Spring 2011

A Comparison of Fundamental Frequency Patterns in Conversational and Clear Speech Produced by Native and Non-Native English Speakers

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Undergraduate Honors Thesis

Honors College
University of South Florida

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SPRING 2011

INTRODUCTION

The most common and natural speaking style during verbal conversation is connected speech. During connected speech, words are strung together in sentences fluently, rather than each being spoken in isolation which produces a staccato-like disfluency in conversation. Although words spoken in isolation provide ample time for the articulators to reach their optimal, or target, positions for distinguishing one speech sound, or phoneme, from another, words in connected speech cannot always achieve such accuracy because of the short amount of time the articulators have to move across many positions. Many times, the articulatory position of phonemes within a word adjusts slightly to accommodate the position of a preceding or succeeding sound. Words link together and one phoneme begins to take on new characteristics because of the influence of either phoneme surrounding it, such as in the phrase “I have to” when the phoneme /v/ becomes the voiceless phoneme /f/ when spoken in conversation. This process is known as coarticulation (Silverman & Pierrehumbert, 1990).

Depending on the setting and context of the conversation, speakers tend to use various strategies during connected speech in order to be more easily understood, including the shift from conversational speech to clear speech. In addition to the changes in articulatory position which signal different speech sounds, the pitch of a speaker’s voice continuously changes from syllable to syllable within both speaking styles. These fluctuations in pitch (intonation) along with duration (quantity) and intensity (stress) of speech sounds over the course of the utterance are the three suprasegmental aspects of speech (Lehiste, 1996). Speakers use the suprasegmentals to convey syntactic information such as when using intonation to indicate the type of utterance the speaker is, such as a question, statement, or command, or when using stress to emphasize which words in the sentence are most important or newer.

When the speaker's message is not be easily understood by the listener for a reason such as background noise, most talkers are able to switch to a more easily understood speaking style referred to as clear speech. In clear speech, the talker attempts to more closely reach the optimal position for a speech sound and reduce the effects of coarticulation described above. Thus, many of the phonological features of a speech sound found in connected speech are more precisely produced in clear speech, compared to conversational speech. For instance, the utterance "And those are our two sons Tim and Tom" when read casually present various aspects of connected speech such as the linking of final consonants directly with vowels as represented by the second underlined section, while the clear speech production of the same phrase "and—those—are—our—sons—Tim—and—Tom" represents the full production of phonemes within that speaking style (Ferguson, S.H., 2007).

While we know much about the types of articulatory changes that occur in clear speech and the ways that they help increase intelligibility in difficult listening environments, less is known about the effects of the clear speech style on speakers' intonation, for both native English-speakers and non-native English speakers. By analyzing and comparing the clear speech style in both talker groups, we can investigate the degree to which non-native speakers have acquired the features of their newly acquired second language, also known as L2. If the clear speech production of non-native English speakers more closely depicts the clear speech production of a native-English-speaker, we can conclude that the speaker is aware of the important phonological rules in their L2, English. This study compares intonational aspects of speech production in both native and non-native speakers during clear and conversational speech styles. To provide some background information, the following material explains the importance of the pitch accent and why it will be compared between native and non-native talkers.

Tonic Syllable and Pitch Accent

In addition to the changes in pitch within intonational phrases, there exists a syllable within each intonational phrase in a sentence containing a drastic pitch change called the tonic syllable. This syllable emphasizes the part of the sentence containing the most important information that the speaker wants the listener to attend to (Silverman & Pierrehumbert, 1990). This emphasis on syllables within sentences, better known as stress, is theorized to be the consequence of the interaction between fundamental frequency, intensity, and duration. According to studies examining the perception of stress in the English language, the most important feature for identifying stress is fundamental frequency followed by duration, then intensity (Lehiste, 1996). Additionally, the drastic change in pitch of the tonic syllable is termed the pitch accent and will be an important aspect of this study as the timing of the accent during a stressed syllable will be acoustically analyzed.

