Native Korean and Mandarin speakers do not produce L* pitch accents typical of nuclear accents in yes/no questions. Instead, L+H* or H* pitch accents similar to those produced in statements are also produced in questions. While native speakers of Korean and Mandarin do not use different pitch accents in different intonational contexts, many produce different tonal patterns, many of these speakers associate different tonal patterns with words that differ in stress pattern. Falling accents, consistent with a H* pitch accent followed by a L- phrase tone were produced in "memorizes" with an initial stressed syllable, and rising accents consistent with a L+H* pitch accent followed by a L- phase tone were produced in "memorial" with an initial unstressed syllable.

In addition, producing no pitch accent in target word poses difficulty for native Korean and Mandarin speakers. Very few nonnative English speaking subjects produced unaccented target words in the postnuclear unaccented context. This indicates that f0 changes are associated with stressed syllables by these speakers.

Finally, speakers with less exposure to English may associate peak f0 with a stressed syllable. The first result that supports this conclusion the different accent patterns produced in "memorizes" and "memorial". Many nonnative English speakers produced a falling HL tonal pattern in "memorizes". This initial H tone produced in this word ensures that a peak f0 be realized within the stressed syllable. There is time for a H* peak to be realized in "memorial", and so a rising LH tonal pattern is produced within this word. The second result that supports this conclusion is the timing of the H* peak in nuclear pitch accented words. The stressed syllable in productions by the less experienced English speakers was produced with the highest level of f0. An f0 peak was realized in the stressed syllable of both "memorizes" and "memorial". This analysis of nuclear accents suggests that a high f0 is associated with the stressed syllable of target words.

CHAPTER 6

DURATION COMPARISONS

Target words were produced in questions and in statements with three levels of prominence. In particular, targets were produced in nuclear accented, prenuclear accented, and unaccented contexts in both intonation patterns. In statements, "memorial, for example, was produced with a nuclear accent in "I know he wrote the word MEMORIAL" nine times", with a prenuclear accent in "He wrote "memorial" NINE times", and after the nuclear accent in "He WROTE "memorial" nine times." Capitalized words were to be produced with the most emphasis. All utterances and their rhythmic structures are provided in Figure 6.1. A prominence grid is used to represent the rhythmic structure of these sentences. The target word "memorial" is provided as an example. Underlined words were produced by subjects with the most emphasis, or prominence, in that utterance. Large asterisks represent syllables that have a rhythmic beat at each level. Beats have the least prominence at the syllable level, and have the greatest prominence at the nuclear accented level. Bracketed sections of this grid represent the level of prominence in the target word being observed in that utterance.

Target words represented by the highest level of this grid, were produced in a nuclear accented context, targets represented by a level below this were produced with a prenuclear accent, and targets represented by the level below this were produced in an unaccented context.

A. NUCLEAR: Target words in nuclear conditions:

```
nuclear accent:  *   *     *     *    [* * *  *]   *     *
pitch accent:    *   *     *     *     * * *  *     *     *
full vowel:       *  *     *     *     * * *  *     *     *
syllable:        *   *     *     *     * * * *  *     *
```

word : ... he wrote the word <u>memorial</u> nine times.
... he write the word <u>memorial</u> nine times?

B. PRENUCLEAR: Target words in prenuclear nuclear contexts:

```
nuclear accent:  *   *     *  *  *  *    *     *
pitch accent:    *   *    [* * *  *]     *     *
full vowel:       *  *     * * *  *      *     *
syllable:        *   *     * * * *  *    *
```

word : ... he wrote "memorial" <u>eight</u> times.
... he wrote "memorial" <u>eight</u> times?

C. UNACCENTED: Target words without and accent:

```
nuclear accent: *       *  * *  *   *    *
pitch accent:    *      *  * *  *   *    *
full vowel:       *    [* **  *] *       *
syllable:        *    **** *     *
```

word : ... <u>write</u> memorial eight times.
... <u>type</u> memorial eight times?

Figure 6.1 The rhythmic structure of test utterances. One target word, "memorial" is provided as an example. Underlined words are produced with a nuclear accent.

This chapter reviews the results and provides a discussion on the effects of accent type and intonation type on unstressed and stressed syllables in productions by five language groups. Six separate five-way ANOVAs were used to analyze these results. Two analyses were run on each of three word pairs differing in stress type: "memorizes/memorial", "electrical/electrician', and "photography/photographic". Syntagmatic comparisons of the raw durations of target syllables in target word pairs were made. Language group was treated as a between subjects variable. Intonation type, accent type, stress type, and repetition were treated as within subject variables. The raw durations of target syllables was the dependent measure. Anova tables for each of these comparions are provided in Appendix E.

There are three sections in this chapter. The first section of this chapter discusses the results from comparisons of first and second syllables in "memorial" and "memorizes"; the second section discusses the results of second and third syllable comparisons in "electrician" and "electrical"; and the third section discusses the results from second and third syllable comparisons in "photographic" and "photography". Each chapter has two parts, the first presents the results of comparisons of early target syllables, the second part presents the results of late target syllable comparisons.

6.1 Duration Comparisons of First and Second Syllables in Memorizes and Memorial

6.1.1 Duration comparisons of first syllables

Productions of the unstressed first syllable in "memorial" and the stressed syllable in "memorizes" were the dependent measures in the analysis described here.

There was no significant main effect of language group [F(4,30)=1.11; p>.36]. These results, although not significant, reveal important patterns and so are discussed here. These average durations are indicative of the overall rate used by subjects within each of the five language groups. When comparing productions of target syllables from each language group, E, K2, and M2 performed similarly producing shorter durations of first syllable "me-" while K1 and M1 productions were longest. These results are illustrated in Figure 6.2. The less proficient English speakers, K1 and M1, produced syllables that were longer than more proficient speakers of the same native language, K2 and M2. With experience in English, these more proficient speakers of English acquired syllable durations that were more like those of E. The length of target syllables is an indicator of rate of speech. The most fluent English speaking group, E, spoke at a faster speech rate and produced shorter syllables overall as indicated by the short durations. The least fluent English speaking groups, M1 and M2, spoke at a slower rate of speech and produced syllables that were longest.

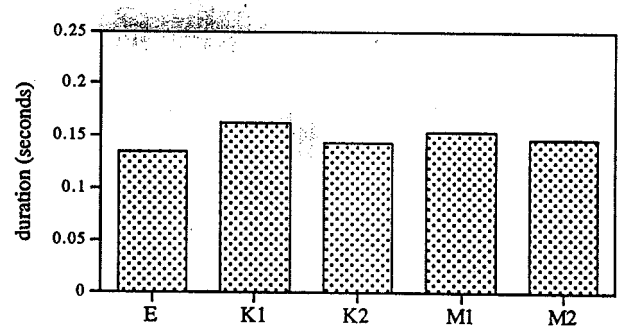


Figure 6.2 Average durations of the initial syllables of "memorizes" and "memorial" produced by five language groups. Standard error bars are not visible.

There was a main effect of intonation [F(1,30)=.669; p>.42]. Average durations of target syllables in questions and in statements, .149 and .148 seconds respectively, were almost identical. There was no main effect of repetition [F(4,120)=.406; p>.80].

There were two significant main effects. The first was a main effect of stress type [F(1,30)=148; p<.001]. This result indicates that the duration of the first syllables of "me-" in target words was affected by the target syllable being stressed in "memorizes" and not stressed in "memorial". The effects of stress type on syllable durations are illustrated in Figure 6.3. The stressed syllable in "memorizes" is .170 seconds and the unstressed syllable in "memorial" is .126 seconds. This relationship can be expressed as a ratio of the unstressed syllable duration relative to the stressed syllable duration. A ratio is derived by dividing the mean duration of the unstressed syllable by the stressed syllable. The unstressed syllable overall is .74 the duration of the stressed syllable.

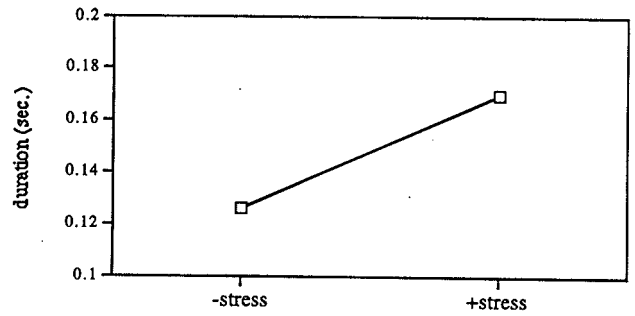


Figure 6.3 The duration of the initial syllable "me-" in "memorial" and memorizes.

There was a significant effect of accent type [F(2,60)=17.7; p<.001]. The effect of accent type on duration of target syllables is illustrated in Figure 6.4. The length of the initial syllable in target words decreases with prominence. A means comparison indicated that the average syllable duration in the nuclear context was significantly greater in the unaccented context [F=33.0; p<.01] and that the average syllable duration in the prenuclear context was significantly less than in the unaccented contexts [F=17.6; p<.01]. Target syllables are shorter in less prominent contexts.

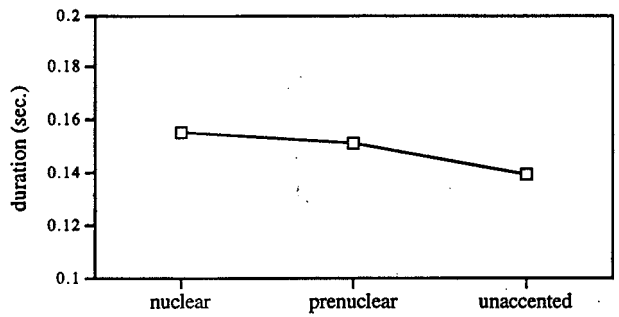


Figure 6.4 The duration of the first syllables in target word "memorizes" and "memorial" produced in three prominence contexts.

There was a significant interaction of stress type and accent type [F(2,60)=15.8; p<.001], and stress type and intonation type [F(1,30)=12.9; p<.002]. Figure 6.5 illustrates the effect of accent type on the duration of unstressed and stressed target syllables. While the unstressed syllable in three accent contexts is similar in duration, the stressed syllable is produced with greater length as the level of prominence increases. Stressed syllables are longest when produced in the most prominent context with a nuclear accent, and shortest when produced in the unaccented context.

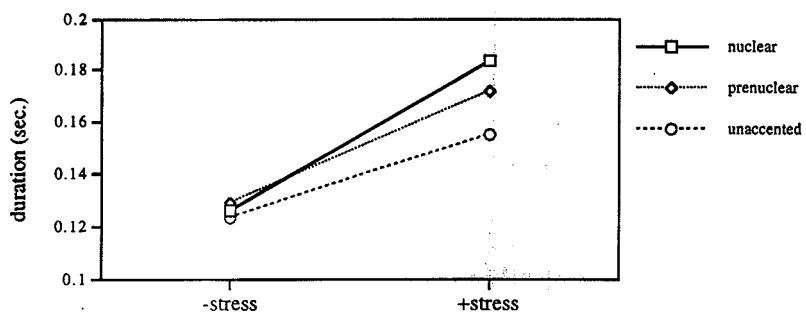


Figure 6.5 The mean durations of productions of the first unstressed syllable in "memorial" and the first stressed syllable in "memorizes" in three accent contexts.

The effect of intonation type on duration of unstressed and stressed target syllables is illustrated in Figure 6.6. Intonation has little effect on the duration of unstressed and stressed syllables type. Duration differentiates target syllables to a greater extent in statements, indicated by the steeper slope of the line connecting unstressed and stressed syllables.

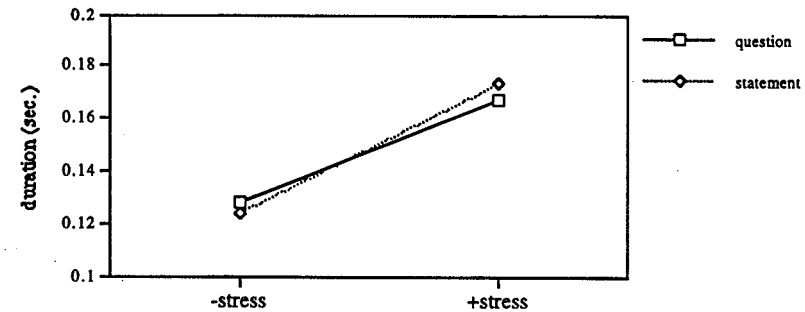


Figure 6.6 The mean durations of unstressed and stressed target syllable "me-" in questions and in statements.

There was no significant 3-way interaction between stress type, accent type, and intonation type [F(2,60)=.421; p>.658]. The same pattern of duration changes in unstressed and stressed syllables occurs in both statements and in questions: while the unstressed syllable is unaffected by changes in prominence, the stressed syllable increases in length as prominence level increases.

The effects of stress on the duration of target syllables were different among language groups as indicated by a significant interaction of language group and stress type [F(4,30)=4.76; p<.01]. These differences are illustrated in Figure 6.7. The duration of the stressed syllable is greater than that of the unstressed syllable for all groups. The relationship of the unstressed syllable to the stressed syllable in productions by E is .73, .88 in productions by K1, .76 in productions by K2; .64 in productions by M1, and .69 in productions by M2. K1 speakers produced the least amount of difference between unstressed and stressed syllables, and M1 speakers produced the greatest difference between target syllables. K2 speakers produced differences between target syllables that were intermediate to K1 and E; M2 speakers produced differences that were intermediate to M1 and E.

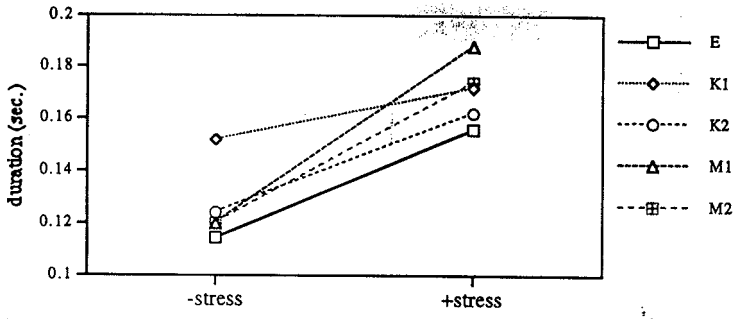


Figure 6.7 The duration of unstressed and stressed target syllable "me-" produced in "memorial" and "memorizes" by five language groups.

Both groups of Korean speakers, K1 and K2, produced less difference between unstressed and stressed syllables than did E speakers. Unstressed syllables were not reduced to the extent that they were by E speakers by both groups of native Korean speakers. Because of this, there is less differentiation in duration between unstressed and stressed syllables. This is most evident in productions by the less experienced K1 group, where the unstressed syllable is .88 the stressed syllable duration. The more experienced K2 group, on the other hand, reduces the unstressed syllable to a greater extent than K1, resulting in a greater separation of stress types; the unstressed syllable is .76 the stressed syllable duration. This relationship is similar to that of E. The greatest difference between K1 and K2 is in production of the unstressed syllable. This indicates that reduction strategies are acquired by the more proficient K2 group.

More proficient M2 speakers also produced length differences between unstressed and stressed syllables that were more like those of E; however, the strategies acquired by these Mandarin speakers are different from those acquired by K2 speakers. Both inexperienced and experienced Mandarin speakers, M1 and M2, produced short unstressed syllables similar to E productions. These Mandarin groups differ in the production of stressed syllables. This suggests that language experience affected production of the stressed syllable in these speakers. M1 speakers produced stressed syllables that were longer than those produced by the remaining four language groups. This greater lengthening resulted in a greater separation of target syllables in their productions. With English experience, M2 speakers spoke at a faster more fluent rate of speech by lengthening stressed syllables to a lesser extent. The length of the unstressed syllable in productions by M2 were 69% the duration of stressed syllables, more like the relationship exhibited in productions by E.

The following summary makes use of two types of comparisons. First is the relationship of the duration of the unstressed syllable relative to the stressed syllable and how this relationship compares to that of native English speakers. A ratio measure of the unstressed to stressed syllable is used to factor out possible effects of speech rate. Also important is to isolate the target syllable (unstressed or stressed) where the greatest change occurs in comparisons of M1 and M2 groups, and K1 and K2 groups. Greater reduction in the length of unstressed syllables by more proficient speakers indicates that reduction strategies are being acquired; while shorter stressed

syllables produced by more proficient speakers indicates that the more proficient speakers are speaking at a faster rate and are not modifying their reduction strategies in unstressed syllables.

K1 speakers produced unstressed syllables that were almost equal in duration to stressed syllables. The unstressed syllables were much longer than those produced by E speakers. The proportion of unstressed to stressed syllables were similar for E and K2. The greatest difference in K1 and K2 productions was in the duration unstressed syllable. K2 speakers produced shorter unstressed syllables indicating that K2 speakers acquired reduction strategies like those of E.

M1 and M2 speakers produced unstressed syllables with durations similar to those produced by E. The difference in duration between unstressed and stressed syllables was greatest in productions by both M1 and M2 indicating that both groups were able to reduce unstressed syllables. The greatest difference between M1 and M2 productions was in the production of stressed syllables. This change resulted in a relationship of unstressed and stressed syllables that was more similar to E.

More proficient K2 and M2 speakers used different strategies to produce syllables that were more like those of E. While K2 speakers produced target syllables that were more like those of E by reducing the unstressed syllable, M2 speakers achieved more native-like productions by reducing the length of the stressed syllable. This is an important difference. Mandarin speakers had little difficulty reducing syllables because reduced syllables occur in Mandarin and are shortened relative to stressed syllables. Korean speakers, in contrast, do not have reduced vowels and so reducing the length of unstressed syllables is something that needs to be acquired. While K1 speakers have not acquired this strategy, K2 speakers produced shorter unstressed syllables indicating that they have acquired this reduction strategy.

There was no significant effect of stress type, intonation, and language group [$F(4,30)=1.86$; $p>.14$]. Language groups performed similarly. The duration of the unstressed and stressed syllables were similar in both statements and in questions. This result was expected because target words produced with the same amount of prominence in each intonation pattern. To illustrate, a L* nuclear accent was used in productions of nuclear accented words in questions, at least by the E group, while a nuclear H* accent was used in nuclear accented words in statements. The tonal patterns of these two pitch accents in target words differ, but both are produced within a nuclear accented word (e.g., "I know he wrote the word MEMORIZES nine times." vs. "Did he write the word MEMORIZES nine times?"), and are the most prominent word in their respective utterances. The duration of target syllables was not affected by whether a L* pitch accent was used (in questions) or a L+H* pitch accent was used (in statements).

There was no significant interaction of language group, stress type, and accent type [$F(8,60)=1.04$; $p>.41$]. Although not significant, these results reveal patterns in productions between language groups that are relevant to this study. These results are illustrated in Figure 6.8a. Figure 6.8b provides the proportion of duration of the unstressed syllable relative to the stressed syllable.

