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The Acoustic Correlates of Stress-Shifting Suffixes in Native and Nonnative English

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by

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Abstract

Although laboratory phonology techniques have been widely employed to discover the interplay between the acoustic correlates of English Lexical Stress (ELS)–fundamental frequency, duration, and intensity - studies on ELS in polysyllabic words are rare, and cross-linguistic acoustic studies in this area are even rarer. Consequently, the effects of language experience on L2 lexical stress acquisition are not clear. This investigation of adult Arabic (Saudi Arabian) and Mandarin (Mainland Chinese) speakers analyzes their ELS production in tokens with seven different stress-shifting suffixes; i.e., Level 1 [+cyclic] derivations to phonologists. Stress productions are then systematically analyzed and compared with those of speakers of Midwest American English using the acoustic phonetic software, Praat. In total, one hundred subjects participated in the study, spread evenly across the three language groups, and 2,125 vowels in 800 spectrograms were analyzed (excluding stress placement and pronunciation errors). Nonnative speakers completed a sociometric survey prior to recording so that statistical sampling techniques could be used to evaluate acquisition of accurate ELS production. The speech samples of native speakers were analyzed to provide norm values for cross-reference and to provide insights into the proposed Salience Hierarchy of the Acoustic Correlates of Stress (SHACS). The results support the notion that a SHACS does exist in the L1 sound system, and that native-like command of this system through accurate ELS production can be acquired by proficient L2 learners via increased L2 input. Other findings raise questions as to the accuracy of standard American English dictionary pronunciations as well as the generalizability of claims made about the acoustic properties of tonic accent shift.

Acknowledgements

Whilst this thesis may bear my name, the credit belongs to so many others as well. The research process has been a long and often arduous journey interspersed with moments of joy and wonder. My heartfelt thanks goes to each and every person who has helped me along the way.

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"Nothing will ever be attempted if all possible objections must first be overcome."

Samuel Johnson—*Rasselas, 1759*

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Chapter I: Introduction

Statement of Problem

It is widely accepted that certain suffixes in English cause a shift in stress in the root morpheme to the syllable directly preceding the suffix (Celce-Murcia, Brinton, & Goodwin, 1996; Kreidler, 2004). These stress-shifting suffixes have been labeled Level 1 [+cyclic] suffixes by generative phonologists (Halle and Kenstowicz, 1991; Kiparsky, 1982). Pronunciation experts, including Celce-Murcia et al. (1996), have claimed that the resultant shift in stress in turn causes a change in the neutralization or vowel reduction in the unstressed syllable. Koffi (personal communication, September 11, 2012) has affirmed that these claims about lexical stress shifts have not yet been supported quantitatively by the subfield of laboratory phonology.

In addition to this concern about validity, although various studies on the acoustic properties of English word stress do exist, the results are somewhat contradictory with regards to which of the three acoustic correlates of stress is most *salient*–i.e., fundamental frequency (F0), duration, or intensity.

Furthermore, there is a lack of information in the literature about the word frequency of individual stress-shifting suffixes in the corpus. Additionally, there is a dearth of cross-linguistic acoustic data on comparisons of productions of Level 1 [+cyclic] derivations by native speakers of English (NES) and nonnative speakers of English (NNES) of different proficiencies and first language (L1) backgrounds.

Background and Need for the Study

Laboratory phonology is a relatively new field that serves as the interface between phonetics and phonology. It seeks to test the validity of claims made by phonologists using instrumental phonetic methods as opposed to solely impressionistic judgments (Cohn, Fougeron,

& Huffman, 2012). According to Prieto (2012), production studies have been employed extensively for phonological and phonetic investigations of prosody, and "[T]here is a long tradition of using acoustic analysis of speech productions under various elicitation conditions in the field or in the laboratory" (p. 528). Ladefoged (2001a) has iterated that these types of acoustic analyses are "the most scientific way of describing speech" (p. 10).

Although various laboratory phonology studies have been conducted on English word stress in general, they have not explored the acoustic properties of the full range of Level 1 [cyclic] suffixes in the lexicon. In fact, studies on English Lexical Stress (ELS) in *polysyllabic* words in general have largely been ignored in favor of disyllabic minimal stress pairs, as in Fry's original studies (1955, 1958).

As mentioned, there is also a lack of consensus in the literature as to the relative importance of the acoustic correlates of stress—F0, duration, intensity, and spectral reduction.[1] Indeed, various contrasting versions of what the author hereby coins the *Salience Hierarchy of the Acoustic Correlates of Stress* (SHACS) have been proposed: F0 > duration > intensity (e.g., Fry, 1955, 1958; Ladefoged, 2003), duration > F0 > intensity (e.g., Adams & Munro, 1978), and duration > intensity > F0 (e.g., Beckman & Edwards, 1994). The latter have reasoned that F0 is only a relevant acoustic correlate of stress with regards to sentential pitch accent.

Sabater (1991) also suggested that there is an additional cue for stress in English which is equally important–i.e., reduced vowel quality in the unstressed syllable. In concordance with this view, many researchers have proposed that the distinction between stressed and unstressed

[1] According to Ladefoged (2006), for all intents and purposes, F0 is synonymous with pitch (measured in Hertz, Hz), duration means vowel length (measured in milliseconds, ms), intensity equates to loudness (measured in Decibels, db), and spectral reduction refers to changes in vowel quality (i.e., tense to lax). Frequency is the number

syllables in English depends upon vowel quality in addition to the three aforementioned acoustic correlates of stress (Fear, Cutler, & Butterfield, 1995; Edmunds, 2009; Hillenbrand, Getty, Clark, & Wheeler, 1995). Specifically, at the word level, the unstressed vowels tend to be produced as the mid-central reduced vowel known as the schwa /ə/, the most common sound in the English language (Celce-Murcia et al., 1996). In a more recent study by T. M. Adams (2006), the results indicated that F0, duration, and intensity “participate in a form of
Cue trading to signify stress in different contexts” (p. 3087). However, Ladefoged (2003) has cautioned that “there is no known algorithm that enables an observer to measure these three quantities and use them as a measure of stress” (p. 94).

Moreover, since most studies have been conducted in the field of first language (L1) acquisition, there is only a limited number of cross-language acoustic case studies on the productions of Level 1 [+cyclic] suffix derivations by NES and NNES, and the effects of L1 background and amount of L2 exposure/input on pronunciation accuracy have not been fully explored.

In their landmark study of foreign accent, comprehensibility, and intelligibility, Munro and Derwing (1995) emphasized the need for further studies on the features of L2 pronunciation that have the most significant effect on intelligibility in English. They have recommended that these should be studies that “include a variety of accents produced by speakers with differing levels of proficiency, and … [that] help to elucidate the relative contributions to intelligibility of specific elements (subsegmental, segmental, prosodic) of pronunciation” (p. 306). Furthermore,

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of cycles of variations in air pressure in one second, and pitch is the auditory feature that allows listeners to perceive a sound on a low-high spectrum where a sound with high frequency is realized as high pitched (Ladefoged, 2006).

Ramus, Nespor, and Mehler (1999) have reiterated the demand for a more determined approach from acoustic phoneticians in order to ascertain the properties of stress in different languages:

> Phonetic science has attempted to capture the intuitive notion that spoken languages have characteristic underlying rhythmic patterns. Languages have accordingly been classified on the basis of their rhythm type. However, although many characteristics of the speech signal have been measured, reliable acoustic characteristics of language classes have not been identified. Measurements estimating the periodicity of either inter-stress intervals or syllables have not helped capturing these intuitive categories, and attempts to classify languages on the basis of acoustic measures have mostly been abandoned. (p. 287)

Although the extent of L2 accentedness is related to many determinants, including language environment and age of speakers, the main mediator of individual differences in L2 accents is the "sound system" of their L1 (Zhang, Nissen, & Francis, 2008, p. 4498). For example, there is growing evidence to suggest that Mandarin L1 speakers have problems pronouncing L2 English stress contrasts because of "strong interference from the Mandarin *tonal* system" (Zhang et al., 2008, p. 4500). As Zhang et al. have stated, even when syllabic stress *is* placed appropriately by Mandarin NNES, they have problems manipulating the acoustic correlates of stress in a native-like manner.

Conversely, various phonetic studies on rhythmic typology strongly indicate that Arabic is a stress-timed language that is "a very likely language to exhibit the same correlates to stress as does English" (de Jong & Zawaydeh, 1999, p. 5). For these reasons, it is edifying to investigate whether Arabic L1 NNES typically produce the acoustic correlates of Level 1 [+cyclic] derivations more accurately than Mandarin L1 NNES. Notwithstanding, Shemshadsara (2011) has provided statistical empirical evidence that Iranian Arabic speakers have more difficulty placing stress in words with stress-shifting suffixes (i.e., Level 1 [+cyclic] derivations) than words with neutral-suffixes (i.e., Level 2 [-cyclic] derivations (Burzio, 1994)). Thus, these data further necessitate the need for a thorough acoustic analysis of stress-shifting suffixes.

Purpose of the Study

Part of the rationale for this project is to validate the widely-held impressionistic assertions in the literature about the morphophonemic properties Level 1 [+cyclic] suffixes by providing quantifiable data. Therefore, the current study is based on quantitative acoustic analyses of the data using laboratory phonology techniques which have the advantage of "replicability and robustness" (Post & Nolan, 2012, p. 544) if suitable sampling and statistical methods are employed.

In addition, this project investigates the dichotomous claims made my acoustical phonetics experts about SHACS. To do this, syllabic F0, duration, and intensity productions are analyzed in Level 1 [+cyclic] derivations by native speakers of Midwestern American English (MWAE) dialect. Due to limitations of time, the researcher does not measure the acoustic correlate of vowel quality (i.e., first and second formants (F_1 and F_2), which is in accordance with Lieberman's study (1960).

From a second language acquisition (SLA) research perspective, the other purpose of this study is to observe whether there is a correlation between exposure to the L2 and/or L1 background and production accuracy of Level 1 [+cyclic] suffix derivations. As Zhang et al. (2008) have succinctly noted, most research in the area of English lexical stress "confound the phonological issue of stress placement with the phonetic problem of native-like stress production" (p. 4498). Thus, production accuracy here refers to a twofold distinction: 1) L2 knowledge of *where* to place the stress in derived words, and 2) *native-like* production of the acoustic correlates of stress. More specifically, this study examines the acoustic correlates of productions of English Level 1 [+cyclic] derivations by Arabic L1 and Mandarin L1 NNES.

Research Questions

1) Do English Level 1 [+cyclic] suffixes such as <ious>, <ial>, <ian>, <ic>, <ical>, <ity>, and <ify> cause a shift in stress when spoken by native speakers of MWAE, and can this be observed quantitatively using acoustic measurements of F0, duration, and intensity?

2) What is the salience hierarchy of the three acoustic correlates of stress (SHACS) in productions of polysyllabic Level 1 [+cyclic] derivations by native speakers of MWAE?

3) How do NNES of different L1 backgrounds (i.e., Arabic and Mandarin) order the correlates of stress similarly or differently to NES?

4) Which acoustic correlates are problematic for Arabic L1 and Mandarin L1 speakers when producing lexical stress contrasts in Level 1 [+cyclic] derivations?

5) Is there a correlation between amount of L2 exposure (years of residence in L2 environment) and/or amount of L2 input (years of L2 study) and *accurate production* of the three acoustic cues? I.e., do these variables show a large effect in:

   a) Accurate placement of stress in Level 1 [+cyclic] derivations.

   b) Native-like[2] production of the acoustic correlates of stress in Level 1 [+cyclic] derivations.

6) Do some stress-shifting suffixes behave idiosyncratically with regards to standard American English dictionary pronunciations?

7) Is there a major pitch change (i.e., a shift in *tonic accent*) from the secondary stressed syllable (i.e., the primary stressed syllable in the stem word) to the primary stressed syllable in Level 1 [+cyclic] derivations as claimed by Ladefoged and Johnson (2010)?

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[2] Hereinafter, *native-like* refers to similarity to Midwest American English.

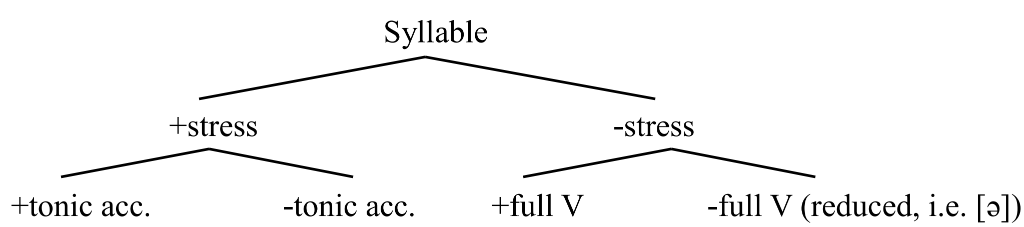
Chapter II: Review of the Literature

Significance of Lexical Stress in English

It is well-established that the English language can be dissected into *segmental* features and *suprasegmental* features. Segments are the inventories of individual sounds that occur in a language (i.e., vowels and consonants), whereas suprasegmentals comprise prosodic elements such as pitch, length, and stress which in turn affect the characteristics of word stress, sentence stress, and rhythm, as well as modifications in the pronunciation of connected speech (Celce-Murcia et al, 1996). In non-tonal languages, suprasegmentals are used to deliver meaning at different levels of conversation, including the discourse, phrase, and word level (Fromkin, Rodman, & Hyams, 2011). Therefore, Beckman and Edwards (1994) suggested that the prosodic composition of an utterance is a means of organizing and conveying the content of a message. In this paper, it is the suprasegmental feature of word stress that is of interest.

Word stress, hereinafter referred to as *lexical stress*, can be defined as “prosodic prominence within a word,” and prosody as “a time series of speech-related information that is not predictable from the simple sequence of phonemes” (Okobi, 2006, p.11). Thus, lexical stress is detectable when linguistic components stand out from their environment; that is, when one syllable is perceived as being more prominent than the others. Sluijter and Van Heuven (1996) defined lexical stress as an abstract property of a word that serves as an indicator to the syllable within the word that has a potential to receive an accent.

It is important to note that in some English words more than one syllable is stressed (e.g., one vowel receives secondary stress); however, one syllable will always receive greater stress than the others. This is because English is a stress-timed language that specifies one syllable in a content word to carry main word stress. This is also known as *primary* stress (Fromkin et al., 2011). Hahn (2004) claimed that primary stress is realized by "combining a detectable change in pitch with increased vowel duration and intensity" (pp. 201-202). On the other hand, Ladefoged and Johnson (2010) did not consider the difference between primary and secondary stressed syllables to be a matter of stress at all (since both have prominence) but rather a matter of pitch change. In their account of degrees of stress, they regarded the "major pitch change … [or] "tonic accent" (Ladefoged & Johnson, 2010, p. 119) to be the determiner of primary stress. Thus, a secondary stressed syllable carries stress, but it does not carry *tonic accent*. Figure 1 shows a revised representation of Ladefoged's system (adapted from "Applied English Phonology (2nd edition)" by M. Yavas, 2011, p. 163).



Primary stressed syllable: +stress, +tonic accent, +full V
Secondary stressed syllable: +stress, -tonic accent, +full V
Unstressed syllable: -stress, -tonic accent, +/-full V

Figure 1. Degrees of Prominence of Different Syllables in a Sentence

Using this system, levels of stress can be assigned numerical values pursuant to the number of pluses a syllable has (i.e., three pluses = 1, two pluses = 2, one plus = 3, and no pluses = 4). Figure 2 shows examples of stress patterns in <explanation> and <exploitation> (adapted from "A Course in Phonetics (4th edition)" by P. Ladefoged, 2001b, p. 97)

	[ɛk.	splə.	néɪ.	ʃən]	[ɛk.	splɔɪ.	téɪ.	ʃən]
Stress	+	-	+	-	+	-	+	-
Tonic accent	-	-	+	-	-	-	+	-
Full V	+	-	+	-	+	+	+	-
Stress pattern:	**2**	**4**	**1**	**4**	**2**	**3**	**1**	**4**

Figure 2. The Combination of Stress, Intonation, and Vowel Reduction in Two Words with Different Stress Patterns

Implications of Isochrony to English L2 Learners

Isochrony, or *Isochronism*, refers to the rhythmic characteristics of some languages (Crystal, 2008). In stress-timed languages such as English or Dutch, the amount of time it takes to produce an utterance is determined by the number of *stressed* syllables (Ramus et al., 1999). This is in contrast to syllable-timed languages such as Spanish or Italian where the number of overall syllables is the determining factor (Ramus et al., 1999). In a syllable-timed language, all syllables in an utterance have equal length and occur at regular intervals (Sabater, 1991). Sabater illustrated the difference in stress (marked with diacritics) with an example sentence in English and Spanish (p. 153; words in parentheses do not appear in the original text):

I 'want you to 'come with me to the 'doctor's to'morrow (English: Stress-timed)

'Que 'ven'gas 'al 'mé'di'co 'con'mi'go 'ma'ña'na (Spanish : Syllable-timed)

One result of these differences is that vowels occupy less space in stress-timed languages than in syllable-timed languages which is the reason why vowel reduction and neutralization are so prevalent in English (Lehiste, 1970; Nespor, Shukla, & Mehler, 2011). As Lee and Cho (2011) explain: “[T]he optimal pattern of prosodic rhythm alternates stressed syllables/vowels and unstressed syllables/vowels as in trochaic or iambic beats, which results in the difference in vowel duration and salience between stressed and unstressed vowels” (pp. 62-63). In stress-timed languages, according to Okobi (2006), "in general it is the primary stressed syllable that is pitch accented when the word of interest is the focus of a phrase (i.e., high focal pitch accent)" (p. 11).

Ladefoged (1975) proposed yet another form of isochrony. He suggested that there are mora-timed languages, such as Japanese and Tamil, which occupy even more vowel space due to having simpler syllabic structures (Nespor et al., 2011). Figure 3 shows the three different types of isochrony (from "Stress-timed vs. Syllable-timed Languages," by Nespor et al., 2011, p. 1149).

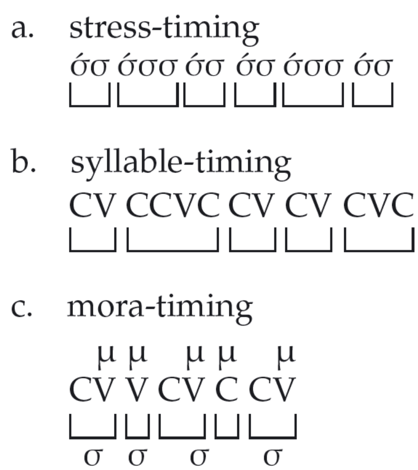


Figure 3. The Different Types of Isochrony

Although it has now been proved that no language is purely stress-timed or syllable-timed (Ladefoged, 2001b, p. 231) but rather lies on a continuum (Sabater, 1991, p. 153), according to Celce-Murcia et al. (1996), "The difference between stressed and unstressed syllables is greater in English than in most other languages–with the possible exception of German, its Germanic language cousin" (p. 132). Therefore, one can confidently surmise that accurate production of stress is essential to the comprehension of L2 English speakers' speech. Ladefoged (2001b, p. 231) suggested that a better typology of rhythmic variations among languages would be to differentiate languages by whether they have "variable word stress" (e.g., unpredictable lexical stress in English) or "fixed phrase stress" (e.g., predictable lexical stress in Arabic), as proposed in Altmann and Vogel's (2002) *Stress Typology Model (STM)* (cited in Altmann, 2006).

It is instrumental to mention a truly comprehensive cross-linguistic dissertation study by Altmann (2006) on the perception and production of second language stress. Figure 4 shows the languages that she used in her study as applied to the STM (adapted from "The Perception and Production of Second Language Stress: A Cross-linguistic Experimental Study," by Altmann, 2006, p. 31).

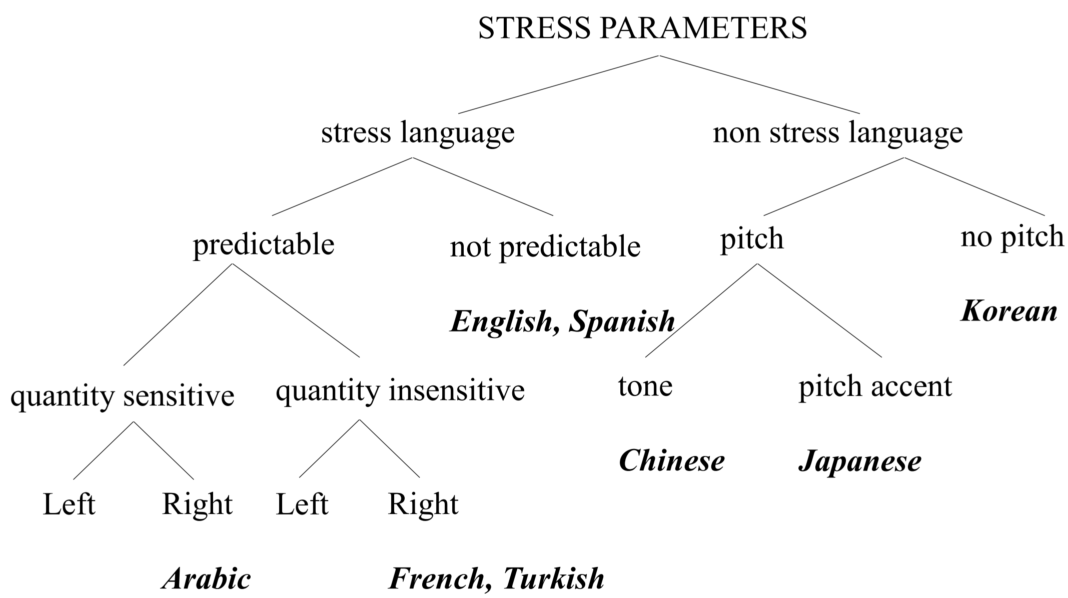


Figure 4. Stress Typology Model

The researcher found interesting and somewhat surprising results:

> On the one hand, learners with predictable stress in their L1 (i.e., Arabic, Turkish, French) had problems perceiving the location of stress but they performed most like the English native speakers in production, who applied a frequency-based common strategy. On the other hand, learners without word-level stress in their L1 (i.e., Chinese, Japanese, Korean) or with unpredictable L1 stress (Spanish) showed almost perfect perception scores;

> however, their productions were quite different from the control group's. Thus, it was found that good perception does not necessarily underlie good production and vice versa. (pp. xii-xiii)

Clearly, the perception study results from Altmann (2006) are not what one might expect. This, however, is not the end of the matter. So far we have only discussed intonation languages. The opposite of an intonation language is a tone language such as Chinese or Thai. In these languages, pitch is used to provide contrast at the syllable or word level rather than the phrase or sentence level (Fromkin et al., 2011).

Ladefoged (2001b) used the four pitch-dependent meanings of the Chinese Mandarin syllable <ma> to demonstrate this concept (i.e., mother (mā): high tone, hemp *(má)*: high-rising tone, horse (*mǎ)*: low-falling tone, and scold (*mà)*: high-sharp-falling tone). He stated that it is common for such languages to exhibit "preservative tone assimilation," whereby the tone of one syllable passes on to the next syllable (p. 238) thus causing a shift in syllabic F0. Clearly, an L1 speaker of a tone language may have great difficulty in accurately producing stress in an unpredictable stress-timed language such as English. Table 1 depicts the tonal contrasts and pitch (i.e., fundamental frequency–F0) fluctuations in Mandarin (adapted from "Teaching Pronunciation: A Course in Phonetics," by Ladefoged, 2001b, p. 237).

Table 1. Tonal Contrasts in Mandarin

Tone number	Description	F0 (Hz)	Tone letter	Example	Gloss
1	high level	55	˥	ma^{1}	Mother
2	high rising	35	˧˥	ma^{2}	Hemp
3	low falling rising	214	˨˩˦	ma^{3}	Horse
4	high falling	51	˥˩	ma^{4}	Scold

Role of Lexical Stress in Intelligibility and Comprehensibility

The construct of intelligibility has been around for many years, and yet it is only recently that it has been acknowledged as the fundamental goal in the teaching of L2 pronunciation. Field (2005) provided a brief history of this concept:

> In 1949, Abercrombie famously remarked that "language learners need no more than a comfortably intelligible pronunciation" (p. 120). The idea was slow to feed through to practice, but in the 1970s many English language teachers worldwide came to recognize that it was unrealistic, time-consuming, and potentially inhibitory to aim for a native-like accent, and that such a goal might not necessarily represent the learners' wishes. They abandoned traditional checklist approaches to pronunciation instruction and instead adopted intelligibility as their criterion. (p. 400)

The leading proponents of L2 intelligibility research are unquestionably Murray Munro and Tracey Derwing. According to these two researchers, "Intelligibility may be broadly defined as the extent to which a speaker's message is actually understood by a listener" (Munro & Derwing, 1995, p. 289). This expansive definition entails, at a minimum, two different types of understanding: (1) The successful identification of words and (2) Understanding the intended meaning of a speaker.

The flip side of the coin, so to speak, is comprehensibility. Munro and Derwing (1995) described comprehensibility as the perception of how easy it is to understand a speaker while Hahn (2004) operationalized this variable as the accuracy with which the intended meaning of a speaker is perceived. The former is a more global view, while the latter implies that comprehensibility can be measured. Both views, however, regard native-like pronunciation as unimportant, unrealistic, and outdated with regards to 'World Englishes' or 'Multiple Englishes'.

Many pronunciation experts believe that a learner's command of suprasegmental features is more essential to communicative competence than his/her command of segmental features.

Therefore, it is claimed that nonnative English speakers (NNES) who do not use native-like stress patterns are more likely to be misunderstood than those who use nonnative-like vowel or consonant sounds (Celce-Murcia et al., 1996). Likewise, McNerney and Mendelsohn (1992) stated that "…a short-term pronunciation course should focus first and foremost on suprasegmentals, as they have the greatest impact on the comprehensibility of learners' English" (p. 186). In addition, Hahn's (2004) study examined the reactions of native English speakers (NES) to nonnative primary stress in English discourse. Her findings reveal the extent to which using primary stress affects the intelligibility of international teaching assistants (ITAs). The results provide unequivocal, empirical support for pronunciation pedagogy that prioritizes suprasegmentals.

In another study, Kang (2010) studied the effects of suprasegmentals on the comprehensibility of ITAs. This construct was operationalized as speaking rate, pausing, stress, and intonation (pitch range). NES judgments were statistically compared (using stepwise regression) to acoustic measurements (using the Praat software) of 12 different pronunciation parameters. Again, suprasegmentals showed an effect on perceived accentedness and comprehensibility. More specifically, the results showed that "the overall pitch range factor best predicted the ratings of ITAs' accentedness, followed by proportion of stressed words to the total number of words, pause duration, and articulation rate" (p. 310). Conversely, speech rate was found to be the best predictor of comprehensibility. Kang (2010) hypothesized that low proficiency speakers are "inclined to give relatively equal pitch to each word regardless of its role in the discourse structure which leads to many sequential high- pitch words" and that "low proficiency ITAs placed stress on many functional words or articles such as 'be', 'the', 'that', and 'this is'" (p. 310). It is also of interest to note that the speech of ITAs who broke suprasegmental rules were rated as “monotonous”, “frustrating’, “boring” and “not at all attractive” (p. 310).

Clearly, these studies highlight the importance of teaching suprasegmentals to L2 learners if English. It is informative to note, however, that Levis (2012) cautions against taking such a biased approach to pronunciation teaching. He argues that segmentals are equally important as suprasegmentals, and that the debate is not useful because “you can’t have one without the other” (¶13). Levis provides the examples of ‘rhythmic structure (a suprasegmental) and vowel quality (a segmental)” which are interdependent, and the close association of “rhythmic structure with consonant clarity” (¶13)”. These arguments notwithstanding, lexical stress is indubitably a salient feature in accentedness, comprehensibility, and intelligibility. Therefore, it must be emphasized in ESL pronunciation courses so that learners can acquire prosodic competence.

Prosodic Information in the Lexicon

Research suggests that the type of prosodic information mentioned thus far (i.e., lexical stress) is included in the entry of every English content word in the lexicon (Fromkin et al., 2011; Okobi, 2006; Sabater, 1991). That is, native speakers of a language generally know, as part of their linguistic competence, which syllable receives primary stress, which receives secondary stress, and which are not stressed at all (Fromkin et al., 2011). Although word stress is not usually a distinctive feature in English, it is distinctive in the case of noun-verb minimal stress pairs (Okobi, 2006). These are pairs of words with the same spelling and similar pronunciations, but different meanings. For instance, the word <present> which can function both as a noun and as a verb depending on where stress falls in the word; i.e., <PREsent>: noun vs. <preSENT>: verb (Lee & Cho, 2011, p. 63). For this reason, noun-verb minimal stress pairs have been used as the tokens in a number of acoustic studies on word stress, most notably in Fry's (1955, 1958) and Beckman's (1986) seminal works.

In addition to these *distinctive* or *contrastive* properties, prominent syllables within an utterance more often act as signals to listeners that signify which words one may potentially encounter in the dialogue. Okobi (2006) attested that a number of studies reveal that stressed syllables are used to infer words in the speech-path. Consequently, he states that, "knowing the stress pattern of a word can greatly reduce the number of competing word candidates" (Okobi, 2006, p. 12). Thus, listeners find it problematic to interpret a word mispronounced with the incorrect stress pattern. As Sabater (1991) explained:

> [I]n processing this word we begin to look up possible words under this wrong stress pattern which will fit the context, and we might arrive at the wrong interpretation or we might not find an appropriate word and we may start wondering about the stress pattern. (p. 151)

Further evidence for the storage of syllabic stress rules in the lexicon comes from experimental research on *spoonerisms*, or the *slip-of-the-tongue* phenomenon (Fromkin et al., 2011; Ladefoged, 2001a; Okobi, 2006; Sabater, 1991). In these cases, a speaker can produce the appropriate stress pattern and number of syllables of the intended word, but cannot articulate the correct phonemic segments of the word. Studies reveal that the most common type of tongue slip involves the transposition of stressed syllables (Ladefoged, 2001a; Sabater, 1991). For example, "*He was on the nerve of a vergeous breakdown* instead of: *He was on the verge of a nervous breakdown"* (Sabater, 1991, p. 151). Ladefoged (2001a) concluded that, "It seems probable that we organize our speech production much as we organize our perception of speech, in terms of units more like syllables than individual speech sounds" (p. 188). We shall now turn our attention to the *articulatory* mechanisms of syllabic stress production.

Physiology of Stress Production and Perception

A stressed syllable is generally articulated by expelling more air out of the lungs and increasing laryngeal activity in relation to unstressed syllables, thereby expending a larger quantity of respiratory energy (Ladefoged, 2001b, p. 231). This muscular energy may be spent contracting the rib cage, elevating the diaphragm using the abdominal muscles, activating the laryngeal muscles (to open and close the vocal cords in the larynx) to increase the pitch, and even adjusting the articulatory motions of the lips and tongue (Ladefoged, 2001a, p. 231). The expulsion of air that is the source of almost all speech sounds is known as the *pulmonic airstream mechanism* (Ladefoged & Johnson, 2010, p. 136). Ladefoged and Johnson (2010) described how these physiological mechanisms work together to produce what we perceive as a stressed syllable:

> When there is an increase in the amount of air being pushed out of the lungs, there is an increase in the loudness of the sound produced. Some books define stress simply in terms of loudness, but this is not a very useful definition is loudness is considered to be simply a matter of the amount of the acoustic energy involved. We have already noted that some sounds have more acoustic energy than others because of factors such as the degree of mouth opening. A much more important indication of stress is the rise in pitch, which may or may not be due to laryngeal action. (p. 250)

The pitch of a sound corresponds to the F0, which is “the number of complete repetitions (cycles) of variations in air pressure occurring in a second” (Ladefoged, 2001b, p. 164). If this involves laryngeal activity, it is analogous to the frequency of vibrations of the vocal cords (Ladefoged, 2001b). The mass of the vocal cords greatly influences the pitch range capabilities of a speaker (e.g., between the sexes). However, pitch can be manipulated by adjusting the tension of the vocal cords using a trilateral muscle in the larynx known as the *cricothyroid muscle* (Munro, 2012). By increasing vocal cord tension, as speaker can produce a higher-pitched sound (Munro, 2012).

In terms of acoustic analysis, one can determine the F0 of a sound by computing the number of peaks of air pressure in its waveform, using a software program (such as Praat) which will automatically measure this value in Hz (Ladefoged, 2001b, p. 164). It is essential to understand that there is not a linear relationship between the auditory perception of pitch change and the frequency of an utterance, as Ladefoged (2001b) explicated:

> A pitch change from 100 to 300Hz is perceived as being the same (within small limits) as one from 300 to 500 Hz, so we can regard frequency as being equivalent to pitch when discussing the pitch of the voice. At frequencies above 1,000 Hz equal increases in frequency are not perceived as equal increases in pitch. The interval from 1,000 to 2,000 Hz is judged to be more like the interval between 2,000 and 4,000 Hz, a doubling of the frequency. (pp. 166-167)

In sum, differences in F0 are perceived as being greater when lower frequencies are involved (see also Baart, 2010, p. 67). This proportional relationship between pitch perception and acoustic frequency has been empirically calculated and can be determined using an auditory frequency scale known as the Bark Scale (Johnson, 2012).

The intensity of a sound, which closely equates to the perceptive quality of "loudness", is proportional to the amplitude (or average size) of the fluctuations in air pressure in the pulmonic airstream (Ladefoged, 2001b, p. 165). Thus, an increase in air pressure leads to a sound of greater intensity (Munro, 2012). According to Ladefoged (2001b):

> [Intensity] is usually measured in decibels (dB) relative to the amplitude of some other sounds. Technically, to get the dB difference one has to compare the power ratio, where the power is defined as the square of the mean amplitude (the mean variation in air pressure). The difference in dB is 10 times the common logarithm of the power ratio of the two sounds or 20 times the log of the amplitude ratio. (p. 165)

With these physiological factors in mind, the following section discusses the various correlates of stress in the English language with regards to acoustical phonetic analysis.

Acoustical Phonetic Correlates of Stress in English

The physical parameters of stress are duration, pitch, and loudness (Sabater, 1991). In acoustic terms, stress is manifested multi-dimensionally with respect to the three corresponding correlates of duration, F0, and intensity (Fry, 1955, 1958; McClean & Tiffany, 1973; Redford, 2007). Native English speakers tend to produce stressed syllables with longer duration, higher F0, and greater intensity than unstressed syllables (Zhang et al., 2008). Thus, from a SLA perspective, errors in some or all of these correlates could impede perception of stress contrast in NNES' speech.