Studies have reported that within English mono-syllabic words, the timing or alignment of the peaks for fundamental frequency are often found to the center or within the first half of the target syllable, with a later drop in pitch following it at the end of the phrase (Silverman & Pierrehumbert, 1990). However, unlike stressed syllables in English, pitch accents in Spanish appears to transition from a low pitch to a high pitch. This transition places the fundamental frequency peak near the end of the stressed syllable in Spanish. Further studies indicate that fundamental frequency valleys align with the beginning of Spanish stressed syllables, opposite of pitch contour in English words (Face, 2001).

A study conducted by Bianchi (2007) examined the acoustic properties of six target vowel produced in /bVd/ words of three talker groups: monolinguals, early bilinguals, and late bilinguals. Monolinguals were defined as native speakers of only English, Early bilinguals were identified as having learned English by the age of 12 and define themselves as English dominant, while late bilinguals were required to have learned English after the age of 15 and considered themselves as Spanish dominant. The words produced by these three talker groups were analyzed in four ways: by measuring first the vowel duration, then the fundamental frequency and the formant frequencies at the midpoint of the vowel, and finally the change in formant frequencies across the vowel duration for both clear and conversational speech styles. The study indicated there were similarities across the four measurements being analyzed between monolingual and early bilingual groups. However, the late bilingual group differed by revealing a reduced relative distance between vowels in connected speech and a smaller increase in vowel duration for clear speech (Bianchi, 2007).

Studies conducted by Bradlow & Bent (2002) suggest that non-native population who perceived English speech sounds used the phonological characteristics and rules within their native language in an attempt to categorize the unfamiliar sound. By applying their knowledge of their native language, non-native listeners may have misidentified the unfamiliar sound with a Spanish sound most similar to it. Studies using categorical identification and discrimination tasks show that the frequency of identification errors increases in non-native listeners compared to monolinguals. A study conducted by Rogers, Demasi, & Krause (2010) also found that production by non-native talkers was influenced by the age at which they learned English. Results indicated that monolingual English speakers and early bilingual learners of English provided native listeners with a greater clear speech benefit—an increase in intelligibility when using clear speech—while late bilingual learners were less able to improve intelligibility and actually worsened overall for the vowel /I/ (Rogers, Demasi, & Krause, 2010).

Furthermore, the study conducted by Zasimovitch (2010) which this paper expands on hypothesized that non-native speakers may produce similar intonation patterns in English as those in their native language, just as previous studies such as Bradlow & Bent (2002) have hypothesized that non-native speakers may perceive certain acoustic in English based on the rules of their first language. In her study, Zasimovitch (2010) compared the location of pitch peaks and valleys within the target syllable for native and non-native English speakers and found substantial differences in production between the groups, but only investigated conversational speech tokens. This study expands on the data collected by Zasimovitch by analyzing clear speech tokens produced by the same talkers and comparing the following variables within both conversational and clear speaking styles: 1) the relative location of the fundamental frequency minimum, 2) the relative location of the fundamental frequency peak, 3) the location of the fundamental frequency minimum relative to the peak, all within the focus, or stressed, syllable. After collecting and analyzing clear speech data, the two sets of data, both clear and conversational speech, will be compared.

METHOD

Purpose

Our purpose for analyzing the clear speech of non-native speakers will be to compare it to their conversational speech and record any differences. With the data collected by Face (2001) regarding the differences in Spanish and English intonations and research conducted by Rogers, Demasi, & Krause (2010) regarding the increase in misidentification of phonemes among bilingual late learners on English, we help determine whether the improvement of the speaker could be more English-like or Spanish-like. The data collected for clear speech includes measuring the fundamental frequency (F0), its maximum (or F0 peak) and its F0 minimum for all target syllables previously recorded. After collecting data, we will compare the results of what is typical in English and what is typical of Spanish which will indicate whether the person became more Spanish-like or English-like. Results may suggest that non-native speakers who produce a more English-like intonational pattern have the knowledge of the English phonological system since they, presumably, are applying those rules when using clear speech to improve intelligibility. A non-native speaker who does not produce a more English-like intonational pattern when shifting from conversational to clear speech suggests that the non-native speaker may not fully understand the English phonological system as they are not implementing the same intonational changes that improve intelligibility for native English-speakers.