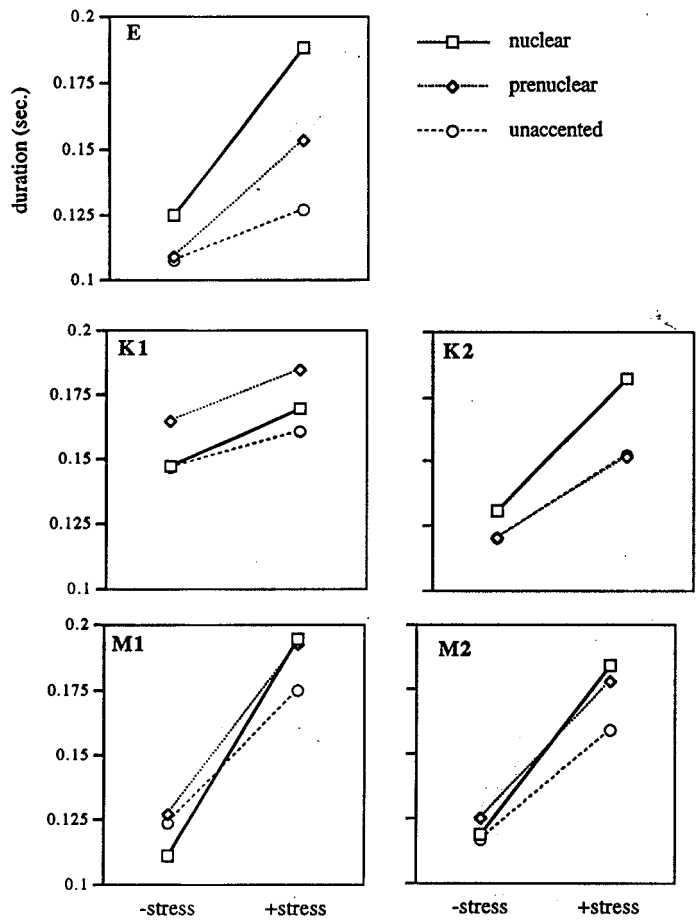


Figure 6.8a The duration of unstressed and stressed first syllable "me-" in "memorial" and "memorizes" produced in three accent contexts by five language groups.

Language Group	Nuclear	Prenuclear	Unaccented
E	.66	.71	.84
K1	.86	.89	.90
K2	.71	.79	.79
M1	.56	.66	.70
M2	.65	.70	.74

Figure 6.8b The duration of the unstressed syllable relative to the stressed syllable in the first syllable of memorial/memorizes in three accent contexts. Ratios were derived by dividing the mean duration of the unstressed syllable by the mean duration of the stressed syllable.

E productions of unstressed target syllables were less affected by accent context than were stressed target syllables. As revealed in the interaction of stress type and accent type, the duration of the stressed syllable increased as prominence level increased. The length of the unstressed syllable was shortest in the unaccented context and was .84 the length of the stressed syllable. As prominence level increased, duration better differentiated unstressed from stressed syllables. In the prenuclear context, unstressed syllables were .71 the stressed syllable duration; and in the nuclear accented context, unstressed syllables were .66 the stressed syllable duration.

Prominence level had less influence on the duration of unstressed and stressed syllables in productions by K1 speakers. The most obvious difference in prominence types was in productions of target syllables in prenuclear contexts. Both unstressed and stressed syllables were longest in prenuclear contexts. Even though both target syllables were longer in this prenuclear accent context, the relationship of unstressed to stressed syllables was similar to nuclear and unaccented contexts. The relationship of the unstressed and stressed target syllables is similar in all accent contexts: unstressed syllables in nuclear accented words were .86 the duration of stressed syllables in this context, were .89 the duration of stressed syllables in the prenuclear context, and were .90 the duration of stressed syllable in the unaccented context. These small differences in percentages expressing the relationship of target syllables indicate that prominence level had less influence on the duration of the stressed syllable as it did in E productions.

Productions by the more experienced K2 group are more like those of the E group. Unstressed syllables were shorter than those produced by K1, and more like those of E. In addition, prominence level differentially affected the duration of stressed syllables in words produced in the nuclear accented context and targets produced in the other two accent contexts. Nuclear accented stressed syllables were longer than prenuclear and unaccented stressed syllables. Unstressed syllables were .71 the duration of stressed syllables in this context compared to .79 in both prenuclear and unaccented contexts. These results together indicate that the K2 speakers are learning to reduce unstressed syllables, and lengthen stressed syllables when they occur in words produced with the highest level of prominence in an utterance. This separation between nuclear and less prominent contexts is similar to that exhibited by E.

Both groups of Mandarin speakers performed similarly in that the length of the unstressed syllable was influenced little by the prominence level, while the stressed syllable was most affected by the nuclear accented context. The difference in M1 and M2 groups is in the duration of stressed syllables in all three accent contexts, as indicated earlier in the main effects of language group and stress type. The more proficient M2 speakers produced stressed syllables that were shorter than those produced by M1 in all three prominence contexts. In M1 productions, unstressed syllables are .56, .66, and .70 the duration of stressed syllables in nuclear, prenuclear, and unaccented contexts. In M2 productions, these percentages were greater in all contexts due to the shorter duration of stressed syllables. These ratios derived from M2 productions in nuclear, prenuclear, and unaccented contexts are .65, .70, and .74, respectively. The durations of target syllables and the relationship of stressed to unstressed syllables are more like those of the E group.

To summarize these results, K2 and M2 groups performed more like the E group than did the less experienced comparison K1 and M2 groups. The more proficient Korean

speakers learned to reduce unstressed syllables in all accent contexts, and they learned to manipulate duration in stressed syllables to reveal differences in accent types. The more experienced Mandarin speakers, already able to reduce unstressed syllables and to lengthen stressed syllables differentially to indicate prominence between nuclear and less prominent accent types, learned to produce stressed syllables that were shorter and more like those of native English speakers.

There was no significant interaction effect between stress type, intonation type, accent type, and language group [$F(8,60)=.961$; $p>.05$]. Language groups performed similarly in that the intonational context of the utterance did not influence the duration of target syllables in different accent contexts. The pattern of results discussed above in the effects of language group, stress type, and accent type is similar in both questions and in statements.

6.1.2 Duration comparisons of second syllables

The unstressed second syllable in "memorizes" and the stressed syllable in "memorial" were compared in this analysis. There was a significant effect of group [F(4,30)=4.46; p<.01], stress type [F(1,30)=386; p<.001], intonation [F(1,30)=4.89; p<.02], and accent type [F(2,60)=65.5; p<.001]. Repetition was not significant [F(4,120)=2.04; p>.05].

The pattern of mean durations of the second syllable "-mor-" in "memorizes" and "memorial" is similar to that found in mean durations of the first syllable "me-" for each language group. Productions by more experienced K2 and M2 speakers were more like those of E speakers. These three groups produced syllable durations that were shorter than less experienced K1 and M1 groups. These results are illustrated in Figure 6.9.

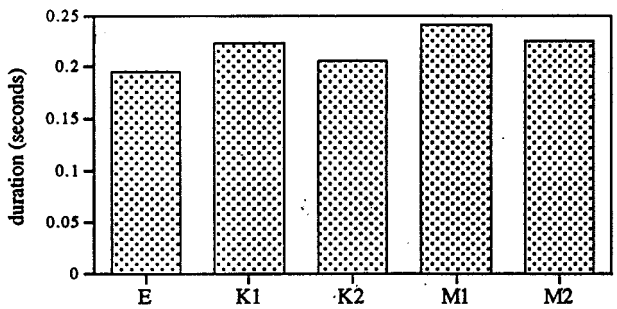


Figure 6.9 Average durations of the second syllables of "memorizes" and "memorial" produced by five language groups. Standard error are not visible.

These differences in duration between less and more experienced language groups can be explained by changes in rate of speech as discussed previously in section 6.5.1. Slower speech rate can account for the longer syllables produced by less proficient K1 and M1 groups.

The mean duration of the stressed syllable was significantly longer than that of the unstressed syllable in productions of the second syllable in target words [F(1,30)=386; p<.01]. The durations of both first and second syllable comparisons are illustrated in Figure 6.10.

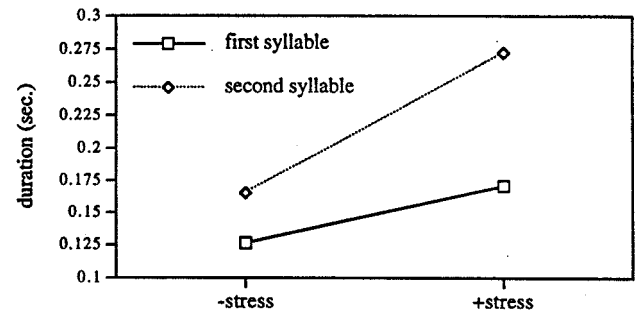


Figure 6.10 The duration of unstressed and stressed syllables of first syllable "me-" and second syllable "-mor-" in "memorizes" and memorial.

Stress differentially affects stressed syllables produced later in target words. First, both the unstressed and stressed second syllable "-mor-" are longer than unstressed and stressed first syllable "me-". This is due to the greater number of segments in the second syllable, and the greater length of later syllables in words (Lehiste, 1974). In addition, later stressed target syllables were lengthened to a greater extent than earlier stressed syllables creating a greater separation between unstressed and stressed syllables. Later unstressed syllables were about 60% the length of stressed syllables (illustrated with a dashed line), while earlier unstressed syllables were 74% the length of stressed syllables (illustrated with a solid line). Stress had a greater affect on syllables occurring later in words.

Differences between target syllables produced in questions and statements, although significant, were very similar [F(1,30)=4.89; p<.05]. The mean duration of syllables produced in questions was .216 sec. (SE=.003) , and .219 sec. (SE=.002) in statements.

The factor accent type had a significant effect on the duration of target syllables [F(2,60)=65.6; p<.001]. These results are illustrated in Figure 6.11. Target syllables are longest in nuclear position, and almost identical in prenuclear and unaccented position. This pattern is different from that seen in productions of first syllables in "memorizes" and "memorial". In productions of first syllables, the duration of target syllables differed in three accent contexts. As the accent context became more prominent, the duration of target syllables increased.

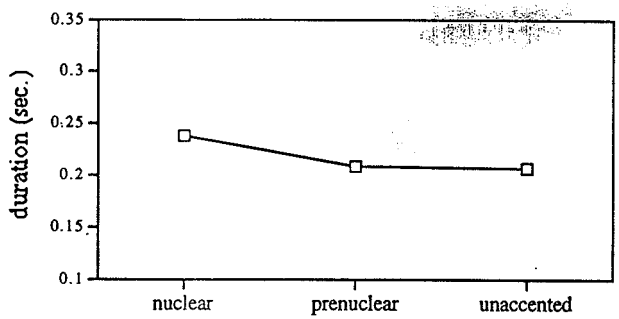


Figure 6.11 The average duration of second syllable "-mor-" in "memorizes" and "memorial" produced with three accent types.

The interaction of stress and accent are provided in Figure 6.12. In productions of this second syllable, the duration of stressed syllables was not differentially affected by less prominent prenuclear and unaccented accent contexts. So while stressed syllables are longer than unstressed syllables overall in these two contexts, the length of the stressed syllable in prenuclear accented words is not different from the length of the stressed syllable in less prominent unaccented words. Stressed syllables were longest when produced in the nuclear accented context, with the highest level of prominence. The unstressed syllable is shortest in comparison to the stressed syllable in this nuclear accent context, with the unstressed syllable being about half as long, .56 the duration of the stressed syllable. In the less prominent contexts, the relationship between unstressed and stressed syllable is not as disparate as in the nuclear accented context. Prenuclear and unaccented unstressed syllables are .62 and .64 the duration of stressed syllables. These differences in unstressed and stressed syllables in all accent contexts are greater than those found in comparisons of first syllable comparisons, however the pattern of separation of target types is similar in both early syllable comparisons and later syllable comparisons. Stressed syllables are longest in the nuclear accented context.

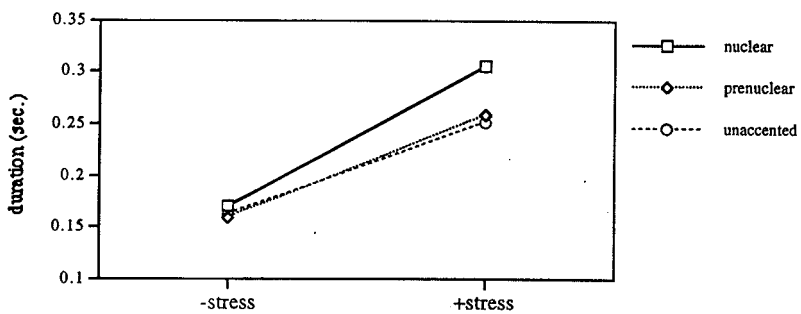


Figure 6.12 The duration of unstressed and stressed target syllable "-mor-" produced in target words with three levels of prominence.

Figure 6.13 illustrates the durations of unstressed and stressed target syllables produced by each language group. Native English speakers produced unstressed and stressed syllables with shorter durations than the non-native-English speaking groups. English speakers also differed from other groups in that duration differentiated unstressed from stressed syllables to a lesser extent than in productions by nonnative English speaking groups. The ratio between the unstressed and stressed syllable was .67 in E productions, .55 in K1 productions, .61 in K2 productions, .62 in M1 productions, and .57 in M2 productions. All language group produced stressed syllables that were much long than unstressed syllables.

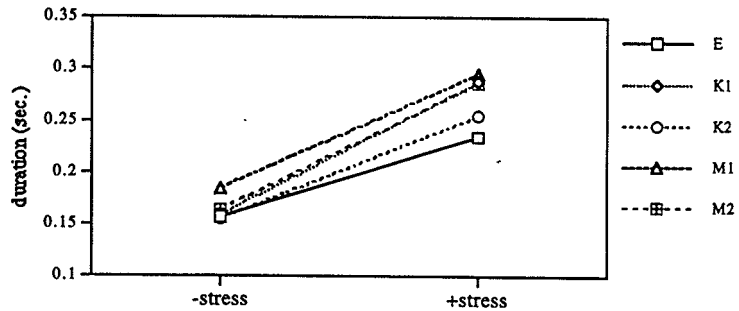


Figure 6.13 The duration of unstressed and stressed second syllables in "memorizes" and "memorial" syllables produced by each language group.

Productions of K1 differed from those of E only in stressed syllable duration. K1 speakers produced stressed syllables that were longer than those produced by E. This longer duration of the stressed syllable resulted in a greater separation of unstressed and stressed syllables in K1. Unstressed syllables were almost half the duration of stressed syllables. Productions of unstressed syllables by K2 were like those of K1 and E. Both groups of Korean speakers produced the unstressed second syllable in "memorizes" with durations like those of native English speakers. The difference between K1 and K2 groups was in the production of the stressed syllable. The duration of the stressed syllables was shorter in productions by K2 and more like those of E. This change resulted in a difference between target syllables that was more like that of E speakers, unstressed syllables were 61. the duration of stressed syllables.

To summarize these results, both K1 and K2 groups produced the unstressed syllable "-mor-" in "memorizes" with durations that were similar to E. K2 productions from those of K1 in duration of the stressed syllable. Stressed syllables in K2 productions were shorter and more like those of E. This change in K2 productions resulted in the relationship of duration in unstressed and stressed syllables being more like that exhibited by E. These results are not like those found in comparisons of the first target syllable "me-". In this earlier comparison, the less experienced Korean speakers were not reducing the unstressed syllable in "memorial" and differences between K1 and K2 were primarily in the reduction of this unstressed syllable by the

K2 group. These differences in results indicate that the location of the unstressed syllable relative to a stressed syllable has an influence on production of unstressed syllables. Reducing an unstressed syllable that occurs immediately before a stressed syllable may be more difficult for K1 speakers than producing an unstressed syllable that immediately follows a stressed syllable.

M1 productions differed from those of E in production of both unstressed and stressed syllables. Both stress types were longer in M1 productions. When observing the separation between similar stress types by M1 and E, (i.e., unstressed syllables produced by M1 and E and stressed syllables produced by M1 and E, M1 productions of the unstressed syllable are most like those of E). These longer unstressed and stressed syllables in M1 productions may be due to a slower speech rate, but the closer proximity of unstressed M1 syllables to those of E, indicate that M1 speakers were reducing unstressed syllables. Differences in duration between unstressed and stressed syllables were greater in M1 productions than in E productions, due to a long stressed syllable. Productions of M1 syllables were .62 the duration of stressed syllables, in comparison to a ratio of .67 in E productions.

M2 productions of unstressed syllables were shorter than M1 and more like those of E while stressed syllables were similar in length to M1. The stressed syllable in both M1 and M2 productions was longer than that of E. M2 speakers succeeded in reducing unstressed syllables to the same extent as E. However, this shorter duration of unstressed syllables (and longer stressed syllables) in M2 productions resulted in making the separation between stress types even greater than M1. The mean duration of unstressed syllables was .57 the duration of stressed syllables, compared to .62 in M1 productions.

To summarize the results of Mandarin speakers, both M1 and M2 groups produced unstressed syllables that were more separated from stressed syllables indicating that both groups of speakers were reducing the unstressed vowel in "memorial". This result was also seen in comparisons of first syllables in "memorial" and "memorizes" produced by both groups of Mandarin speakers. In addition, the greatest change in M2 productions, compared to those of M1, was in the production of the unstressed syllable. While both M1 and M2 speakers reduced unstressed vowels, M2 productions were more similar to those of E. This result is not the same as those found in comparisons of the first syllables in "memorizes" and "memorial". Both M1 and M2 speakers reduced the unstressed first syllable in "memorial" to a duration that was similar to that of E, but only M2 speakers reduced the second syllable in "memorizes" like that of E.

How stress type and accent type affected the durations of targets syllables produced by each language group are illustrated in Figure 6.14a 6.14b. Unstressed syllables were less affected by stress type in all accent contexts by all language groups.

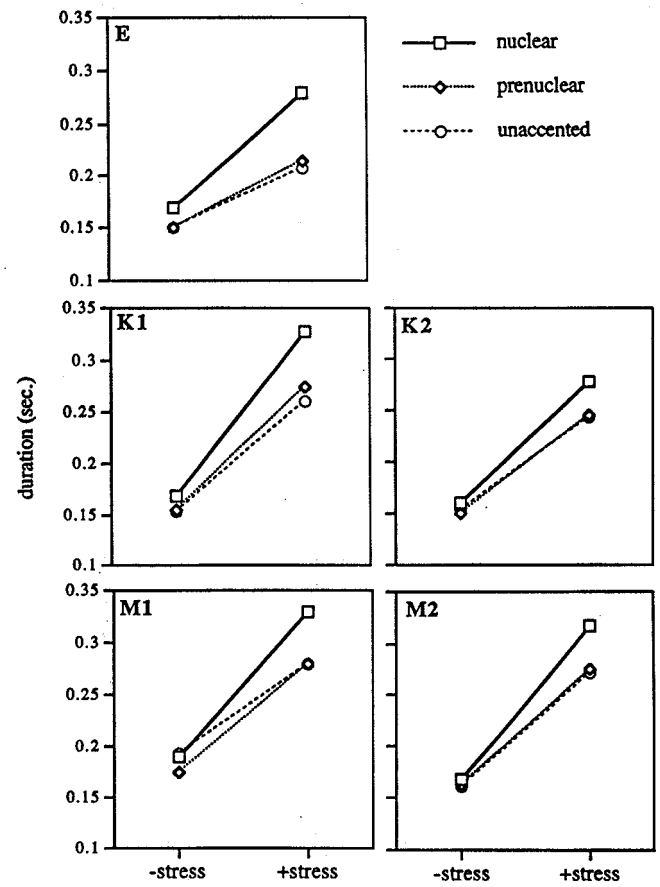


Figure 6.14a The duration of unstressed and stressed second target syllable produced in "memorizes" and "memorial" with three levels of prominence by each language group.