In his seminal works on homographs, Fry (1958) claimed that F0 is the most important acoustic cue in a stressed syllable. In this view, it is the dynamic change of pitch or the intonation of an utterance that is most perceptual (Fry, 1958, p. 151). According to Fry (1955, p. 765), the second most important acoustic cue is duration, followed by intensity. Indeed, he argues that intensity is the weakest of the acoustic cues (Fry, 1955, p. 765, 1958, p. 151). The findings from Morton and Jassem's (1965) study also corroborated Fry's assertion that F0 is the most salient acoustic parameter of stress. In their innovative experiment, they systematically altered the properties of F0, duration, and intensity in nonsense syllables (i.e., /sisi/, /sɔsɔ/ and /sasa/). These stimuli were then played to participants (naïve to the synthetic nature of the tokens) who were instructed to judge the position of the stress. Morton and Jassem (1965) claimed that, "Variations in fundamental frequency produced far greater effects than variations in either intensity or duration, a syllable being marked as stressed if it differed from the 'context' fundamental. A raised fundamental was more efficient than a lowered one" (p. 159).

However, as Beckman and Edwards (1994) contended, "[…] investigations of physical and perceptual correlates of stress have produced many seemingly conflicting results, at least in part because of confusion concerning the phonological categories and structures involved" (p. 7). Conversely, they claimed that F0 is the least salient cue, and that duration and intensity are relatively more salient acoustic cues to stress. They reasoned that F0 is only a relevant acoustic correlate of stress with regards to sentential pitch accent. This assertion only partly agrees with Barto-Sisamout's (2011) claims that the English intonation system uses F0 contours not only to signify word prominence within a phrase, but also to denote syllabic prominence in a word and to differentiate between statements and questions.

To add more confusion to the debate; in an earlier investigation, by Adams and Munro (1978), of the parameters of stress in native and nonnative connected utterances, "duration was by far the most frequently used cue and that amplitude was the least used" (p. 125). Although they reported that NES and NNES did differ significantly in the placement of stress as one would expect, analysis of the data suggests that the two groups do not routinely utilize different acoustic correlates to communicate stress at the sentence level. Ladefoged (2003, p. 90) partly agrees with this ordering of acoustic correlates claiming that duration and pitch are both more reliable cues to syllabic stress than intensity (i.e., F0 ≥ duration > intensity). Indeed he adamantly claimed that, "Intensity is a seldom one of the distinguishing phonetic characteristics of a language despite what you may read" (p. 93). In a more recent study by T. M. Adams (2006), the results indicated that F0, duration, and intensity "participate in a form of cue trading to signify stress in different contexts" (p. 3087). However, Ladefoged (2003) cautioned that "there is no known algorithm that enables an observer to measure these three quantities and use them as a measure of stress" (p. 94).

It is also important to note that while it is true that the pitch of a stressed vowel is generally higher than that of an unstressed vowel, a syllable with a lower pitch than the other syllables is also likely to be perceived as being stressed (Sabater, 1991). Therefore, the primary cue for stress perception appears to be that the pitch of a stressed syllable is markedly *different* from the other syllables in an utterance, as well as having a longer duration and greater intensity (Sabater, 1991). Similarly, in Morton and Jassem's (1965) study, it is reported that while longer and more intense syllables are more readily marked as being stressed, if a syllable is reduced in duration by 40%, it is perceived as being stressed by some listeners.

Sabater (1991) also suggested that there is an additional cue for stress in English which is equally important–i.e., reduced vowel quality in the unstressed syllable. In concordance with this view, many researchers have proposed that the distinction between stressed and unstressed syllables in English depends upon vowel quality in addition to the three aforementioned acoustic correlates of stress (Edmunds, 2009; Fear et al., 1995; Hillenbrand et al., 1995). Specifically, at the word level in English, the unstressed vowels tend to be produced as the mid-central reduced vowel known as the schwa /ə/ (Celce-Murcia et al., 1996). Indeed, it is the most common sound in English. Linblom's (1963) spectrographic studies reveal that the degree of neutralization towards schwa (spectral reduction) is proportional to vowel duration. His model of vowel reduction is fundamentally motivated by "undershoot" in short unstressed syllables (p. 1779). Short duration of unstressed vowels results in a greater effort required to achieve distinct vowel qualities, especially for low vowels. Since contrasts are bound by constraints of distinctiveness, neutralization occurs as opposed to phonetic reduction which would otherwise render vowels unintelligible (Flemming, 2009).

In addition, Gay (1978) found that the first (F_1) and second formants (F_2) are the best indicators of spectral reduction. However, more recently, Flemming (2009) reported that the F_1 and F_2 values for schwa are highly variable as systematically conditioned on its context within a word (i.e., word-final versus word-nonfinal). Nevertheless, Fleming (2009) and Fear et al. (1995) maintained that the distinction between stressed and unstressed syllables in English can be acoustically determined by measuring the three acoustic correlates of stress and/or the quality of a reduced vowel.

Thus, to provide a brief summary of this section: Stress is a relational feature, and a syllable is perceived as being stressed when its acoustic properties are relatively more prominent than the other syllables in an utterance.

Morphophonemic Attributes of English Derivational Suffixes

In the English language, there are a variety of phonological relationships that exist between stem words and derived forms. These suffixal variations did not escape the attention of Chomsky and Halle (1968) in their classic work, *The Sound Pattern of English*. According to Jarmulowicz (2002), "Within the English derivational system, there are suffixes that have very predictable effects on the primary stress of the word stems to which they attach" (p. 193). Celce-Murcia et al. (1996) listed the three ways in which they do this:

1. They may have no effect on the stress pattern of the root word.
2. They may receive strong stress themselves.
3. They may cause the stress pattern in the stem to shift from one syllable to another. (p. 136)

The suffixes in the first category are known as *neutral suffixes*, and they are primarily of Germanic origin (Celce-Murcia et al., 1996). Jarmulowicz, Taran, and Hay (2008) provided the following definition:

> For derived words with phonologically neutral suffixes (e.g., -*ness* and -*er*), no change in the stem's primary stress, consonants, or vowels occurs after the suffix has been added. For example, the addition of the neutral suffix -*ness* on the stem *happy* ["hæpi] results in the derived word *happiness* ["hæpinɪs], which exhibits no stem-internal phonological alternations. (p. 214)

Further examples include common suffixes such as <-ly>, <-ing>, <-ful>, and <-er> (Celce-Murcia et al., 1996). This historical connection is very clear in Table 2 which shows a comparison of neutral suffixed words in English and modern-day German (adapted from "Teaching Pronunciation: A Reference for Teachers of English to Speakers of Other Languages," by Celce-Murcia et al., 1996, p. 136).

Table 2. Neutral Suffixes in English and German

Neutral suffix	English	German
<-en>	THREAT + en	DROH + en
<-er>	BAK + er	BÄCK + er
<-ful>	TACT + ful	TAKT + voll
<-hood>	CHILD + hood	KIND + heit
<-ing>	OPEN + ing	ÖFFN + ung
<-ish>	DEVIL + ish	TEUFL + isch
<-less>	GROUND + less	GRUND + los
<-ship>	FRIEND + ship	FREUND + schaft

It is important to note that there are other neutral suffixes of non-Germanic origin such as <-dom>, <-ness>, <-able>, and <-al>, to name just a few, that behave in exactly the same way by maintaining the stress pattern of the stem morpheme (Celce-Murcia et al., 1996).

Conversely, the suffixes in the second category tend to be of Romance language origin and are mostly borrowed from modern-day French (Celce-Murcia et al., 1996; Harley, 2003). Table 3 illustrates this type of non-neutral suffix which causes the final syllable (the suffix itself) to receive strong primary stress (adapted from "Teaching Pronunciation: A Reference for Teachers of English to Speakers of Other Languages," by Celce-Murcia et al., 1996, pp.136-137).

Table 3. Stress-bearing Suffixes of Romance Language Origin

Suffix	Word
<-aire>	millionaire
	questionnaire
	doctrinaire
<-ee>	refugee
	tutee
	trustee
<-eer>	engineer
	mountaineer
	volunteer
<-oon>	balloon
	saloon
	bassoon
<-esque>	grotesque
	arabesque
	picturesque

These suffixes are therefore known as *stress-bearing suffixes* and all are borrowed, most fairly recently, after 1800 A.D (Harley, 2003). For instance, <-ee> and <-ette> are borrowed from French, <-esque> and <-ese> are from Italian, and <-itis> comes directly from Latin (Harley, 2003).

The third class of suffix is known as a *stress-moving* or *stress-shifting suffix* because there is a shift in stress in the derived word to the syllable directly preceding the suffix. Jarmulowicz (2002) exemplified: “[D]erivations with the suffixes <-tion>, <-ic>, or <-ity> require primary stress to fall on the presuffixal syllable regardless of where primary stress may fall in the stem. This results in stress alternations seen in words like <EDucate–eduCAtion and SYMbol– symBOLic.” (p. 193). Table 4 provides some more examples. According to Harley (2003), these suffixes all entered English via French after 1100 A.D.

Table 4. Stress-shifting Suffixes in English

Suffix	Root Word	Root with suffix
<-eous>	advantage	advanTAgeous
<-ial>	PROVerb	proverbial
<-ian>	PARis	PaRIsian
<-ic>	CLImate	climatic
<-ical>	eCOLogy	ECOLOGical
<-ious>	Injure	injurious
<-ity>	TRANquil	tranquility
<-ion>	EDuCATE	EDUCAtion

In addition to a shift in stress, these suffixes also cause a change in the unstressed syllable by means of a concomitant vowel reduction or neutralization (Celce-Murcia et al., 1996).

Also, as Celce-Murcia et al. (1996) stated: "Because of the nature of tense and lax vowels, there is sometimes an accompanying change in syllable structure or syllabification" (p. 137). These changes in vowel quality and syllabic structure can be seen in the suffixation of <atom>:

Atom	aTOMic	atoMICity
/ˈætəm/	/əˈtɒmɪk/	/ˌætəˈmɪsɪti/

Furthermore, in some situations "suffixation may cause a complete change in vowel quality from tense to lax rather than a shift in stress, as in the words *page* /e/ vs. *paginate* /æ/, and *mime* /i/ vs. *mimic* /ɪ/" (Celce-Murcia et al., 1996, p. 138).

Interestingly, when the root morpheme and the suffix have different historical origins, it is the suffix that regulates the stress pattern in English (Celce-Murcia et al., 1996). Therefore, if a Germanic suffix is added to a Romance word there is no shift in stress (e.g., <agGRESSive> →

<agGRESSively>); but if a Latinate suffix is added to a Germanic stem there will be a resultant shift in stress (e.g., <BREAKable> → <breakaBIlity>).

Harley (2003) schematized a generalization of the ordering of these borrowed suffixes:

[[[Stem]-(-LatinateAffix(es)](-GermanicAffix(es)]. (p. 156)

Since most stems can occur without any derivational affixes, the round parentheses indicate optionality. As such, Germanic affixes can occur without any Latinate affixes, and vice versa. In this scheme, in a word that has both Germanic and Latinate derivational affixes, the Latinate affix(es) will occur inside the Germanic ones (Harley, 2003). In the next sections, we will focus our attention on stress-shifting suffixes since this is the area of investigation in this paper.

A Generative Account of Stress-Shifting Suffixes

Jarmulowicz et al. (2008) further described the morphophonemic effects of stress-shifting suffixes:

> [The] addition of a phonologically nonneutral suffix may alter primary stress placement, consonants, or vowel quality of the stem. For example, the suffix *-ity* is nonneutral, and when added to the base *electric* /Iˈ lEktrIk/ the resulting word, *electricity* /IlEkˈtrIsIti/, exhibits a rightward stress shift and a consonant alternation. (p. 214)

Thus, it will be interesting to explore whether consonantal changes, as well as vowel changes, can be observed acoustically in words containing stress-shifting suffixes.

There are a variety of ways in which these morphophonological processes are formalized, but in this paper I shall describe the Level Ordering system expounded by Kiparsky (1982) in his model of Lexical Phonology. He outlined the coordination of morphological and phonological rules in the lexicon and makes a distinction between *lexical* and *postlexical* phonological processes. In this view, words are formed at different strata in the lexicon, and at each level, the corresponding phonological rules are applied to a complex word before it can advance systematically to the next level (Kiparsky, 1982). Thus, using this model one can differentiate between Level 1 and Level 2 affixes. The former should attach to a stem before the latter. In other words, a Level 1 suffix such as <-ity> or <-tion> applies before a Level 2 suffix such as <-hood> or <-ness>. Level 1 suffixes (also known as "primary suffixes") can be derivational or inflectional and their addition leads to stress changes and shortening. Level 2 suffixes are only derivational and their addition leads to phonological changes in compound stress as illustrated in Figure 5 (adapted from "The Structure of Phonological Representations: Part I," by Kiparsky, 1982, p. 133).

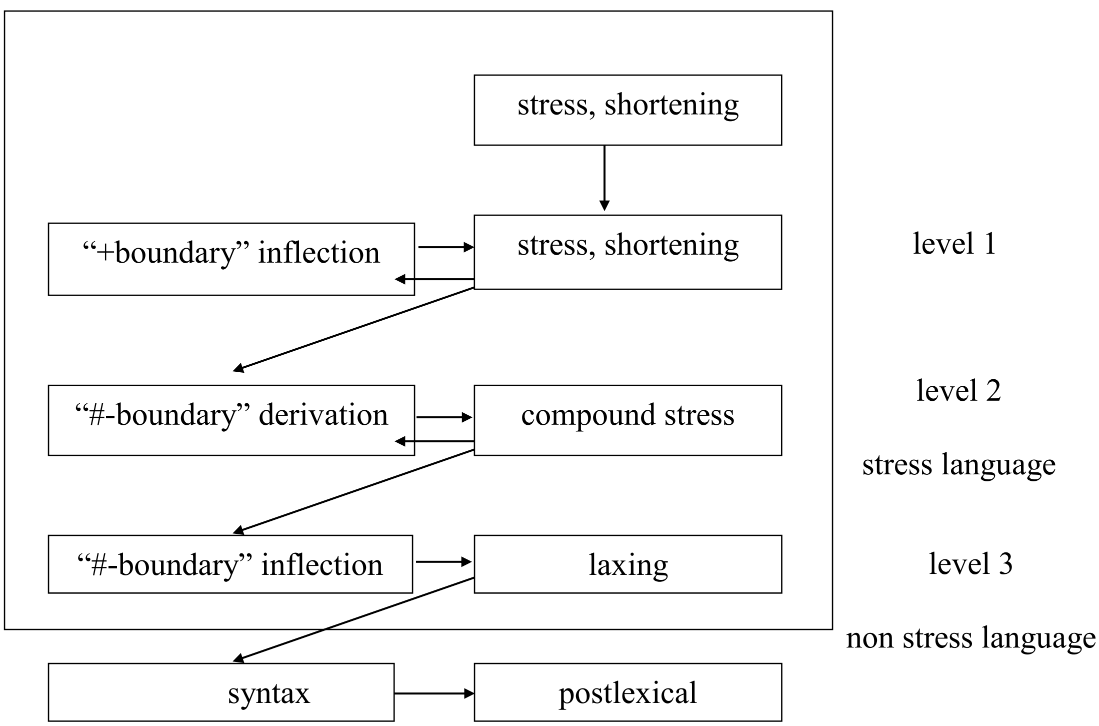


Figure 5. Level Ordering in Lexical Phonology

Booij (2006) delineated Level Ordering with regards to neutral and non-neutral suffixes:

> For English, for instance, it has been proposed that there are two levels. Level 1 is the level of non-native suffixation, which triggers the application of a specific set of phonological rules such as the Main Stress Rule. Level 2 is the level for stress-neutral

> (native derivational and inflectional) suffixes. At this level, the Main Stress Rule no longer applies, thus accounting for the stress-neutrality of these suffixes. This level ordering hypothesis also predicts that stress-neutral suffixes are peripheral to those that influence the stress patterns of words, such as the stress-bearing non-native (Romance) suffixes of English. For instance, in the complex noun *contrastiveness* the stress-shifting suffix *–ive* precedes the stress-neutral suffix *–ness.* (pp. 96-97)

There is, however, a problem with this model. Aronoff (1976) showed it to be empirically invalid (after it was first proposed by Siegel), and called it the “Boundary Paradox” (p. 84). He provided counterexamples to this hypothesis whereby there is a shift in stress even when a Level 2 suffix applies to a complex word after a Level 1 suffix has been affixed. For example, when Level 1 <-ity> is applied after Level 2 <-able> to the word <anaLYZable>, it results in <analyzaBIlity> (Aranoff, 1976, p. 84 (emphasis added by author)).

Consequently, Halle and Kenstowicz (1991) later revised Kiparsky’s model of lexical phonology by suggesting that morphophonemic features (such as primary or “main” stress) generated at Level 1 are filtered back through cyclical phonological rules. Thus, in this cyclical framework, hierarchy of rule application does not dictate phonological outcome. Instead it is dependent upon whether a particular suffix is marked in the lexicon as phonologically cyclic, or [+cyclic] or noncyclic [-cyclic]. Hale and Kenstowicz (1991) provided the following illustrative example:

> To illustrate this approach, the word patentability is derived as follows. On the first cycle, stress is assigned to the root to yield [patent]. Being [-cyclic], the -able suffix does not activate the stress rule. However, the next suffix -ity is [+ cyclic] and the stress rule therefore applies to yield patent-abil-ity. Another key feature of our framework is that cyclic (that is, stress-sensitive) affixes trigger a convention of Universal Grammar that deletes the stresses assigned on earlier passes through the rules of the cyclic block […]. (p. 460)

Hence, the following stress-shifting suffixes mentioned by Celce-Murcia et al. (1996), <eous>, <-ial>, <-ian>, <-ic>, <-ical>, <ious>, <-ity>, and <-ion>, would be stored as Level 1-

type [+cyclic] in the lexicon. In the literature, cyclic vs. noncyclic suffixes have also been labeled phonologically nonneutral vs. neutral and phonologically opaque vs. transparent. (Jarmulowicz, 2002).

Corpus Frequencies of Stress-Shifting Suffixes

Table 5 shows the 20 most frequent English suffixes in 2, 167 suffixed words appearing in 60 randomly selected pages of *The American Heritage Word Frequency Book* (Carroll, Davies, & Richman, 1971). The list was compiled by White, Sowell, and Yanagihara (1989) and applied to third grade research. To be expected, the inflectional suffixes <-s>, -<es>, <-ed>, and <-ing> account for almost two-thirds of the words. In Table 5, the most frequent stress-shifting suffixes are shaded in gray. The most frequent stress shifting suffix by far is the <-ion, -tion, -ation, -ition> morpheme which constitutes around four percent of suffixes in the corpus. Interestingly, the other stress-shifting suffixes (i.e., <-al, -ial>, <-ity, -ty>, <-ic>, <-ous, -eous, ious>, each account for approximately one percent of the suffixes used in American English. All other suffixes, not in the list, constitute just seven percent of the corpus.

Previous and Related Studies on Stress-Shifting Suffixes

Jarmulowicz (2002) hypothesized that native English speaking children's acquisition of morphophonologically conditioned stress changes would be influenced by the frequency of occurrence in the input of the various Level 1 [+cyclic] suffixes. In particular, she was interested in determining when in a child's development does he/she learn that English has cyclic suffixes,when does he/she know when a suffix is cyclic, and when does he/she know that stress is predictable. Jarmulowicz (2002) conducted two studies in order to answer these questions (adapted from “Teaching Elementary Students to Use Word Part Clues,” by White et al, 1989, p. 305).

Table 5. English Suffixes Ranked by Frequency of Occurrence

Rank	Suffix	Part of speech	Number of occurrences in sample	Percentage of all suffixed words
1	<-s, -es>	Plural of noun	673	31
2	<-ed>	Past tense of verb	435	20
3	<-ing>	Progressive tense of verb	303	14
4	<-ly>	Usually an adverb; sometimes an adjective	144	7
5	<-er, -or> (agentive)	Noun (agent)	95	4
6*	<-ion, -tion, -ation, -ition>	Noun	76	4
7	<-ible, -able>	Adjective	33	2
8*	<-al, -ial>	Adjective	30	1
9	<-y>	Adjective	27	1
10	<-ness>	Abstract noun	26	1
11*	<-ity, -ty>	Noun	23	1
12	<-ment>	Noun	21	1
13*	<-ic>	Adjective	18	1
14*	<-ous, -eous, -ious>	Adjective	18	1
15	<-en>	Verb	15	1
16	<-er> (comparative)	Adjective	15	1
17	<-ive, -ative, -itive>	Adjective	15	1
18	<-ful>	Adjective	14	1
19	<-less>	Adjective	14	1
20	<-est>	Adjective	12	1
All others			160	7
Total			2,167	100%**

* Stress-shifting suffix ** “The total actually exceeds 100% due to rounding upward on items in ranks 13-20” (White et al., 1989).

The first study was a small-scale analysis of two fictional and two factual children’s books to determine “the proportional representation of suffixes in children’s literature corpus, thereby allowing the suffix variable to be established” (p. 192).

In the second study (designed using the suffix frequency information collected in the first study), Jarmulowicz (2002) “empirically examined the effect of suffix frequency on school-aged children's judgments of primary stress placement" (p. 192). To do this, she used two groups of 20 children with mean ages of 7:3 (years: months) and 9:5 (years: months), and one "performance ceiling" group of ten adults with a mean age of 36 years (p. 197). The stimuli used were one list of 12 real English derivations and another list of 12 nonsense derivations of stem words containing two syllables and affixed with the following [+cyclic] suffixes: the highest frequency suffix <-tion>, the mid-frequency suffix <-ity>, and the lower frequency suffix <-ic>. Each list also contained filler words that used [-cyclic] suffixes. The lists were recorded onto audiotape in sets of minimal stress pairs. The children listened to the real words first, followed by the nonsense words. They were then "required to make a binary choice indicating their preference for one member of a minimal stress pair" (p. 197).

It is interesting to note how Jarmulowicz (2002) handled the data. First, the proportions were recalibrated using an arcsine transformation (2*(arcsin(sqrt(X))) in order to make the data more salient for linear statistics. Then mean proportions and standard deviations for all the groups were calculated. This clearly demonstrated the adults' ability to accurately assess primary stress on real and nonsense derived words, thus indicating that they were relying on the [+cyclic] phonological features of the suffix. It also showed that the children did not complete the tasks to the same degree of accuracy as the adults. A two-way ANOVA was conducted in order to conclude whether there were significant differences between the 7 and 9 years olds and the suffixes <-tion>, <-ity>, and <-ic>. A main effect of age group was found; as Jarmulowicz (2002) states, "The 9-year-old children were more proficient judges of primary stress than the 7-year-old children" (p. 198). A main effect of suffix was also found, although there was no observable relationship between suffix and age. In Jarmulowicz's (2002) words:

Children in both groups performed at ceiling levels when judging stress placement on real -tion derivations, thereby making further contrasts with these cells impossible. Therefore, a 2 X 2 X 2 ANOVA was used, with age group (7- and 9-year-olds) as the between-subjects variable and suffix (-ity and -ic) and word stem (real and nonsense) as the within-subject variables (p. 198). The results showed that both groups performed better on real <-ity> derivations than nonsense <–ity> derivations while only the 9-year-old group performed significantly better on the real than the nonsense <-ic> derivations.

Overall, the findings from this study indicated that the two independent variables of age and suffix frequency both had an effect on children's acquisition of stress-placement awareness. As Jarmulowicz (2002) summarized:

The hypothesis that suffix frequency would affect children's suffix knowledge was supported. Despite the fact that the judgments on derivations with the two suffixes of lesser frequency (i.e., -ity and -ic) were not significantly different from each other statistically, the most frequent suffix of the three (-tion) had a very robust advantage regardless of whether it was attached to a real or nonsense stem (p. 200). She also advised that further studies be conducted across a broader range of suffixes and ages in order to "clarify the role of frequency in the development of English derivation" (p. 232).

Although this study is derived from the field of child language acquisition, it raises many interesting questions for SLA research. What is the rank order of Level 1 [+cyclic] suffix frequency in the Academic Word List? What are the most frequent stress-shifting suffixes that ESL/EFL learners are exposed to in their course books? Is suffix frequency an important variable in L2 learners' ability to judge where primary stress falls in Level 1 [+cyclic] derivations? If so, is there an accessibility hierarchy of suffix acquisition? Moreover, would proficiency level and/or time spent in an ESL environment (i.e., amount of input) show a main effect in accurate stress placement and production? The latter are questions that I intend to explore in this paper while keeping the variable of suffix frequency as a constant.

In a follow-up study by Jarmulowicz et al. (2008), they investigated “the effects of lexical frequency on children’s production of accurate primary stress in words derived with nonneutral English suffixes” (p. 213). They gave “Berko-like” (p. 217) elicited derived word tasks to 44 third-graders so that this time they could observe children’s production of stress-shifting suffixes.

The same [+cyclic] stress-shifting suffixes (i.e., <-tion>, <-ic>, <-ity>), as in the previous study, were used to create high frequency, low frequency and nonsense derived words. However, because the original suffix corpus was too small, the researchers used an additional method for evaluating suffix frequency using the MRC Psycholinguistic Database (Jarmulowicz et al., 2008, p. 219). The final order of suffix frequency was <-tion>, <-ity> then <-ic> and therefore, the latter two suffixes had switched positions from the previous study.

The researchers used impressionistic techniques to assess the accuracy of children’s productions by employing judges trained in phonetics to listen to and evaluate the utterances based on certain criteria. Overall the results of the study indicated that derived word frequency affects stress production accuracy, and that the individual suffix also has a significant role in stress placement since <tion> productions were more accurate than either <-ic> or <-ity> productions. Interestingly, a relationship between stem word and suffix was found as Jarmulowic et al. (2008) report:

[D]erived word frequency relative to stem frequency was related to performance. Stress was less accurate on derived words that were much lower in frequency than their stems (e.g., tranquil/tranquility) and more accurate on derived words that approximated or exceeded their stem frequency (e.g., motivate/ motivation). (p. 213)

This study provides useful data about ranking stress-shifting suffixes into corpus frequency bands. It would be instructive to investigate whether similar findings can be attained by analyzing the speech of NNES. Moreover, it would be beneficial to future language research to develop methodologies to acoustically analyze the productions of words with stress-shifting suffixes so that findings are not based solely on impressionistic judgments.

In the field of SLA research, Flege and Bohn's (1989) oft-cited study explored the patterns of English stress placement and vowel reduction in productions of four pairs of morphologically related words by NES and Spanish L1 NNES. The tokens consisted of base and derived words (i.e., <able>/<ability>, <Satan>/<Satanic>, <application>/<apply>, <botany>/<botanical>) where the first word in each pair had a stressed first syllable, and the second word had an unstressed first syllable. These were specifically selected as they were "illustrative of the phenomenon of vowel reduction" according to Stockwell and Bowen's (1965) study (cited in Flege & Bohn, 1989, p. 41). It is useful to note that one of each pair of words contains a stress-shifting suffix, although this was not specifically mentioned by the authors.

The researchers transcribed the data by marking stress or lack thereof on the first syllable of each word and then measured the acoustic correlates of duration and intensity between stressed and unstressed vowels. In addition, they also used an optoelectronic instrumental technique known as *glossometry* to measure vowel qualities by calculating the tongue heights of the speakers (Flege & Bohn, 1989, p. 42).

The findings of three-way ANOVAs in which the repeated measure was stress (stressed vs. unstressed) showed that both NES and Spanish L1 NNES were able to produce significant contrasts in duration and intensity between stressed and unstressed vowels. One-way ANOVAs revealed that duration ratios were significantly greater for NES than Spanish L1 NNES, whereas intensity ratios were not significantly different. Furthermore, while the Spanish L1 NNEs were relatively native-like with regards to the acoustic correlates of duration and intensity, they were not native-like with regards to vowel quality. That is, they did not produce reduced vowels with native-like tongue configurations. These results supported the researchers' hypothesis that "stress placement poses less of a problem [to English L2 learners] than vowel reduction" (Flege & Bohn, 1989, p. 59).

Another recent SLA study of major relevance to this thesis is Lee and Cho's (2011) investigation of the acoustic properties of English stressed and unstressed vowels. In a similar methodology to Jarmulowicz et al. (2008), they conducted production experiments, in which 5 Japanese, 5 Korean, and 4 American speakers of English were asked to join Level 1 and Level 2 suffixes to corresponding stem words that were given aurally. The rationale behind this procedure was that participants would have to "tap into their phonological knowledge of suffix types in assigning stress, without having recourse to the spelling of the target stimulus" (p. 79). All the Japanese and Korean subjects had spent less than one year in an English-speaking country. 16 tokens were constructed; that is, eight Level 1 stress-shifting suffixes using <-ation> and < -ity> and eight Level 2 stress non-shifting suffixes using <-ness> and <ment>. Each token was given a rating of at least 3 out of 5 based on its frequency according to the online portal site, Naver (www. Naver.com) (p. 71). Nonsense words were not used. The researchers conjectured that these words would be familiar to the Korean and Japanese participants.

Acoustic analyses were conducted on the digitally recorded production data using the open source acoustic analysis software Praat, Version 4.4.30. According to Lee and Cho (2011):

> Four phonetically trained research assistants measured vowel duration, fundamental frequency, and intensity of each word separately and then the results of the measurements were cross-checked by the researchers and the research assistants. When there were disagreements among the measurements, the research team jointly analyzed the spectrograms of the targets until the disagreements were all resolved. In addition, all the stimuli were transcribed by the researchers and a native English speaker with phonetic training in transcription. (pp. 71-72)

More specifically, they measured the ratios of stressed to unstressed vowels for duration, F0, and intensity. To determine whether there was statistical significance in the differences between the mean ratios of stressed to unstressed vowels for the 3 independent variables, the mean ratio of each factor was entered into an ANOVA, in addition to *post hoc* (Tukey HSD) tests.

Lee and Cho (2011) summarized their findings:

> [N]ative English speakers and Korean speakers were significantly different with regard to duration whereas native English speakers and Japanese speakers with respect to intensity (all, $p<.05$). The results reveal that native English speakers tended to produce stressed vowels significantly longer than unstressed vowels but they did not show much difference between stressed and unstressed vowels in terms of fundamental frequency or intensity. On the contrary, Japanese speakers showed a different pattern from native English speakers in that they produced stressed vowels with greater intensity than unstressed vowels. Korean speakers also showed a similar pattern to Japanese speakers for the three factors, especially with respect to duration and intensity, although somewhat different statistical results were obtained between the two groups. (pp. 73-74)

Interestingly, no significant ratio difference for F0 was found between stressed and unstressed vowels among the 3 language groups. Therefore, Lee and Cho (2011) suggested that Korean and Japanese speakers are only dissimilar to American English speakers with respect to duration and intensity when differentiating between stressed and unstressed vowels. These findings seem to support Beckman and Edwards' (1994) and Beckman and Pierrehumbert's (1986) assertion (and thus reject Fry's (1958) hypothesis) that F0 is the least salient cue to stress. Of further interest to this thesis, Lee and Cho (2011) reported:

> [S]uffix type played a significant role with respect to duration as the participants across language backgrounds showed higher duration ratios of stressed to unstressed

> vowels before stress shifting suffixes (-ity, -ation) than before stress non-shifting suffixes (-ness, -ment). Yet, there was no main effect of suffix type irrespective of stress shifting or non-shifting suffixes with regards to fundamental frequency and intensity. Also, the patterns of suffix types varied depending on individual suffixes and language groups. (pp. 61-62)

In Lee and Cho's (2011) discussion of their results, they suggested possible reasons for their findings in relation to cross-language characteristics. First, they hypothesized that Korean speakers are fairly similar to NES with regards to F0 because "Korean prosody is mainly characterized in terms of a phrase-level pitch accent where F0 patterns are associated with particular syllables within a phrase" and (p. 80). Furthermore, they suggested that since duration and intensity are of little importance in the modern Korean prosodic system (except for a few regional dialects), Korean speakers tend to produce these acoustic correlates in a "nonnative-like fashion" (p. 81). Second, they conjecture that the reason Japanese speakers also did not show much difference to NES in terms of F0 is because in Japanese, as in Korean, F0 patterns are the most salient feature of the prosodic system (i.e., it has "word-level pitch accent") (Lee and Cho, 2011, p. 81). Dissimilarly to Korean though, according to Lee and Cho (2011), Japanese has "mora-timed rhythms in which duration is the most important acoustic cue" and so they argue that this may be the reason why "Japanese speakers were more similar to English speakers than Korean speakers with respect to duration" (p. 81).

As a final note Lee and Cho (2011) claimed that all NES lengthen the final lax vowel in all words with stress-shifting suffixes that contain a non-stress-bearing, syllable-final [ɪ] or [ə] regardless of word length, whereas NNEs tend to lengthen these vowels only in 3-syllable words. They stated that this phenomenon has been widely acknowledged in the literature (Lee & Cho, 2011).

It would be edifying to see whether similar cross-language acoustic studies of Level 1 [+cyclic] suffixes would bear similar results with regards to the hierarchy of salient acoustic correlates. The aforementioned study did not clearly differentiate between amounts of exposure to L2 of NNES, only that they had all spent less than one year in an English-speaking country. Clearly, there would be a large disparity between, for example, a speaker who has spent one week in the target language environment versus a speaker who has spent 11 months in one. Also, only English intermediate-level Korean L1 speakers and only English high-intermediate-level Japanese L1 speakers were used in the study, and these proficiency levels were based on interviews and self-reports. Therefore, it would be interesting to conduct a study to observe whether number of years spent in the L2 country would should a main effect on native-like pronunciation of Level 1 [+cyclic]-suffixed words. Also, only a limited number of stress-shifting suffixes (<-tion>, <-ity>, and <-ic>) were used in the studies mentioned thus far. For that reason, it would be valuable to explore whether different Level 1 [+cyclic] suffixes, such as <-eous>, <-ial>, <-ian>, <-ical>, and <-ious>, have similar acoustic properties in both native and nonnative speech. Finally, in the interests of generalizability, it would be of considerable import to conduct replication studies to determine whether the same hierarchy of salient acoustic correlates (i.e., duration > intensity > F0) are found for these and other languages.

Acoustic Studies on Mandarin L1 Nnes' Productions of Stress

Since it is well known that Chinese speakers of English have difficulty producing native-like lexical stress contrasts, Zhang et al. (2008) conducted a study to determine which correlates are most problematic for Mandarin speakers. They hypothesized that the tonal phonetic categories of Mandarin would interfere with the ordering of these correlates. The rationale for their study is comparable to the justification provided for the investigation described in this thesis:

> Here we attempt to dissociate the question of whether, or to what degree, non-native speakers are able to apply phonological rules of stress placement, in order to focus on the question of whether they are able to correctly produce the phonetic properties that correlate with the English stress contrast under conditions in which they know unambiguously where stress is to be placed. (p. 4498)

They compared the use of F0, duration, intensity, and vowel quality in the production of lexical stress contrasts by ten Mandarin (five male, five female) and ten native English speakers (five male, five female). The Mandarin speakers were all originally from the People’s Republic of China (PRC) and had resided in the U.S. for three to four years, while the English speakers were all native residents of the U.S. Only subjects who self-reported having normal hearing, speech, and language faculties were selected. Also, for the purposes of detailed data analysis, subjects were asked to complete a “language background questionnaire” prior to experimentation (Zhang et al., 2008, p. 4501).