By comparing implementation of pitch accents of native and non-native talkers in clear and conversational speech, the productions of the native and non-native speakers can be categorized as more or less Spanish-like. For the non-native talkers, the timing of pitch accents may help to determine whether the person is applying Spanish or English phonological rules in production. Overall, these data will be helpful to Speech-Language Pathologists working in Accent Reduction as they can provide further knowledge regarding possible reasons why a non-native speaker may have more difficulty improving intelligibility and specifically what features may differ most from native speakers' productions. Previous studies such as one conducted by Rogers, Demasi & Krause (2010) suggest that the later in life a non-native speaker learner English, the less able they are to improve intelligibility by using clear speech. If age of onset affects a person's ability to successful increase intelligibility, we can find which methods of Accent Reduction will be less likely to work with certain groups of non-native speakers, such as late-learners, and with further research, find more effective of improving intelligibility in late-learners of English.

Participants

Participants from the study by Zasimovitch (2010) were part of a larger study and were recruited through flyers on the USF campus and compensated with $10.00 per hour for participation. Participants consisted of three talker groups: ten native English monolingual speakers, fifteen early learners of English, and ten late learners of English. Monolinguals were defined as those who reported speaking only English and had no previous exposure by caregivers or parents who spoke another language, although they may have learned another language in school. Early Learners and Late Learners were native speakers of Spanish were immersed in an English-speaking environment by age 12 or earlier (early learners) or by age 15 or later (later learners).

Materials

The syllables used in this study were previously recorded for the larger study described above conducted by Rogers, Demasi and Krause (2010) while the conversational tokens collected were analyzed by Zasimovitch (2010). For the present study, the clear speech tokens collected by the larger study were analyzed and data for both the conversational and clear speech tokens were compared. During the recording of speech samples, participants were asked to produce the following six words: “bead, bid, bayed, bed, bad” and “bod.” These stimuli differed from one another only by the vowel located in the /bVd/ framework and spanned the vowel space from high to low (/i ,ɪ, eɪ, ɛ, æ/ and /a/). Each word was spoken within the phrase, “Say ____ again” and was read from a monitor within a sound-attenuating booth. Seven repetitions of each word were originally produced in both conversational and clear speech styles, but for this study only two tokens in clear speech were analyzed.

Analysis Procedure

In order to provide consistency within the two sets of data, conversational and clear speech tokens, this study maintained the same method of acoustic analysis as the study conducted by Zasimovitch (2010) and by Rogers, Demasi, & Krause (2010) which investigated the acoustic characteristics of vowel productions and the effects of clear speech on vowel production. All target words within the clear speech utterance, “Say ___ again,” had previously been isolated from the utterance during the associated study conducted by Rogers, Demasi, & Krause (2010). Several conversational speech variables previously measured in Rogers, Demasi, & Krause (2010), including vowel duration and fundamental frequency (F0) and formant frequencies at three time points (near the beginning, middle and end of the main portion of the vowel). These measurements were made using the speech analysis software program, Praat. The present study measured and analyzed the same fundamental frequency variables but this time for the speaking style not yet analyzed, clear speech.

For each of the speakers used in this study, two of the seven repetitions of each target word were selected for fundamental frequency analysis. For almost all of the target words, the first and second repetitions produced were used analyzed, unless the talker demonstrated poor vocal quality or possible disfluencies. Cases in which the first or second repetitions were not usable, another one of the seven repetitions were used in its place. The parameters previously set during the studies conducted by Rogers, Demasi, & Krause (2010) and Zasimovich (2010) for target word isolation and vowel duration were all maintained for this study.

In order to analyze the fundamental frequency variables for the present study, the target vowel within the focus syllable was isolated by using the vowel duration measurements previously obtained in Zasimovich (2010). These measurements identified the vowel onset as the first large positive amplitude peak following the maximum negative of the first periodic cycle with a similar pattern for the remainder of the vowel's waveform. Vowel offset was determined by locating the peak of the first negative pulse of the last cycle of voicing that was consistently similar in amplitude for the remainder of the vowel. For both vowel onset and offset estimates, formant two (F2) landmarks were used to verify these estimates on a wide-band spectrogram.