Language Group	Nuclear	Prenuclear	Unaccented
E	.61	.70	.72
K1	.52	.56	.58
K2	.58	.61	.63
M1	.57	.62	.69
M2	.53	.59	.59

Figure 6.14.b The relationship of the unstressed syllable duration relative to the stressed syllable duration in three accent contexts. Each number is a ratio derived by dividing the mean duration of the unstressed syllable by the mean duration of the stressed syllable.

Stressed syllables were longest when produced in words in nuclear accented contexts, and the duration of stressed syllables was similar in words produced in prenuclear and unaccented contexts. These patterns are similar in all language groups, and is the same pattern found in first syllable comparisons. The durations of the unstressed syllable expressed as a ratio of the stressed syllable duration are provided in Figure 6.14b.

In productions of target syllables by E, the stressed syllable is progressively longer as prominence level increases while the unstressed syllable remains unaffected. In addition, ratios expressing the relationship between unstressed and stressed syllables are smallest in the most prominent accent, nuclear accented words, and less prominent accents, prenuclear and unaccented words. This separation indicates that duration separates prominence levels into two types, most prominent and less prominent. This result is consistent with similar comparisons of first syllable "me-" in E speakers.

As revealed in the effects of stress type and language group, differences between K1 and K2 groups are seen in durations of stressed syllables. Stressed syllables are longer in K1 productions in all three accent contexts. Accent type affects K1 and K2 similarly; both groups of Korean speakers produced stressed syllables that were longest in nuclear accented contexts. In addition, the duration of stressed syllables does not separate prenuclear from unaccented contexts. This pattern is like that of the E group. Korean speakers and English speakers produced nuclear accented syllables that were longer than stressed syllables produced with less prominence.

Differences between the results of E and M1 groups are seen in the durations of unstressed syllables and stressed syllables. Syllables produced by M1 are longer than those produced by E speakers in all three contexts. Nonetheless, the relationship between target syllables produced in three accent types is similar to that of E speakers. These results indicate that these M1 speakers, like native English speakers, lengthen stressed syllables differentially in different accent contexts to indicate prominence level.

M2 speakers differ from M1 speakers in that both unstressed and stressed syllables are shorter in M2 productions. However, M2 unstressed syllables are shortened to a greater extent, as indicated in the main effects of stress and language type. The duration of these unstressed syllables are similar to those produced by E speakers. Shorter unstressed syllables, and longer stressed syllables in M2 productions resulted in a greater separation of target syllables (Figure 6.14). Similar to the relationship of K1 and K2, the duration of stressed syllables in M1 and M2 separate nuclear accented contexts from less prominent contexts.

To summarize these results, each language group, regardless of native language and English language experience, produced unaccented syllables that were not differentially affected by accent type. In addition, the stressed syllable was affected the most by prominence type, being lengthened to a greater extent in nuclear accented productions.

There was a four way interaction between stress type, intonation type, accent type, and language group [$F(8,60)=3.59$; $p<.01$]. Although significant, there was little difference in productions of the three accent types produced in questions and in statements. As discussed in the effects of stress type, accent type, and language

group, unstressed syllables were relatively unaffected by accent type and stressed syllables were most affected by the nuclear accent context, where they were produced with greater length than prenuclear and unaccented contexts. This pattern is similar in questions and in statements.

6.2 Duration Comparisons of the second and third syllables in "electrical" and electrician

6.2.1 Duration comparisons of second syllables

Results of duration comparisons between the second syllable "-le-" in "electrical" and "electrician" are most similar to the pattern of results found in comparisons of the first syllable "me-". This is in part due to the location of these syllables in their respective words, both of these syllables occurring early in the word. Syllables occurring earlier in a word are not as long and are less affected by stress and accent than later syllables comprised of comparable segments (Lehiste, 1964). Another similarity is that when the target syllable is unstressed, it is followed by a stressed syllable; the first syllable in "memorial" and the second syllable in "electrician" are followed by stressed syllables. Similarly, when the target syllable is stressed as in "memorizes" and "electrical", the following syllable is unstressed.

There was a main effect of group [$F(4,30)=2.97$; $p<.034$]. The pattern of results is similar to those found in all previous target syllable comparisons in that the more experienced K2 and M2 groups produced syllables with shorter durations than did the comparable less experienced K1 and M1 groups. As already discussed, these longer durations are due to a slower rate of speech by the less proficient English speakers. These results are provided in Figure 6.15.

Language Group	Mean duration (sec.)	Standard Error
E	.155	.001
K1	.175	.002
K2	.169	.001
M1	.168	.002
M2	.142	.002

Figure 6.15 The average durations of second syllable "-le-" in the word pair "electrician" and "electrical" produced by each language group.

Stressed syllables were significantly longer than unstressed syllables [$F(2,60)=101$; $p<.001$]. Syllables produced in words with a nuclear accent were longer than those produced less prominent accent types, and syllables in prenuclear accented words were longer than those produced in the unaccented context [$F(2,60)=31.9$; $p<.001$]. In addition, the intonation pattern also affected the duration of target syllables [$F(1,30)=8.29$; $p<.01$]; syllables were slightly longer in statements than in questions. Repetition did not have an effect on syllable duration [$F(4,120)=.827$; $p>.51$]. These patterns of the main effects are similar to those found in first syllable "me-" comparisons.

There was no significant effect of stress type and language group [$F(4,30)=2.34$; $p>.07$]. These pattern of these results is relevant to this study and are illustrated in Figure 6.16.

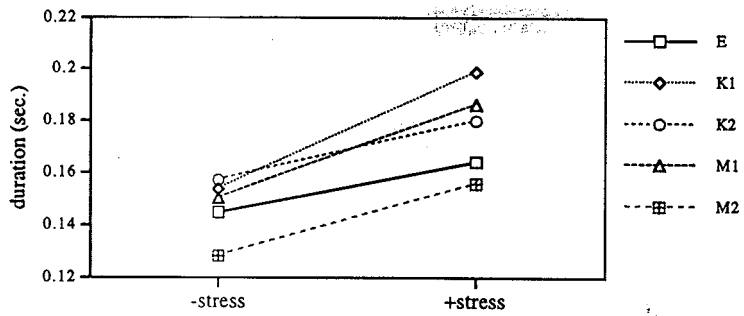


Figure 6.16 The duration of the second syllable "-le-" in "electrical" and "electrician" by each language group.

The stressed syllable durations in productions by the more proficient K2 speakers differed from those by K1 speakers. As Figure 6.16 illustrates, the duration of the unstressed syllable remains similar in productions by K1 and K2 while the stressed syllable in K2 productions is much shorter than that of K1. This change in the duration of the K2 stressed syllable makes the relationship between unstressed and stressed target syllables similar to those of E speakers. The unstressed syllable in K1 productions is .77 the duration of the stressed syllable, and in K2 productions this ratio increases to .87. In productions by E, the unstressed syllable is .88 the duration of stressed syllables. In sum, neither K1 nor K2 speakers produced the unstressed syllable in "electrician" as short as E speakers did, and only K2 speakers produced unstressed and stressed syllables with durations that were similar in proportion to target syllables produced by E by reducing the length of the stressed syllable. In short, neither group of Korean speakers were able to reduce syllables to the extent that E did.

More proficient K2 speakers were unable to reduce the length of the second syllable in "electrician". However, these K2 speakers were able to reduce the length of the first syllable in "memorial". These unstressed syllables occur right before a stressed syllable, and so are in a similar prosodic environment. One might expect K2 speakers to be able to reduce the unstressed syllable in "electrical", given that K2 speakers produced an unstressed syllable in "memorial". A difference between these stress types with "early" unstressed syllables may explain this difference. There is only one unstressed syllable prior to the stressed syllable in "memorial", but there are two unstressed syllables before the stressed syllable in "electrician". Neither of these words conform to a prosodic pattern in Korean, but "electrician" with a later potentially accentable syllable is most unlike any prosodic pattern in Korean. This may make this second syllable particularly difficult to reduce.

M1 speakers produced longer unstressed and stressed syllables than did M2, however duration similarly separates the unstressed from the stressed syllable in M1 and M2 productions. The unstressed syllable is .80 the duration of the stressed syllable in M1 productions, and .82 in M2 productions. M1 productions differ from E in duration of the stressed syllable. The unstressed syllable in "electrician" is like that of E, however the stressed syllable is much longer. M1 speakers were able to reduce this early unstressed syllable. This result confirms that the slower speech of M1 speakers

is primarily due to production of longer stressed syllables. M2 speakers produced both syllables at a much faster rate than E. Both unstressed and stressed syllables in productions by M2 are shorter than those by E.

To summarize these results, M1 speakers produced unstressed syllables that were like those of E, and M2 speakers produced unstressed syllables that were shorter than those produced by E. These results indicate that both M1 and M2 speakers are able to reduce unstressed syllables. M1 speakers produced stressed syllables that were longer than those produced by E. M2 productions are more like E in that the duration of the stressed syllable is similar in length to E. While these two groups of Mandarin speakers were able to reduce unstressed syllables, only the stressed syllable in productions by M2 were like those of E. Experience in English brings the duration of the stressed syllable to lengths more like those produced by native speakers.

The intonation pattern, question or statement, did not affect the duration of unstressed and stressed syllables [$F(1,30)=3.42$; $p>.07$]. In addition, intonation type did not differentially affect the duration of stressed and unstressed target syllables in each language group [$F(4,30)=1.08$; $p>.382$].

There was no interaction of language group, stress type, and accent type [$F(8,60)=4.66$; $p>.875$]. Duration was used by all language groups similarly to separate stressed syllables produced in different accent types. These results are illustrated in Figure 6.17a, and the proportion of duration of the unstressed syllable relative to the stressed syllable in three accent contexts are provided in Figure 6.17b. While all language groups produced stressed syllables that were longest when produced in nuclear accented contexts and separable from less prominent prenuclear and unaccented contexts, M1 speakers produced stressed syllables that were clearly different in three levels of accent. Figure 6.17a illustrates these differences. Lines connecting unstressed syllables to stressed syllables in prenuclear and unaccented contexts are parallel for all language groups, but M1. Parallel lines indicate that the relationship between these target syllables is similar in within these language groups. Productions of unstressed and stressed syllables by M1 in three accent types are not parallel. As accent context becomes more prominent, the steepness of the lines connecting target syllables increases. This difference in separation of accent types is represented in a ratio and is provided in Figure 6.17b. Ratios are smallest in nuclear accented contexts for all language groups, this indicates the greater separation of unstressed and stressed syllables produced in nuclear accented contexts. The relationship of the target syllables in prenuclear and unaccented contexts, however, are similar in productions by E, K1, K2, and M2. This indicates that stressed syllables are lengthened to a similar extent in these less prominent contexts.

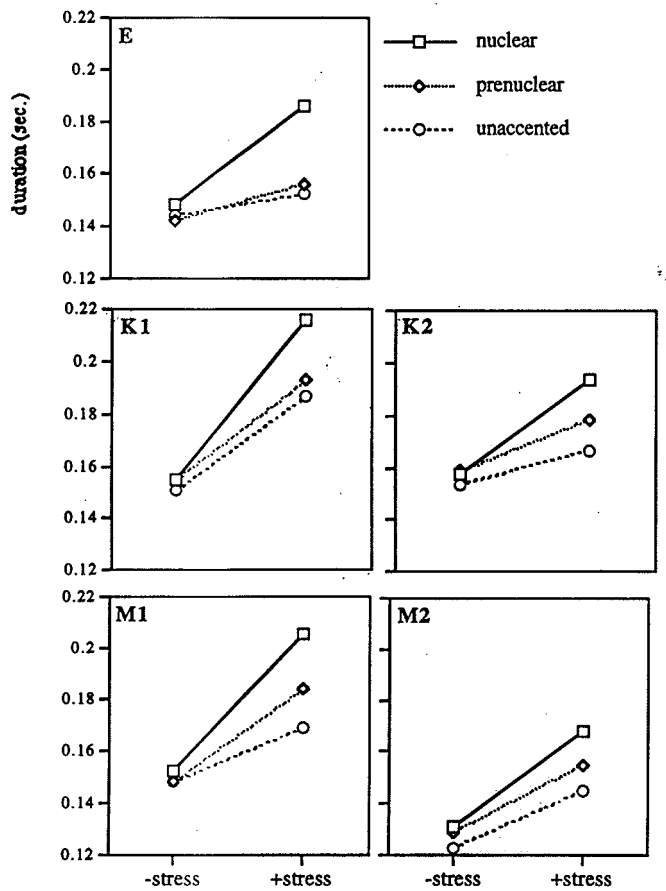


Figure 6.17a The duration of unstressed and stressed syllable second syllable in "electrical" and "electrician" in three accent contexts produced by five language groups.

Language Group	Nuclear	Prenuclear	Unaccented
E	.80	.91	.95
K1	.72	.80	.81
K2	.81	.89	.92
M1	.74	.80	.87
M2	.77	.83	.85

Figure 6.17b The relationship of the unstressed syllable duration relative to the stressed syllable duration in three accent contexts. Each number is a ratio derived by dividing the mean duration of the unstressed syllable by the mean duration of the stressed syllable.

6.2.2 Duration comparisons of third syllable

Results of the sonorant part of the third syllable "-ri-" in "electrical" and "electrician" are similar to the results obtained from second syllable comparisons of "-mor-". Both syllables occur later in target words; stressed syllables in "electrician" and "memorial" are after an unstressed syllable; and unstressed syllables in "electrical" and "memorizes" occur after the stressed syllable in target words.

There was a main effect of language group [F(4,30)=6.18; p<.001]. Similar to earlier comparisons, E speakers produced the shortest syllables. In addition, K2 and M2 productions were shorter than the respective less experienced K1 and M1 groups indicating again that the more proficient speakers spoke at a faster rate of speech. Also like previous target syllable comparisons, productions of stressed syllables were longer than unstressed syllables [F(1,30)=75.4; p<.01]; the duration of target syllables in questions was slightly longer than the duration of target syllables in statements [F(1,30)=5.09; p<.05]; and repetition was not significant [F(4,120)=1.402; p>.24]. In addition, the accent context of target words influenced the duration of syllables in a manner similar to previous syllable comparisons [F(2,60)=31.0; p<.01]. The average duration of "-ri-" overall was .82 sec. in nuclear position, .73 sec in prenuclear position, and .71 sec. in unaccented position. Syllables produced in nuclear accented words were longer than syllables produced in less prominent contexts.

There was a significant interaction of stress type and accent type [F(2,60)=7.10; p<.002]. Like previous comparisons, unstressed syllables were relatively unaffected by accent. Also, the duration of stressed syllables in nuclear accented contexts were longer than those in less prominent contexts. The mean duration of unstressed syllables was .70 the stressed syllable duration in nuclear contexts. Target syllables in prenuclear and unaccented contexts were similar in proportion to stressed syllables, .77 and .75 respectively.

There was no significant interaction between language group and stress type [F(4,30)=.330; p>.85). These results are illustrated in Figure 6.18. Stressed syllables are longer than unstressed syllables in productions by all language groups. Unstressed syllables are .63, .77, .78, .80, and .71 the duration of stressed syllables in productions by E, K1, K2, M1, and M2 groups, respectively.

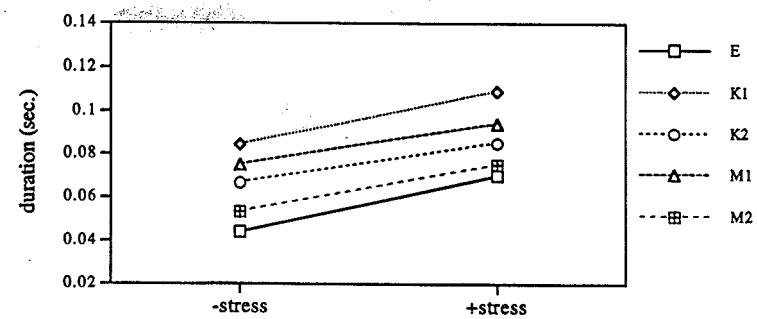


Figure 6.18 The duration of unstressed and stressed third syllables in "electrical" and "electrician" produced by five language groups.

The relationship of syllables differing in stress in K1 and K2 productions differs little. The unstressed syllable is .78 the duration of stressed syllables in K1, and .77 in K2 productions. Productions only differ in that both unstressed and stressed syllables by K1 speakers are longer. This may be explained by a slower speaking rate.

Similarly, productions of M2 differed from those of M1 in that M2 target syllables were shorter. This change is also due to a faster speech rate in M2, given that both unstressed and stressed syllables were shorter in productions by M2.

To summarize, both unstressed and stressed third syllables in "electrical" and "electrician" were shorter in productions by more proficient K2 and M2 speakers in comparison to K1 and M1 speakers. Most similar to E productions are those by the more proficient M2 group; the duration of unstressed and stressed syllables produced by M2 are almost identical to those exhibited by the E group. The relationship of unstressed and stressed syllable durations in both K1 and K2 was similar to that of E. Differences in these two groups of Korean speakers were in productions of both unstressed and stressed syllables. K2 productions of both stress types were shorter than K1 and more like those of E. While K2 productions were longer than E, these speakers were nonetheless able to shorten the length of the unstressed syllable in "electrician."

Accent type similarly affected the production of unstressed and stressed syllables in each language group; there was no interaction of accent, stress type, and language group [F(8,60)=.154; p>.99]. These results are illustrated in Figure 6.19a. Stressed syllables were affected most by accent type in each language group. Stressed syllables produced within nuclear accented words were longer than those produced in prenuclear and unaccented words for all groups. The proportions of duration of the unstressed syllable relative to the stressed syllable duration are provided in Figure 6.19b. In productions by K1, K2, M1, and M2, ratios are smallest in nuclear accented contexts indicating a greater separation of stress types in this most prominent context. In addition, the similarly in ratios derived from durations of target syllables produced in prenuclear and unaccented contexts by these four groups indicate that duration differentiates unstressed from stressed syllables similarly in these less prominent contexts.