Using the classic methodology of Fry (1955, 1958), Lieberman (1960), and Beckman (1986), Zhang et al.’s (2008) stimuli consisted of seven disyllabic minimal noun-verb stress pairs (i.e., <contract>, <desert>, <object>, <permit>, <rebel>, <record>, and <subject>). The stimuli were presented to participants on file cards, and tokens were elicited in isolation; however, only after subjects ‘practiced’ pronouncing the target words in specifically created context sentences, and the semantically neutral frame sentence *“I said* ________ *this time”,* as well as receiving ‘training’ on the role of stress shift in minimal stress pairs (For further details, read Zhang et al., 2008, .4501). This yielded 560 tokens (14 words x 2 repetitions x 20 subjects) to be analyzed instrumentally and perceptually. In addition, Zhang et al. collected and compared acoustic vowel space data using an adaptation of Peterson and Barney’s (1952) data collection approach of measuring F_1 and F_2 values. The procedures for this portion of their study will not be discussed as they are beyond the scope of this thesis. The precise details of the recording equipment and environment used by Zhang et al. are, however, of relevance to this paper. The researchers indicated that:

> All recordings took place in a single-walled sound-attenuated booth and were made using a digital audio recorder (SONY DAT, TCD-D8), Studio V3 amplifier, and a unidirectional Hypercardiod dynamic microphone (Audio-Technica D1000HE). The microphone was placed approximately 20 cm from the speaker's lips at an angle of 45° (horizontal) during recording. The speech tokens were sampled at a rate of 44.1 kHz with a quantization of 16 bits and low-pass filtered at 22.05 kHz. Each token was then saved as an individual sound file and normalized to a RMS amplitude of 70 dB using Praat 4.3 […]. (p. 4501)

Although Zhang et al. (2008) also used subjective acceptability ratings of accentedness, in this paper the interest is focused on how they performed their acoustic measurements of the parameters of stress using the Praat acoustic analysis software. Unlike in the previously described study by Lee and Cho (2011) where the correlates of intensity and F0 were measured within a vowel, Zhang et al. (2008) measured them within a syllable. Therefore, it is useful to know how Zhang et al. used spectrogram and waveform cues to segment syllable boundaries according to Peterson and Lehiste's (1960) segmentation criteria:

> Syllable (and vowel) boundaries were segmented according to the following criteria: (1) word/syllable 1 onset: The first upward-going zero crossing at the beginning of the waveform; (2_) word/syllable 2 offset: The ending point of the sound waveform at the last downward-going zero crossing; (3) syllable 1 offset/syllable 2 onset: In words with a stop consonant as the onset of the second syllable (such as *rebel, contract, object, subject, record*), this was defined at the beginning of the silence of the stop gap. In words with no medial stop consonant (*permit, desert*), then the boundary was marked as the transition between the acoustic (spectrographic) pattern of the initial consonant of the second syllable and the segment immediately preceding it. (p. 4503)

Zhang et al. (2008) then explained how they measured the three correlates of stress based upon these syllabic segmentations:

> [S]yllable (and vowel) durations were calculated in millisecond increments […]. The average intensity measure was calculated as the mean of multiple intensity values extracted and smoothed over the number of time points necessary to capture the minimum predicted pitch of each individual participant. F0 measures were measured as the average value over the entire syllable, and were computed using a Hanning analysis window and the autocorrelation method described in Boersma (1993). When measuring F0, the pitch range for female talkers was set to 100–500 Hz and 75–300 Hz for male talkers, as recommended in the Praat manual. (p. 4503)

In their acoustic data analysis of the measured variables, Zhang et al. (2008) used similar statistical techniques to Lee and Cho (2011). A mixed factorial ANOVA was performed with stress (stressed vs. unstressed) as the within-subjects variable, and L1 and gender as the between-subjects variables. Then *post hoc* (Tukey HSD) tests were performed, all with a critical *p* value of 0.05.

The results of Zhang et al.'s (2008) study indicated that while Mandarin speakers did utilize all four acoustic correlates of duration, intensity, F0, and vowel quality, to differentiate between stressed and unstressed syllables, they exhibited significantly less native-like stress patterns. Interestingly, Mandarin and English speakers' use of duration and intensity were found to be similar for both stressed and unstressed syllables, but Mandarin L1 speakers produced stressed syllables with a higher F0 than NES. With respect to their acoustic vowel space study, Zhang et al. report that there were "significant differences in formant patterns across groups, such that Mandarin speakers produced English-like vowel reduction in certain unstressed syllables, but not in others" (p. 4498). In their conclusion, the researchers propose that both L1 experience with Mandarin lexical tones and various dissimilarities in Mandarin and English vowel inventories may adversely affect Mandarin speakers' productions of English lexical stress contrasts.

Another study, by Keating and Kuo (2012), also found F0 profiles to differ between English and Mandarin although this was dependent upon speech context. While Mandarin speakers' usage of F0 in simulated "tone sweeps" (p. 1051) was very similar to NES, their usage of F0 in one-word utterances was markedly different. That is, Mandarin speakers produced higher F0 and larger ranges of F0 than NES. Also, although the two language groups were closer in their productions of read prose passages, Mandarin speakers had a higher mean value of F0.

Barto-Sisamout (2011) highlighted another difference between English and Mandarin usage of F0 contours. She states that in English, there is a "pitch peak delay where the F0 peak occurs after the stressed syllable in two-syllable stress-initial words" (p. 2553), whereas in Mandarin, the F0 peak actually falls on the stressed syllable. According to Barto-Sisamout, this is owing to the fact that tone languages use F0 contours lexically. With this in mind, it will be interesting to observe whether the presence and absence of a pitch peak delay can be detected in productions of the stem-word token <HIStory> (See Method section) by NES and Mandarin L1 NNES, respectively.

Li and Shuai (2011) examined the suprasegmental features of Chinese-accented English by examining the prosodic correlates of syllable duration and F0 in read speech. They found that mean syllable duration of Mandarin L1 speakers was greater than for NES, while NES produced a much wider pitch (F0) range. This is seemingly in conflict with Keating and Kuo's (2012) findings that showed Mandarin L1 speakers to have a larger pitch range than NES. In congruence with other researchers, Li and Shuai propose that the tone systems of Mandarin and Cantonese are responsible for the prosodic deviations in Chinese learners' English. Incidentally, Mandarin speakers were found to be more similar to NES than Cantonese speakers.

Finally, the results of Jia, Strange, Wu, Collado, and Guan's (2006) study of Mandarin L1 speakers' imitations of American vowels in disyllabic elicitation tokens suggest that age and amount of L2 immersion both impact production accuracy. The researchers maintained that their findings can be explained by a combination of the "Environmental and L1 Interference/Transfer theory" which postulates a "long-term younger-learner advantage in mastering L2 phonology" (p. 1128).

In this paper, the researcher intends to explore whether amounts of L2 input and exposure show any correlation with accuracy of stress placement and/or acoustic correlate production in the data collected in this thesis.

Acoustic Studies on Arabic L1

Nnes' Productions of Stress

Zuraiq and Sereno (2005) analyzed the production of lexical stress by NES and Jordanian Arabic L1 speakers by conducting two experiments. The first experiment followed Fry's (1955, 1958) methodology by inspecting acoustic cues to lexical stress in recordings of English minimal-stress pairs. In accordance with other studies mentioned thus far, stressed vowels were compared to unstressed reduced vowels. Zuraiq and Sereno (2005) selected four acoustic correlates to examine; i.e., F0, duration, intensity, F_2. A Two-way Repeated Measures ANOVA was administered to examine the factors of *stress* (first syllable vs. second syllable stress) and *speaker* (NES vs. Arabic L1 NNES) for each of the four acoustic cues.

The results showed that NES consistently employ all four correlates to signal stress, with reduced F0, duration, intensity, and vowel quality for unstressed syllables. Intriguingly, although Arabic L1 NNES were similar to NES in their usage of duration and intensity parameters, they (like Mandarin speakers) used a larger range of F0 contours to differentiate lexical stress. In addition, F_2 value analysis revealed that Arabic L1 NNES did not reduce unstressed vowels.

Zuraiq and Sereno (2005) conducted a second experiment, this time using Arabic disyllabic minimal stress pairs, with the purpose of examining the acoustic correlates of stress used by Arabic speakers in their L1. Their findings indicated that Jordanian Arabic speakers consistently use F0, duration, and intensity to cue stress in Arabic words, but do not reduce vowels in their L1 either. The researchers therefore hypothesized that Arab learners of English “over-use fundamental frequency cues” to compensate for not reducing vowels in unstressed syllables (p. 4).

Bouchhioua’s (2008) study, which also used minimal-stress pairs, found that duration is not an important correlate of lexical stress in Tunisian Arabic as it is in English. In this language, duration appears only to signify accent. However, this difference in native system stress properties did not seem to result in negative transfer. Bouchhioua (2008) reported that Tunisian Arabic speakers produced significant and contextually appropriate durational contrasts between stressed and unstressed syllables in English words. That said, there was evidence to explain nonnative accentedness. Seemingly, participants did routinely produce longer English segments and words than NES, which as Bouchhioua (2008) suggests, “may reveal their non-nativeness” (p. 535).

From the studies mentioned in the previous two sections, it would appear that, unlike Korean L1 and Japanese L1 NNES who respectively produce the acoustic correlates of duration and intensity in a nonnative-like manner, Mandarin L1 and Arabic L1 NNES produce F0 in a nonnative-like manner. That is, the production of the acoustic cues of duration and intensity do not seem to be so problematic for these two groups of NNES. Therefore, this study seeks to observe whether similar results can be obtained in the productions of stress in *polysyllabic* Level 1 [+cyclic] derivations.

Chapter III: Methodology

Restatement of Research Questions

1) Do English Level 1 [+cyclic] suffixes such as <ious>, <ial>, <ian>, <ic>, <ical>, <ity>, and <ify> cause a shift in stress when spoken by native speakers of MWAE, and can this be observed quantitatively using acoustic measurements of F0, duration, and intensity?
2) What is the salience hierarchy of the three acoustic correlates of stress (SHACS) in productions of polysyllabic Level 1 [+cyclic] derivations by native speakers of MWAE?
3) How do NNES of different L1 backgrounds (i.e., Arabic and Mandarin) order the correlates of stress similarly or differently to NES?
4) Which acoustic correlates are problematic for Arabic L1 and Mandarin L1 speakers when producing lexical stress contrasts in Level 1 [+cyclic] derivations?
5) Is there a correlation between amount of L2 exposure (years of residence in L2 environment) and/or amount of L2 input (years of L2 study) and *accurate production* of the three acoustic cues? I.e., do these variables show a large effect in:
    a) Accurate placement of stress in Level 1 [+cyclic] derivations.
    b) Native-like production of the acoustic correlates of stress in Level 1 [+cyclic] derivations.
6) Do some stress-shifting suffixes behave idiosyncratically with regards to standard American English dictionary pronunciations?
7) Is there a major pitch change (i.e., a shift in *tonic accent*) from the secondary stressed syllable (i.e., the primary stressed syllable in the stem word) to the primary stressed syllable in Level 1 [+cyclic] derivations as claimed by Ladefoged and Johnson (2010, p.119)?

Participants

One hundred participants including 29 MWAE NES (male n = 15; female n = 14), 38 Arabic L1 NNES (male n = 15; female n = 23) from the Kingdom of Saudi Arabia (KSA), and 33 Mandarin L1 NNES (male n = 15; female n = 18) from the People's Republic of China (PRC) participated in the experiment. The author recruited subjects from the student population of the Intensive English Program (IEP), the College ESL program, and the regular undergraduate and graduate student body of a large public university in Minnesota. Additionally, subjects were selected from the local population. This study only used NNES who grew up speaking MWAE dialect, predominantly in Minnesota, and to a lesser extent Wisconsin and Michigan. Prior to acoustic data elicitation, each participant completed a short "factual" (Dörnyei, 2003, p. 8) questionnaire in order to gather the relevant sociometric data for answering the research questions (Appendix A). Figure 6 shows the total number of subjects by language and gender, while Figure 7 shows participants by L1 and proficiency level.

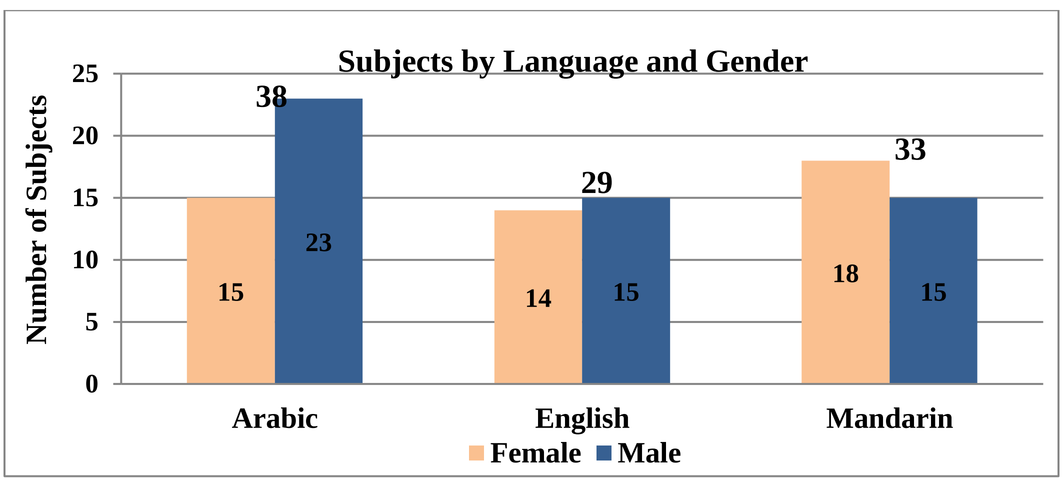


Figure 6. Participants by Language and Gender

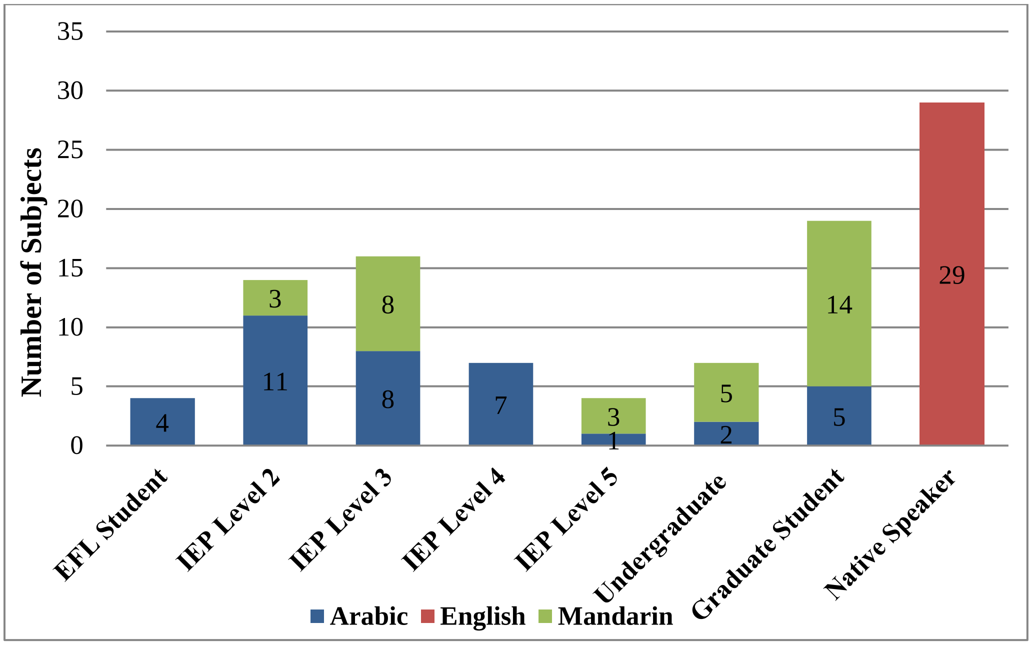


Figure 7. Participants by L1 and English Proficiency Level

Materials

Stimuli. The procedure involved a total of eight tokens including the stem word <HIStory> in addition to seven derived words formed by the addition of seven different stress-shifting suffixes: <hisTORic>, <hisTORical>, <histoRICity>, <hisTORian>, <hisTORify>, <hisTORial>, and <HisTORious>. Although <historial> is obsolete nowadays, and <Historious> is a proper noun (i.e., the name of an internet search engine at http://demo.historio.us/search/), they would suffice for the purposes of this experiment.

Since the same stem was used for all tokens, it was easier to compare the effects of each of the suffixes. Significantly, tokens beginning with /h/ were chosen because this glottal fricative is conventionally employed as the onset of stimuli due to having minimal effects on the proceeding vowels (Koffi, personal communication, March 27, 2013).

Additionally, Post and Nolan (2012) state: "For data to be quantifiable, any variation that is extraneous to the question at hand needs to be factored out or controlled for" (p. 543). Therefore, to control for the moderator variable of suffix frequency, each of the Level 1 [+cyclic] suffixes used has approximately the same corpus frequency of around one percent or less (Carroll et al., 1971; White et al., 1989). Consequently, <-tion>, which has a frequency of around four percent (White et al., 1989) was not used in this study.

Participants produced the eight tokens randomly from the list in the carrier phrase *"Say __________ again".* The carrier phrase was designed so that the words did not carry an onset rise or a pitch accent. According to Maeda (1976), an onset rise occurs at the start of a prosodic phrase, and a pitch accent denotes the main stress in the prosodic phrase. The latter's location can vary depending on whether there is contrastive or emphatic stress. In this case, *"Say"* carries the onset rise, and *"again"* carries the pitch accent.

Recording equipment and environment. The author made all recordings with an Olympus WS-710M Digital Voice Recorder inside a quiet room on campus[3]. In accordance with Zhang et al.'s procedure (2008), the recorder's microphone was situated roughly 20 cm from the informants' lips at an angle of 45 degrees.

Each of the tokens was recorded as an individual sound file. These files were converted from stereo .mp3 files into mono .wav files using Switch Sound File Converter Plus, Version 4.27 by NCH Software at a sampling rate of 44.1 kHz and quantization of 16 bits – the norm criteria for microphone speech in acoustic phonetic studies (Jurafsky & Martin, 2008).

[3] Although the university has a sound-attenuated booth, it was not practicable to use this due to the large number of participants and its distance from the main recruitment location. However, following the recommendations of Plichta (2004), low-frequency noise was reduced as much as possible in the recording room by switching off all electrical appliances that would otherwise cause background hum.

Procedure

Data collection. The procedure used in this study followed the elicitation techniques employed in the classic experiments of Fry (1955, 1958) and Liberman and Pierrehumbert (1984). As Post and Nolan (2012) attest, “Read utterances have been widely used in prosodic research as they allow complete control over parameters relevant to discourse status and number of pitch accents, down to the segmental constituency of relevant syllables, and they facilitate auditory and acoustic analysis” (p. 546). In addition, Ladefoged and Johnson (2010) advise that stress is more readily identifiable in “citation forms” (p. 111).

The researcher showed the eight tokens to the participants on eight separate cards. These cards were shuffled before each elicitation session to eliminate any potential ordering effects. Cowart (1997) provides details on the necessity of randomization and test order in experimental design in applied linguistics. Prior to recording, the participants did not receive any training on the pronunciations of the tokens. The rationale is that they would have to rely upon their phonological knowledge of where to shift the primary stress in the derived tokens.

Data analysis. Acoustic phonetic analyses of the productions were performed in a similar methodology to Flege and Bohn (1989), Zhang et al. (2008), and Lee and Cho (2011) using *Praat* (Version 5.3.31). However, to the best of the author’s knowledge, the proposed method of comparing vowels was novel in that the acoustic correlates in vowels with primary stress were examined in relation to those of *all* the other vowels in the utterance–as opposed to just one of the unstressed vowels (e.g., Flege & Bohn, 1989; Lee & Cho, 2011). In other words, the [+tonic acc.] vowel in each token was acoustically compared to the [-tonic acc.] vowel (Ladefoged, 2001a; See Appendix B). The rationale being, that if a vowel has primary stress, the acoustic cues should be prominent to all the other vowels in word.

Praat scripts were used to semi-automate delineation of vowels (Ryan, 2005) and retrieve the relevant stress analysis data (Yoon, 2008). In total, 2125 vowels were analyzed (excluding errors). First, the grid-maker script was run and vowel segments were defined in the series of spectrogram using an expanded time scale by utilizing Praat's zoom manipulation tool (Appendix C). According to Zhang et al.'s (2008) methodology, when measuring F0, the pitch range for female and male subjects was set to 100–500 Hz and 75–300 Hz, respectively. As Bird and Wang (2012) prescribe, adjusting the pitch settings has the advantage of producing a "much clearer pitch contour" (p. 61).

Once all the spectrograms had been annotated, Yoon's stress analysis script (2008) was run to collect the vocalic mean F0, mean intensity, and duration values. The script utilizes the autocorrelation function of Hanning windows to calculate the mean value over the whole vowel (Boersma & Weenink, 2013). Thus, each individual production was measured for the mean F0 of the primary stressed vowel and the mean of the mean F0 values for all the other vowels (i.e., secondary stressed and unstressed). Similarly, the mean intensity of the stressed vowel and the average of the mean intensity values of all the remaining vowels were measured. Finally, the duration of the primary stressed vowel versus the mean duration of the other vowels were measured. Table D1 shows a sample data log for one Chinese male speaker (Appendix D).

Then, in order to answer *Research Questions 1* and *2,* the corresponding primary stressed to unstressed/secondary-stressed vowel ratios (i.e., [+tonic acc.] : [-tonic. acc] ratio) were calculated for each token to provide *vocalic relative stress values* for duration, intensity, and F0. This concurs with McClean and Tiffany (1973), Flege and Bohn (1989), and Lee and Cho's methodology (2011). As McClean and Tiffany stated:

> In reporting the effects of loudness and rate on the acoustic nature of stress, the primary concern is with the degree of contrast between stressed and unstressed syllables. Thus data is reported [here] in simple ratios of the stressed to unstressed syllabic acoustic magnitudes. (p. 288)

Then paired sample t-tests with a significance level of $p < 0.05$ were used to statistically compare the mean F0, duration, and intensity values *within* each speaker group for the primary-stressed [+tonic] vowels in each token (*P*) to the mean average of the values for all the other [-tonic] vowels (*All*). *P vs. All* t-tests were conducted for each token individually and for all the Level 1 [+cyclic] derivations combined in one group. In addition, Cohen's *d* effect sizes were calculated using the mean scores and standard deviations for each group, since paired t-test values cannot be used for computing effect sizes (Becker, 2000). Oswald and Plonsky (2010) recommend the following criteria for interpreting effect sizes in the field of applied linguistics: *d* = .4 is small, *d* = .7 is medium, and *d* = 1.0 is large. The formula used for computing Cohen's *d* effect sizes was:

$$\text{Cohen's } d = M_1 - M_2 / s_{pooled}$$

$$\text{where } s_{pooled} = \sqrt{[(s_1^2 + s_2^2) / 2]}$$

r_{Yl} = d / √(d² + 4)

Note. d and r_{Yl} are positive if the mean difference is in the predicted direction (Becker, 2000, ¶2).

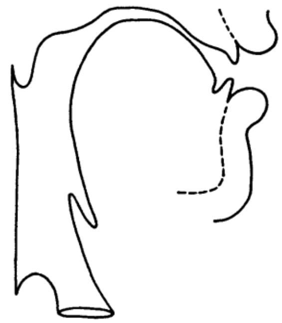
The purpose of these t-tests was to determine whether there was a statistically significant difference between *P* and *All* with regards to the three acoustic cues to stress. Any significance would signify that a stress-shift had indeed occurred and also provide insight into the nature of SHACS (i.e., *Research Questions 1 and 2*).

In order to answer *Research Question 2, 3, 4,* and *5b*, the researcher followed the statistical methods employed by Zhang et al. (2008) and Lee and Cho (2011). To determine whether there was a statistical significance in the differences between the mean ratios of stressed to unstressed vowels for the independent variable of L1 background, the mean ratio of each acoustic factor was submitted to one-way ANOVAs. In addition, Tukey HSD tests were performed with a critical *p* value of 0.05.

At this point, it is important to note that not all of the data collected were included in the aforementioned calculations. If a token was mispronounced by a subject, it was categorized as either a *stress placement error* or a *pronunciation error* and entered into a separate data pool. The latter error type may also include stress placement errors but is deemed more serious with regards to intelligibility as it (also) includes a deletion, and/or addition, and /or substitution of a segment or cluster of segments. Appendix E provides examples of these two different error types. Naturally, any productions containing errors had to be excluded from the main dataset as it would not be a fair test to compare the vocalic relative stress values in words which have been pronounced differently. However, this data was useful to answer *Research Question 5a*. Pearson Product-Moment Correlations were used to determine the strength of relations and effect sizes (*r* values) (Mackey & Gass, 2005) for the operationalized variables of L2 exposure (Years of residency in L2 environment) and L2 input (Years of L2 study). The results from these tests can be triangulated to draw conclusions about possible relationships between native-like stress production and L2 learner experience.

Research Question 6 asks whether any Level 1 [+cyclic] derivations behave idiosyncratically with regards to standard pronunciations given in dictionaries. While analyzing the spectrograms, the acoustic phonetic researcher became aware of a ubiquitous deviation from the dictionary IPA transcription of <historian>: instead of [hɪˈstɔriən] (as stated on Dictionary.com, 2013), many NES and NNES clearly produced an epenthetic palatal glide, /j/, in the ultima, giving [hɪˈstɔri**j**ən]. Furthermore, although no IPA transcriptions for <historial> and <historious> are available in dictionaries, one can reason that the pronunciations would be minimal pairs of [hɪˈstɔriən], and therefore pronounced as [hɪˈstɔriəl] and [hɪˈstɔriəs] respectively. These assumptions are based on knowledge of Level 1[+cyclic] phonological rules and the effects of these two suffixes on other stem words such as <janitorial>, pronounced [dʒæn ɪˈtɔriəl], and <victorious>, pronounced [vɪkˈtɔriəs]. Interestingly, however, there was also a high incidence of /j/ insertion in productions of the suffixes in these two tokens.

A production was adjudged to contain the approximant based on a number of acoustic phonetic factors. Although /j/ has similar formants to the preceding vowel, /i/, the amplitude is generally weaker due to constriction of the vocal tract albeit without the turbulence associated with a greater degree of constriction in other consonants (Maddieson & Emmorey, 1985; "Acoustic Properties of Speech Sounds", 2000). This is the reason why glides are also known as "semi-vowels" and "frictionless continuants" ("Speech Acoustics," 2008). Figure 8 illustrates that in the pronunciation of [j], the velum is raised and the tongue assumes a half-front close position (adapted from "Acoustic Properties of Speech Sounds" by MIT, 2008, slide 21).



[j]

Figure 8. Articulation of a Palatal Approximant

The acoustical consequences of these articulatory features are very low F1 (200 - 300Hz) and high F2 (1850-2100Hz) formant patterns similar to /i/ ("Acoustic Properties of Speech Sounds," 2000; “Speech Acoustics,” 2008). However, one of the defining characteristics of /j/ is that the weaker airflow caused by the slight constriction results in lower amplitude and produces a lighter F1 band on spectrograms as compared with /i/ (“Phonetics and Theory,” 2013). This constriction in the articulation of /j/ also generally results in a higher F3 range (2620-3050Hz) than for /i/ (“Speech Acoustics,” 2008). Perhaps more revealing in the identification process are the “gliding components or transitions between adjacent sounds” (“Speech Acoustics,” 2008, ¶7). These are similar to the transitions which occur when one produces a diphthong except the transition period is more rapid (“Speech Acoustics,” 2008). Thus, as with diphthongs, palatal glides are relatively easy to identify in spectrograms as can be seen in the examples in Appendix F. For classification purposes, the researcher considered a combination of two or more of the aforementioned acoustic features to be evidence of palatal glide epenthesis in the ultima. The number of productions with and without /j/ were then tallied to indicate the proportion of productions with /j/ epenthesis in contrast to those with ‘regular,’ standard dictionary pronunciation (without /j/) for <historian>, <historial>, and <historious>.

Finally, in order to answer *Research Question 7* about the role of “tonic accent shift” (Ladefoged & Johnson, 2010, p. 119), the values of mean F0, intensity, and duration were gathered for both the [+tonic, +stress] primary-stressed vowel (*P*) and the [-tonic, +stress] secondary-stressed vowel (*S*) in each token using the acoustic correlate data already retrieved from running the aforementioned stress-analysis Praat script (Yoon, 2008). Then *P* was statistically compared to *S* for each token *within* the MWAE NES group with regards to the three acoustic correlates using post-hoc paired samples t-tests with a significance level of $p < 0.05$.

In the proceeding results section, the subcategorized pronunciation and stress placement error dataset used to answer *Research Question 5a* shall be dealt with first.

Chapter IV: Results

Pronunciation and Stress Placement Errors

Research question 5a. Figure 9 shows the percentage of errors for each language group. As one would expect, the NES made far fewer errors. For NNES, pronunciation errors were more common than stress placement errors; of course, the reader is reminded that pronunciation errors may also contain stress placement errors.

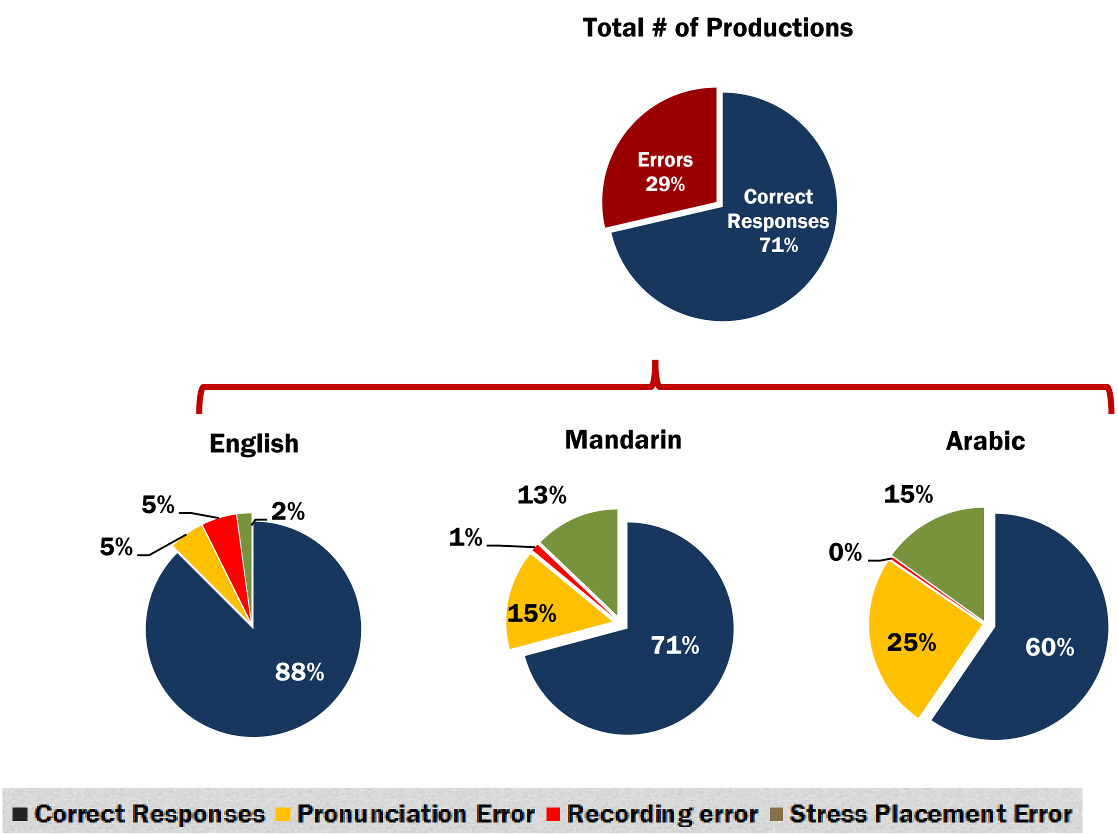


Figure 9. Proportion of Error Types for Each Language Group

Figure 10 shows the percentage of correct responses by token and language group. Also, as one might expect, <historicity> caused the most problems. In fact, NES were no better at accurately producing this word than Mandarin speakers. However, it is important to note that for the two nonsense words (i.e., <historious> and <historial>), the NES performed much better. It is the researcher's contention that although these are not real words, NES were able to use the stress-shifting rules that are stored in the lexicon.

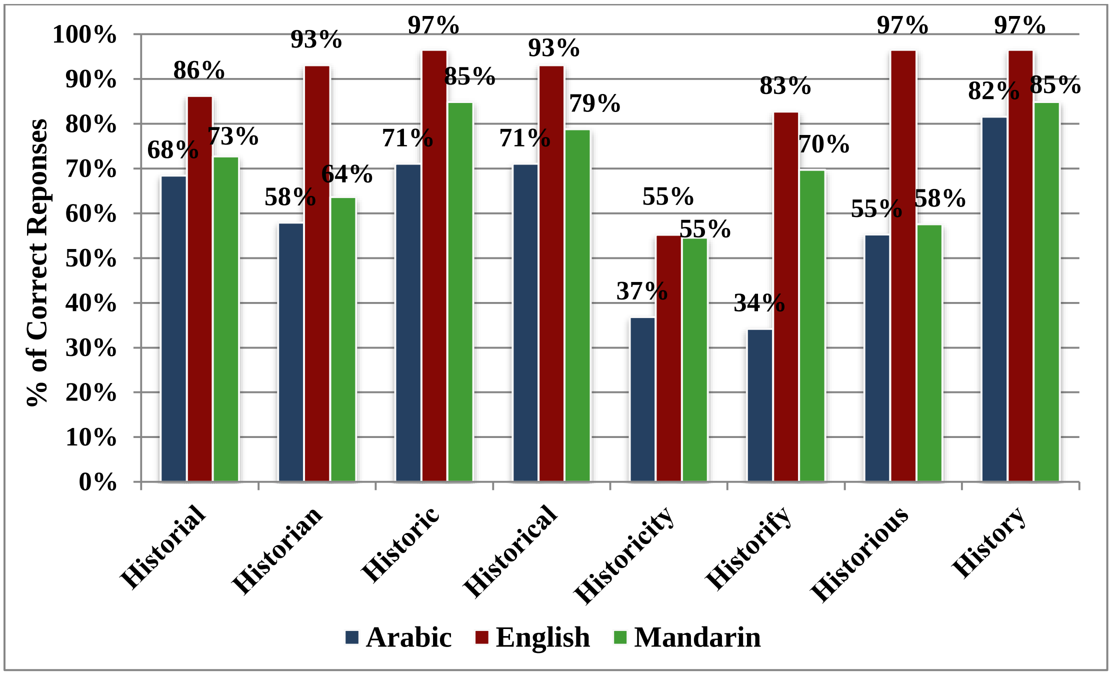


Figure 10. Proportion of Correct Responses by Token and Language Group

In Figure 11, the frequency of errors (pronunciation and stress placement) in the production of the seven Level 1 [+cyclic] derivations (i.e., excluding <history>) for all NNES (Arabic and Mandarin L1 speakers combined) are plotted against years spent living in an English-speaking environment. No significant correlation was found ($r = 0.09$, p = n.s), perhaps because the study did not have a large enough range of participants with respect to this independent variable. Most of the participants had only spent between 0 and 1.5 years in an English-speaking country owing to the fact that they were selected from a university population.