After vowel isolation within the targeted vowel, the speech analysis software, Praat automatically located the fundamental frequency (F0) peak by identifying the maximum Fo within the selection. This automatic pitch tracking feature within the Pratt software was used in the majority of target vowel analysis except during instances where pitch halving, pitch doubling, or an unreliable tracking of a pitch occurred. In such cases, measurements were taken by hand from the waveform by measuring the duration of the target pitch period and converting to frequency (Hz). The experimenter then made minor adjustments to the pitch range setting within the software in order to confirm the estimates by hand. Additional F0 measurements collected in this study included the location of the F0 minimum and the F0 at target vowel onsets and offsets. These time points were determined by adding 5 ms to the point of vowel onset and subtracting 5 ms from the point of vowel offset. In addition to these measurements, the maximum and minimum F0 values were used to develop an estimate of the overall pitch contour throughout the syllable. F0 measurements described above were all recorded in Hertz with corresponding location times recorded in seconds and documented within an Excel spreadsheet.

RESULTS

The following variables from the measurements computed for this study previously described include: 1) the relative location of the fundamental frequency (F0) peak within the vowel; 2) the relative location of the F0 minimum within the vowel; and 3) the location of the F0 minimum relative to the F0 peak. In consistency with the previous study conducted by Zasimovich 2010, the F0 peak within the vowel was computed by subtracting the time of the vowel onset from the time of the F0 peak, then dividing the outcome by the vowel duration previously measured by Rogers, Demasi, & Krause (2010). The relative location of the F0 minimum was computed by subtracting the time of the vowel onset from the time of the F0 minimum, then dividing by the vowel duration. The location of the F0 minimum relative to the F0 peak was computed by subtracting the relative peak location from the relative minimum location. Results with a negative value represent a F0 minimum that precedes the F0 peak, while a positive value represents a F0 minimum that is found later in the vowel, following the F0 peak.

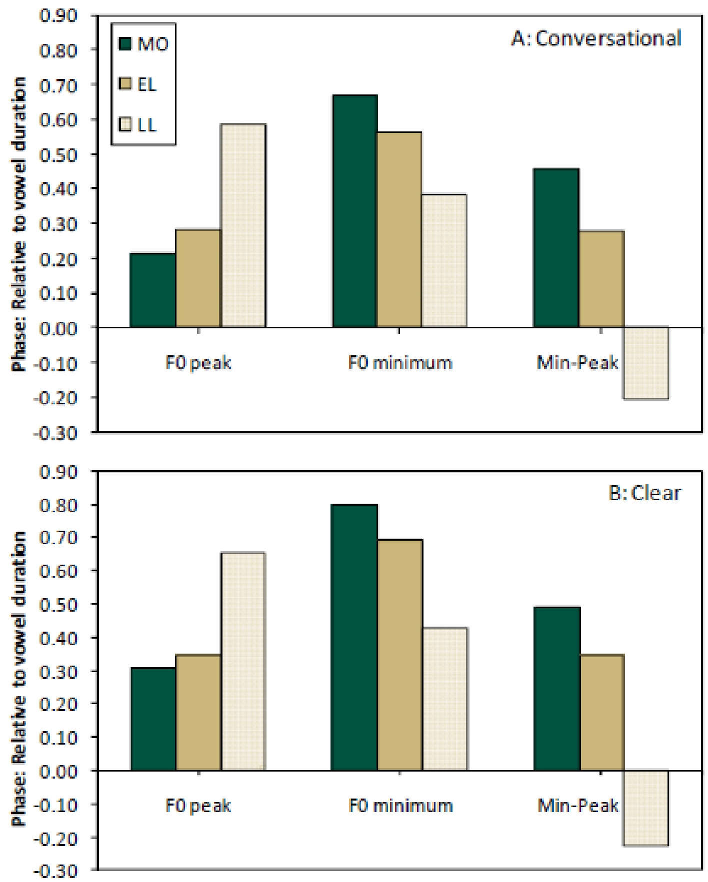

Figure 1: Average phase of F0 peak, F0 minimum, and F0 minimum relative to F0 peak for each talker group and speaking style.