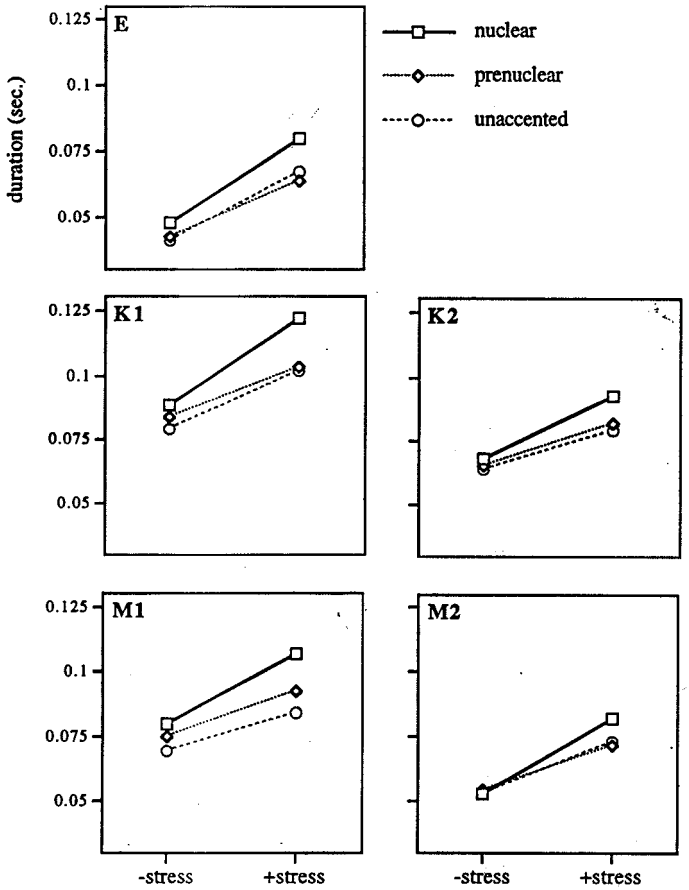


Figure 6.19a The production of unstressed and stressed syllable "-ri-" in "electrician" and "electrical" production with three levels of accent by each language group.

Language Group	Nuclear	Prenuclear	Unaccented
E	60	66	61
K1	73	81	77
K2	73	79	81
M1	75	82	82
M2	65	75	73

Figure 6.19b The relationship of the unstressed syllable duration relative to the stressed syllable duration in three accent contexts. Each number is a ratio derived by dividing the mean duration of the unstressed syllable by the mean duration of the stressed syllable.

The native English speaking group performed differently from these four language groups. The relationship between unstressed and stressed syllables is similar in nuclear and unaccented contexts. These results may be affected by the aspiration of syllable initial [t] in the stressed syllable in "electrician". When this word is produced in a nuclear accented word in English, [t] is produced with increased aspiration. This aspiration increases the duration of that syllable, however, aspiration is not included in durations measures in this experiment. Consequently, while duration of this stressed syllable may increase with more prominence, this increase is not captured in these measures.

In order to understand how aspiration might have affected these measures, it would be necessary to measure the duration of the entire syllable, not just the sonorant portion of syllables. Such a measure would include the aspiration after the release of [t] in "electrical" and "electrician". This measure would include changes in duration within the entire syllable. If VOT varied in productions of target syllable, this measure would capture these differences. This analysis is warranted in future investigations.

6.3 Duration comparisons of second and third syllables in photographic and photography

6.3.1 Duration comparisons of second syllables

The results from comparisons of the early second syllable "-to-" in "photographic" and "photography" are similar comparisons of early syllables in "me-" in "memorial" and "memorizes" and early syllables "-le-" in "electrician" and "electrical." There was a significant main effect of stress type [F(1,30)=174; p<.01]; unstressed syllables were about half the length, .58 the duration, of stressed syllables. There was also a significant main effect of accent context [F(2,60)=12.775; p<.01]. Target syllables were longest in nuclear accented contexts and almost equal in length in prenuclear and unaccented contexts. There was not a significant main effect of intonation [F(1,30)=.051; p>.82], and there was no significant main effect of repetition [F(4,120)=.253; p>.90].

There was a significant interaction effect of stress type and accent type [F(2,60)=28.3; p<.01]. Stressed syllables were most affected by accent type. These results are provided in Figure 6.20. Unstressed syllables in all three accent contexts remained similar in duration while stressed syllables were longest in nuclear accented contexts. These differences resulted in unstressed syllables being .52, .61, and .62 the duration of stressed syllables in nuclear, prenuclear, and postnuclear contexts.

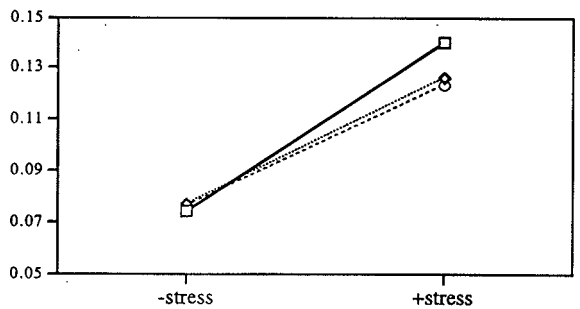


Figure 6.20. The duration of unstressed and stressed second syllables in "photography" and "photographic" produced with three levels of accent.

There was no main effect of language group [F(4,30)=1.37 p>.26]. The pattern of results is similar to productions of early syllable types discussed thus far. Durations are shortest in productions by E, K2, and M2 groups. Productions by the less experienced K1 and M1 groups were longest indicating that less experienced language speakers produced words at a slower rate of speech.

There was not a significant interaction of stress type and language group [F(4,30)= 1.93; p>.12]. These results are displayed in Figure 6.21.

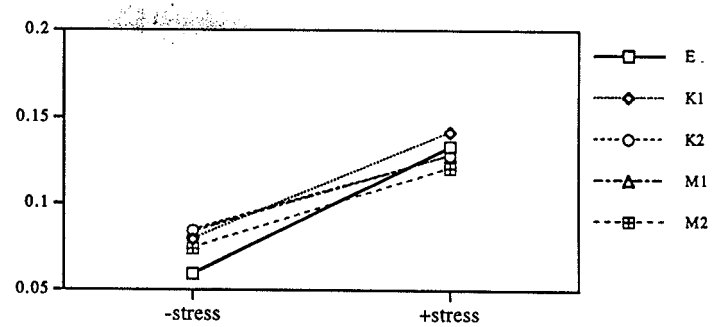


Figure 6.21. The duration of the unstressed and stressed second syllable of "photographic" and "photography" produced by five language groups.

English speakers produced the shortest unstressed syllables. These syllables were .45 the duration of stressed syllables. Neither group of Korean speakers, K1 nor K2, produced unstressed syllables as short as those produced by E. Productions of the stressed syllable in K1 and K2 productions differed. While both K1 and K2 produced unstressed syllables with similar durtions, K2 speakers produced shorter stressed syllables than K1. This difference in stressed syllables resulted in more separation of target syllables in K1 productions; unstressed syllables were .56 the duration of stressed syllables. Shorter stressed syllables in K2 productions resulted in less separation of target syllables; unstressed syllables were .66 the stressed syllable duration. K2 speakers did not produce shorter unstressed syllables, but only produced shorter stressed syllables than those produced by K1. K2 speakers were unable to reduce unstressed syllables both "electrician" and "photographic." Both of these target words are similar in that two unstressed syllables occur before the stressed syllable. Reduction of two consecutive prestressed syllables pose difficulty for both K1 and K2 speakers.

M1 and M2 productions of second syllables in "photography" and "photographic" differ in that both the duration of unstressed and stressed syllables are shorter in M2 productions. The relationship between target syllables is similar. Unstressed syllables are .65 and .61 the stressed syllable in M1 and M2 productions. Experienced M2 speakers spoke at a faster rate producing shorter unstressed and stressed syllables. This is the same result found in productions of second syllable "electrician". M2 speakers productions of unstressed syllables are more like those of E regardless of the position of the unstressed syllable within the word. While more proficient K2 speakers are more likely to produce only one prestressed unstressed syllables with durations more like those of E (i.e., "memorial" but not "electrician"), M2 speakers are able to reduce one or two unstressed syllables prior to a stressed syllable.

There was no significant interaction between language group, stress type, and accent type [F(8,60)=1.62; p>.140]. These results are displayed in Figure 23. It appears that the stressed syllable in productions by the less experienced K1 and M1 speakers are more affected by accent context than are productions by K2 and M2 productions

although this may not the case. These more experienced speakers may be producing the second syllable in "photography" with an aspirated [t]. The target syllable in nuclear accented words may be longer than in less prominent words, due to longer VOT and a longer vowel, but this added duration of VOT does not show here, because only the vowel is measured. This is a weakness of measuring only the vowel duration in comparison syllables. In order to more fully understand how the second syllable in "photography" and "photographic" is affected by accent type, syllable durations including both aspiration and vowel duration are needed. This is the same problem that possibly affected productions of "electrician" and "electrical". Further investigation is warranted. Regardless of the possible differences in VOT produced by speakers in each language groups, the vowel duration in nuclear accented stressed syllables is longer than in prenuclear and unaccented contexts for all groups.

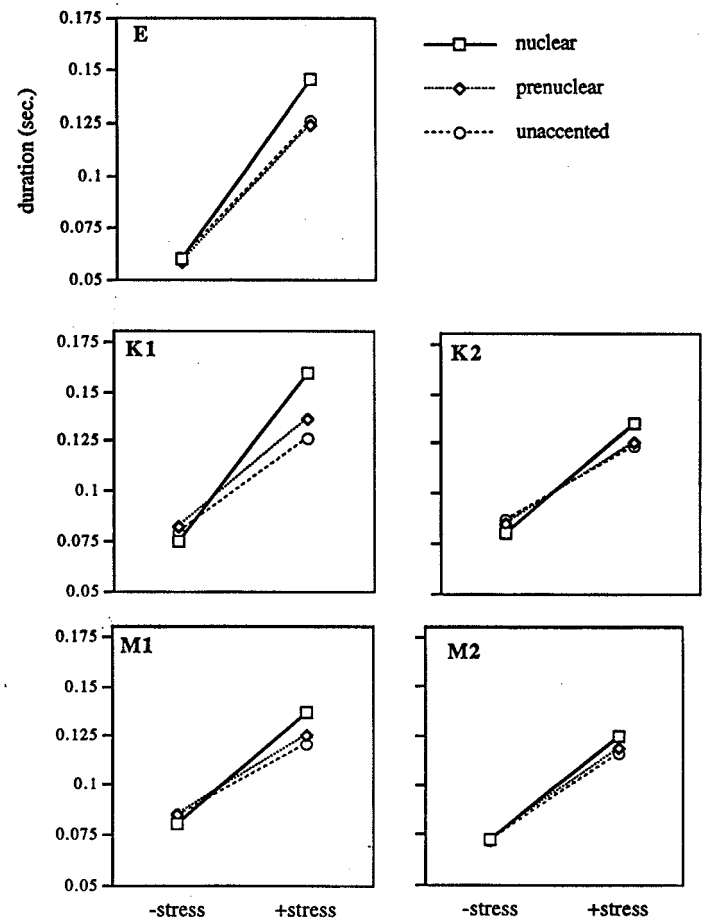


Figure 6.23. The duration of the unstressed and stressed second syllable in "photographic' and "photography' produced with three levels of accent by five language groups.

The intonation pattern did not affect these results. The interaction between stress type, accent type, language group, and intonation was not significant [F(8,60)=.769; p>.630].

6.3.2 Duration comparisons of third syllable "-ra-"

Similar to results of comparisons of later syllables (i.e., "-mor-" in "memorial" and memorizes, and "-ri" in "electrician" and "electrical)" , language groups performed differently in their productions of the third syllable "-ra-" in "photography" and "photographic" , [F(4,30)=4.27; p<.01]. A Tukey-Kramer post hoc analysis indicated that syllables produced by M1 were significantly longer than E (p<.01). Because of slower speech rates, both less proficient M1 and K1 groups produced syllables that were longer than the more proficient M2 and K2 groups. English speakers produced the shortest durations of the five language groups. In addition, stressed syllables were significantly longer than unstressed syllables [F(1,30)=306; p<.01]. Also like previous results, target syllables occurring in nuclear accented contexts were significantly longer than those produced in prenuclear and unaccented contexts (F(2,60)=30.4; p<.01]. There was no effect of intonation type [F(1,30)=1.94; p>.17].

There was a main effect of repetition [F(4,120)=6.83; p<.001]; the first and second repetition (.149 and .150 sec., respectively), of target syllables were longer than the remaining third, fourth, and fifth, (all were .145 seconds). Repetition also interacted with intonation and accent [F(8,240)=2.187; p<.030]. Although significant, only slight differences between repetition occurred; the greatest difference was .006 sec. between statement and question intonation produced in prenuclear contexts in the second repetition. Repetition did not significantly effect language group or stress type (p>.05), and so significant interactions that involved repetition are not relevant to this investigation.

There was a significant main effect of language group and stress type [F(4,30)=6.63; p<.01]. These results are illustrated in Figure 6.23.

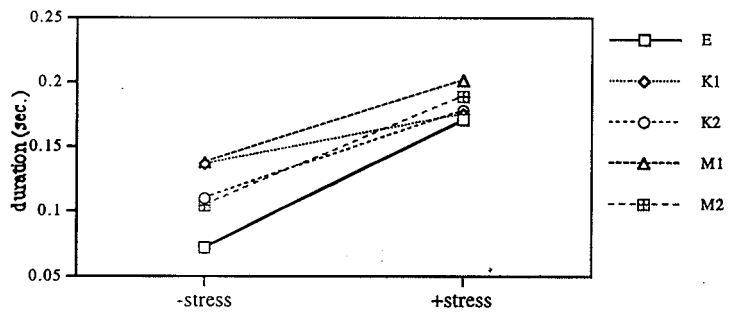


Figure 6.23 The duration of unstressed and stressed syllables produced by five language groups.

Of all language groups, E subjects produced unstressed and stressed syllables that were longest in comparison to unstressed syllables. Unstressed syllables produced by native English speakers were on average .42 the duration of stressed syllables. The more proficient K2 and M2 speakers produced stressed syllables that were longer in comparison to unstressed syllables than did the respective K1 and M1 speakers. Unstressed syllables were .78 the stressed syllable duration in K1 productions compared to .62 in K2 productions. This greatest difference between K1 and K2 was in the duration of unstressed syllables. Unstressed syllables were shorter in K2 productions while there was little difference in K1 and K2 productions of stressed syllables. This indicates that K2 speakers were acquiring reduction patterns of the later "post-stressed" unstressed syllable in "photography". Although K2 productions of unstressed syllables were not like those of E, K2 subjects were reducing unstressed syllables to a greater extent than K1.

This pattern is similar to K2 productions of "post-stressed" target syllables in "memorizes" and "electrical" and unlike K2 productions of the "pre-stressed" syllables in "electrician" and "photographic". There is little change in the duration of unstressed syllables produced by K1 and K2 in words with an unstressed syllable prior to a stressed syllable. K2 speakers produced shorter stressed syllables, but did not produce shorter unstressed syllables. However, K2 speakers produced unstressed syllables that were shorter than those produced by K1 speakers when the unstressed syllable followed a stressed syllable. **With experience in English, these more proficient English speakers acquired reduction patterns more like those of English speakers when the unstressed syllable followed a stressed syllable.**

A different pattern of results was found for productions of "memorial." K2 speakers produced the unstressed first syllable of this word similar to productions of E. This word differs from "electrician" and "photographic" in that there is only one unstressed syllable before the stressed syllable, as previously discussed. This indicates that not only is it more difficult for Korean speakers to produce unstressed syllables that occur before a stressed syllable, but that it is even more difficult for Korean speakers to produce two unstressed syllables before a stressed syllable. Moreover, while English experience may enable acquisition of a single initial unstressed syllable as in "memorial", native-like production of two initial unstressed syllables may not be acquired as evident in productions of "electrician" and "photographic".

M2 productions of unstressed syllables differ most from those of M1. While both the unstressed and stressed syllables are shorter in productions by M2, unstressed syllables are reduced to a greater extent by M2. This greater reduction in M2 productions results in greater separation of unstressed and stressed syllables. Unstressed syllables are .68 the stressed syllable duration in M1 productions and .55 in M2 productions. This indicates, as do results of previous comparisons of target syllables, that M2 speakers are acquiring reduction patterns more similar to those of E. While Korean speakers appear to acquire reduction patterns more easily after a stressed syllable, Mandarin speakers are not limited by this constraint. With exposure to English, M2 speakers produced unstressed syllables regardless of the stress pattern of the word.

There was not a significant interaction between language group, stress type, and accent type [F(8,60)=.484; p>.863]. Nor was there an interaction between language group, stress type, and intonation [F(4,30)=.460; p>.764]. These results are illustrated in Figure 6.24a.

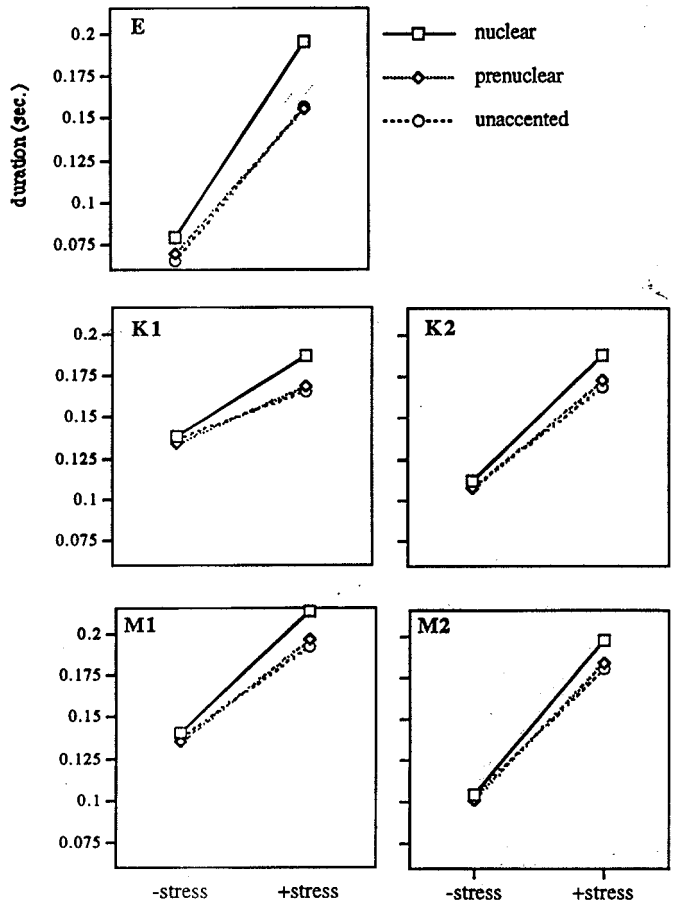


Figure 6.24a The mean durations of unstressed and stressed syllables produced with three levels of accent by five language groups.

Language Group	Nuclear	Prenuclear	Unaccented
E	.40	.44	.41
K1	.74	.79	.82
K2	.60	.62	.64
M1	.66	.69	.72
M2	.53	.55	.58

Figure 6.24b The relationship of the unstressed syllable duration relative to the stressed syllable duration in the third syllables of "photography" and "photographic" in three accent contexts. Each number is a ratio derived by dividing the mean duration of the unstressed syllable by the mean duration of the stressed syllable.

As revealed in the interaction of stress type and language group, durations are longest in stressed syllables in produced in words in nuclear accented position. The proportion of duration in unstressed syllables relative to stressed syllables is provided in Figure 6.23b. In all language groups, but E, ratios are smallest in the nuclear accented context, greater in the prenuclear context, and greatest in the unaccented context. E subjects performed differently from these groups. Ratios are smallest in unaccented and nuclear accented contexts. This indicates that duration differences between unstressed syllables are similar in a context where words are produced with a pitch accent to words produced in a postnuclear context without a pitch accent. These results are similar in both statements and in questions; there was not a significant interaction between language group, stress type, accent type, and intonation [$F(8,60)=.767$; $p>.63$].