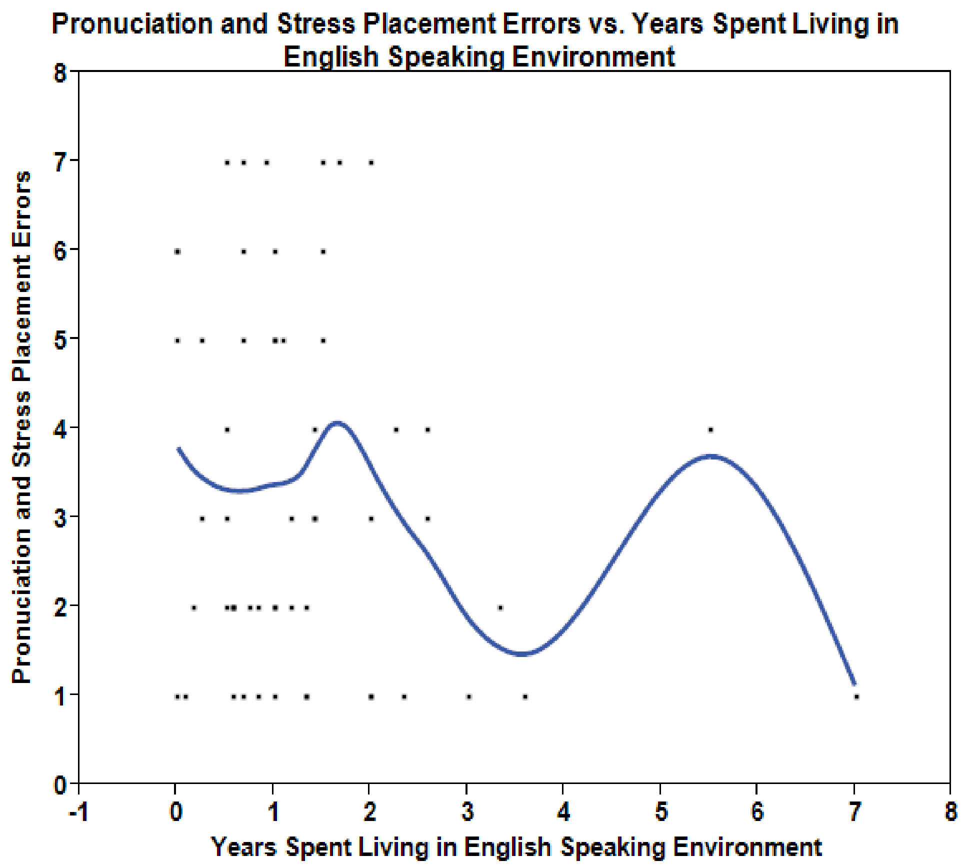


Figure 11. Frequency of Pronunciation and Stress-Placement Errors vs. Years in L2 Environment

However, the smooth curve in Figure 12 shows that a significant correlation was found (*r* = - .26, *p* < .05.) for years of English language study and frequency of errors.

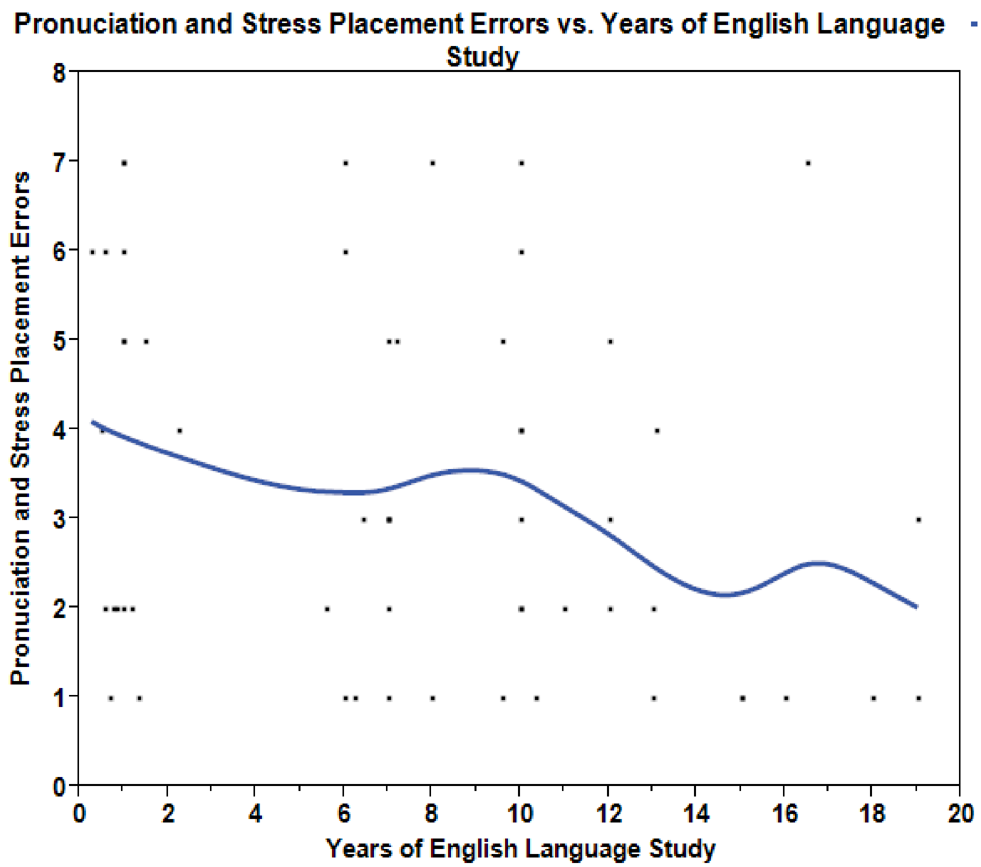


Figure 12. Frequency of Pronunciation and Stress-Placement
Errors vs. Years of L2 Study

Table 6 provides a recapitulation of the operationalized proficiency levels from Level 1 (= EFL student) to Level 8 (=native speaker), and the number of subjects within each group. This sociometric data will be employed in correlations of number of pronunciation and stress placement errors versus proficiency level. Naturally, one would expect the number of errors to decrease as the level increases.

Table 6. Number of Participants by Operationalized Proficiency Levels

Level	Proficiency	Arabic	English	Mandarin	Total
1	EFL Student	4			4
2	IEP Level 2	11		3	14
3	IEP Level 3	8		8	16
4	IEP Level 4	7			7
5	IEP Level 5	1		3	4
6	Undergraduate	2		5	7
7	Graduate Student	5		14	19
8	Native Speaker		29		29

Figure 13 shows the number of pronunciation and stress placement errors in Level 1 [+cyclic] productions plotted against proficiency levels 1 to 8 for all non-native speakers (i.e., Arabic and Mandarin L1 NNES). There was a significant correlation between the two variables (r = -0.53, p < 0.00). Therefore, as one would expect, NNES produce fewer errors, the higher their level of English proficiency.

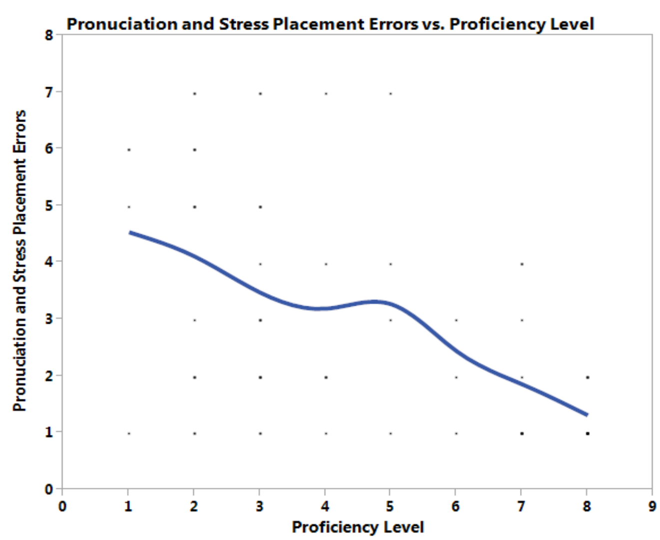


Figure 13. Frequency of Pronunciation and Stress-Placement Errors vs. English Proficiency Level

Main Dataset

Research questions 1, 2, 3, and 4. Table 7 shows the mean vocalic stress ratios for the three acoustic correlates of stress for all three language groups. On average, all 3 language groups produced primary-stressed vowels with higher F0, greater intensity, and longer duration. However, for each factor, the ratios were larger for English speakers than Mandarin and Arabic speakers. Thus, even though the NNES were differentiating the stress in suffixed words, they did not do so to such a great extent as NES.

Table 7. Mean Relative Stress Ratios of Primary [+tonic acc.] to
Non Primary Vowels [-tonic acc.] for the Three Acoustic Correlates by Language Group

Language Group	F0	SD	Intensity	SD	Duration	SD
Arabic	1.07	0.30	1.05	0.06	1.29	0.70
English	1.13	0.34	1.06	0.04	1.61	0.63
Mandarin	1.08	0.18	1.04	0.05	1.57	0.58

Acoustic correlates of stress in Midwest US English. Tables 8 to 15 provide the results of the paired sample t-tests for determining whether there was a statistically significant difference between the [+stress] primary-stressed vowel (*P*) and the [-stress] vowels (*All*) in MWAE NES speech for each of the eight individual tokens, plus all seven of the Level 1 [+cyclic] derivations combined.

Table 8 shows that there was no statistical difference between the values of F0 for *P* and *All* in the stem word, <history>, $t\ (27.0) = 1.98$, $p = 0.06$, but there was a small Cohen's *d* effect size ($d = .4$). There are therefore good reasons to think that the primary-stressed vowel in <history> is slightly more prominent to the other vowel(s) in the word with respect to F0, although this should be investigated with a larger sample size to boost the potential of the t-test (Mackey & Gass, 2012). Significantly, the paired samples t-test did find that there was a statistical difference between *P* and *All* with respect to intensity usage, *t* (27.0) = 2.36, *p* <0.05. The Cohen's *d* effect size was, however, very small (*d* = .17). Furthermore, a statistical difference was found between mean duration values in <history> for *P* and *All*, *t* (27.0) = -5.05, *p* < 0.00, and the Cohen's *d* effect size was large (*d* = -1.49). However, the ratio was in the opposite direction as expected from lexical stress theory; i.e., the non-primary [-tonic] vowels were on average much longer than the primary [+tonic] vowel in [hís].This is likely due to the fact that, for most speakers, there are no unstressed [-stress] vowels in <history>, and because the secondary-stressed vowel, [i], in the ultima is a tense vowel as compared to a lax vowel, [ɪ], in [hís] (Fromkin et al., 2011). Regardless, intensity and duration appear to be the most salient cues to lexical stress in the stem word.

Table 8. Paired Sample t-Test Results for P vs. All in
Stem Token <History> for Native English Speakers

<history>	Mean	SD	N	*p-value*	*t-statistic*	*df*
F0 of P	190.93 Hz	61.59	28.00	0.06	1.98	27.00
F0 of All	166.41 Hz	60.42	28.00			
Intensity of P	72.98 dB	7.05	28.00	0.03	2.36	27.00
Intensity of All	71.71 dB	7.67	28.00			
Duration of P	65.25 ms	11.65	28.00	0.00	-5.05	27.00
Duration of All	104.63ms	35.64	28.00			

Table 9 shows that there was a statistically significant difference between the values of F0 for *P* and *All* in <historial>, *t* (24.0) = 3.55, *p* < 0.00, and there was a small Cohen's *d* effect size (*d* = .5). Likewise, there was a significant statistical difference between the intensity values of *P* and *All*, *t* (24.0) = 8.17, *p* < 0.00, and a small Cohen's *d* effect size (*d* = .5). Additionally, *P* was significantly different from *All* with respect to duration, *t* (24.0) = 13.32, *p* < 0.00, and there was a very large effect size (Cohen's *d* = 3.5) indicating that duration was also an important cue to stress in this token. In fact, the difference between the means of *P* and *All* was greater than three standard deviations. Clearly, all three acoustic correlates play a significant role in differentiating lexical stress in this token.

Table 9. Paired Sample t-Test Results for P vs. All in
<Historial> for Native English Speakers

<historial>	Mean	SD	N	*p-value*	*t-statistic*	*df*
F0 of P	174.14 Hz	50.00	25.00	0.00	3.55	24.00
F0 of All	153.39 Hz	38.19	25.00			
Intensity of P	75.03 dB	6.11	25.00	0.00	8.17	24.00
Intensity of All	71.63 dB	7.20	25.00			
Duration of P	123.68 ms	23.40	25.00	0.00	13.32	24.00
Duration of All	60.82 ms	9.83	25.00			

Table 10 shows that there was no statistical difference between the values of F0 for *P* and *All* in <historian>, *t* (26.0) = 1.12, *p* = n.s, although there was a small Cohen's *d* effect size (*d* = .2). However, there was a significant statistical difference between the intensity values of *P* and *All*, *t* (26.0) = 7.88, *p* < 0.00, and a medium Cohen's *d* effect size (*d* = .6). Additionally, *P* was significantly different from *All* with respect to duration, *t* (26.0) = 13.89, *p* < 0.00, and there was a very large effect size (Cohen's *d* = 3.4) indicating that duration was over three standard deviations greater in P. Of course, numerical differences between the three correlates cannot be directly compared based on effect sizes alone since they are measured in different units, and, more importantly, perceived in different manners by human ears. Notwithstanding, intensity and duration seem to be especially important cues to stress in this token.

Table 10. Paired Sample t-Test Results for P vs. All in <Historian> for Native English Speakers

<historian>	Mean	SD	N	*p-value*	*t-statistic*	*df*
F0 of P	178.38 Hz	49.82	27.00	0.27	1.12	26.00
F0 of All	168.00 Hz	62.77	27.00			
Intensity of P	75.20 dB	6.09	27.00	0.00	7.88	26.00
Intensity of All	70.70 dB	7.69	27.00			
Duration of P	130.02 ms	24.98	27.00	0.00	13.89	26.00
Duration of All	64.53 ms	11.71	27.00			

Table 11 shows that there was no statistical difference between the values of F0 for *P* and *All* in <historic>, t (27.0) = 1.06, p = n.s, and there was a small Cohen's d effect size (d = .2). Conversely, there was a significant statistical difference between the intensity values of *P* and *All*, t (27.0) = 10.15, $p < 0.00$, and a moderate Cohen's d effect size (d = .7). Furthermore, *P* was significantly different from *All* with respect to duration, t (27.0) = 8.32, $p < 0.00$, and there was a very large effect size (Cohen's d = 2.1) indicating that duration was more than two standard deviations greater in the primary-stressed vowel. Thus, duration and intensity appear to be the important cues to stress in this token.

Table 11. Paired Sample t-Test Results for P vs. All in
<Historic> for Native English Speakers

<historic>	Mean	SD	N	*p-value*	*t-statistic*	*df*
F0 of P	173.95 Hz	57.35	28.00	0.30	1.06	27.00
F0 of All	162.35 Hz	64.10	28.00			
Intensity of P	75.16 dB	6.52	28.00	0.00	10.15	27.00
Intensity of All	70.46 dB	7.20	28.00			
Duration of P	108.11 ms	25.92	28.00	0.00	8.32	27.00
Duration of All	62.71 ms	15.73	28.00			

Table 12 shows that there was a statistical difference between the values of F0 for *P* and *All* in <historical>, *t* (26.0) = 3.98, *p* < 0.00, and there was a small Cohen's *d* effect size (*d* = .4). Additionally, there was a significant statistical difference between the intensity values of *P* and *All*, *t* (26.0) = 9.68, *p* < 0.00, and a medium Cohen's *d* effect size (*d* = .6). Moreover, *P* was significantly different from *All* with respect to duration, *t* (26.0) = 7.73, *p* < 0.00, and there was a very large effect size (Cohen's *d* = 1.9).

Table 12. Paired Sample t-Test Results for P vs. All in
<Historical> for Native English Speakers

<historical>	Mean	SD	N	*p-value*	*t-statistic*	*df*
F0 of P	185.05 Hz	58.56	27.00	0.00	3.98	26.00
F0 of All	161.87 Hz	45.15	27.00			
Intensity of P	75.62 dB	7.00	27.00	0.00	9.68	26.00
Intensity of All	71.22 dB	7.83	27.00			
Duration of P	103.50 ms	22.65	27.00	0.00	7.73	26.00
Duration of All	68.21 ms	12.02	27.00			

Table 13 shows that there was no statistical difference between the values of F0 for *P* and *All* in <historicity>, *t* (15.0) = 0.29, *p* = n.s, and there was a negligible Cohen's *d* effect size (*d* = .0). Additionally, there was no significant difference between the intensity values of *P* and *All*, *t* (15.0) = 1.89, *p* = n.s, and a very small Cohen's *d* effect size (*d* = .2). Conversely, *P* was significantly different from *All* with respect to duration, *t* (15.0) = -5.54, *p* < 0.00, and there was a very large effect size (Cohen's *d* = -2.0). However, as was the case with <history>, the negative values indicate that the mean average duration of non-primary vowels was greater than the mean duration of the primary vowel. Thus, the precise relationship of the three acoustic correlates to lexical stress-shift in this token is not clear-cut. Suffice it to say, the reason may be related to the *pentasyllabic* form of this word.

Table 13. Paired Sample t-Test Results for P vs. All in
<Historicity> for Native English Speakers

<historicity>	Mean	SD	N	*p-value*	*t-statistic*	*df*
F0 of P	162.07 Hz	53.92	16.00	0.78	0.29	15.00
F0 of All	159.75 Hz	44.39	16.00			
Intensity of P	72.36 dB	6.03	16.00	0.08	1.89	15.00
Intensity of All	70.83 dB	6.31	16.00			
Duration of P	55.01 ms	17.80	16.00	0.00	-5.54	15.00
Duration of All	86.59 ms	14.15	16.00			

Table 14 shows that there was no statistical difference between the values of F0 for *P* and *All* in <historify>, *t* (23.0) = 1.47, *p* = n.s, but there was a small Cohen's *d* effect size (*d* = .3). However, there was a significant statistical difference between the intensity values of *P* and *All*, *t* (23.0) = 8.98, *p* < 0.00, and a moderately large Cohen's *d* effect size (*d* = .7). In addition, *P* was significantly different from *All* with respect to duration, *t* (23.0) = -2.32, $p < 0.05$, and there was a medium effect size (Cohen's *d* = .6), but as with <history> and <historicity>, the ratio was contrariwise to what would be expected. Nonetheless, intensity and negative-duration appear to be significantly involved in the realization of lexical stress in this token.

Table 14. Paired Sample t-Test Results for P vs. All in <Historify> for Native English Speakers

<historify>	Mean	SD	N	*p-value*	*t-statistic*	*df*
F0 of P	184.39 Hz	65.95	24.00	0.15	1.47	23.00
F0 of All	167.78 Hz	36.05	24.00			
Intensity of P	76.08 dB	5.70	24.00	0.00	8.98	23.00
Intensity of All	71.54 dB	6.92	24.00			
Duration of P	103.89 ms	21.32	24.00	0.03	-2.32	23.00
Duration of All	118.38 ms	26.40	24.00			

Table 15 shows that there was no statistical difference between the values of F0 for *P* and *All* in <historious>, *t* (27.0) = 1.00, *p* = n.s, but there was a very small Cohen's *d* effect size (*d* = .2). However, there was a significant statistical difference between the intensity values of *P* and *All*, *t* (27.0) = 9.67, $p < 0.00$, and a medium Cohen's *d* effect size (*d* = .6). In addition, *P* was significantly different from *All* with respect to duration, *t* (27.0) = 11.37, $p < 0.00$. Plus, there was a very large effect size (Cohen's *d* = 3.0) meaning that duration of *P* was three orders of standard deviation greater than the duration of *All*. Again, differences are likely to be greater between units of time (milliseconds) than between units of loudness (decibels) or fundamental frequency (Hertz). Nonetheless, there is good reason to believe that intensity and duration are the more salient acoustic cues to lexical stress in this token.

Table 15. Paired Sample t-Test Results for P vs. All in
<Historious> for Native English Speakers

<historious>	Mean	SD	N	*p-value*	*t-statistic*	*df*
F0 of P	174.16 Hz	47.14	28.00	0.33	1.00	27.00
F0 of All	165.12 Hz	47.30	28.00			
Intensity of P	75.26 dB	6.86	28.00	0.00	9.67	27.00
Intensity of All	70.54 dB	8.00	28.00			
Duration of P	121.47 ms	23.65	28.00	0.00	11.37	27.00
Duration of All	69.61 ms	7.44	28.00			

The bar graph in Figure 14 summarizes the information from the paired-samples t-tests in Tables 8 to 15 by comparing the mean values of F0 in *P* and *All* in each of the eight tokens as produced by MWAE NES. Interestingly, F0 was only significantly different in *P* compared to *All* in <historial> and <historical> although the difference was close to being significant in <history> as well. Notwithstanding, as the graph illustrates, the relative mean F0 of primary-stressed [+tonic] vowels was greater in every token. This indicates that, on average, the primary vowel of each token was prominent due to a higher pitch.

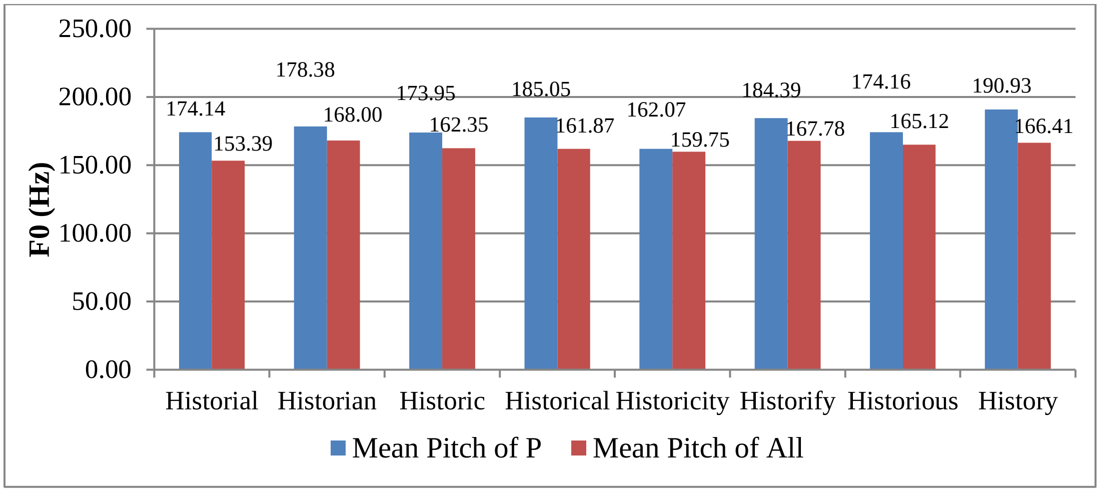


Figure 14. Mean Native Speaker F0 values (Hz) for
Primary-stressed [+tonic] vowels (*P*) and the Mean F0 of all
Non-Primary [-tonic] Stressed Vowels (*All*) per Token

The bar graph in Figure 15 summarizes the information from the paired-samples t-tests in Tables 8 to 15 by comparing the mean values of intensity in *P* and *All* in each of the eight tokens as produced by MWAE NES. The t-tests and post hoc Cohen's *d* effect sizes confirm that the relative intensity of the primary-stressed [+tonic] vowel was statistically greater in all the tokens except <historicity> (although the mean value of *P* was larger than *All* for this token, too). This shows that, on average, the primary vowel of each token was prominently louder.

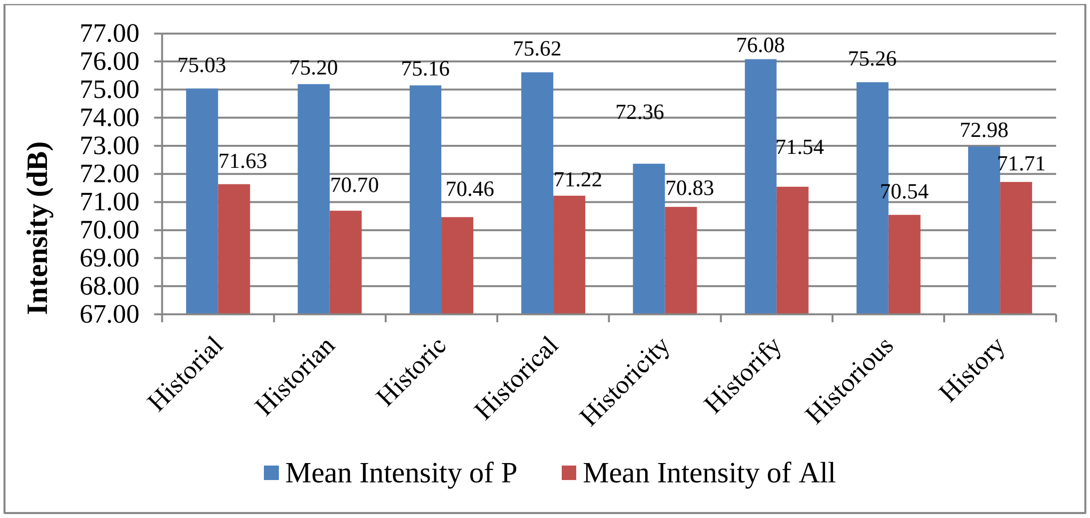


Figure 15. Mean Native Speaker Intensity Values (dB) for Primary-stressed [+tonic] Vowels (*P*) and the Mean Intensity of all Non-primary [-tonic] Stressed Vowels (*All*) per Token

The bar graph in Figure 16 summarizes the information from the paired-samples t-tests in Tables 8 to 15 by comparing the mean values of duration in *P* and *All* in each of the eight tokens as produced by MWAE NES. The results indicate that duration of the primary-stressed [+tonic] vowel was significantly different from the mean average duration of the non-primary [-tonic] vowels for all eight tokens. However, the mean duration of *P* was actually shorter than *All* in <history>, <historicity>, and <historify>. Therefore, on average, the duration of the primary vowel in each token was only prominently longer in five of the tokens.

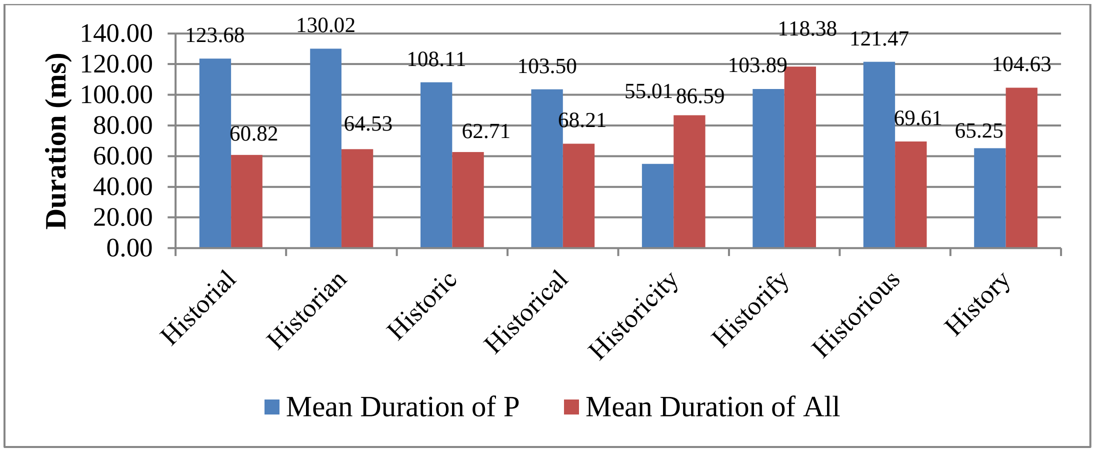


Figure 16. Mean Native Speaker Duration Values (ms) for Primary-stressed [+tonic] Vowels (*P*) and the Mean Duration of all Non-primary [-tonic] Stressed Vowels (*All*) per Token

Acoustic correlates of stress in Arabic L2 English. Tables 16 to 23 provide the results of the paired sample t-tests for determining whether there was a statistically significant difference between the [+stress] primary-stressed vowel (*P*) and the [-stress] vowels (*All*) in Arabic L1 NNES speech for each of the eight individual tokens, plus all seven of the Level 1 [+cyclic] derivations combined.

Table 16 shows that there was no statistical difference between the values of F0 for *P* and *All* in <history>, *t* (30.0) = -0.08, *p* = n.s, and the Cohen's *d* effect size was negligible (*d* = -.0). The negative value of *d* indicates that the mean F0 of *P* was actually slightly lower than *All*. Likewise, there was also no significant statistical difference between the intensity values of *P* and *All*, *t* (30.0) = 0.79, *p* = n.s, and the Cohen's *d* effect size was insignificant (*d* = .1). Additionally, *P* was not significantly different from *All* with respect to duration either, *t* (30.0) = -1.34, *p* = n.s. Again, there was a negligible negative effect size (Cohen's *d* = -.3) meaning that duration of *P* was slightly shorter than *All* on average. Thus, for the stem token, we can conclude that none of the acoustic correlates were important in differentiating lexical stress in the speech of Arabic L1 NNES.

Table 16. Paired Sample t-Test Results for P vs. All in
Stem Token <History> for Arabic L1 Speakers

<history>	Mean	SD	N	*p-value*	*t-statistic*	*df*
F0 of P	186.00 Hz	54.48	31.00	0.94	-0.08	30.00
F0 of All	186.64 Hz	60.25	31.00			
Intensity of P	62.49 dB	10.04	31.00	0.44	0.79	30.00
Intensity of All	61.96 dB	9.88	31.00			
Duration of P	78.16 ms	24.52	31.00	0.19	-1.34	30.00
Duration of All	86.61 ms	32.67	31.00			

Table 17 shows that there was a statistical difference between the values of F0 for *P* and *All* in <historial>, t (25.0) = 2.64, $p < 0.05$, and there was a very small Cohen's *d* effect size (d = .2). Similarly, there was also a significant statistical difference between the intensity values of *P* and *All*, t (25.0) = 6.09, $p < 0.00$, and the Cohen's *d* effect size was small (d = .3). Moreover, *P* was significantly different from *All* with respect to duration, t (25.0) = 5.70, $p < 0.00$, with a large Cohen's *d* effect size of 1.6. Unlike the previous token, all three acoustic correlates appear to play a significant role in the production of lexical stress in <historial> by Arabic L1 NNES.

Table 17. Paired Sample t-Test Results for P vs. All in
<Historial> for Arabic L1 Speakers

<historial>	Mean	SD	N	*p-value*	*t-statistic*	*df*
F0 of P	178.78 Hz	51.32	26.00	0.01	2.64	25.00
F0 of All	168.51 Hz	51.71	26.00			
Intensity of P	65.04 dB	9.41	26.00	0.00	6.09	25.00
Intensity of All	62.33 dB	9.20	26.00			
Duration of P	116.28 ms	40.15	26.00	0.00	5.70	25.00
Duration of All	69.07 ms	14.28	26.00			

Table 18 shows that there was a statistical difference between the values of F0 for *P* and *All* in <historian>, *t* (21.0) = 3.80, *p* < 0.00, and there was a very small Cohen's *d* effect size (*d* = .2). In addition, there was a significant statistical difference between the intensity values of *P* and *All*, *t* (21.0) = 5.40, *p* < 0.00, with a small Cohen's *d* effect size (*d* = .4). Furthermore, *P* was significantly different from *All* with respect to duration, *t* (21.0) = 4.59, *p* < 0.00, with a large Cohen's *d* effect size (*d* = 1.3). As with <historial>, all three acoustic correlates were used by Arabic L1 NNES to produce lexical stress in <historian>.

Table 18. Paired Sample t-Test Results for P vs. All in
<Historian> for Arabic L1 Speakers

<historian>	Mean	SD	N	*p-value*	*t-statistic*	*df*
F0 of P	174.86 Hz	48.32	22.00	0.00	3.80	21.00
F0 of All	163.59 Hz	49.16	22.00			
Intensity of P	64.23 dB	8.85	22.00	0.00	5.46	21.00
Intensity of All	61.10 dB	8.62	22.00			
Duration of P	117.08 ms	48.06	22.00	0.00	4.59	21.00
Duration of All	69.38 ms	14.35	22.00			

Table 19 shows that there was no statistical difference between the values of F0 for *P* and *All* in <historic>, *t* (26.0) = 0.82, *p* = n.s, and there was a very small Cohen's *d* effect size (*d* = .2). However, there was a significant statistical difference between the intensity values of *P* and *All*, *t* (26.0) = 5.98, *p* < 0.00, with a small Cohen's *d* effect size (*d* = .5). Meanwhile, with respect to duration, there was no statistically significant difference between *P* and *All*, *t* (26.0) = 0.96, *p* = n.s, although there was a small Cohen's *d* effect size (*d* = .3). For <historic>, only intensity seems to be an important cue in lexical stress in the speech of Arabic L1 NNES.

Table 19. Paired Sample t-Test Results for P vs. All in
<Historic> for Arabic L1 Speakers

<historic>	Mean	SD	N	*p-value*	*t-statistic*	*df*
F0 of P	183.10 Hz	75.79	27.00	0.42	0.82	26.00
F0 of All	171.49 Hz	55.86	27.00			
Intensity of P	64.78 dB	10.28	27.00	0.00	5.98	26.00
Intensity of All	59.82 dB	10.07	27.00			
Duration of P	95.29 ms	43.99	27.00	0.34	0.96	26.00
Duration of All	85.74 ms	20.90	27.00			

Table 20 shows that there was no statistical difference between the values of F0 for *P* and *All* in <historical>, *t* (26.0) = 1.63, *p* = n.s, although there was a small Cohen's *d* effect size (*d* = .3). Meanwhile, there was a significant statistical difference between the intensity values of *P* and *All*, *t* (26.0) = 8.05, *p* < 0.00, with a small Cohen's *d* effect size (*d* = .4). However, with respect to duration, there was no statistically significant difference between *P* and *All*, *t* (26.0) = 0.29, *p* = n.s, with an insignificant Cohen's *d* effect size (*d* = .1). As with its related Level 1

[+cyclic] derivational stem, <historic>, only intensity seems to be an important cue in defining primary-stressed vowels in the production of <historical> by Arabic L1 NNES.