These averages are represented in Figure 1, with a comparison of this study's clear speech measurements and the previous study's conversational speech measurements. The graphs for both clear and conversational speech include separate bars for monolingual speakers (MO, green), early learners of English (EL, gold) and late learners of English (LL, tan). Each graph also includes the following three sets of these talker group's bars: the first set of bars represent the fundamental frequency peak location within the syllable; the second set of bars represent the fundamental frequency location within the syllable; the third set of bars represent the fundamental frequency minimum relative to the fundamental frequency peak. The numerical averages for these F0 measurements can be found in Table 1.

Talker group	F0 peak alignment	F0 minimum alignment	Minimum time – Peak time
Conversational speech			
MO	0.212	0.667	0.456
EL	0.284	0.562	0.279
LL	0.588	0.382	-0.206
Clear speech			
MO	0.310	0.799	0.489
EL	0.347	0.694	0.347
LL	0.656	0.429	-0.227

Table 1: F0 peak alignment values, F0 minimum alignment values, and F0 minimum relative to F0 peak for MO, EL, and LL.

In regards to the first set of bars displaying the fundamental frequency (F0) peak location averages for all three talker groups, the F0 peak occurred at about 30% of the syllable duration for MO talkers and at about 35% for EL talkers. However, LL were found to have F0 peaks occurring at about 65% of the vowel duration. Although the peak alignment occurred somewhat later for EL talkers in comparison to MO talkers, both averages for peak alignment in MO and EL talkers were much earlier than LL talkers during clear speech. In comparison with MO talkers, EL experienced a difference in F0 peak alignments of only 2.3% while LL experienced a difference of 34.6%. This observation in which peak alignment is found much later for LL than for MO or EL talkers was also seen in the conversational speech. As found in Figure 1, both clear and conversational speech share this observation, however it must be noted that although the average location of peak alignment was found to be significantly later in the vowel duration for LL than for MO and EL during conversational speech, there were also small yet notable differences in peak locations for all three talker groups. During this shift, all three talker groups' F0 peak alignments experienced a shift to the right within the vowel duration which included a shift in peak alignment for MO by about 10%, EL with the smallest shift of 6.3% to the right, and LL with the largest shift of 6.8% to the right. It should also be noted that F0 peak alignments were closer for MO and EL during clear speech than in conversational speech.

On the contrary, the F0 minimum alignment presented in second set of bars in Figure 1, was found to be significantly later in LL talkers than in MO and EL, occurring at about 80% of the syllable duration for MO talkers, 70% for EL talkers, and only at about 45% of the vowel duration for LL. F0 minimum alignment occurred in relatively similar positions within the second half of the vowel, yet LL produced an average F0 minimum during the first half of the vowel. In comparison with MO talkers, EL experienced a F0 minimum 10.5% earlier in the vowel while LL experienced a F0 minimum 37% earlier in the vowel. This gap between LL and the two other talker groups was found to be much greater in clear speech than it was observed during conversational speech. Other smaller, yet notable differences in F0 minimum locations during the shift from conversational to clear speech include a F0 minimum locations 13.2% later for both MO and EL, and only 4.7% later in the vowel for LL. In other words, when attempting to produce clear speech, the F0 minimum alignment around 43% between the vowel onset and offset for LL while the average location of F0 minimums for MO, the talker group they are trying to exemplify, was located at 80% into the vowel.

Regarding the location of the F0 minimum relative to the F0 peak (min-peak) presented in the third set of bars of clear speech, the average location of the F0 minimum was found to be approximately 49% later in the vowel than the F0 peak time for MO and 35% later for EL. However, the average location of F0 minimum was found to be approximately 22% earlier in the vowel for LL, as indicated by the negative value for min-peak in Figure 1 and Table 1. Thus, on average, the F0 minimum precedes the F0 peak in LL during clear speech. It should also be noted that similar differences for all three talker groups were also previously observed for conversational speech.