6.4 Discussion

The native language of second language speakers of English affected productions of unstressed and stressed syllables in a second language. The results derived from duration measures indicate that the subjects' L1 influences the ability to reduce unstressed syllables in English. Korean is not a stress language, and so no structure like a stressed or unstressed syllable distinguishes syllable types. Korean speakers with less exposure to spoken English had the greatest difficulty in producing short unstressed syllables in target words. Mandarin, in contrast, is a stress language. Unstressed syllables have no underlying tonal specification and are shorter than stressed syllables. Native Mandarin speakers with less exposure to English had little difficulty in producing reduced unstressed syllables.

In addition, productions by more Mandarin and Korean speakers who were more proficient in spoken English produced unstressed and stressed syllables that were more like those produced by native English speakers. Both K2 and M2 speakers spoke at a faster rate of speech and produced durations in unstressed and stressed syllables that were close in durations produced by E. In addition, K2 speakers -in comparison to K1- produced unstressed syllables that were more like those of E by reducing unstressed syllables to a greater extent than stressed syllables. M2 speakers -in comparison to M1- produced stressed syllables that were more like those of E by reducing the length of stressed syllables to a greater extent than unstressed syllables.

English speakers produced the shortest durations in both unstressed and stress syllables in all comparisons but one. (The more proficient M2 speakers produced shorter unstressed and stressed in the comparison of the second syllable in "electrical/electrician".) These shorter syllables indicate that English speakers spoke at a faster rate than the nonnative English speakers. The less proficient K1 and K2 groups produced the longest unstressed and stressed target syllables, while the more proficient K2 and M2 speakers produced unstressed and stressed syllables that were closer in durations to E.

All language groups produced unstressed target syllable that were shorter than stressed syllables. Comparisons between productions of unstressed and stressed syllables produced by M1 and M2, and K1 and K2, were made to observe where the greatest amount of change occurred. Greater reduction in the length of unstressed syllables indicates that reduction strategies were being used while greater reduction in the length of stressed syllables indicates that reduction strategies are not being acquired. In addition, the relationship between unstressed and stressed syllables produced by each language group was observed by deriving a ratio. The smaller the ratio, the greater duration differentiates unstressed from stressed syllables.

6.4.1 The relationship between unstressed and stressed syllables

The greatest difference between the less English proficient Mandarin group, M1, and the more proficient M2 group was in productions of the stressed syllable. While both target syllables produced by M2 were shorter than those produced by M1, stressed syllables were reduced to a greater extent in all words, except in the third syllable in "photography", soon to be discussed. The greater change in the stressed syllable indicates that changes in speech rate within M2 had a greater effect on stressed syllables.

Neither M1 nor M2 groups produced unstressed syllables in "photography" with durations similar to those produced by E.

Greater differences in durations between M1 and M2 productions of stressed syllables may have been because M1 speakers were already reducing unstressed syllables. The ratios derived from unstressed and stressed syllable comparisons in M1 were often smaller than those derived from E productions. These smaller ratios indicate that these Mandarin speakers were making greater distinctions between unstressed and stressed syllables than E. In addition, the mean durations of the unstressed syllables in most target words were produced with durations similar to E. In productions of "memorial", "memorizes", "photographic", and electrician", the duration of unstressed target syllables were like those of E. Smaller ratios, and similar unstressed syllable durations suggest that M1 speakers are able to reduce unstressed syllables.

Neither M1 nor M2 speakers produced the unstressed third syllable in "photography" with durations that were like those of E. While both target syllables were shorter in duration in M2 productions, the duration of the syllable "graph" was still about twice as long as that of E. This syllable appeared to pose difficulty for Mandarin speakers. "Graph" when stressed is produced with a low front vowel. This was the only word in this study produced with this vowel. The full vowels in all other target words were front or back mid vowels. Reduced vowels in English are typically more central, and often produced with a schwa. The differences between full vowels realized with a mid vowel and a schwa are not as great as the difference between [ ] and schwa. The segmental content of syllables may have influenced these productions.

Mandarin speakers of English are able to reduced unstressed syllables in English, because Mandarin has stressed and unstressed syllables. Syllables that have no tonal specification are reduced in Mandarin and are produced with shorter durations. M1 speakers are not fluent speakers of English and speak at a slower rate of speech. However, these speakers are still able to reduce unstressed syllables. Stressed syllables, on the other hand, pose more difficulty for M1 speakers. Articulating a full vowel in stressed syllables may take more effort than producing an unstressed vowel. Mandarin speakers know how to reduce a vowel, but they may not be able to produce full vowels as easily. Full vowels contrast in English and Mandarin, but unstressed vowels do not. In short, Mandarin speakers need to acquire new articulations for a larger number of English vowels, they do not need to acquire reduction strategies. As Mandarin speakers become more proficient in English, they are able to produce full vowels in English with less difficulty. If less difficulty is represented in shorter durations, than the greater shortening of stressed vowels in productions by M2 indicate that full vowels have been acquired.

Unstressed syllables posed the greatest difficulty for Korean speakers. Productions of unstressed syllables by K1 speakers were longer than those of produced in by E in all target words but "memorizes". Productions of the unstressed second syllable in this word were like those of E. Producing a short unstressed syllable in this word did not pose difficulty for these less proficient K1 speakers. In contrast, K2 subjects produced a longer word-initial unstressed syllables in "memorial". The unstressed syllable in this word was similar in length to the stressed syllable in "memorial". This suggests that K1 speakers could reduce an unstressed syllable that followed a stressed syllable, as in "memorizes", but could not reduced an unstressed syllable that occurred prior to a stressed syllable, in "memorial". The location of the unstressed syllable affected these K1 productions. The possible prosodic similarity between words with initial stressed syllables, and patterns of prominence in Korean may explain these results.

In Korean, all words after a prominent word are dephrased and are therefore produced without a prominent accent (Jun, 1994). In addition, the prominent word occurs first in an accentual phrase, and a prominent tonal rise is localized around the first syllable of a word. In "memorizes", the first syllable is stressed and potentially accented, and the unstressed syllable lies after the stressed syllable. For a Korean speaker, this pattern is like that of the accentual phrase, where the first syllable in prominent word is produced with an initial rise. It may also be that this first syllable is longer than those following. Kang (1996) results indicate that prominent words are longer than those that are less prominent. Perhaps the initial syllable in a Korean word in focus is produced with the greatest lengthening. Reduction of the post-stressed syllable in "memorizes" posed no difficulty for K1 speakers. So, when comparing the duration of stressed and unstressed second syllables, we find that less experienced K1 speakers are able to reduce the second syllable in "memorizes." However, the word "memorial" with stress on a later syllable does not conform to the prosodic pattern found in the accentual phrase, with an earlier unstressed syllable occurring before the potentially accented syllable. K1 speakers in this case are unable to reduce a syllable that occurs before the stressed syllable. And so, in comparisons of first syllable "me-", we find that K1 speakers do not reduce the length of the unstressed syllable in "memorial".

The results of duration comparisons made in the remaining target words suggest that like the post unstressed syllable in "memorizes", the unstressed syllables that followed stressed syllables in "electrical" and "photography" were more readily acquired by native Korean speakers. This conclusion was based on the following summary of results. K1 speakers produced longer unstressed and stressed syllables than did K2 speakers. In words with a late stressed syllable, (i.e.., "electrician" and "photographic", the greatest difference between K1 and K2 productions was in the duration of the stressed syllable). There was almost no difference between the duration of the unstressed (pre-stress) syllable. In other words, both K1 and K2 speakers were unable to shorten the second syllable in "electrician" and the second syllable in "photographic". K2 speakers were, however, able to produce shorter stressed syllables. So while the speech rate of K2 speakers was faster, this was because stressed syllables -not unstressed syllables- were shorter. In contrast, K2 speakers were able to produce shorter unstressed syllables in "electrical" and "photography". In these words, the unstressed syllable is after the stressed syllable. K2 speakers produced shorter stressed syllables, but they also produced shorter unstressed stressed syllables compared to those of K1.

K2 speakers were able to reduce post stressed syllables in all target words: "memorizes", "electrical", and "photography", and they were unable to reduce unstressed prestressed syllables in "electrician" and "photographic". This supports the conclusion that post-stressed syllables are more like a prosodic in Korean, and so Korean speakers are more likely to acquire reductions strategies in words with this rhythmic structure. K2 speakers were also able to reduce the initial syllable in "memorial". In fact, this is where the greatest change occurred between K1 and K2 of all comparisons. Producing one unstressed syllable -in "memorial"- may be less difficult than producing a later unstressed syllable -in "photographic" and "electrician". While the former pattern is unlike a prosodic pattern in Korean, the latter pattern is more unlike a Korean prosodic pattern.

6.4.2 Duration in target syllables with varying levels of prominence

Target words were produced within words that were in a nuclear accented context, a prenuclear context, and a postnuclear unaccented context. From the analysis of accent

types used in productions of "memorizes" and "memorial" by all subjects in Chapter 5, Section 5.1, we know that prominent pitch accents produced with increased changes in f0, were produced in nuclear accented contexts. E subjects did not produce pitch accents in the other two contexts, while most subjects in the remaining groups produced pitch accents with progressively smaller f0 movements in prenuclear and unaccented contexts. Pitch accents, when produced, were realized within the stressed syllables of target words. If changes in duration coincide with changes in f0, then one might expect the duration of stressed syllables to be affected by whether a pitch accent was produced in target words, and the amount of f0 change that occurred within that pitch accent.

All language group productions were similarly affected by prominence level. The unstressed syllable in target words was unaffected by how prominent the word was, while the stressed syllable was differentially affected by prominence context. All speakers produced stressed syllables with the longest durations in the prenuclear context. (The only exception, was in the production of the first syllables in "memorial" and "memorizes" by K1 speakers. In their productions, syllables in prenuclear contexts were longer.) In addition, the stressed syllables in prenuclear and postnuclear contexts were similarly affected. The duration of stressed syllables in these two contexts were similar in duration. This was expected for E, who produced a pitch accent only in nuclear accented contexts. This pattern was found in productions by nonnative speakers of English. Although pitch accents in prenuclear contexts were realized with greater changes than those in postnuclear contest, the stressed syllables in these productions were nonetheless similar.

Native Korean productions of target words differed from native Mandarin productions. The ability of Korean subjects to reduce unstressed syllables was negatively affected by their native language. "Stress" for these speakers is a new language construct. K1 speakers had difficulty in reducing all target syllables, except the second syllable in "memorial". K2 speakers had difficulty in reducing unstressed syllables that occurred before a stressed syllable. The ability of Mandarin subjects to reduce unstressed syllables was positively affected by their native language. "Stress" for these subjects is a similar language structure. Both K1 and K2 speakers were able to produce short unstressed syllables, like those of E.

Both Korean and Mandarin speakers were produced stressed syllables that were longer when produced with a nuclear pitch accent. This result is not surprising for M2. Stressed syllables in Mandarin, are produced with more fully realized tones. Prominence affects the tonal realization and the length of stressed syllables (Jin, 1996). Because of this, one would expect native Mandarin speakers to produce increasingly longer stressed syllables in progressively more prominent words in English. Stress is a similar construct in English and Mandarin. M1 and M2 speakers performed as predicted producing stressed syllables with longer durations in nuclear accented contexts.

Korean speakers, on the other hand, do not distinguish unstressed from unstressed syllables in Korean. No particular syllable is associated with changes in prominence. Although the first syllable in a prominent word is produced with a tonal rise, this rise is associated with a word or phrase in Korean, not a particular syllable. Consequently, associating longer duration with stressed syllables in English, is different from Korean. Less proficient K1 speakers made this association, however, and produced longer stressed syllables in nuclear accented contexts than in the other two remaining contexts. This new linguistic pattern, was produced at the early stages

of English language acquisition. Lengthening stress syllables posed no problem to K1 speakers, however, shortening unstressed syllables did.

CHAPTER 7

INTENSITY MEASURES

The average intensity in stressed syllables has recently been found to not be representative of what a listeners hear as stress (Sluijter & vanHeuvan, 1996). In this research, spectrally balanced intensity was instead found to be a better correlate of stressed syllables. Results from earlier research observing the average intensity or peak intensity in stressed syllables was not conclusive (see Fry, 1955, Liberman, 1966; Beckman, 1986). As a result, intensity was concluded to a less reliable feature of stress (and accented stressed syllables, Beckman, 1986) than duration and fundamental frequency.

Most recently, Sluijter and vanHeuvan (1995, 1996) have found that measures of overall intensity are weak correlates of stressed syllables in Dutch and in English. In this research, intensity measured above and below 500 Hz was analyzed in stressed and unstressed syllables produced in focussed and nonfocussed words. They found that there were greater increases in intensity above 500 Hz in stressed syllables compared to those of unstressed syllables. In addition, they found that differences in intensity measures between unstressed and stressed syllables were greatest in focussed target words. When they compared the intensity of unstressed and stressed syllables averaged across all frequencies, they found that there were less reliable differences in average intensity between unstressed and stressed syllables. Sluijter and vanHeuvan (19976) have also shown that changes in intensity above 500 Hz influence the perception of stress to a similar extent as duration changes. Consequently, fluctuations in intensity above 500 Hz is a reliable correlates of stress. Intensity averaged across all frequencies, as previous results indicated, is a poor correlate of stress.

At the time of this experiment, is was not possible to measure intensity only above 500 Hz. Because average intensity has recently been found to be a poor measure of changes in unstressed and stressed syllable, only two accent conditions were observed: a nuclear accented condition where the greatest differences in average intensity between unstressed and stressed syllables might occur, and a postnuclear unaccented condition where the least difference between target syllables might occur.

Average intensity derived from the total RMS within target syllables averaged across the duration of the syllable was used as the dependent measure in this analysis. This analysis was made on "memorizes" and "memorial" produced in statements where a nuclear accent was most likely to be produced and in a postnuclear unaccented condition where targets were most likely to be produced without an accent. These were similar conditions used in Sluijter and vanHuevan's productions experiments. The target word "memorial", provided as an example here, was produced in the following statements in nuclear accented conidition and an unaccented condition. Capitalized words are produced with the most focus.

Nuclear Accented: "I know he wrote the word MEMORIAL nine times."
Postnuclear Unaccented: "He didn't actually WRITE memorial"nine times."

Separate four-way analysis were run on the first and second syllables in "memorial" and "memorizes" to analyze the effects of accent conidition on the average intensity of unstressed and stressed syllables in each language group. Language group was treated as a dependent variable and stress type (initial stress and second syllable stress), accent type (nuclear accented and unaccented), and repetition were treated as repeated variables. The average intensity within the first and second syllables of target words, measured in dB, was the dependent variable.

7.1 Comparisons of first syllables in memorizes and memorial

There was a main effect of stress type [F(1,30)=38.6; p<.001]. The stressed syllable in "memorizes" was greater in average intensity than was the unstressed syllable in "memorial" . The mean intensity of the stressed syllable was 70.57 dB. and the unstressed syllable was 68.86 dB. There was also a significant main effect of accent type [F(1,30)=375; p<.001]. Syllables produced in a nuclear accented context had greater intensity than those produced in an unaccented context. Accented syllables were produced with an average intensity of 70.45 dB. and unaccented syllables, 68.98 dB. Repetition was also significant [F(4,120)=3.15; p<.02]. Subjects produced target syllables with progressively less intensity throughout the experiment, each subsequent repetition being less intense that the prior one. Repetition did not interact with any other factor (p>05).

There was not a main effect of language group [F(4,30)=1.07; p>.390]. Relevant to this experiment are the interactions involving stress type, accent, and language group. There was not an interaction between stress type and language group [F(4,30)=1.60); p>.199]. Because the pattern of these results is relevant to this study, these results are provided in Figure 7.1 to illustrate the relationship between the intensity level in unstressed and stressed syllables produced by each language group.

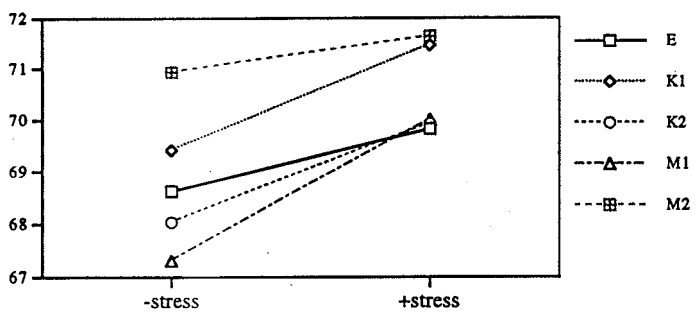


Figure 7.1 The mean average intensity in the unstressed and stressed first syllables in "memorial" and "memorizes" by each language group.

The average intensities of the unstressed first syllable in "memorial" are plotted on the left part of this graph, the mean average intensities of the stressed syllable in "memorizes" are plotted on the left. Lines connect these two syllables to indicate the change in average intensity between these syllables when unstressed and unstressed. All language groups produced an unstressed syllable with less average intensity than

the stressed syllable. Greater differences between the average intensity in unstressed and stressed syllables are indicated by the greater steepness in the lines connecting unstressed and stressed syllables.

The mean intensities of target syllables are separated less by intensity in productions by E and M2, as indicated by shallower connecting lines. The relationship between unstressed and stressed syllables in these two language groups is similar indicated by parallel lines connecting target syllables in these two groups. The greatest difference in average intensity in unstressed and stressed syllables were derived from productions by M1. This group produced an unstressed syllable that was less intense than any other language group, and this created a greater difference between target syllables. The means derived from K1 and K2 productions are intermediate to productions by native English speakers and native Mandarin speakers.

The relationship between target syllables is similar in productions by K1 and K2. While productions by K2 are greater in intensity overall than K1, the relationship between target syllables remains the same. This is indicated by the parallel lines connecting target syllables derived from K1 and K2 productions. M1 productions are different from M2 productions in two ways. First, M2 productions of target syllables have greater intensity than do M1 productions. Second, the difference between unstressed and stressed syllables is greater in productions by M1.

There was no significant interaction between language group, stress type, and accent type [F(4,30)=1.88; p>.140], however, the pattern of results is important to the current investigation. These results are provided in Figure 7.2. The target syllables produced in an unaccented context are provided in the left portion of this figure. These words were produced after the nuclear accented word in the phrase "He didn't actually WRITE memorizes/memorial eight times." (Target syllables are underlined.)

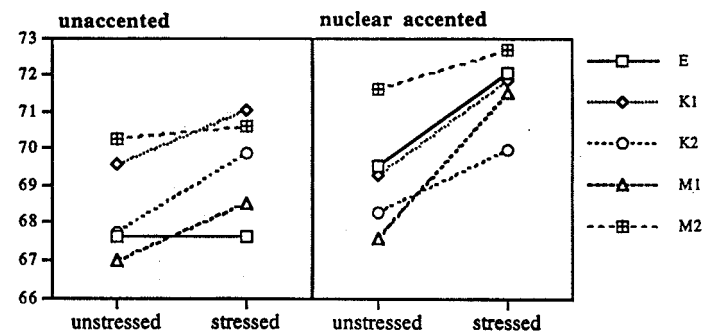


Figure 7.2 The intensity of unstressed and stressed word initial syllables in "memorial" and "memorizes" produced in an unaccented and nuclear context by each language group.