Table 20. Paired Sample t-Test Results for P vs. All in <Historical> for Arabic L1 Speakers

<historical>	Mean	SD	N	*p-value*	*t-statistic*	*df*
F0 of P	183.79 Hz	62.30	27.00	0.11	1.63	26.00
F0 of All	168.68 Hz	51.83	27.00			
Intensity of P	65.84 dB	9.75	27.00	0.00	8.05	26.00
Intensity of All	61.97 dB	9.93	27.00			
Duration of P	85.77 ms	27.21	27.00	0.77	0.29	26.00
Duration of All	84.45 ms	20.81	27.00			

Table 21 shows that there was no statistical difference between the values of F0 for *P* and *All* in <historicity>, *t* (13.0) = -0.84, *p* = n.s, and a very small negative Cohen's *d* effect size (*d* = -.2). The negative values indicate that the mean F0 of *P* was actually lower than the mean F0 of *All* which is contrary to what one would expect based on ELS theory. Meanwhile, there was a significant statistical difference between the intensity values of *P* and *All*, *t* (13.0) = 3.79, *p* < 0.00, with a small Cohen's *d* effect size (*d* = .3). Similarly, there was a significant difference between *P* and *All*, *t* (13.0) = -3.45, *p* < 0.00, albeit a negative one with a Cohen's *d* effect size (*d* = -1.23). Interestingly, this negative ratio is the same as occurred in NES productions. In sum, for <historicity> in Arabic L1 NNES speech, increased intensity and shorter duration were the significant acoustic correlates of the primary-stressed vowel.

Table 21. Paired Sample t-Test Results for P vs. All in
<Historicity> for Arabic L1 Speakers

<historicity>	Mean	SD	N	*p-value*	*t-statistic*	*df*
F0 of P	177.49 Hz	47.54	14.00	0.41	-0.84	13.00
F0 of All	185.52 Hz	41.08	14.00			
Intensity of P	62.86 dB	9.40	14.00	0.00	3.79	13.00
Intensity of All	60.23 dB	9.38	14.00			
Duration of P	66.52 ms	16.63	14.00	0.00	-3.45	13.00
Duration of All	93.46 ms	26.12	14.00			

Table 22 shows that there was no statistical difference between the values of F0 for *P* and *All* in <historify>, t (12.0) = -0.37, p = n.s, and an inconsequential Cohen's *d* effect size (d = -.0). Likewise, there was no significant statistical difference between the intensity values of *P* and *All*, t (12.0) = -0.39, p = n.s, with a similarly negligible Cohen's *d* effect size (d = -.1). The negative values indicate that the mean intensity of *P* was actually lower than the mean intensity of *All.* Counterintuitively, there was also a significant negative difference between duration of *P* and *All*, t (12.0) = -5.35, $p < 0.00$, with a large Cohen's *d* effect size (d = -1.51). As in the previous case, this negative ratio of duration is the same as occurred in NES productions. Therefore, for <historify> in Arabic L1 NNES speech, only *shorter* duration was a significant acoustic correlate of the primary-stressed vowel.

Table 22. Paired Sample t-Test Results for P vs. All in <Historify> for Arabic L1 Speakers

<historify>	Mean	SD	N	*p-value*	*t-statistic*	*df*
F0 of P	172.29 Hz	60.18	13.00	0.72	0.37	12.00
F0 of All	170.07 Hz	62.09	13.00			
Intensity of P	66.37 dB	8.77	13.00	0.71	-0.39	12.00
Intensity of All	67.32 dB	11.66	13.00			
Duration of P	83.11 ms	30.86	13.00	0.00	-5.35	12.00
Duration of All	131.07 ms	32.73	13.00			

Table 23 shows that there was no statistical difference between the values of F0 for *P* and *All* in <historious>, *t* (20.0) = -0.38, *p* = n.s, and an insignificant Cohen's *d* effect size (*d* = -.1). Again, the negative values indicate that the mean F0 of *P* was actually lower than the mean F0 of *All* which contradicts ELS theory. However, there was a significant positive difference between the intensity values of *P* and *All*, *t* (20.0) = 8.58, *p* = < 0.00, with a small Cohen's *d* effect size (*d* = .3). Additionally, there was also a significant positive difference between *P* and *All* with regards to duration, *t* (20.0) = 4.45, *p* < 0.00, with a large Cohen's *d* effect size (*d* = 1.00) meaning that the difference between the two means was about one standard deviation. For <historious> in Arabic L1 NNES speech, the significant acoustic correlates of the primary-stressed vowel appear to be the same as in MWAE speech; i.e., intensity and duration.

Table 23. Paired Sample t-Test Results for P vs. All in
<Historious> for Arabic L1 Speakers

<historious>	Mean	SD	N	*p-value*	*t-statistic*	*df*
F0 of P	181.77 Hz	47.35	21.00	0.71	-0.38	20.00
F0 of All	185.21 Hz	57.53	21.00			
Intensity of P	64.48 dB	9.40	21.00	0.00	8.58	20.00
Intensity of All	61.17 dB	9.68	21.00			
Duration of P	114.45 ms	36.58	21.00	0.00	4.45	20.00
Duration of All	83.96 ms	23.12	21.00			

The bar graph in Figure 17 summarizes the information from the paired-samples t-tests in Tables 16 to 23 by comparing the mean values of F0 in *P* and *All* in each of the eight tokens as produced by Arabic L1 NNES. The results reveal that F0 was only significantly different in *P* compared to *All* in <historial> (this also occurred in MWAE speech) and <historian>. Unlike in MWAE NES productions where the F0 of *P* was always prominent, the graph illustrates that three of the tokens were actually produced on average with a lower F0 in the primary-stressed [+tonic] vowel; namely, <historicity>, and to a lesser degree, <historious> and <history>.

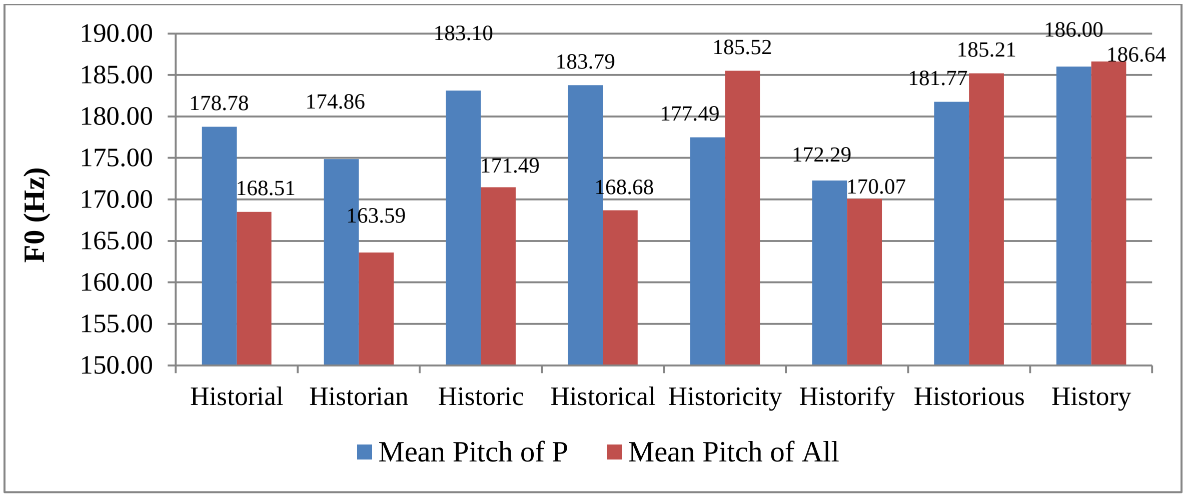


Figure 17. Mean Arabic L1 Speaker F0 values (Hz) for Primary-stressed [+tonic] Vowels (*P*) and the Mean F0 of all Non-primary [-tonic] Stressed Vowels (*All*) per Token

The bar graph in Figure 18 summarizes the information from the paired-samples t-tests in Tables 16 to 23 by comparing the mean values of intensity in *P* and *All* in each of the eight tokens as produced by Arabic L1 NNES. The t-tests and post hoc Cohen's *d* effect sizes confirm that the relative intensity of the primary-stressed [+tonic] vowel was statistically greater in all the tokens except <history> (although the mean value of *P* was larger than *All* for this token, too) and <historify> (negative intensity ratio of *P* vs. *All*).

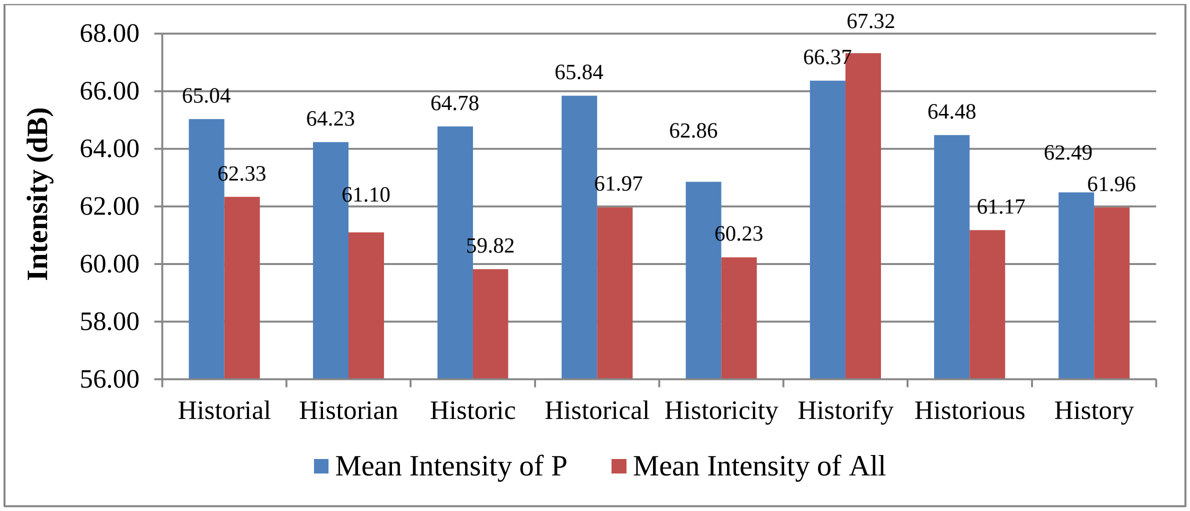


Figure 18. Mean Arabic L1 Speaker Intensity Values (dB) for Primary-stressed [+tonic] Vowels (*P*) and the Mean Intensity of all Non-primary [-tonic] Stressed Vowels (*All*) per Token

The bar graph in Figure 19 summarizes the information from the paired-samples t-tests in Tables 16 to 23 by comparing the mean values of duration in *P* and *All* in each of the eight tokens as produced by Arabic L1 NNES. The results indicate that duration of the primary-stressed [+tonic] vowel was significantly different from the mean average duration of the non-primary [-tonic] vowels for five of the tokens, excluding <history>, <historic>, and <historical>. Furthermore, as was the case in MWAE speech, the mean duration of *P* was actually shorter than *All* in <history>, <historicity>, and <historify>.

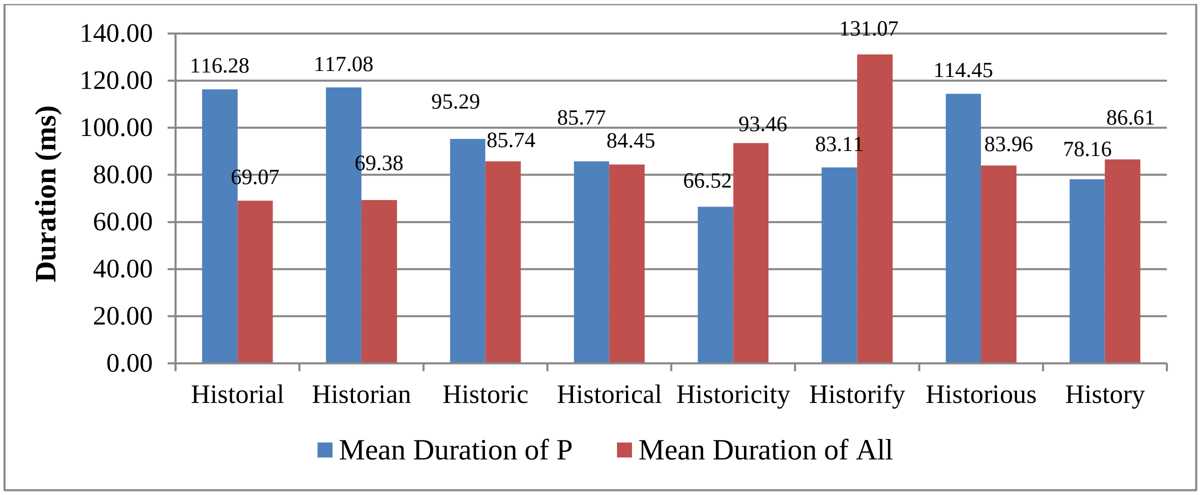


Figure 19. Mean Arabic L1 Speaker Duration Values (ms) for Primary-stressed [+tonic] Vowels (*P*) and the Mean Duration of all Non-primary [-tonic] Stressed Vowels (*All*) per Token

Acoustic correlates of stress in Mandarin L2 English. Tables 24 to 31 provide the results of the paired sample t-tests for determining whether there was a statistically significant difference between the [+stress] primary-stressed vowel (*P*) and the [-stress] vowels (*All*) in Mandarin L1 NNES speech for each of the eight individual tokens, plus all seven of the Level 1 [+cyclic] derivations combined.

Table 24 shows that there was a significant statistical difference between the values of F0 for *P* and *All* in <history>, t (27.0) = 3.78, p = < 0.00, with a large Cohen's d effect size (d = .9). Similarly, there was a significant difference between the intensity values of *P* and *All*, t (27.0) = 4.71, p = < 0.00, with a small Cohen's d effect size (d = .4). However, there was no significant positive difference between *P* and *All* with respect to duration, t (27.0) = -1.30, p = n.s, and an insignificant Cohen's d effect size (d = -.3) The negative values indicate that the mean duration of *All* was actually longer than the mean duration of *P*, in tandem with the results for the other two language groups. In sum, for <history> in Mandarin L1 NNES productions, the significant acoustic correlates of the primary-stressed vowel appear to be F0 and intensity.

Table 24. Paired Sample t-Test Results for P vs. All in
Stem Token <History> for Mandarin L1 Speakers

<history>	Mean	SD	N	*p-value*	*t-statistic*	*df*
F0 of P	234.86 Hz	68.50	28.00	0.00	3.78	27.00
F0 of All	177.92 Hz	56.65	28.00			
Intensity of P	65.81 dB	9.27	28.00	0.00	4.71	27.00
Intensity of All	62.66 dB	8.38	28.00			
Duration of P	99.16 ms	19.89	28.00	0.20	-1.30	27.00
Duration of All	109.94 ms	41.28	28.00			

Table 25 shows that there was no significant statistical difference between the values of F0 for *P* and *All* in <historial>, *t* (23.0) = 1.45, *p* = n.s, despite having a large Cohen's *d* effect size (*d* = 1.1). In addition, there was a significant difference between the intensity values of *P* and *All*, *t* (23.0) = 3.94, *p* = < 0.00, also with a large Cohen's *d* effect size (*d* = 1.2). Similarly, there was a significant difference between *P* and *All* with respect to duration, *t* (23.0) = 9.60, *p* < 0.00, and a very large Cohen's *d* effect size (*d* = 2.3) Thus, for <historial> in Mandarin L1 NNES productions, the significant acoustic correlates of the primary-stressed vowel appear to be intensity and duration, and perhaps also F0 due to the large effect size.

Table 25. Paired Sample t-Test Results for P vs. All in
<Historial> for Mandarin L1 Speakers

<historial>	Mean	SD	N	*p-value*	*t-statistic*	*df*
F0 of P	208.87 Hz	51.39	24.00	0.16	1.45	23.00
F0 of All	195.48 Hz	45.16	24.00			
Intensity of P	66.60 dB	9.90	24.00	0.00	3.94	23.00
Intensity of All	64.50 dB	9.96	24.00			
Duration of P	149.64 ms	39.10	24.00	0.00	9.60	23.00
Duration of All	79.78 ms	16.96	24.00			

Table 26 shows that all three acoustic correlates were significant indicators of primary [+tonic] stress in the production of <historian> by Mandarin L1 NNES. First, there was a significant statistical difference between the values of F0 for *P* and *All*, *t* (20.0) = 4.44, *p* < 0.00, with a moderate Cohen's *d* effect size (*d* = .5). Second, there was a significant difference between the intensity of *P* and *All*, *t* (20.0) = 4.81, *p* = < 0.00, and a small Cohen's *d* effect size (*d* = .3). Third, there was a significant difference between *P* and *All* with respect to duration, *t* (20.0) = 16.82, *p* < 0.00, with a very large Cohen's *d* effect size (*d* = 3.6) meaning that, on average, the primary-stressed [+tonic] was over three and a half standard deviations longer than the mean average length of all the other vowels combined.

Table 26. Paired Sample t-Test Results for P vs. All in
<Historian> for Mandarin L1 Speakers

<historian>	Mean	SD	N	*p-value*	*t-statistic*	*df*
F0 of P	214.74 Hz	50.38	21.00	0.00	4.44	20.00
F0 of All	191.77 Hz	48.17	21.00			
Intensity of P	68.59 dB	8.59	21.00	0.00	4.81	20.00
Intensity of All	65.83 dB	9.20	21.00			
Duration of P	154.40 ms	26.15	21.00	0.00	16.82	20.00
Duration of All	75.00 ms	17.01	21.00			

Table 27 shows that there was no significant statistical difference between the values of F0 for *P* and *All* in Mandarin L1 NNES productions of <historic>, t (27.0) = -.43, p = n.s, and a negligible Cohen's *d* effect size (d = -.1). Significantly, the mean F0 of *P* was actually lower than the mean F0 of *All*, hence the negative values. Likewise, there was no significant difference between the intensity of *P* and *All*, t (27.0) = 1.65, p = n.s, with a very small Cohen's *d* effect size (d = .2). On the other hand, there was a significant difference between *P* and *All* with respect to duration, t (27.0) = 6.21, $p < 0.00$, with a large Cohen's *d* effect size (d = 1.5) meaning that, on average, the primary-stressed [+tonic] vowel was one and a half standard deviations longer than the mean average length of all the other vowels in the word combined. In sum, duration was the most salient acoustic cue to stress in Mandarin L1 NNES productions of <historic>.

Table 27. Paired Sample t-Test Results for P vs. All in
<Historic> for Mandarin L1 Speakers

<historic>	Mean	SD	N	*p-value*	*t-statistic*	*df*
F0 of P	203.16 Hz	50.31	28.00	0.67	-0.43	27.00
F0 of All	206.75 Hz	49.42	28.00			
Intensity of P	66.40 dB	9.10	28.00	0.11	1.65	27.00
Intensity of All	64.43 dB	9.90	28.00			
Duration of P	142.49 ms	37.18	28.00	0.00	6.21	27.00
Duration of All	90.66 ms	31.65	28.00			

Table 28 shows that there was no significant statistical difference between the values of F0 for *P* and *All* in Mandarin L1 NNES productions of <historical>, t (25.0) = 1.93, p = n.s, and a very small Cohen's *d* effect size (*d* = .2). Nonetheless, there was a significant difference between the intensity of *P* and *All*, t (25.0) = 6.31, $p < 0.00$, with a small Cohen's *d* effect size (*d* = .4). In addition, there was a significant difference in duration between *P* and *All*, t (25.0) = 6.13, $p < 0.00$, with a large Cohen's *d* effect size (*d* = 1.5), as was the case in the previous token. For <historical>, intensity and duration were the most salient acoustic cues to ELS in Mandarin L1 NNES productions.

Table 28. Paired Sample t-Test Results for P vs. All in
<Historical> for Mandarin L1 Speakers

<historical>	Mean	SD	N	*p-value*	*t-statistic*	*df*
F0 of P	202.98 Hz	52.00	26.00	0.07	1.93	25.00
F0 of All	190.42 Hz	50.90	26.00			
Intensity of P	68.06 dB	8.11	26.00	0.00	6.31	25.00
Intensity of All	64.72 dB	8.23	26.00			
Duration of P	122.80 ms	31.00	26.00	0.00	6.13	25.00
Duration of All	85.95 ms	18.05	26.00			

Table 29 shows that there was no significant statistical difference between the values of F0 for *P* and *All* in Mandarin L1 NNES productions of <historicity>, *t* (17.0) = 1.43, *p* = n.s, and a very small Cohen's *d* effect size (*d* = .2). However, there was a significant difference between the intensity of *P* and *All*, *t* (17.0) = 3.13, $p < 0.05$, also with a very small Cohen's *d* effect size (*d* = .2). Notwithstanding, there was no significant difference in duration between *P* and *All*, *t* (17.0) = -1.17, *p* = n.s. The Cohen's *d* effect size was negative and small (*d* = -.4), indicating that the mean duration of *P* was shorter than the mean duration of *All* as occurred in the speech of the other two language groups. In sum, for <historicity>, intensity was the most salient acoustic cues to ELS in Mandarin L1 NNES productions.

Table 29. Paired Sample t-Test Results for P vs. All in
<Historicity> for Mandarin L1 Speakers

<historicity>	Mean	SD	N	*p-value*	*t-statistic*	*df*
F0 of P	213.35 Hz	45.39	18.00	0.17	1.43	17.00
F0 of All	203.97 Hz	57.90	18.00			
Intensity of P	65.88 dB	8.43	18.00	0.01	3.13	17.00
Intensity of All	63.68 dB	9.37	18.00			
Duration of P	87.97 ms	25.79	18.00	0.26	-1.17	17.00
Duration of All	96.52 ms	20.28	18.00			

Table 30 shows that there was a significant statistical difference between the values of F0 for *P* and *All* in Mandarin L1 NNES productions of <historify>, *t* (22.0) = 4.20, $p < 0.00$, and a small Cohen's *d* effect size (*d* = .4). Additionally, there was a significant difference between the intensity of *P* and *All*, *t* (22.0) = 5.18, $p < 0.00$, also with a small Cohen's *d* effect size (*d* = .3). Conversely, there was no significant difference in duration between *P* and *All*, *t* (22.0) = -.47, *p* =

n.s, and the Cohen's *d* effect size was negligible (*d* = -.1). The negative values indicate that the mean duration of *P* was shorter than the mean duration of *All*, as was the case in the speech of the other two language groups even though their results were statistically significant. Thus, for <historify>, F0 and intensity were the most salient acoustic correlates in the primary-stressed [+tonic] vowel in Mandarin L1 NNES productions.

Table 30. Paired Sample t-Test Results for P vs. All in
<Historify> for Mandarin L1 Speakers

<historify>	Mean	SD	N	*p-value*	*t-statistic*	*df*
F0 of P	202.34 Hz	55.12	23.00	0.00	4.20	22.00
F0 of All	184.69 Hz	45.21	23.00			
Intensity of P	68.67 dB	8.99	23.00	0.00	5.18	22.00
Intensity of All	65.75 dB	8.94	23.00			
Duration of P	115.94 ms	34.55	23.00	0.65	-0.47	22.00
Duration of All	119.31 ms	22.93	23.00			

Table 31 shows that all three acoustic correlates were significant indicators of primary stress in the production of <historious> by Mandarin L1 NNES. There was a significant statistical difference between the values of F0 for *P* and *All*, t (18.0) = 2.60, $p < 0.05$, and a medium Cohen's *d* effect size (*d* = .6). Additionally, there was a significant difference between the intensity of *P* and *All*, t (18.0) = 4.45, $p < 0.00$, with a small Cohen's *d* effect size (*d* = .3). Conversely, there was no significant difference in duration between *P* and *All*, t (18.0) = 8.15, $p < 0.00$, and the Cohen's *d* effect size was very large (*d* = 2.3).

Table 31. Paired Sample t-Test Results for P vs. All in <Historious> for Mandarin L1 Speakers

<historious>	Mean	SD	N	*p-value*	*t-statistic*	*df*
F0 of P	219.50 Hz	46.53	19.00	0.02	2.60	18.00
F0 of All	196.30 Hz	37.28	19.00			
Intensity of P	68.72 dB	8.56	19.00	0.00	4.45	18.00
Intensity of All	66.14 dB	8.93	19.00			
Duration of P	155.57 ms	35.79	19.00	0.00	8.15	18.00
Duration of All	90.30 ms	19.68	19.00			

The bar graph in Figure 20 summarizes the information from the paired-samples t-tests in Tables 24 to 31 by comparing the mean values of F0 in *P* and *All* in each of the eight tokens as produced by Mandarin L1 NNES. The results reveal that the mean F0 of *P* was higher than the mean F0 of *All* in all but one of the tokens, namely <historic>. However, *P* was only statistically different to *All* in the following tokens: <history>, <historian>, <historify> and <historian>. There was also a large effect size of *P* vs. *All* in <historial>.

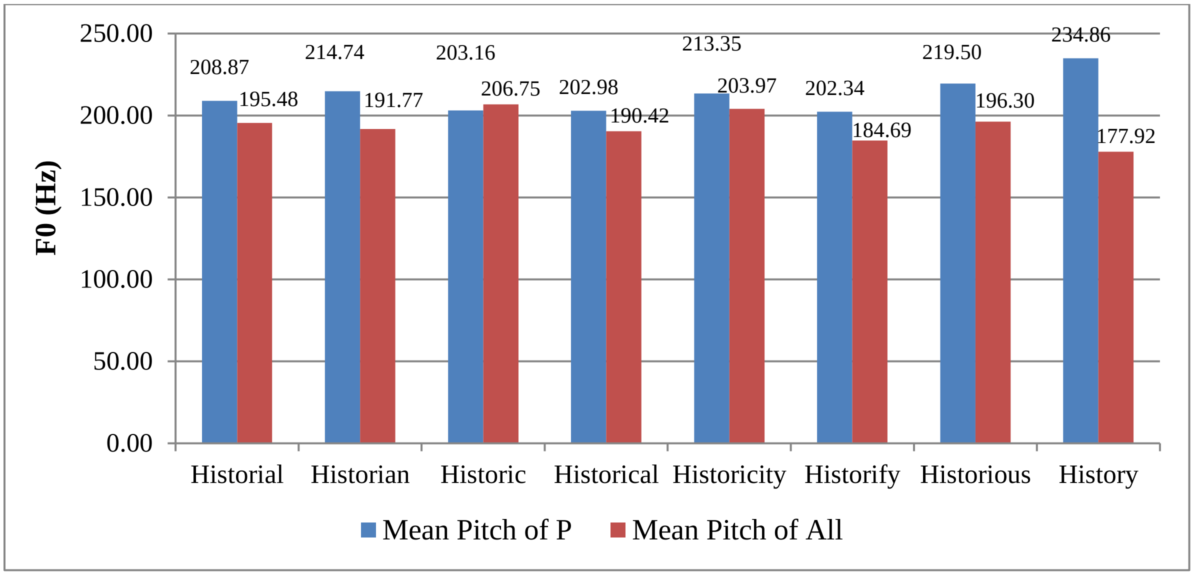


Figure 20. Mean Mandarin L1 Speaker F0 Values (Hz) for Primary-stressed [+tonic] Vowels (*P*) and the Mean F0 of all Non-primary [-tonic] Stressed Vowels (*All*) per Token

The bar graph in Figure 21 summarizes the information from the paired-samples t-tests in Tables 24 to 37 by comparing the mean values of intensity in *P* and *All* in each of the eight tokens as produced by Mandarin L1 NNES. The t-tests and post hoc Cohen's *d* effect sizes confirm that the relative intensity of the primary-stressed [+tonic] vowel was statistically greater in all the tokens, except <historic> (although the mean value of *P* was larger than *All* for this token, too).

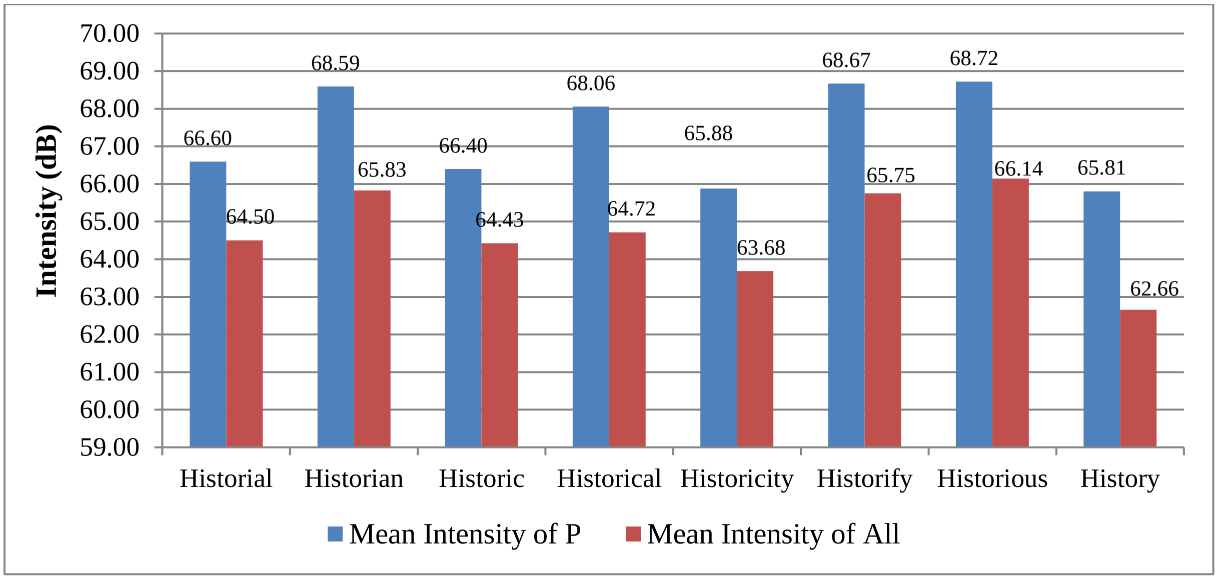


Figure 21. Mean Mandarin L1 Speaker Intensity Values (dB) for Primary-stressed [+tonic] Vowels (*P*) and the Mean Intensity of all Non-primary [-tonic] Stressed Vowels (*All*) per Token

The bar graph in Figure 22 summarizes the information from the paired-samples t-tests in Tables 24 to 31 by comparing the mean values of duration in *P* and *All* in each of the eight tokens as produced by Mandarin L1 NNES. The results indicate that duration of the primary-stressed [+tonic] vowel was significantly different from the mean average duration of the non-primary [-tonic] vowels for five of the tokens, excluding <history>, <historicity>, and <historify>. However, the negative *P* vs. *All* ratios for these tokens are in conformity with the results from the MWAE NES and Arabic L1 NNES groups.

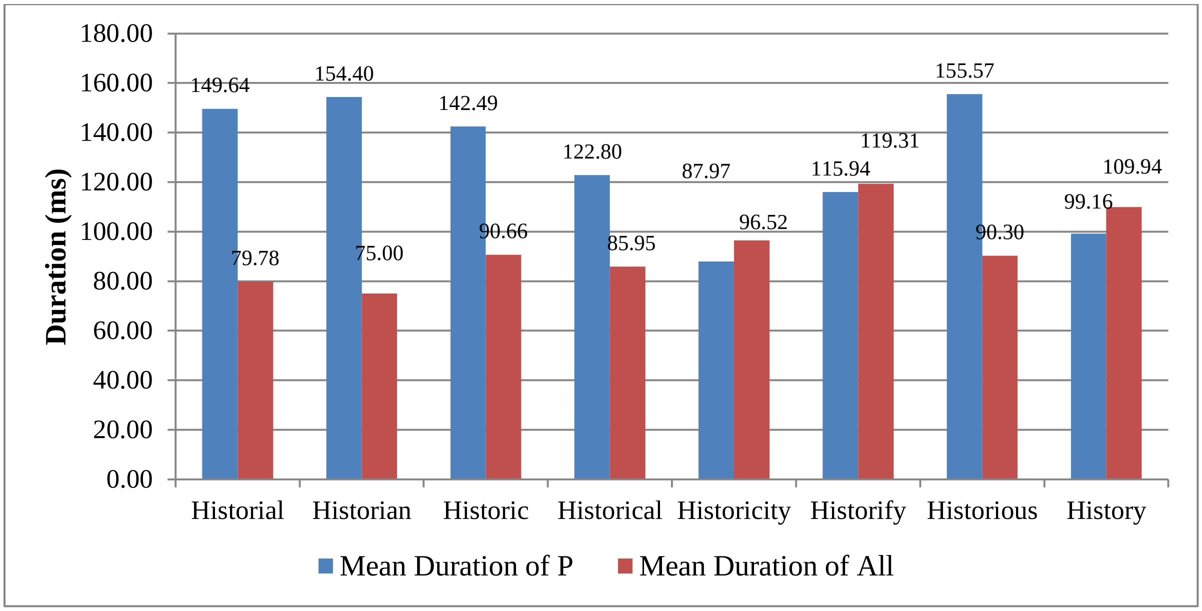


Figure 22. Mean Mandarin L1 Speaker Duration Values (ms) for Primary-stressed [+tonic] Vowels (*P*) and the Mean Duration of all Non-primary [-tonic] Stressed Vowels (*All*) per Token

Summary. Table 32 summarizes the significant findings from all the P vs. All paired-sample t-tests for all three language groups, so that the reader may have a better overall picture of the ways in which lexical stress manifests itself in the speech of the different L1 groups.

Table 32. Most Salient Acoustic Correlates of Primary Stressed [+tonic] Vowels in Level 1 [+cyclic] Derivations per Language Group

Token	Language Group	F0	Intensity	Duration
<history>	English	✗	✓	✓(negative)
	Arabic	✗	✗	✗
	Mandarin	✓	✓	✗
<historial>	English	✓	✓	✓
	Arabic	✓	✓	✓
	Mandarin	?	✓	✓
<historian>	English	✗	✓	✓
	Arabic	✓	✓	✓
	Mandarin	✓	✓	✓
<historic>	English	✗	✓	✓
	Arabic	✗	✓	✗
	Mandarin	✗	✗	✓
<historical>	English	✓	✓	✓
	Arabic	✗	✓	✗
	Mandarin	✗	✓	✓
<historicity>	English	✗	✗	✓(negative)
	Arabic	✗	✓	✓(negative)
	Mandarin	✗	✓	✗
<historify>	English	✗	✓	✓(negative)
	Arabic	✗	✗	✓(negative)
	Mandarin	✓	✓	✗
<historious>	English	✗	✓	✓
	Arabic	✗	✓	✓
	Mandarin	✓	✓	✓

✓ = salient acoustic correlate ✗ = non-salient acoustic correlate
? = borderline saliency based on a non-significant difference between *P* and *All* but a large effect size

Research questions 3 and 4. The mean ratios for each factor in the seven Level 1 [+cyclic] derivations (i.e., excluding <history> were then entered into ANOVAs to discover similarities and differences in the ways that different L1 groups order the acoustic correlates of stress, as well as to reveal potential pronunciation problem areas for Mandarin L1 and Arabic L1 NNES. The results are shown in Table 33.