A single factor analysis of variance (ANOVA) was performed with each of the three dependent variables described above, F0 peak location, F0 minimum location, and location of F0 minimum relative to F0 peak, and the independent variable as the three talker groups. The first ANOVA (with F0 peak location as the dependent variable) was highly significant [$F(2,417)=33.83$, $p<.0005$]. Three post-hoc independent samples t-tests comparing the performance of pairs of groups showed that peak location did not differ significantly for the MO and EL talker groups ($p=.278$), but that peak location was significantly later in the syllable for the LL talker group than for both the MO and EL talker groups ($p<.0005$ in both cases). In this and the following cases in which multiple t-tests were used, Bonferroni adjustment of the significance criterion was used.

The second ANOVA, comparing F0 minimum across the three talker groups, was also significant [$F(2,417)=24.44$, $p<.0005$]. Three post-hoc independent samples t-tests were also used to compare the pairs of talker groups. In this case, all three groups were shown to differ significantly from one another. The alignment of the F0 minimum was found to be significantly earlier for the EL than for the MO talker group ($p=.011$). However, the alignment of the F0 minimum was found significantly earlier for the LL talker group than for either of the other two groups (p<.0005 for both).

The third ANOVA, comparing the location of the F0 minimum relative to the F0 peak across the three talker groups was also significant [F(2,417)=35.62, p<.0005] and the three post-hoc independent samples t-tests showed that all three talker groups differed significantly from one another in their performance. The F0 minimum was found to be significantly earlier, relative to the F0 peak, for the EL talker group than for the MO talker group (p=.032). Additionally, the average F0 minimum for both MO and EL talker groups occurred later than the F0 peak yet was found significantly earlier than the F0 peak for LL talker groups than for both the MO and EL talker groups (p<.0005 for both).

Although the averages above were found to be significant, it must be noted that the large differences in a relatively small number of talkers' studies may have disproportionately contributed to the means. In order to better understand the individual differences between these data, the percent of cases for each talker group for the following occurrences were calculated: 1) the F0 minimum preceding the peak and 2) the F0 peak occurring in the second half of the syllable. The results of this analysis are shown in Figure 2 and numerically recorded in Table 2. This analysis revealed results consistent with the tendencies suggested by the ANOVAs in which the F0 minimum occurred before the peak for a majority of the vowels spoken by the LL talkers at about 63%. However, only 18% of the vowels spoken by MO and 28% of the vowel spoken by EL talkers displayed an F0 minimum before the F0 peak. Similarly, the F0 peak occurred in the second half of the vowel for 64% of the vowels produced by LL talkers yet only 33% for MO and 26% for EL talkers. The patterns observed in both sets of data mentioned above for clear speech were also previously observed in conversational speech, with little change in numerical value as shown in Table 2.