The right side of this graph displays the results from productions in a nuclear accented target. Target words were produced in the phrase. "I know he wrote the word MEMORIZES/MEMORIAL nine times." (Target syllables are underlined.) The following describes the results from E speakers. The average intensity of both target

syllables in this context is greater than those produced in the unaccented context. The average intensity of both syllables in a nuclear accented word is boosted in comparison to an unaccented context. The average intensity of the stressed syllable, however, increases to a greater extent indicated by the steep line connecting target syllables in the accented context. All target words were produced with a L+H* pitch accent in this context. It can be concluded that first, the average intensity of a word increases when produced with an accent, and that the average intensity in stressed syllables increase to a greater extent. These are the same results found by Sluijter & vanHuevan (1997).

M2 productions are most like those of E. The average intensity of both target syllables increases in comparison to unaccented syllables, and the intensity of the stressed syllable increases to a greater extent. M1 productions were not like those of M2 or E. There was little change in the average intensity of the unstressed syllable, the mean intensity was around 67 dB. in the unstressed syllable in unaccented and accented contexts. The average intensity of accented stressed syllables, on the other hand, increased to a much greater extent in the nuclear accented context. The average intensity of nuclear pitch accented words did not increase as a whole, only the intensity in the stressed syllable increased. These M1 subjects are producing stressed syllables with greater intensities regardless of the accent context.

Productions by K1 and K2 are different from E, M1, and M2. The average intensity of target syllables and the relationship between target syllables remained relatively unaffected by the accent context in productions by both K1 and K2. Unstressed syllables were produced with less intensity than stressed syllables, and the average intensity of these syllables remained unaffected by the accent context. Subjects in these two groups produced stressed syllables with greater intensity regardless of accent context.

Only the more proficient M2 speakers produced unstressed and stressed syllables that were differentially affected by accent context. Their productions were like those of E. In both E and M2, when target words were produced within a nuclear accented context, with a prominent pitch accent, both unstressed and stressed syllables were produced with greater intensities. The intensity of the stressed syllable was boosted to a greater extent when produced with a nuclear pitch accent. In other words, stressed syllables have greater average intensity in stressed syllables produced with a nuclear accent in productions by E and M2.

7.2 Comparisons of second syllables in memorizes and memorial

The results of second syllable comparisons were similar to those of first syllable comparisons. There was a main effect of word [F(1,30)=20.2; p<.001]; the mean intensity of the stressed syllable in "memorial" (71.47 dB.) was greater than the unstressed syllable in "memorizes" (70.46 dB.). There was a main effect of accent [F(1,30)=8.31; p<.001]. Syllables in nuclear accented words had greater average intensities (72.41 dB.) than those in unaccented words (69.52 dB.). There was also a main effect of repetition [F(4,120)=17.4; p<.018]. The average intensity was least in the 4th and 5th repetition and greatest in the 1st and 2nd repetition. Similar to first syllable comparisons, this indicates that speakers spoke with progressively less intensity throughout that entirety of the experiment. Repetition did not interact with any other factor (p>.05). Also like first syllable comparisons, there was not a main effect of language group [F(4,30)=.666; p>.620].

There was no significant interaction of stress type and language group [F(4,30)=1.75);p>.165]. These results were also similar to those derived from syllable one comparisons. There was no significant interaction of language group, stress type, and accent type [F(4.30)=.203; p>.203]. These results, relevant to this discussion, are provided in Figure 7.3.

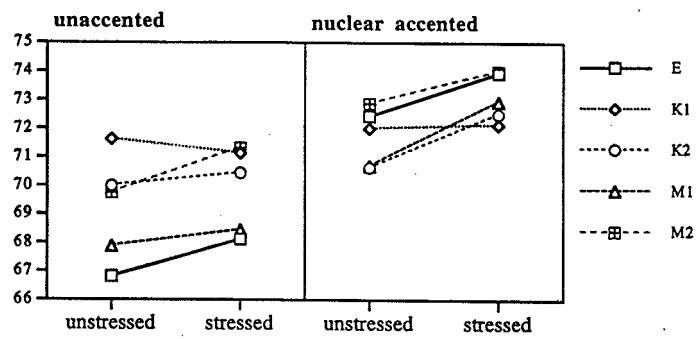


Figure 7.3 The average intensity (dB.) of unstressed and stressed second syllables in "memorizes" and "memorial" produced by each language group in two accent contexts.

The left side of this graph displays second syllables in target words produced in "memorizes" (unstressed syllable) and "memorial" (stressed syllable) in the postnuclear unaccented condition, and the right side of this graph displays target syllables produced in the nuclear accented condition. The steepness of lines connecting E productions in both sides of this graph, is similar. In comparisons of second syllables derived from E productions, stressed syllables have greater intensity than unstressed syllables in both unaccented and accented contexts. The intensity in unstressed and stressed syllables is similarly affected by accent context. This is unlike comparisons of first syllables in target words where target syllables were differentially affected in the nuclear condition. In productions of first syllables, the average intensity of the stressed syllable increased to a greater extent than unstressed syllables.

M2 productions were most like those of E. The intensities of target syllables were greatest in accented contexts, and both the unstressed and stressed syllables were similarly affected in the nuclear accent condition; the intensity of the stressed syllable did not increase more than the unstressed syllable in when produced in a focussed word. The lines connecting unstressed to stressed syllables in the postnuclear condition are parallel to those in the nuclear condition.

The pattern of intensity differences in first and second syllable comparisons are similar in E and M2. While syllables in accented contexts have greater intensities than those in unaccented contexts, only the word-intial syllables in "memorizes" and "memorial" are differentially affected by accent condition. The intensity of the stressed syllable in "memorizes" increases to a greater extent than is the unstressed initial syllable in "memorial" in the nuclear accent condition. The relationship between the second and stressed syllable in "memorial" and the unstressed syllable in "memorizes" is unaffected by accent condition.

The relationship between unstressed and stressed syllable intensitites were similar in first and second syllable comparisons In productions by M1, intensity levels of target syllables in the unaccented context are less than those in the accented context. In addition, stressed syllables in both contexts have greater intensity than unstressed syllables. This is illustrated by the positive slopes of lines connecting target syllables in both accent contexts. Unlike E and M2, accent context differentially affected differences in intensity between unstressed and stressed second syllables. The intensity level of stressed syllables in a nuclear accented context increased more than the unstressed syllable in this context. This is similar to the results of M1 comparisons of first syllables. These results indicate that first, syllables in accented contexts are produced with greater intensities than those produced in unaccented contexts, and second, unstressed and stressed syllables are differentially affected be accent condition. The intensity in stressed syllables increases to a greater extent than the intensity in unstressed syllables.

The relationship between target syllables in K1 productions was not affected by the accent context. While the average intensities of target syllables are greatest in the accented context, the difference between the intensities in unstressed and stressed syllables remains similar in these two accent contexts. In other words, accent type has no effect on the intensity level of these unaccented and accented syllables. In fact, the mean average intensity of stressed syllables is less than that of unstressed syllables.

Productions by K2 speakers differ from those of K1 in that stressed syllables in the accented contexts have greater intensities than unstressed syllables. The unstressed syllable in "memorial" is similar in intensity to the stressed syllable in "memorizes" in an unaccented context. This relationship is illustrated in the left graph of Figure 7.3. In an accented context, the stressed syllable in "memorial" is greater than the unstressed syllable in "memorizes". This is illustrated in the right graph of Figure 7.3. Only stressed syllables in accented contexts are greater in intensity than unstressed syllables in these second syllables. This result is not like that of first syllable comparisons. In this earlier comparison, stressed syllables had greater intensities than unstressed syllables in both unaccented and accented contexts. These intensities in target syllables were unaffected by the accent context.

The results from intensity comparisons are inconclusive. Results from first and second syllable comparisons reveal that there are no significant differences in productions by language groups. There was no main effect of language group in

either comparison ($p>.05$), nor was there a signifant interaction invloving language group ($p<.05$).

It is also difficult of summarize the patterns of results in a consise manner. Very generally, E speakers produced stressed syllables that had greater intensities than unstressed syllables (except in first syllable comparisons of "memorizes" and "memorial"). Accent condition affected the intensities of both unstressed and stressed syllables indicating that the intensity level in a word increase when produced in a nuclear accented word. And, stressed syllables were affected most in the nuclear accented condition. This effect was most evident in first syllable comparisons, where the intensity in the stressed syllable of "memorizes" increased to a greater extent than the unstressed syllable in "memorial".

M1 and M2 speakers performed most like E speakers. Stressed syllables had greater intensities than unstressed syllables; the intensities of both syllables were greatest in the nuclear accented condition; and stressed syllables were longest in comparison to unstressed syllables in the nuclear accented condition. In short, unstrssed and stressed syllables are differentiated by intensity, and this difference is greater in more prominent, focused words.

In K1 productions, intensities of unstressed and stressed syllables were not influenced by whether they were produced in a nuclear accented condition, or in an unaccented condition. Only the stressed first syllable in "memorizes" had greater intensity than the unstressed first syllable in "memorial". However, these intensities were relatively unaffected by the accent condition. This result indicates that intensity separates unstressed from stressed syllables in the beginnings of words, and that prominence does not affect the intensity of syllables. This pattern is more like that of Korean where only the beginnings of words and phrases are produced with prominent acoustic changes. It is suggested that comparisons be made within more word pairs to oberve wether stressed syllables are associated with intensity changes, or if the begninnings of words are associated with intensity changes.

K2 speakers productions were similar to E, M1, and M2 in that stressed syllables that had greater intensity than unstressed syllables. Also similar to these language groups, stressed syllables in K2 productions were affected more by accent condition that were unstressed syllables. The intensity of the stressed syllables was greater in the nuclear accented context, while unstressed syllables were relatively unaffected. What separates K2 productions from E, M1, and M2 is that the intensity of the unstressed syllables did not change in accent conditions. The intensity level of unstressed syllables remained similar in both unaccented and accented conditions, suggesting that prominence level only affects the stressed syllable in K2 productions.

CHAPTER 8

CONCLUSION

8.1 Models of Phonetic Acquisition

Two models of phonetic and phonological acquisition have

8.1.1. SLM

Production of segments in an L2
How similar is one L1 segment to one L2 segment?
What role does exposure in the L2 play upon acquisition?
Phones:

Similar
Different
Identical

8.1.2 PAM

Makes predictions on the perception of sound contrasts in an L2 based on contrasts that exist in the L1.
First contact model, that really doesn't make predictions on how experience may alter the perception of L2 contrasts.

Contrasting phones are assimilated into the L2 based on how similar they are to a native contrast.

Contrasts

Two Category Assimilation
Category -Goodness Difference
Single-Category Difference
Nonassimilable

Emperical support fo these two models have been derived from perception studies of consonants (Best, et.al, 1988; Best, 1990; Best andStrange, 1992; Flege, 1989; Flege and Bohn, 1989; Polka, 1991; Yamada and Tohkura, 1992) and most recently vowels (Fox, Flege, and Monro, 1994; Flege, Monro, and Fox, 1994; Best, Faber, and Levitt, 1997) and from production studies of vowels and consonants (Flege, 1987; Flege, 1988; Flege, 1991; Flege, Monro, and MacKay, 1995.

The conclusions drawn from these studies suggest that L1 sounds that are similar to L2 sounds -but not identical- may not be assimilated into the percepetions and productions within the second language.

Results from investigations of the acauisition of individual sounds have indicated that similar sounds are the most difficult to acquire. Even with many years of exposure,

native-like production may not be acquired (Flege, 1987, Flege, 1991; Flege, Munro, and MacKay, 1995). Results from related studies (Peng, 1993; Flege, 1987) have also indicated that similar sounds in the L1 and L2 may merge into one sound used in both languages. Whether this will happen depends on how similar these sounds are.

Results from investigations of the perception of nonnative contrasts have indicated that similar phones are assimilated into a single category are the most difficult for nonnative speakers to perceive differences between (Best, 1988; Best and Strange, 1992).

8.2 Difficulties in Analyzing Intonation

The current study was conducted to try to understand how prosodic structures are acquired in a second language. Specifically the following question was asked: How are intonation patterns acquired in a stress language (English) by speakers of a stress language (Mandarin) and a nonstress language (Korean). Because f0 is a common phonetic correlate of the intonation systems in English, Korean, and Mandarin, it was hypothesized that acquisition prosody in English would be acquisition of a "similar" linguistic structure by native Mandarin and Korean speakers.

Analyzing acquisition of intonation is a much more complex analysis than is the acquisition of a segment, and so the SLM and the PAM may not be able to explain how intonational differences are assimilated into a second language. When one observes how segments are acquired in a second language, one assumes that similar or different sements exist within the L1 and the L2. What this means is that the analysis of segments includes only an analysis sound production or perception at one linguistic level, a segmental level. When one observes suprasegmentals, many different linguistic levels must be taken into account.

As an illustration, one can observe how the sements [t] and [d] are produced in an L2. Acoustic correlates of these sounds are measured including VOT, length of alveolar closure; and the amount of voicing during the stop closure. All of these attributes are correlates of these consonants and while they also may be attributes of other consonants (e.g., [p] and [b]), they are not attributes of anything other than segments. In obervations of fundamental frequency, however, not just one level of linguistic analysis is being observed. When investigating intonation patterns in a stress-accent language such as English, one needs to observe suprasegmentals including duration, intensity, and f0.

Intonation invloves more than one level of analysis in English. Intonation patterns, or tunes, have meaning associated with the. Rising intonation is used within yes/no questions, falling intonation patterns are used in statements. This intonation pattern is not simply overlaid onto an utterance. It is bound to the utterance in particular ways. Because pitch accents are tied to particular stressed syllables in English, different linguistic levels are necessarily involved in English intonation. Stressed syllables are lexically specified. They are a potentially accentable syllable whose location is predetermined in the lexicon. Intonation then, involves at least two levels of linguistic analysis; a lexical and intonation level. The choice of pitch accents and phrase tones are intonational choices. The timing of pitch accents, however, is bound to the lexicon; the location of a stressed syllable controls the location of pitch accents.

Suprasegmental analysis of stressed and unstressed syllables cannot be understood without knowing the intonational context. The duration, the intensity, and the f0

characteristics of unstressed and stressed syllables depends on the intonational context. Unstressed syllables are reduced in comparison to stressed syllables, but the degree of acoustic dissimilarity between unstressed and stressed syllables depends entirely on how prominent the words are produced.

Not only does an intonational analysis ivolve more than one linguistic level, but the suprasegmentals that are involved in intonation, are also part of other linguisitc structures. For example, the duration of vowels in English is not only affected by prominence, but there are other factors that influence vowel duration in English. Low vowels such as [a] in "pot" are longer than the high vowels such as [I] in "pit". Vowel length is also sensitive word-final consonants. The vowel [a] in "pod" is longer than the vowel in "pot". In addition, the amount of aspiration in prevocalic consonants may affect the length of a vowel. This possibility was raised in the Duration Section of this dissertation. Vowels are longer in stressed syllables than in unstressed syllables. Unstressed and stressed vowels are longer in prominent word; and stressed vowels longest in nuclear accented. This illustrates how vowel duration is affected by many linguistic levels. Fundamental frequency is also a part many linguistic levels. This is most evident in Mandarin Chinese.

At a segmental level, there are intrinsic differences in fundamental frequency within vowels. High vowels, such as [i] in "beat", are produced with higher f0 than are low vowels, such as [œ] as ub "bat". In addition, the voiceless consonants raises the initial f0 levels within following vowels. This means that the initial portion of [i] in "Pete" has higher f0 levels than the initial part if [i] in "beat". In addition, tones are part of a syllable's structure in Mandarin in that stressed syllables are ascribed a specific tonal shape. For this reason, f0 is an intrinsic acoustic property of syllables. Utterances in Mandarin are produced with different intonational tunes. Question tunes differ from statements tunes in that questions are produced within the higher regions of a person's pitch range, and statements are produced lower in a person's pitch range. The intonation pattern within Mandarin utterances influences the pitch range in which tone-bearing syllables are produced. Rising tones, for example, rise to higher levels in f0 in questions than in statements.

Mandarin is a also a stress language. Stressed syllables within multisyllabic words have a specified tone. Unstressed syllables do not. Prominence affects the realization of tones within stressed syllables. The more prominent a word is, the more fully realized the tones in stressed syllables. The f0 shape of unstressed syllables is governed by the shape of surrounding stressed syllables. Fundamental frequency is an acoustic property of tones and intonational tunes in Mandarin Chinese. In addition, prominence relationships between words are conveyed through the extent of tonal changes in stressed syllables.

In English, fundamental frequency is a property of pitch accents and phrase tones that govern intonation patterns. Pitch accents are associated with prominent words, and the alignment of pitch accents within words is by the location of stressed syllables. While understanding Mandarin intonation means knowing stress, tone, intonational tunes, and prominence relationships; understanding English intonation means knowing stress, pitch accents, phrase accents, intonational tunes, and prominence relationships.

Korean intonation is different from both English and Mandarin. It is not a stress language, nor does it have tones. F0 is a property of phrase accents. Specific changes in f0 mark the edges of utterances in Korean. Accentual phrases are

prosodic phrases that have specified tonal pattern. Prominent words are produced within the LH tonal movements of the accentual phrase. This LH pattern is not associated with any particular syllable in Korean, but is instead produced within the first few syllables of prominent words. By expanding the pitch range, this LH pattern can be realized with greater changes in f0. Equally prominent words are likely to be produced within two prosodic phrases. In this way, a prominent LH rise can be produced within both prominent words. For these reason, phrasing is an important aspect of Korean intonation. The greater the number of prominent words in an utterance, the greater the number of accentual phrases. Intonational meaning is conveyed through the use of different boundary tones. A final rise occurs in questions, and final fall occurs in statements.

F0 in Korean is a defining aspect of the accentual phrase. The f0 characteristics of the accentual phrase have no intonational meaning. That is, an initial rise marks a boundary, it does not add meaning to an utterance. Final boundary tones have intonational meaning. An utterance-final high is used in question intonation, while an utterance-final fall is used within statements. These boundary tones are not bound to any specific word and are produced at the end of an intonational phrase.

To know Korean intonation is to know accentual phrases, boundary tones, and phrasing. To know Mandarin is to know tones, tunes, and stress. To know English is to know pitch accents, phrase tones, and stress. And most important to knowing all of these languages is to know how prominence relationships affect all of these linguistic structures.

Fundamental frequency then is an important attrubute on the intonational systems in these three languages, and the way that f0 operates within these intonational systems is affected by the role of f0 in other linguistic levels, such as tone in Mandarin. How duration and intensity changes are involved in intonation systems are less understood. Because English is a stress language, and pitch accents are bound to stressed syllables, durational and intensity changes are also part of intonational prominence. And like f0, duration and intensity changes are also parts of other linguistic levels. Less is known about how prominence affects the duration and intensity of words and syllables in Korean and Mandarin. Because Mandarin is a stress language, we can predict that duration and intensity changes may indicate prominence relationships, as in English. We can also predict, that because Korean does not have stress, that duration and intensity changes may have less of a role in prominence relationships.