Table 33. ANOVA Results for the Three Acoustic Correlates of Stress in Level 1 [+cyclic] Derivations

Acoustic Correlate	df	F	Sig.
F0	484	2.799	.062
Intensity	484	5.246	.006
Duration	484	11.904	.000

One-way ANOVA/Tukey post-hoc tests found that neither Arabic nor Mandarin speakers were statistically different from native speakers with regards to F0 usage as an acoustic cue to ELS (Figure 23).

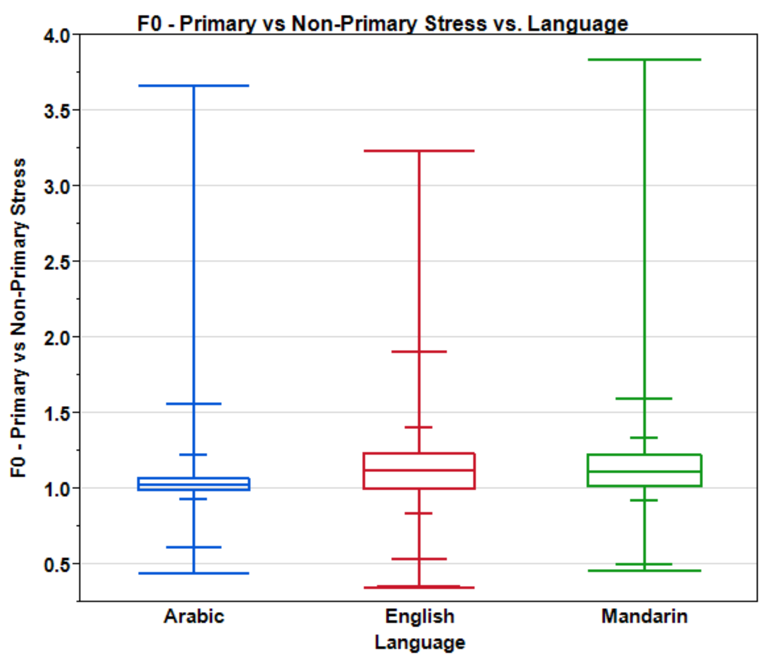


Figure 23. Comparative Usage of F0 as an Acoustic Cue to ELS in Level 1 [+cyclic] Derivations

However, there was a significant difference with regards to intensity. One-way ANOVA/Tukey post-hoc tests found that native English speakers and Mandarin speakers were statistically different from each other (p <.05). Clearly, Mandarin L1 speakers are not using intensity in a native-like manner (Figure 24).

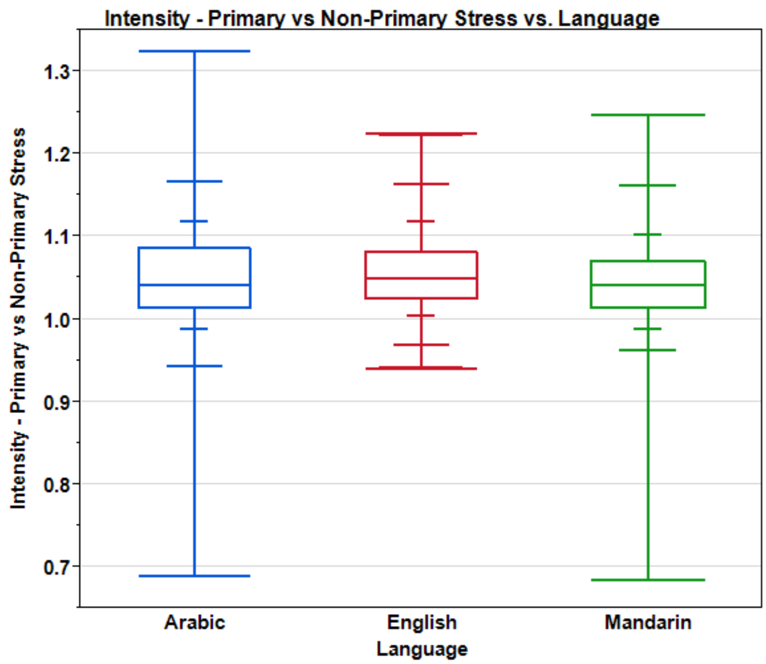


Figure 24. Comparative Usage of Intensity as an Acoustic Cue to ELS in Level 1 [+cyclic] Derivations

Conversely, Figure 25 shows that it was Arabic L1 speakers who were statistically different from both Mandarin L1 speakers and NES with respect to duration ratios of stressed to unstressed vowels. Thus, Arabic L1 speakers tend to underuse duration as an acoustic cue to lexical stress in Level 1 [+cyclic] derivations.

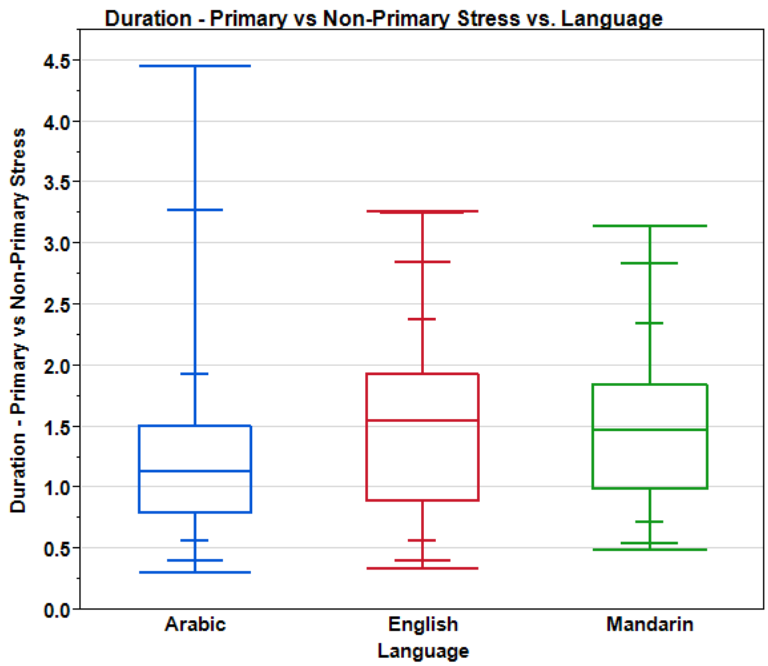


Figure 25. Comparative Usage of Duration as an Acoustic Cue to
ELS in Level 1 [+cyclic] Derivations

Research question 5b. Figures 26 and 27 show years of English L2 study versus native-like production of F0 (difference from the norm; i.e., difference from the mean NES ratio) in lexical stress contrasts. While there was no significant correlation for Arabic L1 speakers (r = .14, *p* = n.s), there was a significant correlation for Mandarin L1 speakers (r = - .49, *p* < .05). Therefore, the longer that the Chinese subjects had claimed to have spent learning English, the more native-like they used pitch as an acoustic cue in lexical stress contrasts.

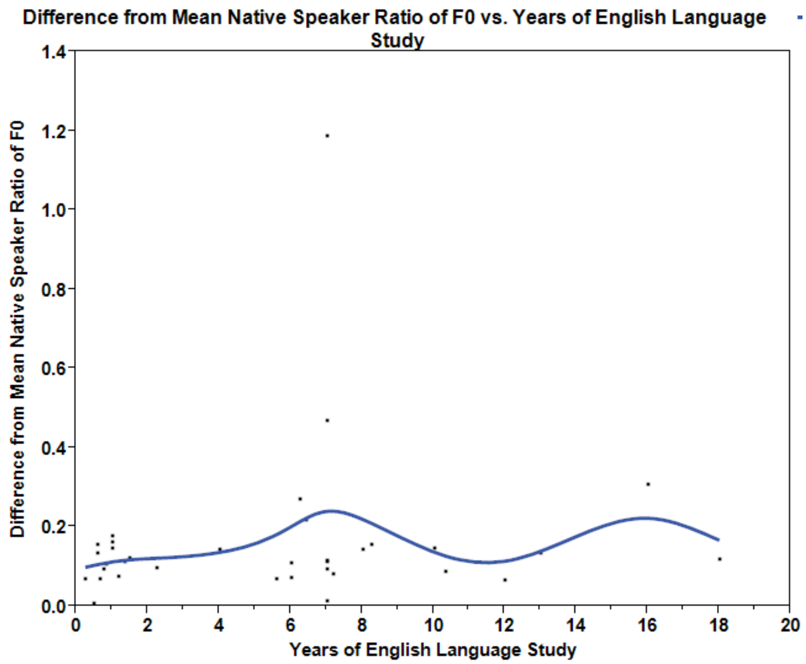


Figure 26. Difference of Mean Arabic L1 Speaker Ratio of F0 from Mean Native Speaker Ratio of F0 vs. Years of L2 English Study

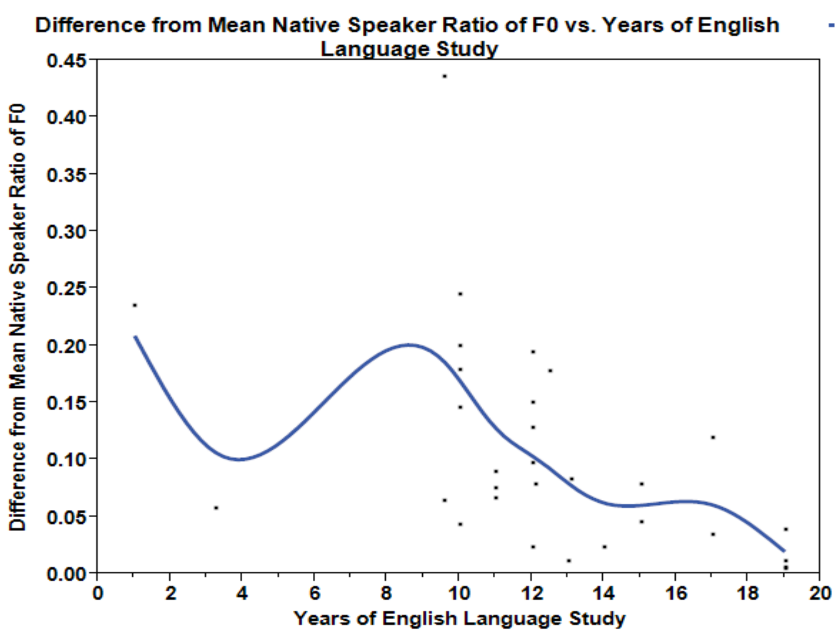


Figure 27. Difference of Mean Mandarin L1 Speaker Ratio of F0 from Mean Native Speaker Ratio of F0 vs. Years of L2 English Study

Meanwhile, it was Arabic L1 speakers, not Mandarin L1 speakers (r = -.12, *p* = n.s), whose pronunciation improved with respect to duration usage as a result of increased English language study (Figures 28-29). Figure 28 shows that difference from mean NES ratio of duration and years of English L2 study were significantly correlated for Arabic speakers (r= -.28, *p* < .05).

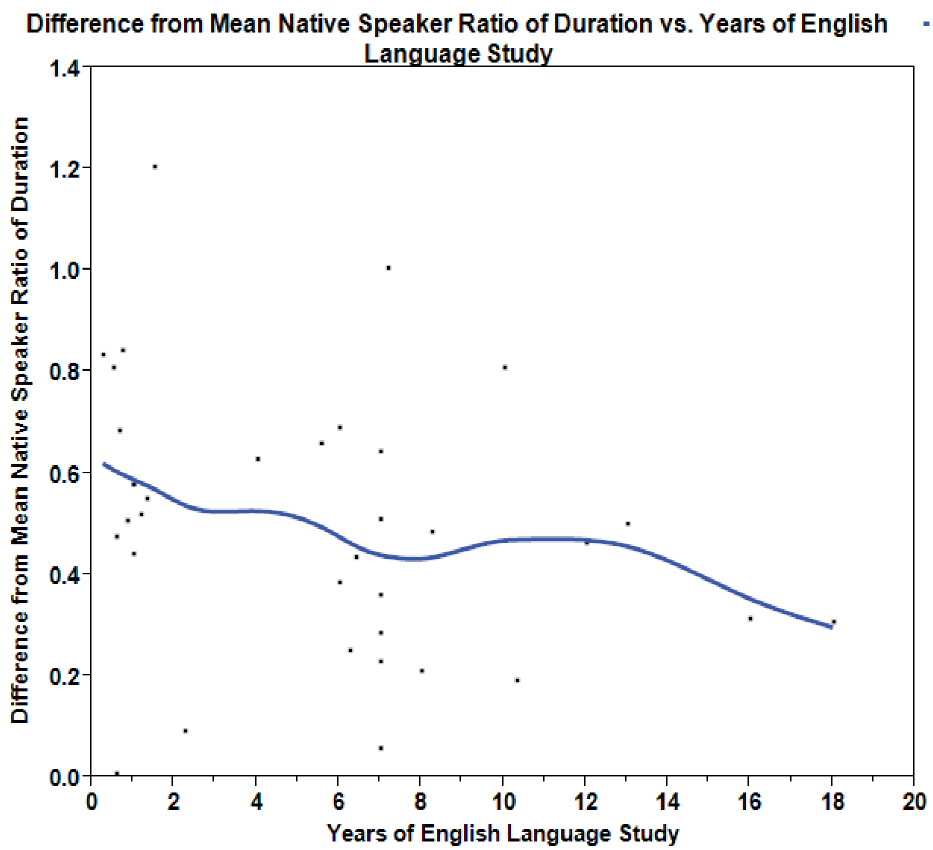


Figure 28. Difference of Mean Arabic L1 Speaker Ratio of Duration from Mean Native Speaker Ratio of Duration vs. Years of L2 English Study

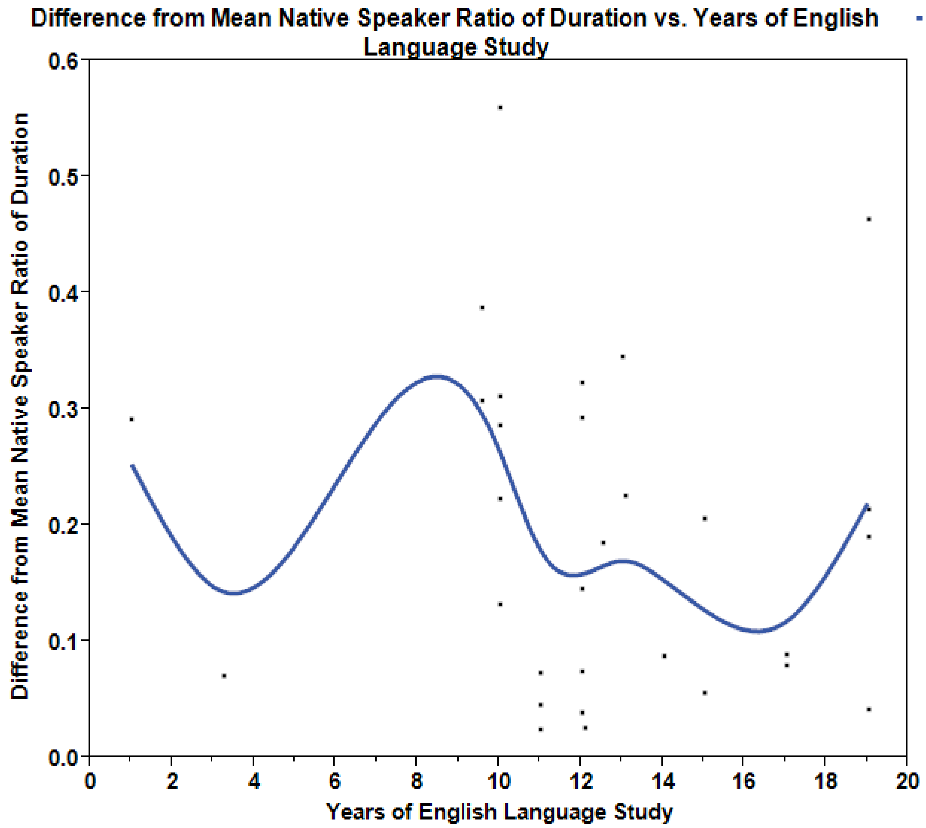


Figure 29. Difference of Mean Mandarin L1 Speaker Ratio of Duration from Mean Native Speaker Ratio of Duration vs. Years of L2 English Study

In terms of intensity production accuracy, there was a non-significant correlation between difference from mean NES ratio of intensity and years of English L2 study for both Arabic L1 NNES, $r = -.27$, $p = n.s$ (Figure 30), and Mandarin L1 NNES, $r = .13$, $p = n.s$ (Figure 31).

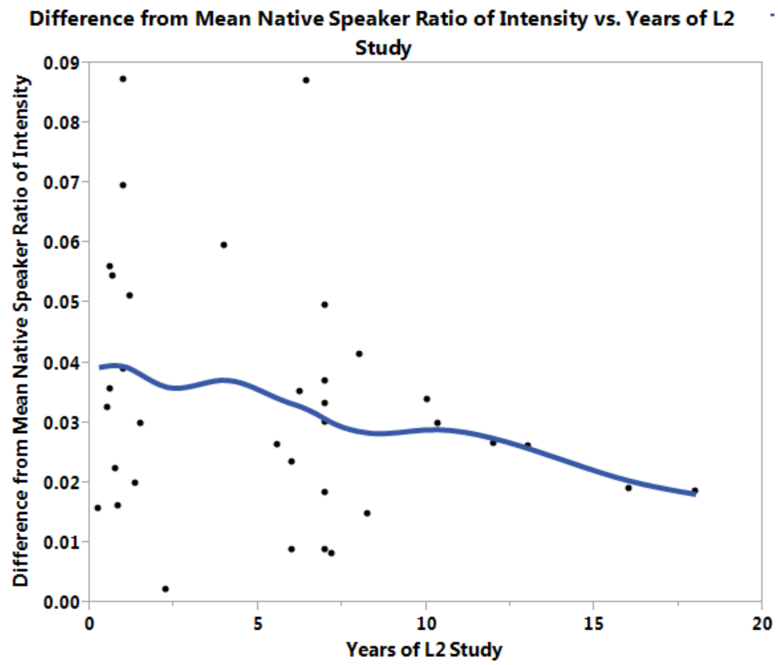


Figure 30. Difference of Mean Arabic L1 Speaker Ratio of Intensity from Mean Native Speaker Ratio of Intensity vs. Years of L2 English Study

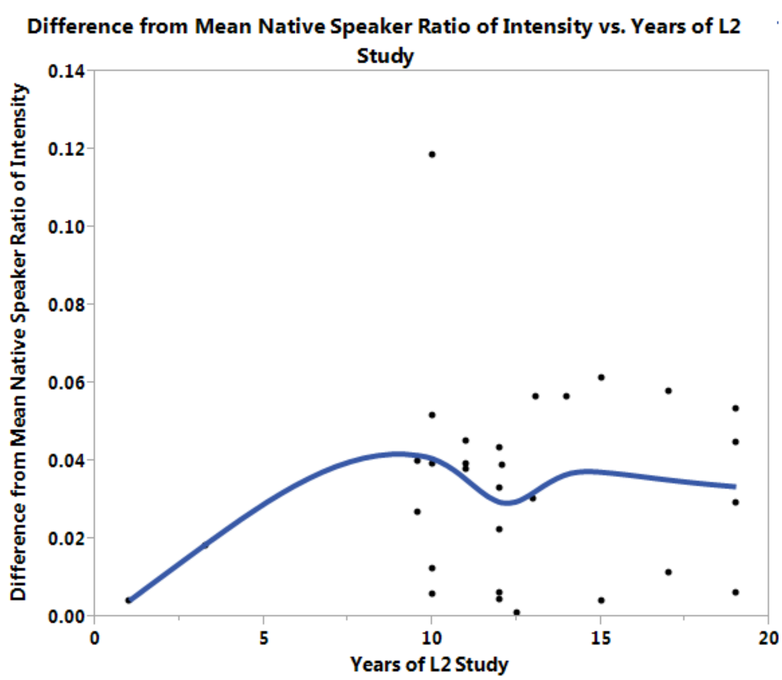


Figure 31. Difference of Mean Mandarin L1 Speaker Ratio of Intensity from Mean Native Speaker Ratio of Intensity vs. Years of L2 English Study

Figure 32 shows the production accuracy of F0 versus proficiency level (see Table 6 for operationalized proficiency level values) for Arabic L1 NNES. There was a non-significant correlation between the two variables (r = -0.49, p = n.s).

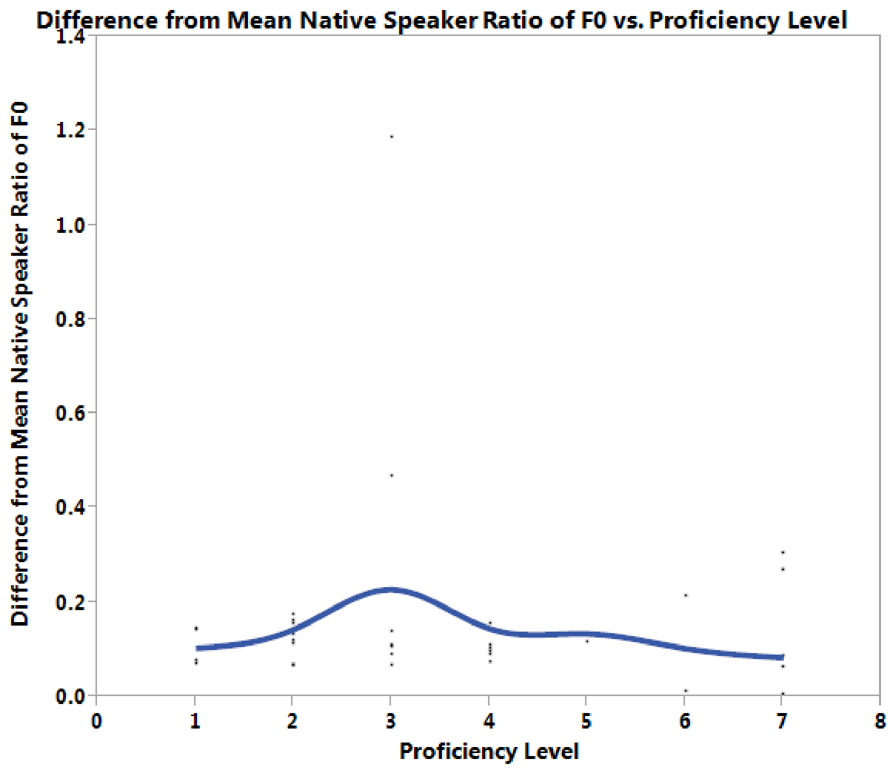


Figure 32. Difference of Mean Arabic L1 Speaker Ratio of F0 from Mean Native Speaker Ratio of Duration vs. English Proficiency Level

Figure 33 shows the production accuracy of F0 versus proficiency level (see Table 6 for operationalized proficiency level values) for Mandarin L1 NNES. There was a significant correlation between the two variables (r = -0.01, p = < 0.05). Therefore, Mandarin L1 NNES produce F0 in lexical stress contrasts in Level 1 [+cyclic] derivations in a more native-like manner, the higher their level of English proficiency.

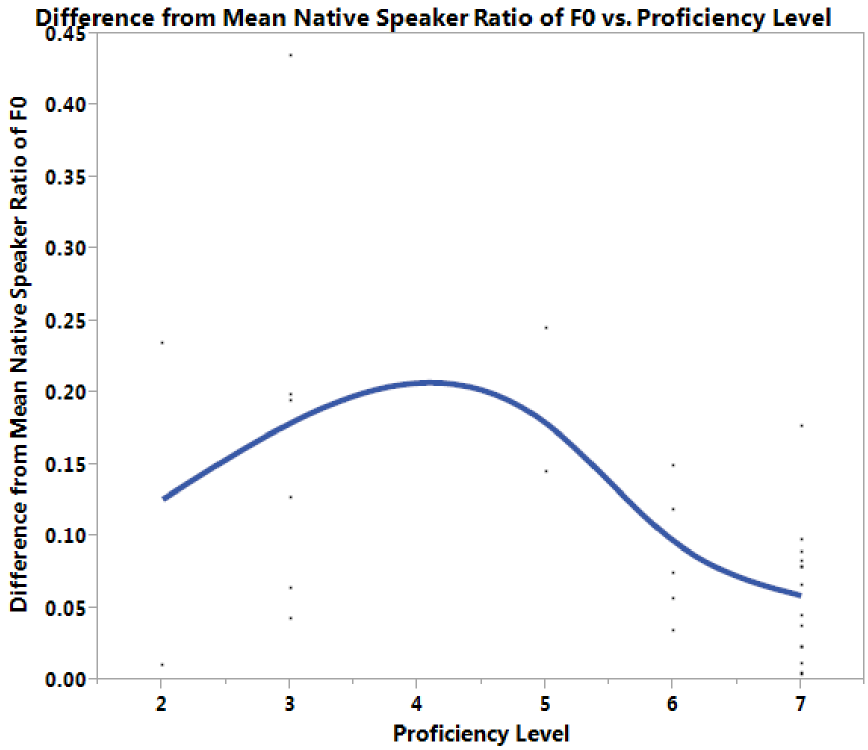


Figure 33. Difference of Mean Mandarin L1 Speaker Ratio of F0 from Mean Native Speaker Ratio of Duration vs. English Proficiency Level

Figure 34 shows the production accuracy of durational contrasts versus proficiency level (see Table 6 for operationalized proficiency level values) for Arabic L1 NNES. There was a significant correlation between the two variables ($r = -0.29$, -$p = < 0.05$ [one-tailed]). Therefore, Arabic L1 NNES produce duration in lexical stress contrasts in Level 1 [+cyclic] derivations in a more native-like manner, the higher their level of English proficiency.

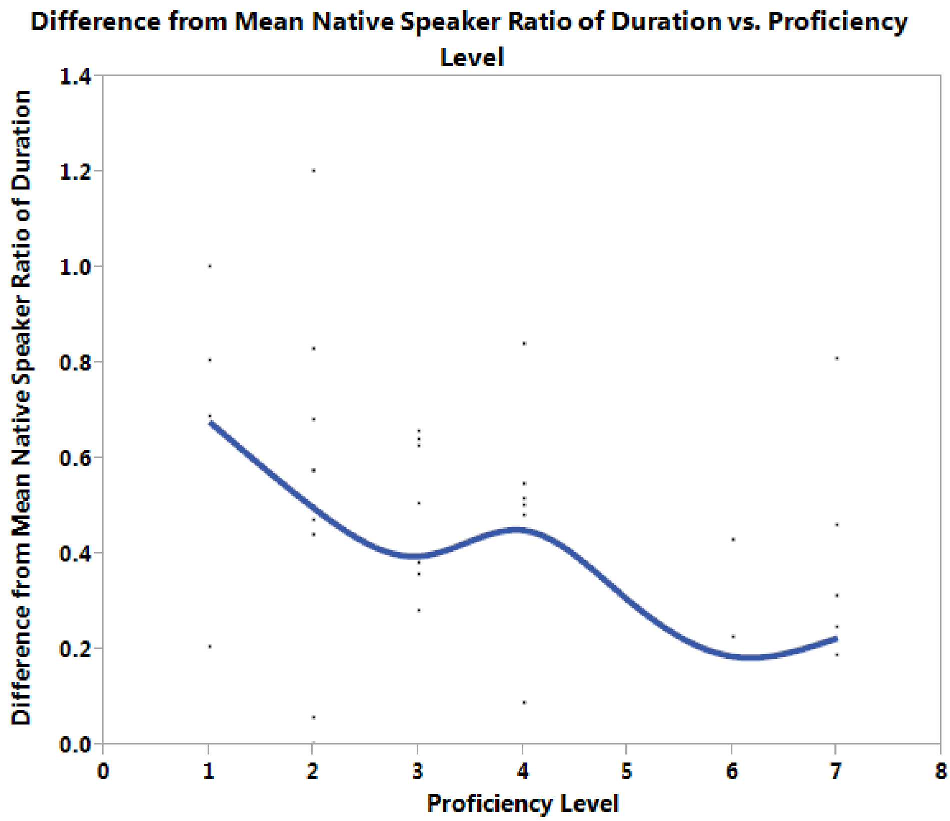


Figure 34. Difference of Mean Arabic L1 Speaker Ratio of Duration from Mean Native Speaker Ratio of Duration vs. English Proficiency Level

Figure 35 shows the production accuracy of durational contrasts versus proficiency level (see Table 6 for operationalized proficiency level values) for Mandarin L1 NNES. There was a significant correlation between the two variables (r = -0.38, p = < 0.05). Therefore, Mandarin L1 NNES produce duration in lexical stress contrasts in Level 1 [+cyclic] derivations in a more native-like manner, the higher their level of English proficiency.

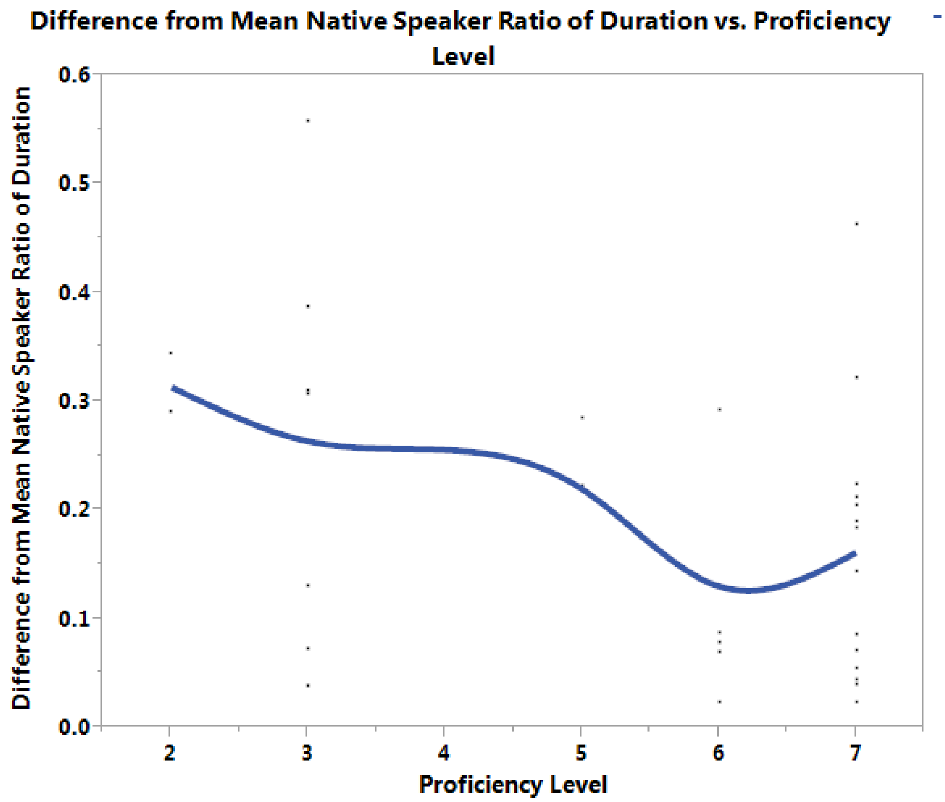


Figure 35. Difference of Mean Mandarin L1 Speaker Ratio of Duration from Mean Native Speaker Ratio of Duration vs. English Proficiency Level

As was the case when we plotted production accuracy of intensity against years of L2 study, there were also non-significant correlations when we plotted it against proficiency level for Arabic L1 NNES (r = 0.13, p = n.s) in Figure 36 and Mandarin L1 NNES (r = 0.12, p = n.s) in Figure 37. This is mainly because the average intensity ratio of *P* vs *All* was very similar for all three language groups despite the existence of various proficiency levels in the NNES groups. It seems intensity is neither a difficult acoustic correlate of stress for NNES to master, nor a particularly important acoustic cue in accentedness. Thus, the results lend credence to the theory that intensity is the least salient acoustic cue to ELS.

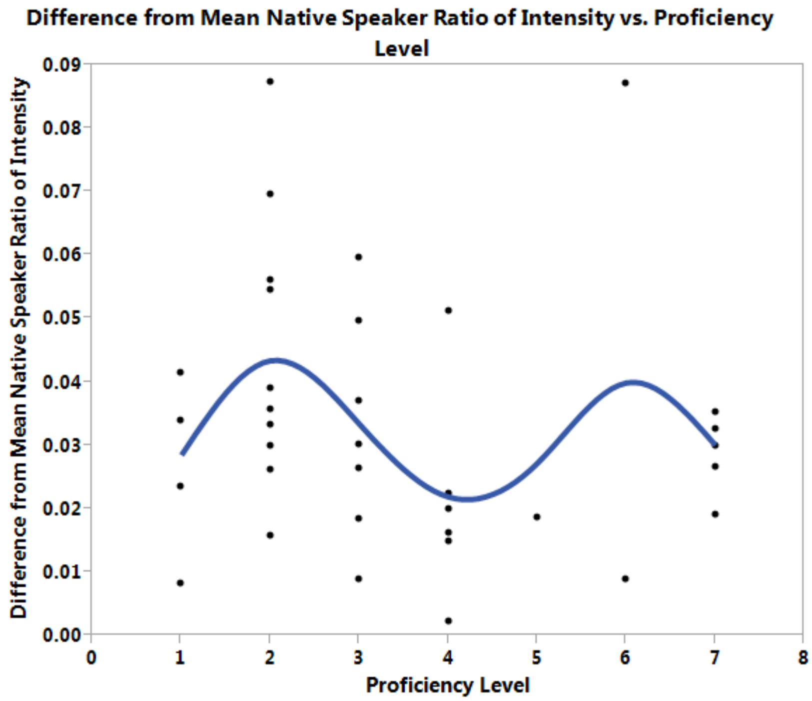


Figure 36. Difference of Mean Arabic L1 Speaker Ratio of Intensity from Mean Native Speaker Ratio of Duration vs. English Proficiency Level

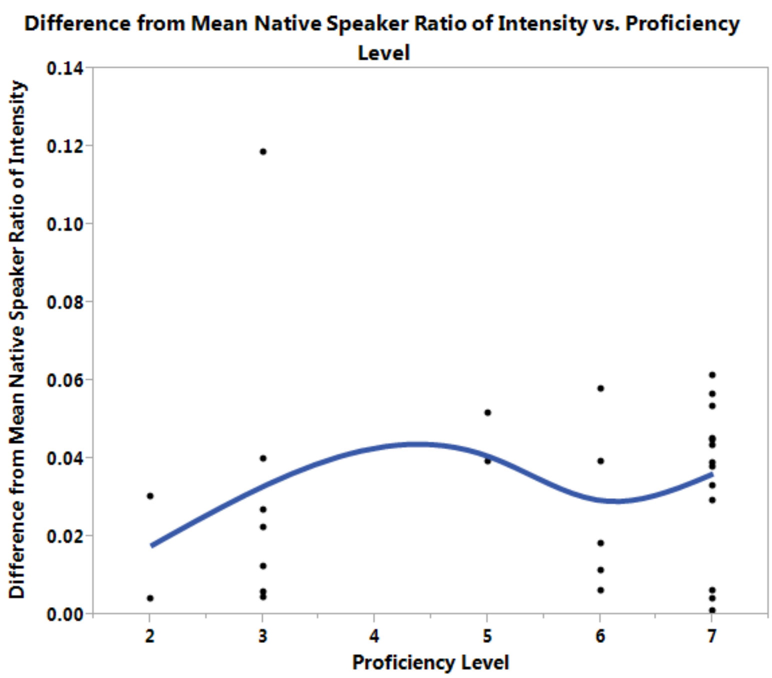


Figure 37. Difference of Mean Mandarin L1 Speaker Ratio of Intensity from Mean Native Speaker Ratio of Duration vs. English Proficiency Level

Research question 6. Figure 38 shows the proportion of productions of <historian>, <historious>, and <historial> by MWAE NES which were in accordance with the standard dictionary pronunciations in comparison to the proportion of productions which included an epenthetic /j/ in the suffix. Almost half of the MWAE subjects (48.2%) pronounced <historian> with the palatal glide in the suffix. For <historious>, slightly more than half of the MWAE speakers (51.72%) produced a clear /j/. Astonishingly, for <historial>, *all* of the NES pronounced it as [hɪˈstɔri**j**əl]. In other words, none of the MWAE NES pronounced it according to standard American English pronunciation (e.g., Dictionary.com, 2013). Appendix F provides several spectrograms which illustrate the presence and/or absence of this phenomenon in the productions of these three Level 1 [+cyclic] derivations.