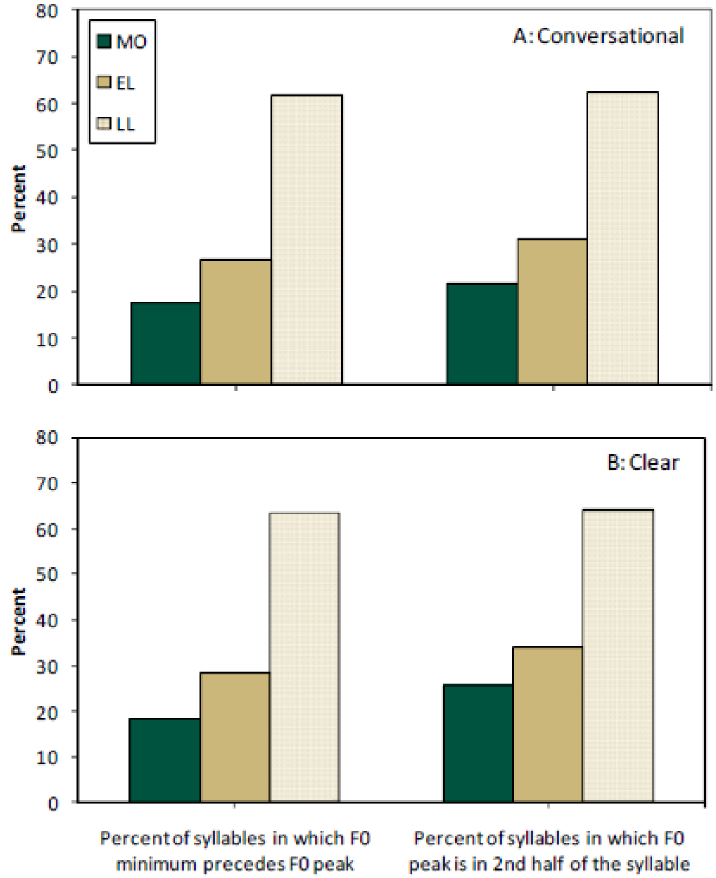

Figure 2- Percent of syllables with F0 minimum preceding peak and F0 peak in the second half of the syllable for each listener group and speaking style.

Talker group	Percent of syllables with F0 minimum before peak	Percent of syllables with F0 in 2^{nd} half of the syllable
Conversational speech		
MO	17.50	21.67
EL	26.67	31.11
LL	61.67	62.50
Clear speech		
MO	18.33	25.83
EL	28.33	33.89
LL	63.33	64.17

Table 3: Percent of syllables with F0 minimum before F0 peak and percent of syllables with F0 in the second half of the syllable for MO, EL, and LL.

DISCUSSION

The purpose of this study was to compare fundamental frequency patterns across three talker groups in clear speech and compare with the same data collected for conversational speech in the previous study conducted by Zasimovitch (2010) in order to assess each group's ability to manipulate fundamental frequency. This manipulation, or shift from conversational to clear speech, is used by speakers in order to compensate for less intelligible speech within difficult listening conditions. For non-native speakers specifically, this manipulation is also used to create a more native-like production in an attempt to produce more intelligible speech, or clear speech.

In addition to assessing each group's abilities to manipulate frequency and provide insight to acquiring prosody of a second language,

The three talker groups were classified as MO, EL, and LL. Each group was classified as such by two principal factors which included L1 language dominance and the age of immersion within an English speaking environment. The following three dependent variables in clear speech were measured in order to assess differences in fundamental frequency using a single factor analysis of variance (ANOVA) for each: 1) relative location of the fundamental frequency peak within the vowel; 2) relative location of the fundamental frequency minimum within the vowel; and 3) the location of the fundamental frequency minimum relative to the peak.

Previous studies have suggested that the age of immersion within an English-speaking environment may influence the phonological transfer of L1 to L2 (Bradlow & Bent, 2002). This transfer may be a contributing factor to the noted difficulty experienced by some non-native speakers in both accuracy of speech perception and intelligibility of speech production. Bradlow & Bent (2002) also propose that L2 adults may not realize subtle yet distinguishing cues that create difference between speech sounds. The study also suggests that when categorizing speech sound for L2, non-native speakers mistakenly place L2 sounds in the category most similar to the already existing phonological inventory of L1, thus incorrectly producing and identifying L2 sounds. These errors can be attributed to the conflicting rules of the L1 and their superimposition on L2 (Bradlow & Bent, 2002). Based on the findings of these previous studies, we hypothesized that the shifts in intonation patterns from conversational speech to clear speech of non-native English speakers that more closely characterized that of a monolingual native English-speaker suggest that non-natives have the phonological knowledge of L2 (English) are appropriately applying that knowledge in clear speech. In such cases, the L2 clear speech production should appear more English-like with similar fundamental frequency patterns. Those who did not present such English-like characteristics in intonation were compared to typical Spanish intonation patterns in order to determine if those non-native speakers were producing a more Spanish-like intonation pattern and thus, lacking the appropriate phonological knowledge of L2 by incorrectly identifying and producing L2 sounds due to L1 influence.