8.2.1 Acquisition of Intonation in a Second Language

Questions asked within this study are not as simple as, "How is a segment, or a segmental contrast, acquired in a second language," but are instead more complex. When observing how intonation patterns are acquired in an L2, one is asking how a system of intonation is learned. This is not a matter of learning new intonational tunes, or patterns, and applying them to utterances in an L2. It is a matter of understanding how intonation interacts with segments, syllables, words, and phrases.

Fitting intonation acquisition into theories the Speech Learning Model and the Perceptual Assimilation Model for the reasons just described is difficult. Relevant to Mandarin speakers learning English, this study was based on the hypothesis that Mandarin speakers would percieve the f0 pattern in tones to be like those in specific intonation patterns in English. That is, they would percieve a tonal pattern associated

with a syllable in Mandarin to be similar to an intonation pattern in English. Pitch accents, like Mandarin tones, are produced in stressed syllables. Resulting from this association, Mandarin speakers would produce intonation patterns in English with tonal movements similar to those of tones. Statement intonation patterns in English consisting of a H* L- L- tonal patterns is similar to falling tone 4 in Mandarin, and question intonation consisting of L* H- H% is similar to tone 3 in Mandarin. These tonal patterns are associated with the stressed syllable by Mandarin speakers, given that tones are associated with stressed syllables in Mandarin. Mandarin speakers are transferring lexical tones in the L1 into intonation in the L2. Statement and question intonation patterns in the L2 are similar structures. They are not identical because tonal movements are not a property of stress in English (as in Mandarin), but are instead a property of pitch accented stressed syllables. The stressed syllables in words produced with no pitch accent have no specified tonal pattern. This is a potential problem for Mandarin speakers of English. These speakers must learn to produce stressed syllables without a particular f0 pattern. There are other possible reasons that intonation patterns are similar, and not identical, structures for Mandarin speakers. Changes in duration and intensity associated with changes in prominence in English, may not be associated with prominent stressed syllables in Mandarin.

Hypotheses were also made regarding how Korean speakers would acquire intonation patterns in English. Fundamental frequency, duration, and intensity changes are not associated with any particular syllable in Korean. The problem that native Korean speakers face is one of stress. What is a stressed syllable to a Korean speaker? Stressed syllables are often produced with tonal changes in English, they are also longer and more intense when produced in prominent words. Unstressed syllables, on the other hand are shorter, less intense, and are produced with no particular tonal pattern. It was hypothesized in this study that Korean speakers would associate the tonal rise in prosodic phrases with stressed syllables in English. Korean speakers would be less likely to produce a tonal fall in a stressed syllable, because accentual phrases in Korean are not initiated with tonal falls. Consequently, it was hyothesized that different pitch accents would not be produced by Korean speakers who were beginning to learn spoken English. One rising tonal pattern would be produced in stressed syllables regardless of the intonational context. It was also hypothesized that stressed syllables were more likely to be produced without a pitch accent in unaccented contexts. Because stressed syllables don't exist in Korean, and because tonal shapes are not associated with particular syllables, Korean speakers might be more likely to produced unaccented words. In addition, it was hypothesized that unstressed syllables in English would not be reduced in duration and intensity in comparison to stressed syllables. Reduction of unstressed syllables is a new linguistic contstruct for native Korean speakers. For this reason, less proficient Korean speakers of English were expected to produce unstressed and stressed syllables with similar durations and intensities.

8.4 Acquisition of Intonation in Nonnative Speakers
8.4.1 Korean Speakers of English

Korean speakers who are first exposed to spoken English, are faced with a system of intonational prominence that is bound to stressed syllabes, an unfamiliar structure in Korean. Both English and Korean emphasize word by producing them with prominent f0 changes. However, in Korean, prominence is linked to changes in intonational phrasing and the boundary tones that mark these phrases, while in English prominence is linked to pitch accents. Korean speakers with less exposure to

English were expected to transfer the tonal characteristics of thier L1 into L2 productions.

The saliency of the English stressed syllable appears to be clear to a nonnative speakers of Korean. Korean speakers with very little exposure to spoken English produced prominent acoustic changes in stressed syllables. The results of this study show that Korean speakers produce rising accents, but only in the word "memorial" with a later stressed syllable. The strategy taken by these speakers with little exposure to English is to produce a rising accent pattern in "memorial" and a falling accent pattern in "memorizes". By doing this, a high f0 peak is reached within the stressed syllable. Comparisons of the f0 excursion in these two target words indicated that two different tonal patterns were being produced by K1 speakers. While native English speakers produced a long intial rise in both words, K1 speakers produced a long intitial rise only in "memorial".

Korean speakers associated a high tone with stress. It was hypothesized that Korean speakers would produce no pitch accent in less prominent words. Targets were produced in postnuclear contexts to observe how words that are unaccented by native English speakers are produced by nonnative speakers. English speakers produced no accent in target words in this context, while the majority of K1 speakers continued to produce rising accents in "memorial" and falling accents in "memorizes". These Korean speakers were unable to produce target words with the tonal characteristics of surrounding tones. Korean speakers with little exposure to English produce stressed syllables with a high pitch pattern.

The Speech Learning Model predicts that similar linguistic constructs will be the most difficult to acquire in a second language. The results of this experiment indicate that this is the case. Unlike the native English speakers, Korean speakers with little exposure to English did not produce tonal patterns consistent with L* pitch accents; they associated the stress pattern of words with a tonal shape and produced different tonal patterns in target words differing in stress patterns; and they associated stressed syllables with tonal changes. The more proficient K2 speakers in this experiment were very fluent in English. Two speakers had "foreign accents" that were almost not detectable. Nonetheless, productions of f0 patterns in K2 were not like those of the native English speakers. These very proficient Korean English speakers, as a group, did not produce L* pitch accents and consistently produced rising accents in "memorial" and falling accents in "memorizes" in all intonation contexts. These speakers did not produce unaccented target words. Although the tonal patterns in targets produced in unaccented contexts were greatly reduced in comparison to those produced in accented contexts, the majority of K2 speakers produced "memorizes" and "memorial" with different f0 patterns. These "new" linguistic patterns were not acquired by these very proficient native Korean speakers of English.

Do Korean speakers who are first learning English reduce unstressed syllables? Korean speaker produced stressed syllables with prominent changes in pitch. Pitch changes are produced in prominent Korean words, and so pitch changes are similar tonal patterns in Korean and in English. But what about unstressed syllables? Do Korean speakers reduce the duration and intensity of unstressed syllables in relationship to stressed syllables? In productions by native English speakers, unstressed syllables were shorter in duration and had less average intensity than stressed syllables in productions by native English speakers.

There are no reduced syllables in Korean. While the duration and intensity of words and phrases may increase as their prominence increases, other less important words are not reduced in comparison. Duration and intensity increase in prominent words and do not decrease in less prominent words in Korean. It is conceivable then that Korean speakers would lengthen stressed syllables, but not reduce unstressed syllables. The results from this study suggest that this is the case. K1 speakers did not shorten the first unstressed syllable in "memorial". This syllable was similar in length to the stressed syllable in "memorizes". The results from comparisons of all target syllables indicated that K1 speakers were not reducing unstressed syllables, but were lengthening stressed syllables. When a word or phrase is in focus in a Korean utterance, it too is produced with longer durations (Kang, 1996). These K1 speakers were producing stressed syllables in English with additional length. By doing this, stressed syllables were longer in comparison to unstressed syllables. In addition, the more prominent the target words' context, the longer the stressed syllables. English speakers did the same thing. As target words became more prominent, native English speakers produced stressed syllables with longer durations. So while Korean speakers lengthened stressed syllables differentially in different prominent contexts, they did not reduce the length of unstressed syllables.

So, Korean speakers produced rising pitch accents in stressed syllables, and also produced stressed syllables with longer durations in more prominent contexts. Unstressed syllables, however, were not reduced. Korean speakers correctly associated acoustic changes with stressed syllables, but did not reduce unstressed syllables. Not having stress in Korean influenced productions of unstressed syllables in English.

The SLM predicts that similar structures in a second language will eventually be acquired with exposure to the target language. According to the SLM, reduction of unstressed syllables in productions by more proficient native Korean speakers, K2, should be acquired. More proficient Korean speakers were able to produce shorter unstressed syllables, but the ablity to do this was limited by Korean intonation. Words that follow a prominent word are grouped together with the prominent word in a prosodic phrase. Syllables that follow a prominent rise are produced without prominent acoustic changes. This pattern influenced productions in English. K2 speakers were able to reduce syllables that followed stressed syllables. K2 speakers were less likely to shorten unstressed syllables that occured before a stressed syllable. So while exposure to English did affect the ability to shorten unstressed syllables, this ability was limited by the stress pattern of words.

To summarize these conclusions, the results of this study suggest that the intonation system of Korean continues to influence productions of English intonation patterns. Even though the degree of influence that the L1 system has on the L2 system may differ, patterns of the L1 intonation system are still evident in productions by very fluent Kroean nonnative speakers of English.

8.4.2. Mandarin Speakers of English

Mandarin speakers need to acquire different aspects about English intonation than do Korean speakers. Mandarin and English both have stressed syllables with which acoustic prominence is associated. This increases the liklihood that stressed syllables in English will be associated with greater changes in pitch, intensity, and duration than are unstressed syllables. While changes in duration and perhaps intensity may be associated with stressed syllables, pitch changes may pose some confusion to

Mandarin speakers acquiring English. While pitch contours are part of syllable structure in Mandarin, pitch contours are part of intonation structure in English.

When speaking Mandarin, native Mandarin speaker produces stressed syllables with a specifiec tonal shape, characteristic of stressed syllables in Mandarin. The more prominent a word is, the more enhanced the tonal patterns, the longer the duration, and the more intense the stressed syllables. This is similar to English productions. An English speaker produces stressed syllables with longer durations and perhaps greater intensities than unstressed syllables. The more prominent a word is, the greater these differences between unstressed and stressed syllables. In terms of duration and intensity then, Mandarin and English are similar. The results of duration and intensity differences between unstressed and stressed syllables confirm this. Both Mandarin speakers and English speakers produced shorter and less intense unstressed syllables than stressed syllables. In addition, these acoustic differences were greatest in words produced within a very prominent sentential context. Mandarin speakers with less exposure to English spoke at a slower rate of speech, as is expected of less proficient language speakers, but they still produced stressed syllables that were longer than unstressed syllables.

In terms of the Speech Learning Model, "stress" is a similar linguistic construct in both languages, and intensity and duration are similar acoustic features of stress in these languages. Mandarin speakers produced unstressed and stressed syllables with duration and intensity characteristics similar to those produced by native English speakers. This suggests that Mandarin speakers positively transfer the acoustic characteristics of stressed and unstressed syllables in their L1 into their productions in the L2, English. But stressed syllables are not lexically associated with any particular tonal shape in English as they are in Mandarin. F0 shapes are part of a system of tones in Mandarin, and a part of only prominent stressed syllables in English. Associating different tonal shapes to stressed syllables is not a new concept for native Mandarin speakers, but associating different tonal shapes with intonation is. The use of f0 then is a "new" linguistic construct for Mandarin speakers.

At the outset of this experiment it was hypothesized that Mandarin speakers would transfer particular tonal shapes associated with Mandarin tones to intonational shapes in English. This implies, for example, that "memorial" would be produced with a falling tonal contour in statements and a rising tonal contour in questions. This hypothesis was wrong. It appears that Mandarin speakers associate stressed syllables with a high pitch. Certainly, the way that stress is taught in English to nonnative speakers, explicitly reinforces this association. (A discussion of this possibility continues in the next section.) Associating a particular shape with a stressed syllable is a better hypothesis. This is more like Mandarin. Stressed syllables have a particular shape, and this shape does not change in different intonational tunes. For a native speaker of Mandarin to produce one word, "memorial" for example, with two different tonal patterns is not like anything in Mandarin. The meaning of this word would change, if it were a Mandarin word.

The results of this study indicate that high pitch is associated with a stressed syllable, and this association is not lost even in contexts where stressed syllables in English are produced without pitch accents. This leads to the next hypothesis, and that is Mandarin speakers will associate tonal changes with stressed syllables in English and not only with intonational prominence. "Not only" here because in English, pitch accents are part of intonational prominence and not an inherent feature of stressed syllables, whereas in Mandarin tonal changes are associated with intonational

prominence and are also an inherent feature of stressed syllables. As discussed earlier, tonal changes are associated with stressed syllables in the L1 and with intonation in the L2. This means that a high pitch will be associated with stressed syllables regardless of their intonational prominence. This was the case. Mandarin speakers produced words in postnuclear contexts with visible recognizable tonal shapes. "Memorizes" was produced with a falling tonal contour. This word has a first stressed syllable, and a higher pitch was produced in this word. "Memorial" was produced with a tonal rise in the stressed syllables. This word has a later stressed syllable, and a rise to this syllable occured from the first unstressed syllable to the stressed syllable. The most proficient Mandarin-English speakers produced these patterns in these two words.

So, what made these more proficient speakers of English more proficient that the less proficient speakers? The alignment of tonal movements with stressed syllables in M2 speakers were more like those of the native English speakers.

XXX

8.5 ESL Materials reinforce stress as accent

The majority of nonnative speakers produced stressed syllables with a high f0. This is surprising; one Mandarin speaker and two Korean speakers were rated by the experimenter as being as proficient as native English speakers. The scores were 98, 99, and 99.5 out of a possible 100. These three speakers did not produce falling tonal patterns in stressed syllables in questions, nor did they produce "memorizes" and "memorial" without tonal movements in unaccented contexts.

This pattern is reinforced by ESL texts that teach that important words are produced with higher pitch. Exerpts from the most commonly used ESL pronunciation texts are provided below to illustrate how pitch is explicitly taught as being an intrinsic part of stress in English.

Pronouncing American English: Sounds, Stress, and Intonation, Second Edition

In every word of two or more syllables, one syllable is stressed. That means that the vowel sound in that syllable is said louder, is said on a higher pitch, and is held longer than the other vowel sounds in the same word. This pattern is called syllable stress. (Orion, 1997).

Well Said, Advanced English Pronunciation

"What makes a syllable sound stressed or emphasized in American English? A combination of thee three features creates syllable stress.

Length: The vowel in the stressed syllable is longer.

Pitch: The stressed syllable has a higher pitch.

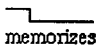
Clear Vowel: The stressed syllable has a full, clear, vowel. (Grant, 1993).

Manual of American English Pronunciation, Fourth Edition

We put stress on a syllable when we pronounce it with such emphasis as to give it more importance than the surrounding syllables and make it stand out among them: for example the com- of comfortable /ˈkˈmfˈrtˈbˈl/. Stress is sometimes caused accent. (Prator, J. & B.W.Robinett, 1972).

Stress in each of these texts is associated with "higher pitch" and "accent". Higher pitch is an acoustic attribute of prominent stressed syllables produced with H* or L+H* pitch accents. What these texts fail to teach is that stressed syllables can also be produced without a high pitch. They can be produced with a prominent low pitch accent, they can also be produced without an accent. In short, what most ESL text teach is that a stressed syllable is produced with a H* or L+H* pitch accent.

These texts use various types of notation to illustrate the pitch changes in stressed syllables. In Manual of American English Pronunciation, "memorizes" and "memorial" would be described as having the following intonation pattern:



The pitch pattern written above "memorizes" roughly describes a H* pitch accent, the pitch pattern written above "memorial" roughly describes a L+H* pitch accent. These pitch patterns also describe the tonal patterns that Korean speakers were producing in their utterances. Two different pitch accent patterns are used to describe the stress patterns in these words. K1 and K2 speakers produced different pitch accents in "memorial" and "memorizes". In addition, they produced these different pitch accents in these words in unaccented contexts where no pitch accent was produced by native English speakers.

8.4.2 Mandarin Speakers of English

8.5 Possible Misguided Influence of Language Materials

Do ESL texts and instructors facilitate acquisition of various types of pitch accents, and content words produced with no accent at all? These are questions related to prominence. The predominant pitch accent in student-directed speech may by H* or L+H* pitch accents, but it is also likely that L* pitch accents are also used in yes/no questions directed to students. This of course, is only a personal observation. The information provided in ESL texts is a more objective look at the way prominence is dealt with in the ESL classroom.

There is one standard pitch accent taught in ELS texts. In an ESL text, Clear Speech, the author writes,

We help listeners to notice the focus word (the most important word) by changing the pitch. The sound of our voices rises on the focus word and then falls. This makes a contrast with less important words. English speakers pay attention to this change in pitch." (Gilbert, J. 1993).

Representative sentences -with pitch patterns provided- taken from examples that this author uses to illustrate this point are:

1. I broke the record.

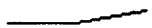
2. Put this in the refrigerator.

3. I want some shoes.

The visual cue is provided to illustrate the way the pitch rises within the stressed syllable. The stressed syllable in the important words are produced with a high pitch level. Even focussed words in yes/no questions are explicitly said to have a rising tonal pattern. The excerpt below is taking from another ESL pronunciation text: Focus on Pronunciation

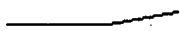
"In a sentence, the most important words will be pronounced on a higher pitch than other stressed words."

"In the following sentences, pitch jumps up to a stressed syllable of the important word. After that it may continu to go up or it may stay at the same level or even drop a little-but not to a very low pitch."



1. Are you staying?

2. Did you buy that one?



3. Is he expecting you?

4. Do you have any identification?

In yes/no questions, English speakers produced a falling L* accent in the prominent word. E subjects in this study all produced a L* pitch accent in nuclear accented productions of targets produced in questions. This would then be a likely context where a different pitch accent might be taught. Instead, a high pitch is still associated with the stressed syllable.

Producing multisyllabic word without a pitch accent is not explicitly (nor implicitly) taught in an ESL text. ESL materials have confused stress with physical attributes, rather than

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Appendix A
Spoken English Proficiency Test

Spoken English Test

Name _____ Native Country _____
Date _____

Part 1: (Formal Dialogue) Take a few minutes to read the passage below. Please read the passage aloud.

Learning to speak a foreign language fluently and without an accent isn't easy. In most educational systems, students spend many years studying grammatical rules, but they don't get much of a chance to speak. Arriving in a new country can be a frustrating experience. Although they may be able to read and write very well, they often find that they can't understand what people say to them. English is especially difficult because the pronunciation of words is not clearly shown by how they're written. But the major problem is being able to listen, think, and respond in another language at a natural speed. This takes time and practice.

Part 2: (Informal Dialogue) Take a few minutes to read the passage below. Please read the passage aloud.

A: Hi, Bob. Gee, I haven't seen you in a while. How are you doing?

B: Not so good. Unfortunately, I've had a bad cold for the last three or four days, and I feel a little tired. How about you? What have you been up to recently?

A: Well, I just came back from a weekend at the shore. Do you know Liz? She invited me out to her family's place on Martha's Vineyard.

B: Is her house on the beach or in town?

A: It's a few minutes away from a big beach on the south coast. We usually walked out there in the morning, brought sandwiches and soft drinks with us, and stayed all day.