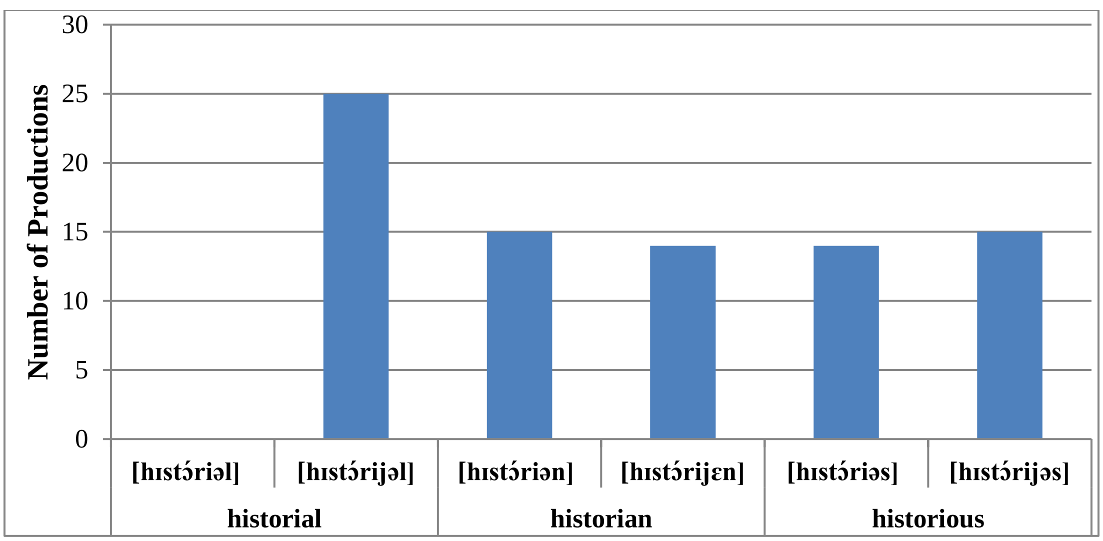


Figure 38. Proportion of Standard American English Dictionary Pronunciations vs. Proportion of Alternative Pronunciations with Epenthetic Palatal Glide by MWAE NES

The case was no different for NNES as they too exhibited a high proportion of palatal glide epenthesis. Figure 39 illustrates the proportion of productions of <historian>, <historious>, and <historial> by Mandarin L1 NNES which were in accordance with the standard dictionary pronunciations in comparison to the proportion of productions which included an epenthetic /j/ in the suffix. 80.95% pronounced <historian> with the palatal glide in the suffix while 68.42% pronounced <historious> with the epenthetic /j/. As with the MWAE NES, *all* of the Mandarin L1 speakers pronounced <historial> as [hɪˈstɔri**j**əl].

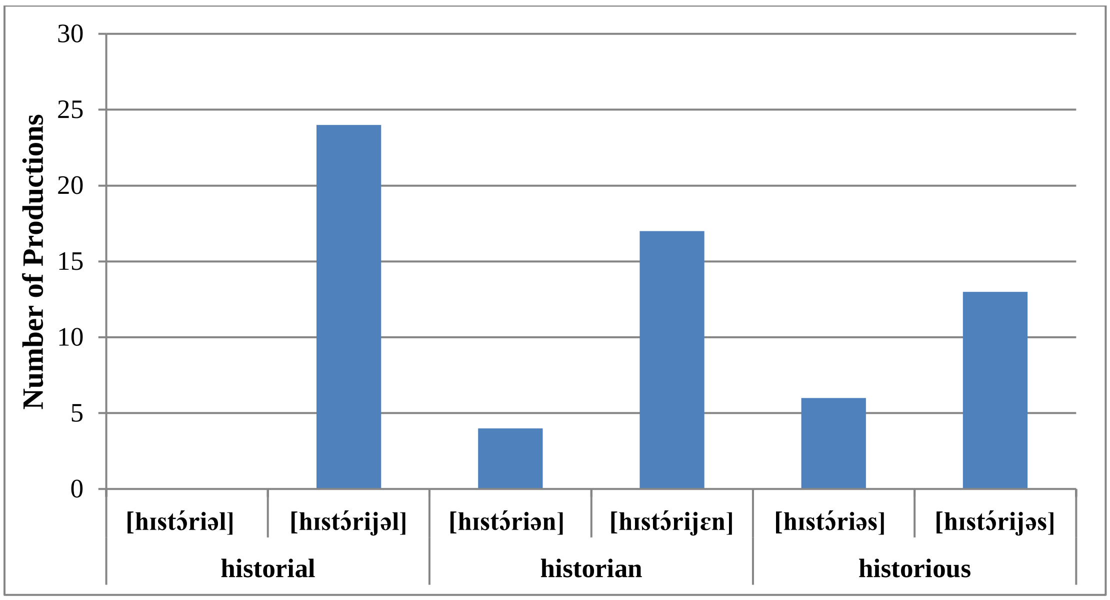


Figure 39. Proportion of Standard American English Dictionary Pronunciations vs. Proportion of Alternative Pronunciations with Epenthetic Palatal Glide by Mandarin L1 NNES

Figure 40 shows the proportion of productions of <historian>, <historious>, and <historial> by Arabic L1 NNES which were in accordance with the standard dictionary pronunciations in comparison to the proportion of productions which included an epenthetic /j/ in the suffix. 59.09% pronounced <historian> with the palatal glide in the suffix while 47.62% pronounced <historious> with the epenthetic /j/. The majority of Arabic L1 speakers (80.77%) pronounced <historial> as [hɪˈstɔri**j**əl].

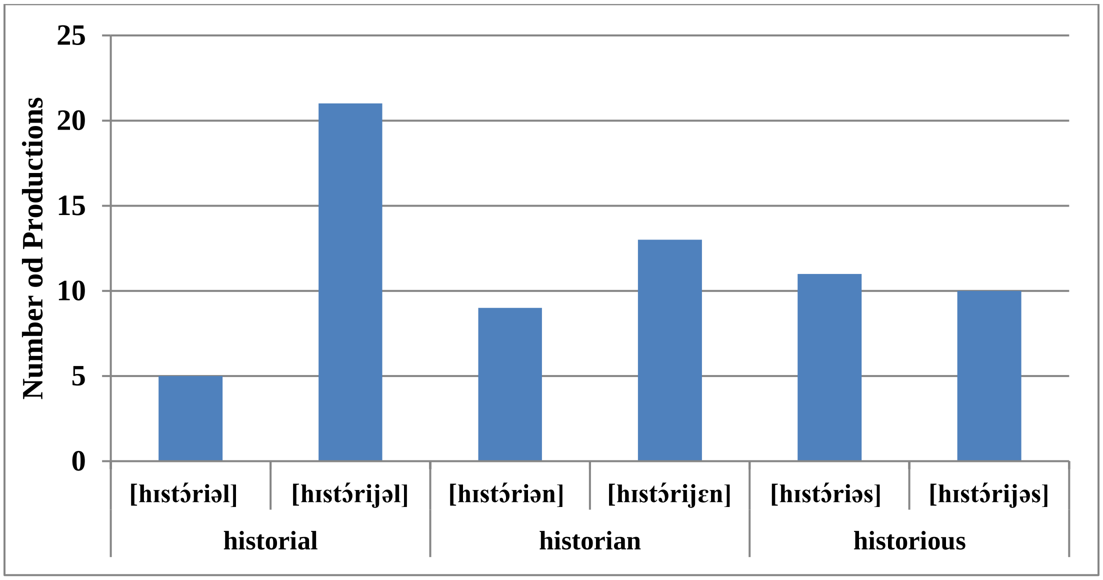


Figure 40. Proportion of Standard American English Dictionary Pronunciations vs. Proportion of Alternative Pronunciations with Epenthetic Palatal Glide by Arabic L1 NNES

Research question 7. Tables 34 to 41 provide the results of the paired sample t-tests for determining whether there was a statistically significant difference between the [+tonic, +stress] primary-stressed vowel (*P*) and the [-tonic, +stress] secondary-stressed vowel (*S*) in each of the eight tokens for MWAE NES.

<History>. Table 34 shows that only two of the acoustic correlates were significant distinguishers of primary stress [+tonic, +stress] from secondary stress [-tonic, +stress] in the production of the stem word <history> by MWAE NES. Contrary to the theory of *tonic accent* which states that the major determiner of primary stress is the “major pitch change” (Ladefoged & Johnson, 2010, p. 119), no significant statistical difference was found between the values of F0 for *P* and *S*, *t* (27.0) = 1.76, *p* = n.s, although there was a small Cohen’s *d* effect size (*d* = .4) indicating some interaction between variables. Of course, the mean value of F0 in *P* was noticeably higher than in *S*, so it may seem surprising that they are not statistically different.

Nevertheless, the results for *P* vs. *S* for the other two variables were also antithetical with regards to Ladefoged and Johnson's (2010) proposition that a [+tonic, +stress] syllable would *only* differ from a [-tonic, +stress] syllable because of a "pitch peak" (p. 119). Indeed, there was a significant difference between the intensity of *P* and *S*, t (27.0) = 2.59, $p < 0.05$, with a very small Cohen's d effect size ($d = .2$). Naturally, one would expect a small effect size for intensity since variations in decibels are not as numerically great as variations in duration or frequency. Moreover, there was a significant difference in duration between *P* and *S*, t (27.0) = -5.56, $p <$ 0.00, and the Cohen's d effect size was negative and very large ($d = -1.6$). As previously mentioned, this is probably because the secondary-stressed vowel, [i], in the ultima is a tense vowel as compared to a lax vowel, [ɪ], in [hís] (Fromkin et al., 2011).

Table 34. Paired Sample t-Test Results for P vs. S in Stem Token <History> for Native English Speakers

<history>	Mean	SD	N	*p-value*	*t-statistic*	*df*
F0 of P	190.93 Hz	61.59	28.00	0.09	1.76	27.00
F0 of S	166.21 Hz	67.51	28.00			
Intensity of P	72.98 dB	7.05	28.00	0.02	2.59	27.00
Intensity of S	71.09 dB	8.11	28.00			
Duration of P	65.25 ms	11.65	28.00	0.00	-5.56	27.00
Duration of S	113.04 ms	40.79	28.00			

<Historial>. Table 35 shows again that only intensity and duration were significant markers of primary stress [+tonic, +stress] in contrast to secondary stress [-tonic, +stress] in the production of the Level 1 [+cyclic] derivation, <historial>, by MWAE NES. There was no significant statistical difference between the values of F0 for *P* and *S*, t (24.0) = 0.91, p = n.s, with a negligible Cohen's *d* effect size (*d* = .1). However, there was a significant difference between the intensity of *P* and *S*, *t* (24.0) = 6.83, *p* < 0.00, with a moderate Cohen's *d* effect size (*d* = .6). In addition, there was a significant difference in duration between *P* and *S*, *t* (24.0) = 15.05, *p* < 0.00, and the Cohen's *d* effect size was very large (*d* = 3.9).

Table 35. Paired Sample t-Test Results for P vs. S in
<Historial> for Native English Speakers

<historial>	Mean	SD	N	*p-value*	*t-statistic*	*df*
F0 of P	174.14 Hz	50.00	25.00	0.37	0.91	24.00
F0 of S	168.82 Hz	53.31	25.00			
Intensity of P	75.03 dB	6.11	25.00	0.00	6.83	24.00
Intensity of S	70.54 dB	8.45	25.00			
Duration of P	123.68 ms	23.40	25.00	0.00	15.05	24.00
Duration of S	56.25 ms	8.03	25.00			

<Historian>. Also at odds with Ladefoged and Johnson's (2010) notions of the role of pitch in tonic accented primary stress, Table 36 shows yet again that only intensity and duration were significant distinguishers of primary stress [+tonic, +stress] from secondary stress [-tonic, +stress] in the production of <historian> by MWAE NES. There was no statistical difference between the values of F0 for *P* and *S*, *t* (26.0) = -0.17, *p* = n.s, with an inconsequential Cohen's *d* effect size (*d* = -.0). Conversely, there was a significant difference between the intensity of *P* and *S*, *t* (26.0) = 6.38, *p* < 0.00, again with a medium Cohen's *d* effect size (*d* = .6). Moreover, there was a significant difference in duration between *P* and *S*, *t* (26.0) = 14.64, *p* < 0.00, and the Cohen's *d* effect size was conspicuously large (*d* = 4.0).

Table 36. Paired Sample t-Test Results for P vs. S in
<Historian> for Native English Speakers

<historian>	Mean	SD	N	*p-value*	*t-statistic*	*df*
F0 of P	178.38 Hz	49.82	27.00	0.87	-0.17	26.00
F0 of S	180.05 Hz	61.58	27.00			
Intensity of P	75.20 dB	6.09	27.00	0.00	6.38	26.00
Intensity of S	70.66 dB	8.59	27.00			
Duration of P	130.02 ms	24.98	27.00	0.00	14.64	26.00
Duration of S	54.48 ms	10.09	27.00			

<Historic>. As with the previous tokens, Table 37 shows that only intensity and duration were significant distinguishers of primary stress [+tonic, +stress] from secondary stress [-tonic, +stress] in the production of <historic> by MWAE NES. There was no statistical difference between the values of F0 for *P* and *S*, *t* (27.0) = -1.01, *p* = n.s, with a very small Cohen's *d* effect size (*d* = -.2) indicating that F0 is actually lower in *P* than *S* on average. Conversely, there was a significant difference between the intensity of *P* and *S*, *t* (27.0) = 5.94, *p* < 0.00, with a moderate Cohen's *d* effect size (*d* = .5). Furthermore, there was a significant difference in duration between *P* and *S*, *t* (27.0) = 10.13, *p* < 0.00, and the Cohen's *d* effect size was very large (*d* = 2.5).

Table 37. Paired Sample t-Test Results for P vs. S in
<Historic> for Native English Speakers

<historic>	Mean	SD	N	*p-value*	*t-statistic*	*df*
F0 of P	173.95 Hz	57.35	28.00	0.32	-1.01	27.00
F0 of S	190.55 Hz	84.90	28.00			
Intensity of P	75.16 dB	6.52	28.00	0.00	5.94	27.00
Intensity of S	71.36 dB	7.76	28.00			
Duration of P	108.11 ms	25.92	28.00	0.00	10.13	27.00
Duration of S	55.43 ms	15.00	28.00			

<Historical>. Unlike the previous tokens, Table 38 shows that all three acoustic correlates were significant distinguishers of primary stress [+tonic, +stress] from secondary stress [-tonic, +stress] in the production of <historical> by MWAE NES. This time, a statistical difference existed between the values of F0 for *P* and *S*, t (26.0) = 3.57, $p < 0.00$, with a small Cohen's *d* effect size ($d = .3$). Likewise, there was a significant difference between the intensity of *P* and *S*, t (26.0) = 8.20, $p < 0.00$, with a medium Cohen's *d* effect size ($d = .6$). Additionally, there was a significant difference in duration between *P* and *S*, t (26.0) = 10.51, $p < 0.00$, and the Cohen's *d* effect size was very large ($d = 2.5$).

Table 38. Paired Sample t-Test Results for P vs. S in
<Historical> for Native English Speakers

<historical>	Mean	SD	N	*p-value*	*t-statistic*	*df*
F0 of P	185.05 Hz	58.56	27.00	0.00	3.57	26.00
F0 of S	170.18 Hz	50.17	27.00			
Intensity of P	75.62 dB	7.00	27.00	0.00	8.20	26.00
Intensity of S	71.19 dB	8.30	27.00			
Duration of P	103.50 ms	22.65	27.00	0.00	10.51	26.00
Duration of S	59.14 ms	11.34	27.00			

<Historicity>. As occurred in the analyses of other acoustic relationships in this word, <historicity> differs somewhat from the other tokens. Table 39 shows that none of the acoustic correlates were significant distinguishers of primary stress [+tonic, +stress] from secondary stress [-tonic, +stress] in the production of <historicity> by MWAE NES. First, there was no significant statistical difference between the values of F0 for *P* and *S, t* (15.0) = -2.03, *p* = n.s, with a very small and negative Cohen's *d* effect size (*d* = -.2). Second, there was no significant difference between the intensity of *P* and *S, t* (15.0) = 0.20, *p* = n.s, with an inconsequential Cohen's *d* effect size (*d* = .0). Third, there was no significant difference in duration between *P* and *S*, *t* (15.0) = -1.87, *p* = n.s, and a medium and negative Cohen's *d* effect size (*d* = -.6).

Table 39. Paired Sample t-Test Results for P vs. S in
<Historicity> for Native English Speakers

<historicity>	Mean	SD	N	*p-value*	*t-statistic*	*df*
F0 of P	162.07 Hz	53.92	16.00	0.06	-2.03	15.00
F0 of S	171.28 Hz	48.87	16.00			
Intensity of P	72.36 dB	6.03	16.00	0.85	0.20	15.00
Intensity of S	72.19 dB	6.00	16.00			
Duration of P	55.01 ms	17.80	16.00	0.08	-1.87	15.00
Duration of S	63.44 ms	10.89	16.00			

<Historify>. This token behaved similarly to the first few tokens in that intensity and duration were found to be the significant acoustic correlates in differentiating primary stress [+tonic, +stress] from secondary stress [-tonic, +stress]. Table 40 shows that there was no significant statistical difference between the values of F0 for *P* and *S, t* (23.0) = -0.09, *p* = n.s, with a negligible negative Cohen's *d* effect size (*d* = -.0). Evidently though, there was a significant difference between the intensity of *P* and *S*, *t* (23.0) = 5.27, *p* < 0.00, with a medium Cohen's *d* effect size (*d* = .6). Also, there was a significant difference in duration between *P* and *S*, *t* (23.0) = 9.22, *p* = < 0.00 and a very large Cohen's *d* effect size (*d* = 2.8).

Table 40. Paired Sample t-Test Results for P vs. S in <Historify> for Native English Speakers

<historify>	Mean	SD	N	*p-value*	*t-statistic*	*df*
F0 of P	184.39 Hz	65.95	24.00	0.93	-0.09	23.00
F0 of S	185.93 Hz	74.41	24.00			
Intensity of P	76.08 dB	5.70	24.00	0.00	5.27	23.00
Intensity of S	72.05 dB	7.61	24.00			
Duration of P	103.89 ms	21.32	24.00	0.00	9.22	23.00
Duration of S	55.80 ms	12.05	24.00			

<Historious>. As before, intensity and duration were found to be the significant acoustic correlates in differentiating primary stress [+tonic, +stress] from secondary stress [-tonic, +stress] in MWAE NES productions of <historious>. Table 41 shows that there was no significant statistical difference between the values of F0 for *P* and *S*, *t* (27.0) = 0.71, *p* = n.s, with a very small Cohen's *d* effect size (*d* = -.1). However, there was a significant difference between the intensity of *P* and *S*, *t* (27.0) = 6.59, *p* < 0.00, with a moderate Cohen's *d* effect size (*d* = .6). Also, there was a significant difference in duration between *P* and *S*, *t* (27.0) = 12.60, *p* = < 0.00 and a very large Cohen's *d* effect size (*d* = 3.5).

Table 41. Paired Sample t-Test Results for P vs. S in
<Historious> for Native English Speakers

<historious>	Mean	SD	N	*p-value*	*t-statistic*	*df*
F0 of P	174.16 Hz	47.14	28.00	0.48	0.71	27.00
F0 of S	169.63 Hz	50.85	28.00			
Intensity of P	75.26 dB	6.86	28.00	0.00	6.59	27.00
Intensity of S	70.41 dB	9.23	28.00			
Duration of P	121.47 ms	23.65	28.00	0.00	12.60	27.00
Duration of S	57.69 ms	11.07	28.00			

Summary. The bar graphs in Figure 41 highlight the information from the paired-sample t-tests comparing the F0 values in *P* and *S*. Pitch was only found to be a significant marker of primary stress [+tonic, +stress] as opposed to secondary stress [-tonic, +stress] in one token; i.e., <historical>.

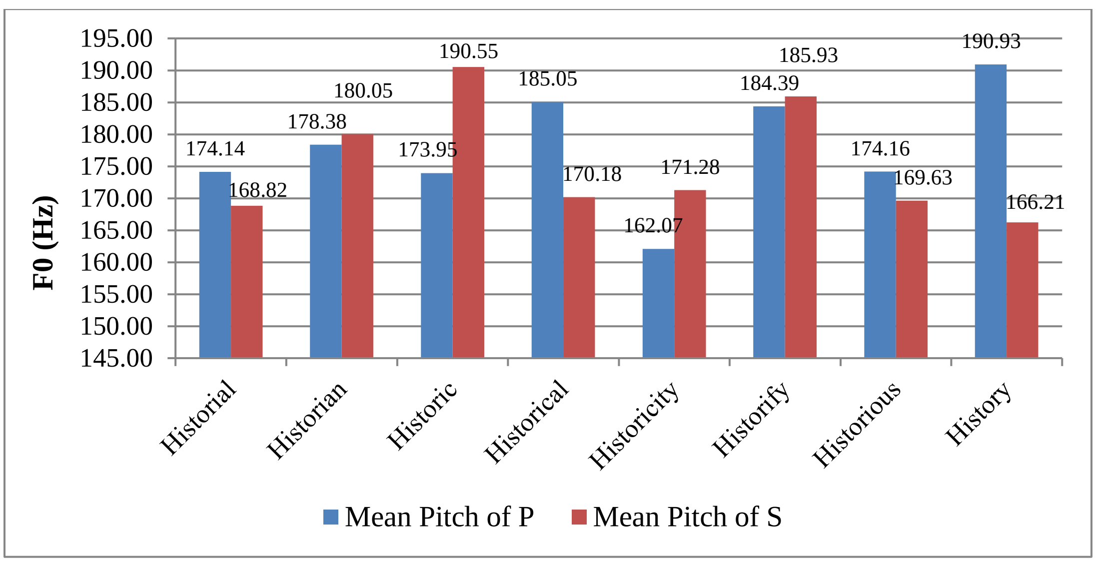


Figure 41. Mean Native Speaker F0 values (dB) for Primary [+tonic, +stress] (*P*) and Secondary [-tonic, +stress] (*S*) Stressed Vowels per Token

Figure 42 summarizes the findings from the paired-sample t-tests comparing intensity values in *P* and *S*. Intensity was a significant distinguisher of primary-stressed [+tonic, +stress] vowels from secondary-stressed [-tonic, +stress] vowels in all the tokens except <historicity>.

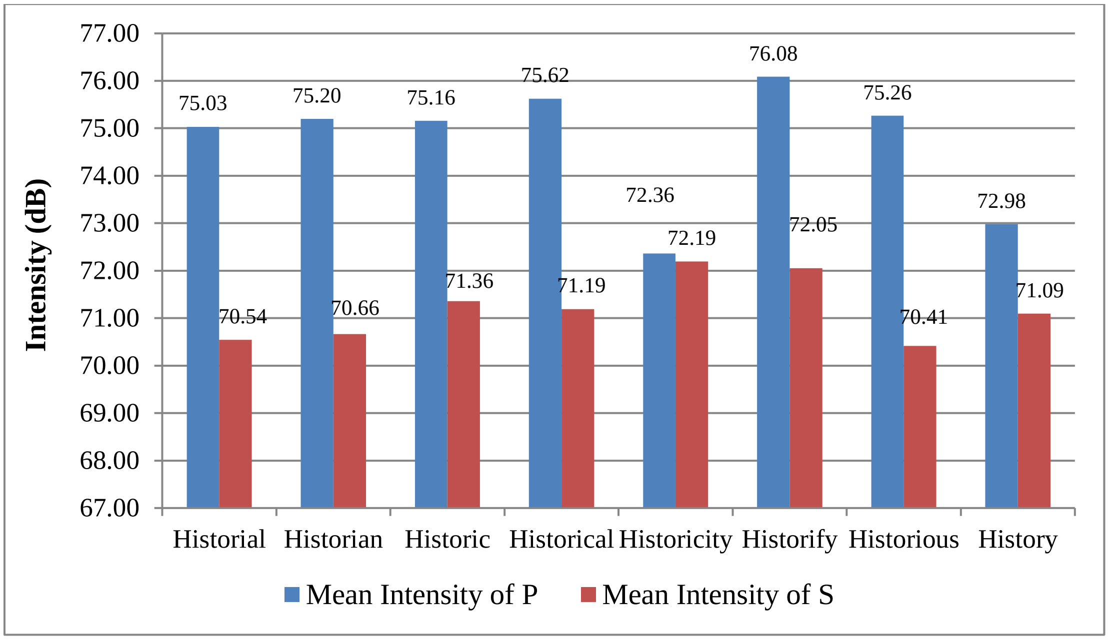


Figure 42. Mean Native Speaker Intensity Values (dB) for Primary [+tonic, +stress] (*P*) and Secondary [-tonic, +stress] (*S*) Stressed Vowels per Token

The bar graphs in Figure 43 compare the mean duration values for *P* and *S*. In all but one of the paired sample t-tests (i.e., *P* vs. *S* in <historicity>), duration was shown to be a significant indicator of tonic accent; that is, a longer vowel differentiated the primary-stressed [+tonic, +stress] vowel from the secondary-stressed [-tonic, +stress] vowel.

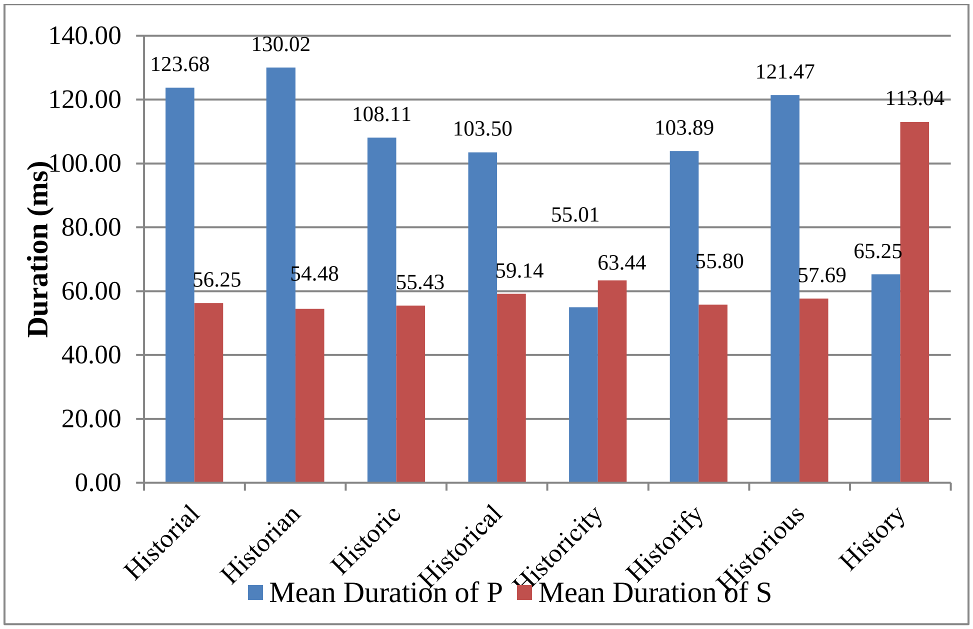


Figure 43. Mean Native Speaker Duration Values (ms) for Primary [+tonic, +stress] (*P*) and Secondary [-tonic, +stress] (*S*) Stressed Vowels per Token

Finally, Table 42 provides an overview of the relevant acoustic correlates for each token with respect to tonic accent shift (i.e., primary vs. secondary stress).

Table 42. Most Salient Acoustic Correlates of Tonic Accent Shift in Primary-Stressed Vowels [+tonic, +stress]

Token	F0	Intensity	Duration
<history>	×	✓	✓
<historial>	×	✓	✓
<historian>	×	✓	✓
<historic>	×	✓	✓
<historical>	✓	✓	✓
<historicity>	×	×	×
<historify>	×	✓	✓
<historious>	×	✓	✓

✓ = salient acoustic correlate × = non-salient acoustic correlate

Chapter V: Discussion

With the study's research questions in mind, one can make the following observations.

1) **Quantitative observation of stress-shifts in NES Level 1 [+cyclic] word productions**

In accordance with the pronunciations stated in common textbooks and dictionaries, at least 90% of native speakers of MWAE placed the primary stress on the vowel preceding the suffix in the Level 1 [+cyclic] derivations (Figure 9), and 97% (3% were miscellaneous recording errors) placed it on the first vowel in <history> (Figure 10). For these accurate productions, native speakers of MWAE on average produced primary-stressed vowels with higher F0, greater intensity, and longer duration than the average of the rest of the vowels combined as indicated by the positive vocalic relative stress ratios in Table 7. More conclusively, Table 32 shows that for each token, at least one correlate had a significantly different value in the primary-stressed vowel than in the mean of all the other vowels combined. In other words, the primary vowel was prominent due to the contrast in one or more acoustic features, we can conclude that stress-shifts in Level 1 [+cyclic] derivations can be observed quantitatively, at least for the words used in this study.

It should be noted, however, that in some cases the length of the primary-stressed vowel was significantly shorter than the mean of all the other vowels, namely in <history>, <historicity>, and <historify>. When one examines these tokens, the reason for this anomaly becomes clear: these three tokens all have a tense vowel, [i] (or diphthong in the case of <historify>, in the ultima which is inherently longer than the lax vowel, [ɪ] (or [ɔ] in <historify>), in the primary-stressed vowel. Although comparing the primary vowel with one reduced vowel as in Lee and Cho's investigations (2011) would indubitably yield positive durational contrasts, the author maintains that the *P* vs. *All* method used in this study is beneficial. The reason being, it highlights the fact that duration may not be a useful indicator of primary stress if the word contains unstressed vowels which are [+tense]. Notwithstanding, the [+tonic,+stress] vowels in <history> and <historify> were still positively prominent with regards to intensity, and thus, quantifying stress-shifts only becomes problematic in <historicity> (see Table 32). It is the contention of this researcher that this may be due to the *pentasyllabic* nature of this token, and thus more research is needed on the acoustic correlates of English lexical stress (ELS) in five-syllable words.

2) **Salience Hierarchy of the Acoustic Correlates of Stress (SHACS)**

Table 7 shows the mean vocalic relative stress ratios for duration, F0, and intensity which are 1.61, 1.13, and 1.06, respectively. It is important to note that this information alone is not sufficient to determine the SHACS in Level 1 [+cyclic] derivations since the ratios for each acoustic cue are measured in different units (i.e., Hertz, decibels, and milliseconds) which are not calibrated to be perceptively equivalent or directly comparable. For example, we often see a larger Cohen's *d* effect size for duration in *P* vs *All* than for intensity; however, this does not mean that intensity is a less salient cue. Obviously, the amount of decibels, or fundamental frequency for that matter, cannot increase by the same numerical value as say the difference in milliseconds between a long and short vowel. As M. J. Munro elucidated, the auditory system does not interpret pitch, intensity, and duration in such a linear fashion (personal communication, September 21, 2013). That is, a small vocalic relative stress ratio of F0 may be perceptually equivalent to a much larger ratio of stressed vs. unstressed vowel duration values. For these reasons, a better way to identify the most salient acoustic cues to lexical stress might be to use some form of acoustic correlate weighting scale which equates the different unit measurements as in more robust stress analysis methods such as Linear Predictive Coding (LPC) (e.g., Silva, Macedo, & Barreto, 2011) or other techniques which employ probabilistic algorithms (e.g., Freij & Fallside, 1988). Unfortunately, delving into the realm of perceptual psychoacoustics is beyond the scope of this paper.

Nevertheless, the results of the paired sample t-tests on the *P* vs. *All* analyses of MWAE NES productions do provide a more convincing description of SHACS than the mean vocalic relative stress ratios alone (Table 32). Antithetically, at least with regards to many of the leading theories on SHACS (e.g., Adams & Munro, 1978; Fry, 1955, 1958), the results from this study suggest that intensity is at least the most reliable, if not the most salient, cue to ELS. Indeed, the intensity of the primary-stressed [+tonic, +stress] vowel was statistically greater than the mean intensity of the non-primary [-tonic, +stress] vowels in all eight tokens (Table 32). Based on frequency of significances, duration was the next most salient cue to ELS as it was also statistically different in *P* vs. *All* in all the tokens, albeit with a shorter duration in three of the tokens as previously discussed. Surprisingly, fundamental frequency (F0) was the least salient acoustic correlate as it was only statistically higher in *P* in two of the tokens, namely <historial> and <historical>. It would be interesting to conduct further research to see whether the final segment, [l], has any bearing on the prominence of F0 in these two tokens.

Based on these findings, one could reasonably argue that the SHACS in Level 1 [+cyclic] derivations is: intensity > duration > F0. Is this a characteristic of words with stress-shifting suffixes, or even polysyllabic words in general? It is not possible to tell at this point, but suffice it to say, more acoustic investigations of ELS in polysyllabic words are needed, particularly with other tokens containing stress-shifting suffixes. Moreover, these studies should develop or utilize existing acoustic cue weighting scales so that the vocalic relative stress ratios for the three correlates can be compared as equivalently as possible. For now, it appears that the results in this study most closely support the findings of Beckman and Edwards (1994) that F0 is the least salient cue to stress as it is only important in defining sentential pitch accent. Their notion of SHACS (i.e., duration > intensity > F0) most closely resembles the hierarchy proposed here.