The first ANOVA, displaying the relative location of the fundamental frequency peak within the vowel, revealed that for the MO and EL groups, peaks occurred early in the syllable at about 18% of the syllable duration for MO and about 28% of the syllable duration for EL. Contrastively, LL produced syllables with peaks occurring at about 63% of the syllable duration which was found to be significantly later than the MO and EL groups. These findings also found to be consistent with studies contributed by Silverman & Pierrehumbert (1990) which found that native English-speakers produce F0 peaks aligned on average to the left or center of the syllable in mono-syllabic words. Our findings supported the data collected by Silverman & Pierrrehumbert (1990) by identifying the higher percentage of F0 peaks during the first half of syllables produced by in MO and EL (about 74% of MO talkers and about 66% of EL talkers) while only 35% of the LL talkers produced peaks in this early position.

The second ANOVA, comparing the average relative location of the fundamental frequency minimum within the vowel, also identified significant differences between the three groups of talkers. F0 minimums were found to be significantly earlier for EL in comparison with MO and most significantly earlier for LL. Additional calculations supported this finding and identified that about 63% of LL talkers produced minimums in the first of half of the syllable, a significant contrast in comparison with the MO and EL who produced the majority of F0 minimums during the second half of the syllable (approximately 82% of MO talkers and about

72% of the EL talkers). When compared to other production studies for variations of Spanish, these findings are consistent with the patterns being produced by the LL group due to Spanish L1 influence. Fundamental frequency minimums occurring near the onset of the syllable have been documented and were also found with a decrease in this pattern's frequency of occurrence across the three groups ranging from LL, to EL, to finally MO (Face, 2001).

Literature regarding the establishment of a Standard TOBI for Spanish intonation transcription, frequently references a pattern in Spanish which is characterized by a fundamental frequency minimum at the onset of the syllable followed by a fundamental frequency peak occurring toward the end of the same stressed syllable (Face, 2006). Face (2006) found that a contrast exists between intonation patterns of Spanish and English which allow for a transfer of phonological knowledge to take place between an L1 (Spanish) and an L2 (English) in non-native English-speakers.

Vowel characteristics measured in EL and LL that present a F0 minimum near the onset of the first half of the vowel and F0 peak near the end of the second half of the syllable can be attributed to Spanish influence (Face, 2006). Based on the data collected by Bradlow & Bent (2002) we also expected a negative correlation between the age of immersion of a non-native English-speaker and the amount of Spanish influence observed in the productions of the EL and LL. Thus, the LL talker group which contained the oldest age of immersion was expected to demonstrate the most frequent instances of Spanish influence on intonation. The earlier the age of immersion, such as in EL talker group, the less amount of Spanish influence on intonation on production English sounds as well as an increased sensitivity in perception of English sounds.

In order to better understand the frequency of this occurrence among individual talkers participating in this study, the third ANOVA was generated in order to compare the relative location of the F0 minimum relative to the F0 peak within the target vowel. This measurement confirmed that the LL group most frequently produced the typical Spanish intonation pattern previously identified by Face (2006) than EL. Again, the Spanish intonation pattern found F0 peaks earlier than minimums while typical English intonation patterns find F0 peaks after minimums. F0 peaks and F0 minimums in EL more often were found closer to F0 peaks and F0 minimums in the MO talker group than that of LL, lending support to the hypothesis that age of immersion affects the application of L1 phonological rules on L2. Ongoing analysis suggests a switch to more native-like patterns for EL but not LL during clear speech, suggesting a distinct awareness and control of L2 prosodic features by the EL talker group (Rogers, Demasi, Krause, 2010).

Future research should investigate other methods of improving intelligibility in late-learners of the English language, as our study found that clear speech alone does not demonstrate optimal or near-optimal intonation patterns exhibited in native English-speakers, thus affecting overall intelligibility. By researching other possible methods of creating more English-like fundamental frequency patterns in late-learners, professionals such as Speech-Language Pathologists in the field of Accent Reduction can identify more suitable methods of improving intelligibility and in turn provide more effective treatment for those non-native English speakers affected by their age of immersion into the English language.

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