B: I've heard enough! Would you take me along some time?

A: With pleasure.

Part 3: Complete the following incomplete sentences:

1. On sunny days, I ...

2. When I was young, I ...

3. My friend asked me ...

4. If the weather had been bad, ...

5. We can't meet between 5:00 and 7:00, so let's ...

Part 4: You will be asked to answer one of the following questions. You will have a few minutes to answer the question.

1. How much English do you speak each day? In what types of situations do you speak English?

2. Please describe you family, your brothers and sisters; your parents; etc...

Appendix B: Personal Information & Language Information

Today's Date: _____
SSN#: _____-_____-_____
Local Telephone #: (_____)_____
Permanent Telephone #: (_____)_____

1. Name: _____
last first middle

2. Gender (circle one) female male

3. Date of birth: _____

4. Where were you born? _____
city country

5. Where have you lived most of your life?
_____
city country
For how long? _____

6. What is your native language? _____
What languages can you speak?
_____

7. What foreign speaking countries have you lived in? How long?
_____

8. At what age did you begin studying English? _____

How long (years and months) did you study English in you native country?
_____

Were any of your teacher native speakers of English? _____

9. How long (years and months) have you studied English in the United States?
_____

When did you arrive in the United States? ____/____/____

10. Have you had any conversation, listening, and/or speaking courses? _____ If "yes", please describe them in terms of their contents and length.

11. How often do you speak English on a daily basis? (check one)
_____ 0 - 2 hours
_____ 3 - 5 hours
_____ 6 or more hours

12. How would you rate your listening and speaking skills in English? (check one)
_____ excellent
_____ very good
_____ good

_____ fair

13. Please include any other information that might be relevant to your language ability.

Appendix C. Sample dialogue number 13 used in the experiment.

13

electrician
memorizes

A: I know he wrote the word ELECTRICIAN nine times.

Did he write the word MEMORIZES nine times?

B: No. He wrote memorizes EIGHT times.

A: Did you say memorizes EIGHT times?

B: Well, in fact. He didn't actually WRITE memorizes eight times.

A: Well then. Let me ask you this. Did he TYPE memorizes eight times?

B: No. Wrong again. He SAID memorizes eight times.

Appendix D

ANOVA Table
memorizes/memorial
Durations
Syllable 1 Comparisons

Source	df	SS	MS		F-Val.	P-Val.
group		4	0.184	0.046	1.113	0.3689
WS var.		30	1.244	0.041		
stress		1	1.031	1.031	148.64	0.0001
stress*group		4	0.132	0.033	4.761	0.0043
WS var.		30	0.208	0.007		
int		1	0.001	0.001	0.669	0.42
int*group		4	0.004	0.001	0.74	0.5724
WS var.		30	0.039	0.001		
accent		2	0.1	0.05	17.686	0.0001
accent*group		8	0.111	0.014	4.93	0.0001
WS var.		60	0.169	0.003		
rep		4	0.002	.0004	0.406	0.8043
rep*group		16	0.008	.0004	0.461	0.9607
WS var.		120	0.127	0.001		
stress*int		1	0.013	0.013	12.902	0.0012
stress*int*group		4	0.007	0.002	1.862	0.1431
WS var.		30	0.029	0.001		
stress*accent		2	0.058	0.029	15.847	0.0001
stress*accent*group		8	0.015	0.002	1.039	0.4178
WS var.		60	0.109	0.002		
int*accent		2	0.001	.0003	0.384	0.683
int*accent*group		8	0.011	0.001	1.394	0.2179
WS var.		60	0.061	0.001		
stress*rep		4	0.005	0.001	1.491	0.2091
stress*rep*group		16	0.007	.0004	0.537	0.9225
WS var.		120	0.101	0.001		
int*rep	4	0.004	0.001		1.602	0.1783
int*rep*group		16	0.017	0.001	1.629	0.0712
WS var.		120	0.079	0.001		
accent*rep		8	0.008	0.001	1.161	0.3238
accent*rep*group		32	0.018	0.001	0.641	0.934
WS var.		240	0.208	0.001		

stress*int*accent	2	0.001	.0004		0.421		0.6582
str*int*acc*grp 8	0.005	0.001		0.961		0.4745	
WS var.	60	0.039	0.001				
stress*int*rep	4	0.004	0.001		1.72		0.1499
stress*int*rep*group	16	0.014	0.001		1.576		0.0854
WS var.	120	0.069	0.001				
stress*accent*rep	8	0.004	.0004		0.734		0.6616
stress*acc*rep*grp	32	0.026	0.001		1.199		0.2224
WS var.	240	0.161	0.001				
int*accent*rep 8	0.006	0.001		1.061		0.3913	
int*accent*rep*group	32	0.025	0.001		1.089		0.3475
WS var.	240	0.17	0.001				
stress*int*accent*rep	8	0.005	0.001		0.825		0.5816
str*int*acc*rep*grp	32	0.018	0.001		0.785		0.7911
WS var.	240	0.169	0.001				

Appendix E

ANOVA Table
memorizes/memorial
Durations
Syllable 2 Comparisons

Source	df	SS	MS		F-Val.	P-Val.
group		4	0.532	0.133	4.466	0.006
WS.var	30	0.893	0.03			
stress		1	6.129	6.129	386.8	0.0001
stress*group		4	0.18	0.045	2.833	0.0418
WS.var	30	0.475	0.016			
int		1	0.005	0.005	4.899	0.0346
int*group		4	0.004	0.001	1.017	0.4142
WS.var	30	0.031	0.001			
accent		2	0.446	0.223	65.56	0.0001
accent*group		8	0.045	0.006	1.665	0.1259
WS.var	60	0.204	0.003			
rep		4	0.008	0.002	2.041	0.093
rep*group		16	0.013	0.001	0.794	0.6895
WS.var	120	0.125	0.001			
stress*int		1	0.001	0.001	2.22	0.1467
stress*int*group		4	0.003	0.0001	0.133	0.9691
WS.var	30	0.016	0.001			
stress*accent		2	0.192	0.096	52.41	0.0001
stress*accent*group		8	0.01	0.001	0.693	0.696
WS.var	60	0.11	0.002			
int*accent		2	0.004	0.002	2.119	0.1291
int*accent*group		8	0.007	0.001	1.032	0.4225
WS.var	60	0.054	0.001			
stress*rep		4	0.039	0.01	10.42	0.0001
stress*rep*group		16	0.023	0.001	1.533	0.0989
WS.var	120	0.112	0.001			
int*rep	4	0.002	0.001		1.083	0.3681
int*rep*group	16	0.006	0.004		0.691	0.7986
WS.var	120	0.067	0.001			
accent*rep		8	0.007	0.001	1.226	0.2845
accent*rep*group		32	0.026	0.001	1.177	0.2447
WS.var	240	0.167	0.001			
stress*int*accent		2	0.004	0.002	3.87	0.0263

stress*int*acc*group	8	0.015	0.002		3.593	0.0018
WS.var	60	0.031	0.001			
stress*int*rep	4	0.001	0.001		0.746	0.5626
stress*int*rep*group	16	0.007	0.001		0.892	0.5799
WS.var	120	0.059	0.001			
stress*accent*rep	8	0.003	0.001		0.569	0.803
stress*acc*rep*group	32	0.012	0.0001		0.564	0.9729
WS.var	240	0.164	0.001			
int*accent*rep	8	0.004	0.0001	0.877	0.5369	
int*accent*rep*group	32	0.015	0.0001		0.912	0.6073
WS.var	240	0.12	0.0001			
stress*int*accent*rep	8	0.008	0.001		2.061	0.0404
str*int*acce*rep*grp	32	0.017	0.001		1.158	0.2651
WS.var	240	0.169	0.001			

Appendix F

Electrican/Electrical
Duration
Syllable 2 Comparisons

Source	df	SS	MS	F-Val		P-Val
group		4	0.311	0.078	2.97	0.0353
WS.var.		30	0.786	0.026		
stress		1	0.489	0.489	101.29	0.0001
stress * group	4	0.045	0.011	2.339		0.0778
WS.var.		30	0.145	0.005		
inton		1	0.005	0.005	8.288	0.0073
inton * group		4	0.002	0.001	0.891	0.4811
WS.var.		30	0.017	0.001		
accent		2	0.111	0.056	31.871	0.0001
accent * group	8	0.007	0.001	0.482		0.864
WS.var.		60	0.105	0.002		
rep		4	0.002	.0004	0.7	0.5932
rep * group		16	0.01	0.001	1.055	0.4056
WS.var.		120	0.069	0.001		
stress * inton		1	0.002	0.002	3.422	0.0742
stress * inton * group	4	0.002	0.001	1.083		0.3824
WS.var.		30	0.015	.0004		
stress * accent	2	0.059	0.03	23.003		0.0001
stress * accent * group	8	0.005	0.001	0.466		0.875
WS.var.		60	0.078	0.001		
inton * accent		2	0.002	0.001	1.449	0.2429
inton * accent * group	8	0.007	0.001	1.73		0.1098
WS.var.		60	0.032	0.001		
stress * rep		4	0.003	0.001	1.479	0.2127
stress * rep * group		16	0.014	0.001	1.539	0.0969
WS.var.		120	0.066	0.001		
inton * rep		4	0.001	.0002	0.535	0.7099
inton * rep * group		16	0.003	.0001	0.451	0.9644
WS.var.		120	0.049	.0004		
accent * rep		8	0.007	0.001	2.134	0.0334
accent * rep * group		32	0.009	.0002	0.77	0.8103
WS.var.		240	0.092	.0003		
stress * inton * accent	2	.0001	.0003	0.084		0.9191
stress * inton * accent * grp		8	0.004	0.001	1.227	0.2994

WS.var.	60	0.027	.0004		
stress * inton * rep	4	0.001	.0003	1.077	0.3709
stress * inton * rep * grp	16	0.007	.0004	1.427	0.1404
WS.var.	120	0.039	.0004		
stress * accent * rep	8	0.007	0.001	2.443	0.0147
stress * accent * rep * group	32	0.011	.0003	0.941	0.5625
WS.var.	240	0.091	.0003		
inton * accent * rep	8	0.002	.0002	0.578	0.7952
inton * accent * rep * group	32	0.011	.0003	0.946	0.5546
WS.var.	240	0.087	.0004		
stress * inton * acc * rep	8	0.005	0.001	2.118	0.0348
strss * inton * acc * rep *grp	32	0.017	0.001	1.746	0.0105
WS.var.	240	0.073	.0004		

Appendix G

Electrical/Electrician
Duration
Syllable 3 comparisons

Source	df	SS	MS	F-value	P-Value
group		4	0.413	0.103	6.177	0.0009
WS.var.		30	0.501	0.017	
stress		1	0.263	0.263	75.351	0.0001
stress * group	4	0.005	0.001	0.33	0.8555
WS.var.		30	0.105	0.003	
inton		1	0.001	0.001	5.086	0.0316
inton * group		4	0.003	0.001	4.449	0.0061
WS.var.		30	0.006	.0001	
accent		2	0.048	0.024	30.984	0.0001
accent * group	8	0.009	0.001	1.358	0.2334
WS.var.		60	0.047	0.001	
rep		4	0.001	.0002	1.216	0.3076
rep * group		16	0.003	.0001	0.886	0.5867
WS.var.		120	0.026	.0002	
stress * inton		1	.0004	.0004	1.933	0.1747
stress * inton * group	4	.0001	.0001	0.105	0.98
WS.var.		30	0.007	.0002	
stress * accent	2	0.011	0.006	7.096	0.0017
stress * accent * group	8	0.001	.0001	0.154	0.9958
WS.var.		60	0.047	0.001	
inton * accent		2	0.001	0.001	3.296	0.0438
inton * accent * group	8	0.002	.0002	1.215	0.306
WS.var.		60	0.011	.0001	
stress * rep		4	0.006	0.001	7.173	0.0001
stress * rep * group		16	0.004	.0002	1.376	0.1648
WS.var.		120	0.023	.0001	
inton * rep		4	.0001	.0005	0.328	0.8588
inton * rep * group		16	0.003	.0001	1.474	0.1204
WS.var.		120	0.016	.0001	
accent * rep		8	0.002	.0002	1.123	0.3484
accent * rep * group		32	0.008	.0002	1.346	0.1105
WS.var.		240	0.043	.0001	
stress * inton * accent	2	.0001	.0001	0.676	0.5126

stress * inton * accent *grp	8	0.002	.0002	1.984	0.0639
WS.var.	60	0.007	.0001		
stress * inton * rep	4	0.001	.0002	1.891	0.1163
stress * inton * rep * grp	16	0.002	.0001	1.121	0.3441
WS.var.	120	0.015	.0001		
stress * accent * rep	8	.0004	.0001	0.328	0.955
stress * accent * rep * grp	32	0.007	.0002	1.47	0.0565
WS.var.	240	0.037	.0001		
inton * accent * rep	8	0.001	.0001	0.693	0.6978
inton * acc * rep *group	32	0.006	.0001	1.255	0.1723
WS.var.	240	0.035	.0001		
stress * inton * accent * rep	8	0.001	.0001	0.996	0.4401
strss * inton.* acc *rep*grp	32	0.004	.0001	0.861	0.6854
WS.var.	240	0.034	.0001		

Appendix H
Duration Measures
Photography/Photographic
Second Syllable Comparisons

Source	df	SS	MS	F-Val	P-Value
language group	4	0.065	0.016	1.373	0.2668
WS.var.		30	0.357	0.012	
stress		1	1.537	1.537	175.0 0.0001
stress * group	4	0.069	0.017	1.972	0.1244
WS.var.		30	0.264	0.009	
intonation		1	.0001	1.84E-05	0.051 0.8233
int * group		4	0.002	4.21E-04	1.16 0.3481
WS.var.		30	0.011	3.63E-04	
accent		2	0.021	0.011	12.77 0.0001
accent * group	8	0.01	0.001	1.465	0.1893
WS.var.		60	0.05	0.001	
rep		4	.0003	9.09E-05	0.253 0.9074
rep * group		16	0.007	4.56E-04	1.269 0.2284
WS.var.		120	0.043	3.59E-04	
stress * int		1	0.002	0.002	5.267 0.0289
stress * int * group		4	0.001	2.22E-04	0.682 0.61
WS.var.		30	0.01	3.26E-04	
stress * accent	2	0.044	0.022	28.31	0.0001
stress * accent * group	8	0.01	0.001	1.613	0.14
WS.var.		60	0.046	0.001	
int * accent		2	0.002	0.001	3.934 0.0248
int * accent * group		8	0.003	4.33E-04	1.795 0.0958
WS.var.		60	0.014	2.41E-04	
stress * rep		4	0.005	0.001	3.399 0.0114
stress * rep * group		16	0.005	3.20E-04	0.926 0.5422
WS.var.		120	0.041	3.46E-04	
int * rep	4	0.001	3.53E-04	1.861	0.1217
int * rep * group		16	0.001	9.22E-05	0.487 0.9496
WS.var.		120	0.023	1.89E-04	
accent * rep		8	0.002	2.72E-04	1.25 0.2705
accent * rep * group		32	0.01	3.21E-04	1.475 0.0552
WS.var.		240	0.052	2.17E-04	
stress * int * accent		2	0.003	0.001	5.679 0.0055
stress * int * accent * group		8	0.001	1.86E-04	0.769 0.6308
WS.var.		60	0.014	2.41E-04	

stress * int * rep	4	0.001	1.28E-04	0.586	0.6734
stress * int * rep * group	16	0.002	1.20E-04	0.547	0.9163
WS.var.	120	0.026	2.19E-04		
stress * accent * rep	8	0.003	3.14E-04	1.209	0.294
stress * accent * rep *group	32	0.004	1.31E-04	0.504	0.9889
WS.var.	240	0.062	2.60E-04		
int * accent * rep	8	0.001	8.94E-05	0.352	0.9443
int * accent * rep * group	32	0.003	9.64E-05	0.38	0.9992
WS.var.	240	0.061	2.54E-04		
stress * int * accent * rep	8	0.002	2.48E-04	1.059	0.3928
stress * int * accent *rep*grp	32	0.007	2.23E-04	0.952	0.5458
WS.var.	240	0.056	2.35E-04		

Appendix I
ANOVA Table
Durations Measures
Photography/Photographic
Syllable 3 Comparisons

Source	df	SS	MS	F-Value	P-Value
group	4	0.545	0.136	4.273	0.0074
WS.var.	30	0.956	0.032		
stress	1	2.597	2.597	306.335	0.0001
stress * group	4	0.225	0.056	6.623	0.0006
WS.var.	30	0.254	0.008		
int	1	0.001	0.001	1.942	0.1737
int * group	4	0.002	0.001	1.449	0.2424
WS.var.	30	0.011	3.78E-04		
accent	2	0.087	0.043	30.407	0.0001
accent * group	8	0.018	0.002	1.578	0.1507
WS.var.	60	0.085	0.001		
rep	4	0.013	0.003	6.825	0.0001
rep * group	16	0.006	3.74E-04	0.767	0.7193
WS.var.	120	0.059	4.88E-04		
stress * int	1	0.001	0.001	4.113	0.0515
stress * int * group	4	0.001	1.37E-04	0.46	0.7641
WS.var.	30	0.009	2.97E-04		
stress * accent	2	0.037	0.019	14.734	0.0001
stress * accent * group	8	0.005	0.001	0.484	0.8632
WS.var.	60	0.075	0.001		
int * accent	2	0.001	0.001	2.61	0.0818
int * accent * group	8	0.005	0.001	2.865	0.0091
WS.var.	60	0.014	2.28E-04		
stress * rep	4	0.003	0.001	2.023	0.0955
stress * rep * group	16	0.006	3.91E-04	0.911	0.5588
WS.var.	120	0.051	4.29E-04		
int * rep	4	.0002	5.61E-05	0.244	0.913
int * rep * group	16	0.003	2.18E-04	0.944	0.5219
WS.var.	120	0.028	2.30E-04		
accent * rep	8	0.001	1.49E-04	0.658	0.7283
accent * rep * group	32	0.007	2.06E-04	0.908	0.6135
WS.var.	240	0.054	2.27E-04		
stress * int * accent	2	.0001	2.28E-05	0.068	0.9345
stress * int * accent * group	8	0.002	2.58E-04	0.767	0.6325
WS.var.	60	0.02	3.36E-04		

stress * int * rep	4	0.001	2.62E-04	1.206	0.3119
stress * int * rep * group	16	0.002	1.22E-04	0.56	0.9076
WS.var.	120	0.026	2.17E-04		
stress * accent * rep	8	0.001	1.76E-04	0.701	0.6909
stress * accent * rep *group	32	0.007	2.19E-04	0.873	0.6673
WS.var.	240	0.06	2.51E-04		
int * accent * rep	8	0.004	0.001	2.187	0.0291
int * accent * rep * group	32	0.007	2.11E-04	0.868	0.6753
WS.var.	240	0.058	2.43E-04		
stress * int * accent * rep	8	0.003	3.30E-04	1.444	0.1788
stress * int * acc * rep*grp	32	0.008	2.47E-04	1.083	0.3554
WS.var.	240	0.055	2.28E-04		