In the meantime, it is evident that speakers are able to utilize any or all of the three acoustic correlates to mark lexical stress in a particular word. In the speech of MWAE NES, only two of the tokens, <historial> and <historical>, were produced with significantly greater values of all three correlates. Therefore, perhaps T.M. Adams (2006) described it best when he posited that the three acoustic signals “participate in a form of cue trading to signify stress in different contexts” (p. 3087).

3) **Nonnative ordering of the acoustic correlates of stress**

On average, both Arabic L1 NNES and Mandarin L1 NNES produced primary-stressed vowels with higher F0, greater intensity, and longer duration, albeit with smaller vocalic relative stress ratios for each of the acoustic correlates than NES (Table 7). It is noteworthy that these ratios were in roughly the same proportions as for NES; i.e., duration > F0 > intensity. However, as previously explained, due to perceptual dissimilarities, one cannot assert that this is the SHACS for these speakers.

Nonetheless, the paired sample t-test analyses of *P* vs. *All* do provide insight into the SHACS for each NNES group, both of which differ from the NES model. Clearly, there are some similarities and differences in the ways that different L1 speakers produce lexical stress contrasts in different contexts, with considerable overlap between the three groups (Table 32). Let us now examine the NNES groups independently.

Mandarin English L2 speakers perhaps deviated more from the NES norm in that they tended to use F0 as a salient acoustic cue to ELS more often. In four of the tokens (i.e., <history>, <historian>, <historify>, and <historious>) they used a statistically higher F0 in *P* than in *All* (Table 32). Additionally, there was a large effect size of F0 in their productions of <historial> as signified by the question mark in Table 32. Thus, the results seem to concur with earlier studies which indicate that Chinese speakers of English over-use F0 as an acoustic cue to ELS (e.g., Keating & Kuo, 2012; Zhang et al., 2008).

Encouragingly, the results in this study also support the findings of Zhang et al. (2008) in that Mandarin and English speakers' use of duration and intensity were similar. For intensity, only <historic> yielded no significances in Mandarin L1 NNES productions, whereas for duration, *P* was not statistically different from *All* in only <history>, <historicity>, and <historify> (Table 32). Interestingly, these were the same three tokens which NES (and Arabic speakers for the latter two) produced a negative ratio of duration in *P* vs. *All*. Previously, the author posited that this was due to the tense vowel or diphthong in the ultima which is longer than the lax vowel in the primary-stressed vowel. When one listens to the recordings and views the spectrograms of Mandarin L1 NNES productions of these tokens, the reason that Chinese speakers do not produce such negative durational contrasts become clear. It is very common for Mandarin English L2 speakers to *clip* the final syllable or segment in an utterance. This can mean vowel reduction and/or consonant deletion in the ultima in Mandarin-accented English. For example, instead of /hɪstərísɪti/, they may say [hɪstərísɪtə]–reducing the tense vowel to a schwa. Another frequent example of *clipping* is the deletion of the alveolar liquid, /l/, and alveolar nasal, /n/, when they occur as the final phoneme. In many cases, the acoustic phonetic researcher could not tell the difference between a Chinese speaker's production of [hɪˈstɔr i ən] and [hɪˈstɔr i əl]. It was decided that these would not be counted as pronunciation errors because a) there would not be enough data left in the main dataset to analyze, b) they did not affect any of the [+stress] vowels, and more importantly c) they were regarded as innate characteristics of Mandarin-accented English–a legitimate dialect of English when one considers *World Englishes.*

Despite the differences mentioned thus far, Mandarin English L2 speakers were actually similar to MWAE NES with regards to the SHACS in that intensity seemed to be the most salient correlate. However, it is hard to gauge which is the more important cue out of duration and F0. Therefore, based on these results, the SHACS for Mandarin English L2 speakers appears to be: intensity > F0 ≥ duration.

Meanwhile, although Arabic English L2 speakers did differ from native speakers as to the exact combination of significant acoustic correlates with individual tokens, overall they produced ELS more similarly to NES than Mandarin English L2 speakers. That is, intensity appears to be the most salient cue to stress for Arabic English L2 speakers and F0 is relatively unimportant. Durational contrasts between P and All were not as numerous as they were for NES although Arabic English L2 speakers also produced negative duration ratios for <historicity> and <historify> (Table 32). They did not, however, produce any significant contrasts in duration between P and All in <history>, <historic>, and <historical>. Curiously, for <history>, no statistical differences at all were found for any of the acoustic correlates in Arabic English L2 speech (Table 32).

Unlike Chinese speakers who did not produce any token with exactly the same combination of salient acoustic correlates as NES, Saudi speakers produced <historial> and <historious> with the same combination; i.e., F0, intensity, and duration for <historial> and intensity and duration for <historious> (Table 32). To conclude this section, the SHACS for

Arabic L1 NNES in Level 1 [+cyclic] productions seems to be the same as NES: intensity >> duration > F0.

4) **Problematic acoustic correlates for Arabic L1 and Mandarin L1 speakers**

We have already discussed the fact that, based on the paired sample t-tests of *P* vs. *All*, Chinese subjects tend to use more pitch contrasts than NES to differentiate ELS, which almost certainly leads to accentedness. Somewhat surprising then, Figure 23 shows that one-way ANOVA and posthoc Tukey tests of the *P* vs. *All* dataset found that neither Mandarin nor Arabic L1 speakers were statistically different from NES with regards to F0 usage as an acoustic correlate of ELS in Level 1 [+cyclic] derivations (<history> productions were excluded). That said, the *p* value was close to being significant ($p = 0.6$). Therefore, we can surmise that the differences in relative vocalic stress ratios of F0 production in *P* vs. *All* were very small. Table 7 shows that the mean ratio of F0 for NES was actually higher than Mandarin L1 NNES, but Figure 23 shows that the maximum F0 ratio in P vs. All was higher for the Chinese subjects. Meanwhile, the boxplots in Figure 23 do tell us that MWAE NES use a wider range of F0 to discriminate ELS than NNES. Mandarin L1 speakers use a slightly smaller F0 range which seems to confirm the findings of Li and Shuai (2011), while disagreeing with those of Keating and Kuo (2012). The latter, however, did note that the large F0 ranges were more evident in one-word utterances, and the stimuli used in this study were in carrier phrases. Regardless, based on the t-tests and ANOVAs, there are clearly differences in the ways in which Mandarin L1 NNES and NES use F0 in ELS. For Arabic L1 speakers, the boxplot in Figure 23 indicates that they use a much more limited range of F0 as the 25% and 75% percentile lines are close to the median. This limited F0 range may also account for Arabic-accented English.

With regards to nonnative production of intensity, the results from ANOVA/Tukey posthoc tests found that Mandarin L1 NNES were significantly different from NES. This was somewhat unexpected based on previous studies of Mandarin English L2. From table 7 though, it is clear that Mandarin L1 subjects used a lower ratio of intensity and so underuse this prosodic correlate. Thus, although t-tests reveal that intensity was significantly different in P vs. All in all but one of the tokens, Mandarin L1 NNES still do not employ this cue in a native-like manner.

Also relevant to the question of problematic prosodic correlates, Figure 25 illustrates that on average Arabic L1 NNES significantly under-use durational contrasts between *P* and *All* to emphasize primary stress. This may be due to the fact that Arabic English L2 speakers tend not to reduce vowels as suggested by Zuraiq and Sereno (2005). Not reducing the unstressed vowels in a token would certainly result in smaller durational contrasts between the primary [+tonic] and non-primary [-tonic] vowels. The ANOVA results also support Bouchhioua's (2008) study which found that duration is not an important correlate of lexical stress in Tunisian Arabic as it is in English and negative transfer may lead to non-native accentedness, if not unintelligibility. This would explain why the acoustic phonetic researcher had a hard time aurally adjudicating whether many of the Arabic L1 NNES productions contained stress-placement error, or not.

In sum, Arabic L1 NNES tend not to reduce unstressed vowels in Level 1 [+cyclic] derivations and use a limited F0 range to differentiate stress-shifts. Conversely, Mandarin L1 NNES use F0 more as a salient marker of primary stress while under-using intensity contrasts.

5) **Correlation between amount of L2 exposure and/or amount of L2 input** and:

a) **Accurate placement of stress in Level 1 [+cyclic] derivations**

Figure 12 illustrates that the longer learners of English have spent studying the language (i.e., increased L2 input), the fewer pronunciation and stress-placement errors they make in stress-suffixed words ($p < 0.05$). Naturally, one would expect this result, but when L2 exposure (i.e., years of residence in L2 country) was plotted against number of errors, it did not yield significant correlations (Figure 11). The author contests that this was due to the fact that there was a very limited range of the independent variable; that is, as the scatter plots in Figure 11 indicate, the vast majority of participants in this study had only spent between one and two years in an English-speaking country. For this variable to produce significant results, a study with a much larger range of L2 residency values would be needed. Of course, it would be difficult to collect this sort of data in a university setting as most international students are only short-term residents.

It would be edifying to note at this point that the author was not expecting the variable of "Years of L2 Study" to yield significantly correlated results. Actually, I had thought that the questionnaire was poorly constructed since any answer to the question is ambiguous. That is, 10 years of English L2 study could mean any number of actual learning hours. For example, one subject may have studied English for 10 years but only for two 45-minute sessions per week, while another may have studied intensively every day for 2 years. In addition, the author is aware that some of the Saudi participants, in particular, indicated that they had begun studying English since their arrival in the US, when in fact they had begun learning English in elementary school. They confided that they did not feel that their English education in their home country was adequate enough. Indeed, they were quite adamant about this. Therefore, what is interesting from a psychological viewpoint, is that this strong correlation relates to how many years of English L2 education subjects *feel* they have received.

Regardless of discrepancies in the preceding sociometric data collection methods, the results in Figure 13 remove all doubt on the matter. It clearly shows that Arabic and Mandarin

L1 NNES produce fewer errors the higher the level of their English L2 proficiency with a significance of $p < 0.00$ and a medium effect size of $r = -.05$.

b) **Native-like production of the acoustic correlates of stress in Level 1 [+cyclic] derivations**

According to Figure 27, there is a statistically significant correlation ($p < 0.05$) and a moderate effect size ($r = -.5$) between amount of L2 input (i.e,, years of English L2 study) and Mandarin L1 NNES' ability to produce native-like F0 contours in lexical stress contrasts. Furthermore, Figure 33 shows that there was also a significant correlation when native-like production of F0 was correlated with English L2 proficiency level, albeit with a very small effect size ($r = -0.0$, $p < 0.05$). These correlations are particularly interesting since the t-tests on Mandarin English L2 productions revealed an over-usage of F0 as a prosodic correlate, and the ANOVAs revealed that Chinese speakers use a smaller range of F0 than NES. Therefore, the results of this correlation encouragingly suggest that Chinese learners of English are able to overcome their innate difficulties when producing ELS through increased L2 study.

Similarly, while the aforementioned ANOVAs revealed that Arabic L1 speakers were statistically different from NES with regards to duration usage as a prosodic cue, correlations of production accuracy of duration versus amount of L2 study (Figure 28) and proficiency level (Figure 34) both yielded significances, approximately $r = -.3$, $p < 0.05$ in each case. Therefore, through increased acquisition of the English language, Saudi learners are also able to vanquish the detrimental effects of negative transfer from their L1 sound system.

To conclude the answer to this research question, correlations did not find any significant relationship between any of the independent variables and native-like production of intensity. Partly, this is not surprising because from the summarized information in Table 32, we can deduce that intensity is already employed as a prosodic correlate in almost every token by both groups of NNES. . Even though ANOVAs did reveal that Mandarin L1 NNES significantly under-used intensity ($p < 0.05$), the Cohen's d effect size was very small ($d = .1$). As conjectured earlier, the lack of correlations may be because the average intensity ratio if P vs. All was very similar for all three language groups and that intensity was not a difficult acoustic stress cue to master. Perhaps that is why previous studies have claimed that it is the least important cue to ELS; in other words, because it is not hard for NNES to manipulate, it is not a determiner of accentedness, comprehensibility, or intelligibility

6) **Palatal glide epenthesis in the stress-shifting suffixes: <ian>, <ious>, and <ial>**

One of the unexpected findings of this study was the high incidence of /j/ epenthesis in the tokens <historian>, <historious>, and <historial> (Figures 38-40). Indeed, the results suggest that [hɪˈstɔri**j**ən] be included as an alternative pronunciation to [hɪˈstɔriən] in standard American English dictionaries since almost half of the MWAE NES subjects pronounced it this way. Although no IPA transcription is available for <historial> since it is an archaic word (Dictionary.com, 2014), or for <historious> since it is a proper noun (Historious.us, 2014), one can infer that dictionary pronunciation entries for words containing the Level 1 [+cyclic] suffixes, <-ial> and <-ious>, such as <ministerial> and <glorious>, may need to be revised. In fact, it may be the case that the inclusion of /j/ be considered *the* main pronunciation of words containing these suffixes as the vast majority of MWAE NES produced the palatal glide in this study.

7) **Lack of evidence for "tonic accent shift" in polysyllabic Level 1 [+cyclic] derivations**

T-tests failed to support Ladefoged and Johnson's (2010) notion that tonic accent shift (i.e., the differentiator between primary (*P*) and secondary-stressed (*S*) syllables) is caused by a "major pitch change" (p. 119) in the primary-stressed vowel, at least with respect to polysyllabic Level 1 [+cyclic] derivations (Tables 34-41). In fact, the only token where F0 distinguished *P* from *S* was <historical>, and even then, intensity and duration were also significantly greater (Table 42).

Contrarily, the results reveal that intensity and duration are the relevant prosodic correlates in assigning primary status to a vowel (Table 42). Even in the disyllabic stem word, <historic>, these two correlates were the most salient. Thus, more studies on the features of tonic accent shift in polysyllabic words should be conducted to determine whether the theory holds true.

Limitations of the Study

The most obvious limitation of this study is that none of the data were cross-checked by another researcher. Ideally, a random sample of 20% of the acoustic measurements (i.e., spectrogram textgrid delineations) would have been re-annotated by an independent acoustic phonetician who was blind to the purpose of the study as per Zhang et al. (2008). Cohen's kappa could then be used to check for inconsistencies in the data coding system by cross-referencing the stress analysis data (Mackey & Gass, 2005). Unfortunately, this was not feasible given that the author is not a professional researcher, and his colleagues (fellow graduate students) did not have sufficient time to spare. At least, the stress analysis data itself was collected automatically using a Praat script (Yoon, 2008), thus reducing the possibility of human error.

Another limitation is that only one example of each Level 1 [+cyclic] suffix was used (each with the same stem), which limits the generalizability of the results in this study. Therefore, it would be informative for further studies to be conducted using a wider range of stems so that the acoustic properties of individual suffixes can be investigated. Likewise, more combinations of polysyllabic words could be used as tokens. For instance, <historicity> was observed to have somewhat idiosyncratic characteristics with regards to SHACS which highlights the need for more studies on words with five or more syllables.

In addition, the researcher only investigated the acoustic correlates of fundamental frequency, intensity, and duration, omitting another important acoustic cue–vowel quality. As Levis (2012) affirms, the suprasegmental feature - prosodic structure - and the segmental feature–vowel quality–are “interdependent” (¶13). Many other researchers attest to the significance of vowel reductions in lexical stress (Celce-Murcia et al., 1996; Edmunds, 2009; Fear et al., 1995; Field, 2005; Hillenbrand et al., 1995). For example, it would be advantageous for other studies to measure F1 and F2 values to observe whether Arabic L1 speakers’ under-use of duration as a salient acoustic cue is indeed due to a deficiency in vowel neutralizations in unstressed vowels as hypothesized.

Furthermore, the evidence provided in this paper in relation to /j/ epenthesis in words with <ial> <ian>, and <ious> demands further research before standard dictionary pronunciations of words with these suffixes are revised. Approximants are notoriously difficult to acoustically distinguish from vowels, and sometimes must be identified by phonological rather than articulatory means (“Speech Acoustics,” 2008). This is not to suggest that the data presented here is not valuable or even valid; however, it is important to build upon this research by investigating the issues further “using more objective spectral measurement techniques” (Hunt, 2009, p. 18).

Lastly, this research focused on one dialect of English–Midwest American English–and so it would be edifying for future studies to test the replicability of the findings in this study in other varieties of English with regards to ELS production, tonic accent shift, and palatal glide epenthesis in Level 1 [+cyclic] derivations.

Chapter VI: Conclusion

The results presented in this paper yield insight into several interdependent issues related to lexical stress in polysyllabic English words containing stress-shifting suffixes. First and foremost, this study provides support to the view that the acoustic correlates of stress do indeed have a hierarchy of relative salience, hereinafter named SHACS. The SHACS proposed here is intensity > duration > fundamental frequency (F0). While this does not exactly match any of the schemes described in the literature, it most closely resembles the SHACS postulated by Beckman and Edwards (1994): duration > intensity > F0. Most likely, SHACS is context dependent. For instance, Fry's (1955, 1958) notion of SHACS (i.e., F0 > duration > intensity>) may only be relevant to disyllabic homographs while intensity may only be the most salient acoustic cue in three and four syllable words. Clearly, more studies on English lexical stress (ELS) in a wide range of polysyllabic words are needed to validate this hypothesis.

What is certain though is that relative vocalic stress ratios of the three acoustic cues play an important role in differentiating lexical stress patterns, and there does appear to be a *native-norm* for ordering these acoustic signals. Indeed, the various significant correlations described in this paper support this notion.

From a second language acquisition perspective, there is good evidence to suggest that native-like command of the acoustic correlates is attainable for English language learners. Although speakers with different inherent L1 sound systems encounter different problems when trying to acquire native-like stress production, encouragingly, it appears that they can overcome these difficulties through increased input of the L2. Not only do experienced English language learners produce fewer pronunciation errors, they also produce prosodic contrasts in a more native-like manner. For instance, although Saudi speakers inherently under-use duration as acoustic cue to ELS (perhaps by not fully reducing vowels), they are able to use this acoustic correlate more accurately as their language skills progress. Similarly, Chinese learners of English are able to overcome the negative transfer of their tonal system by producing pitch in a more native-like manner as they advance in their studies.

Furthermore, the present results do *not* support Ladefoged and Johnson's (2010) theory of tonic accent shift. Instead, the results actually suggest the opposite; that is, intensity and duration appear to be responsible for contrasts between primary and secondary stressed vowels. It will be interesting to observe whether these findings can be replicated, and whether the variables of token length (disyllabic vs. polysyllabic words) and/or token delivery method (read utterances vs. natural speech) have any effect.

Finally, with regards to pronunciation, this investigation provides convincing evidence for a possible revision of standard American English dictionary IPA transcriptions. At least for the words in this study, the suffixes <-ial>, <-ian>, and <-ious> were more commonly pronounced by native and nonnative speakers with the epenthetical insertion of a palatal glide, [j]. Thus, future studies should explore the presence or absence of this phenomenon in other dialects of English, both native and nonnative.

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Appendix A: Sociometric Background Questionnaire

The following questions ask you about your basic personal information and your English language learning experience. Please answer all the questions by putting a circle ○ in the appropriate block. Thank you very much for your help!

1. What is your age (in years)?

18	19	20	21	22	23	24	25	26	27
28	29	30	31	32	33	34	35	36	37
38	39	40	41	42	43	44	45	46	47
48	49	50	51	52	53	54	55	56	57

2. What is your gender?

Male	Female

3. What is your nationality?

American (United States) U.S.A.	Saudi (Kingdom of Saudi Arabia) K.S.A.	Chinese (People's Republic of China) P.R.C.

4. What is your first language (mother tongue)?

English	Arabic	Mandarin Chinese

5. For how many years have you been studying English?

Years				
0	1	2	3	4
5	6	7	8	9
10	11	12	13	14
15	16	17	18	19

Months				
0	1	2	3	4
5	6	7	8	9
10	11			

6. For how long have you lived in an English-speaking country (in years and months)?

Years				
0	1	2	3	4
5	6	7	8	9
10	11	12	13	14
15	16	17	18	19

Months				
0	1	2	3	4
5	6	7	8	9
10	11			

7. What is your level of English?

IEC Pre-Level 1	IEC Level 1	IEC Level 2
IEC Level 3	IEC Level 4	IEC Level 5
College ESL Undergraduate	Undergraduate Student	Graduate Student
Native Speaker of English		

THANK YOU VERY MUCH – I REALLY APPRECIATE

Appendix B: Ladefogedian Stress Patterns of the Stimuli

Table B1

Token/ Variable	CV					Stress Pattern
1.<history>	[hís]	[tri]				1 2
Stress	+	+				
Tonic accent	+	-				
Full vowel	+	+				
2.<historic>	[hɪs]	[tɔ́r]	[ɪk]			2 1 3
Stress	+	+	-			
Tonic accent	-	+	-			
Full vowel	+	+	+			
3.<historical>	[hɪs]	[tɔ́r]	[ɪ]	[kəl]		2 1 3 4
Stress	+	+	-	-		
Tonic accent	-	+	-	-		
Full vowel	+	+	+	-		
4.<historicity>	[hɪs]	[tə]	[rís]	[ɪ]	[ti]	2 4 1 3 3
Stress	+	-	+	-	-	
Tonic accent	-	-	+	-	-	
Full vowel	+	-	+	+	+	
5.<historial>	[hɪs]	[tɔ́r]	[i]	[əl]		2 1 3 4
Stress	+	+	-	-		
Tonic accent	-	+	-	-		
Full vowel	+	+	+	-		
6.<historify>	[hɪs]	[tɔ́r]	[ɪ]	[faɪ]		2 1 3 3
Stress	+	+	-	-		
Tonic accent	-	+	-	-		
Full vowel	+	+	+	+		
7.<historious>	[hɪs]	[tɔ́r]	[i]	[əs]		2 1 3 4
Stress	+	+	-	-		
Tonic accent	-	+	-	-		
Full vowel	+	+	+	-		
8.<historian>	[hɪs]	[tɔ́r]	[i]	[ən]		2 1 3 4
Stress	+	+	-	-		
Tonic accent	-	+	-	-		
Full vowel	+	+	+	-		

Note. Adapted from "Teaching Pronunciation: A Course in Phonetics," by Ladefoged, 2001, p. 97.

❖ Phonetic transcriptions based on International Phonetic Alphabet (IPA) pronunciations provided by Dictionary.com (2013).

Appendix C: Sample Spectrogram Illustrating Vowel Delineation Procedure

All 800 spectrograms were delineated as in the example below where ‘P’ corresponds to the primary-stressed vowel, ‘S’ is the secondary-stressed vowel, and ‘US’ refers to an unstressed vowel.

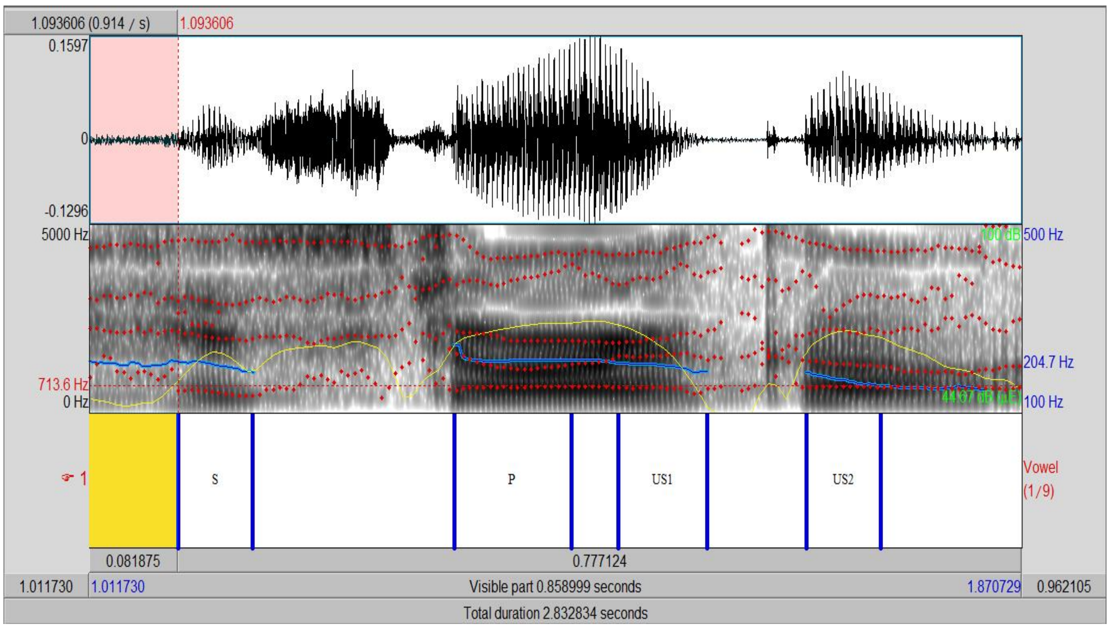

Figure C1. <Historical> as spoken by a Midwest American female

Appendix D: Sample Data Log for a Chinese Male Speaker

Table D1

Token	Mean F0 (Hz)			Mean Duration (ms)			Mean Intensity (dB)		
	Primary Stressed Vowel (*P*)	Non-primary Vowels (*All*)	*P* vs. *All* Ratio	Primary Stressed Vowel (*P*)	Non-primary Vowels (*All*)	*P* vs. *All* Ratio	Primary Stressed Vowel (*P*)	Non-primary Vowels (*All*)	*P* vs. *All* Ratio
History	147.09	109.98	1.34	74.27	97.05	0.77	74.81	68.15	1.10
Historial	169.86	134.50	1.26	119.09	60.07	1.98	78.11	75.98	1.03
Historian	176.53	134.54	1.31	145.68	63.13	2.31	77.48	73.08	1.06
Historic	151.79	121.48	1.25	104.39	56.12	1.86	78.96	72.00	1.10
Historical	163.08	132.99	1.23	113.01	75.34	1.50	78.08	74.54	1.05
Historicity	155.9	124.54	1.25	60.29	96.13	0.63	74.64	74.54	1.00
Historify	172.02	145.40	1.18	86.16	135.38	0.64	78.27	72.70	1.08
Historious	166.56	131.83	1.26	138.65	80.07	1.73	77.56	75.32	1.03

Subject	Age	Gender	Nationality	L1	Level	Years of L2 Study	Years in L2 Environment
C1-m	24	Male	PRC	Mandarin	Undergraduate	17	5.42

❖ The *P vs. All Ratio* refers to the vocalic relative stress value for each acoustic correlate.

Appendix E: Examples of the Error Types: Stress Placement and Pronunciation

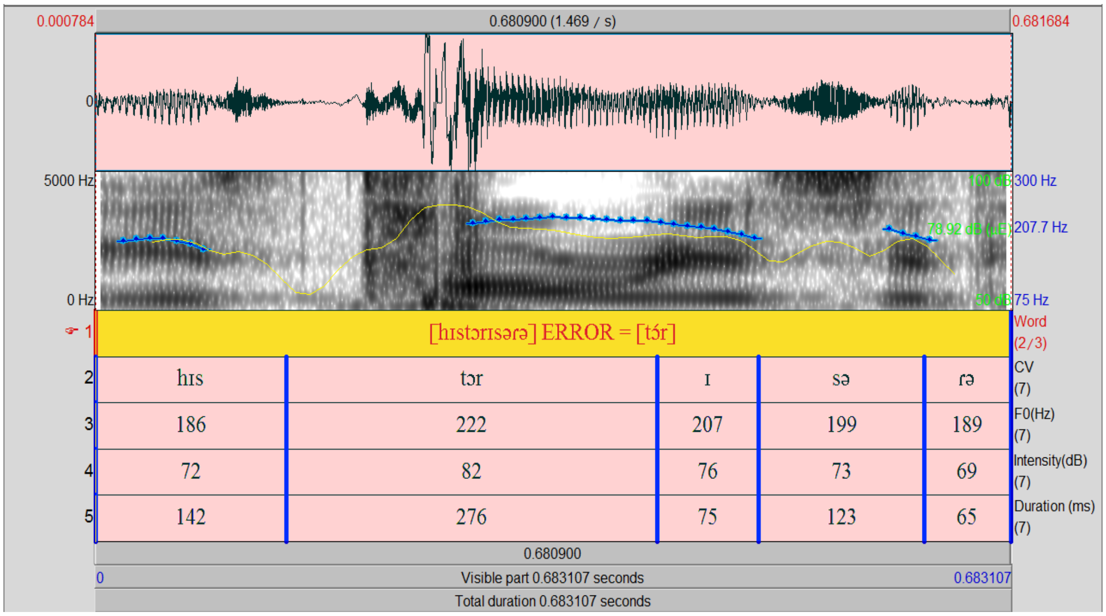

Figure E1. Example of a Stress Placement Error by a Chinese Male Graduate Student

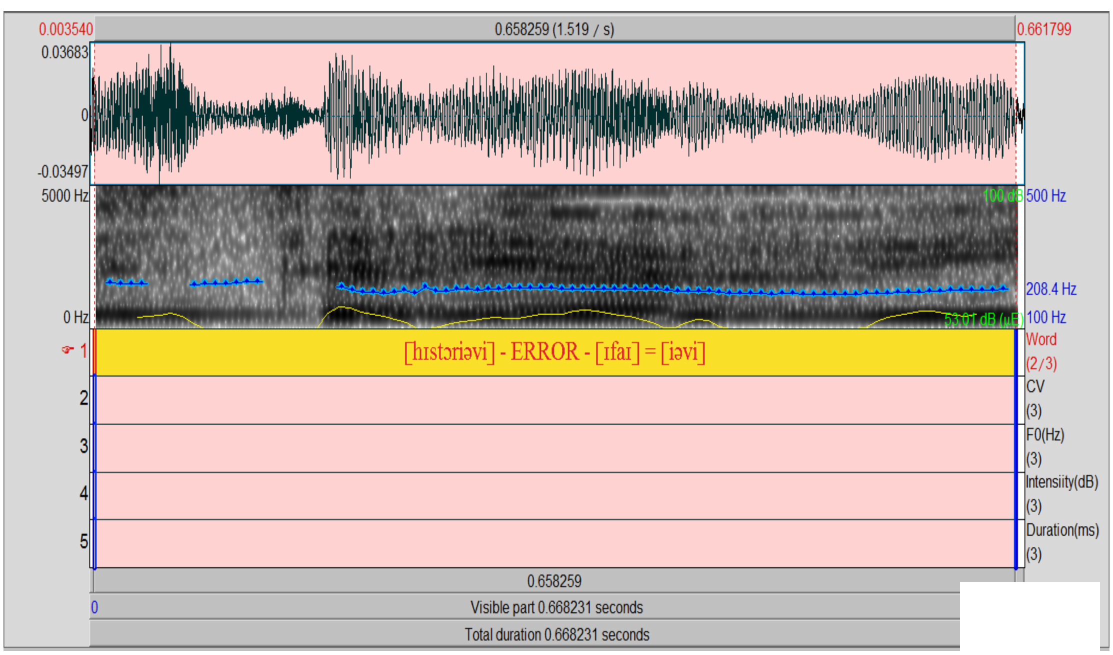

Figure E2. Example of a Pronunciation Error by a Saudi Female Upper Intermediate IEP Student

Appendix F: Evidence of Palatal Approximant Epenthesis

The following spectrograms illustrate productions of <historian>, <historial>, and <historious> which either concur with standard American English dictionary pronunciations or conflict with them through the addition of the epenthetic glide, /j/, in the Level 1 [+cyclic] suffix.

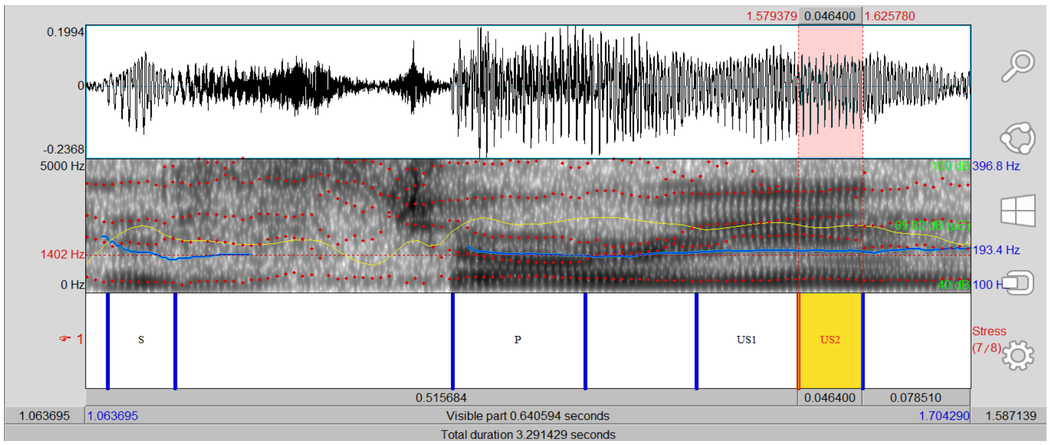

Figure F1. <Historian> Produced by a Midwest American Male in Accordance with the Standard Dictionary Pronunciation, [hɪstɔ́riən], *without* an Epenthetic /j/

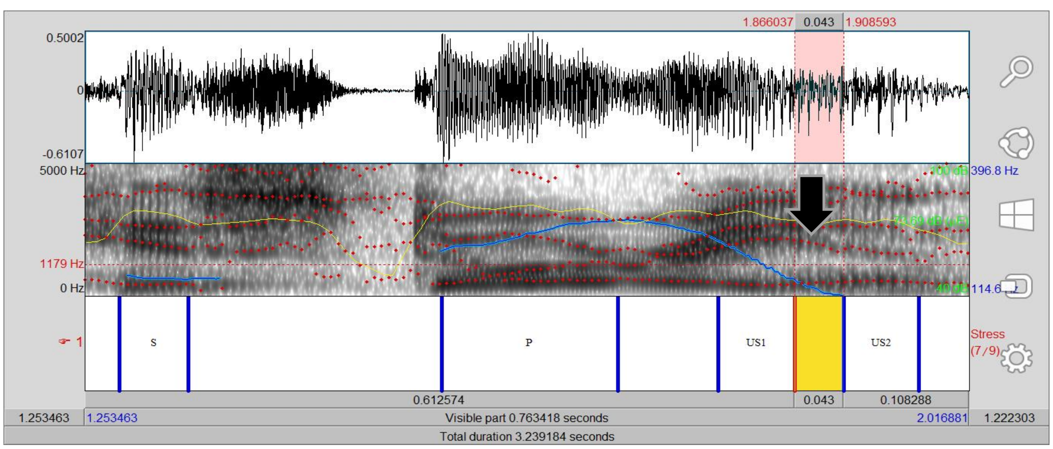

Figure F2. <Historian> Produced by a Midwest American Male as [hɪstɔ́rijən] *with* an Epenthetic /j/ in the Onset of the Ultima

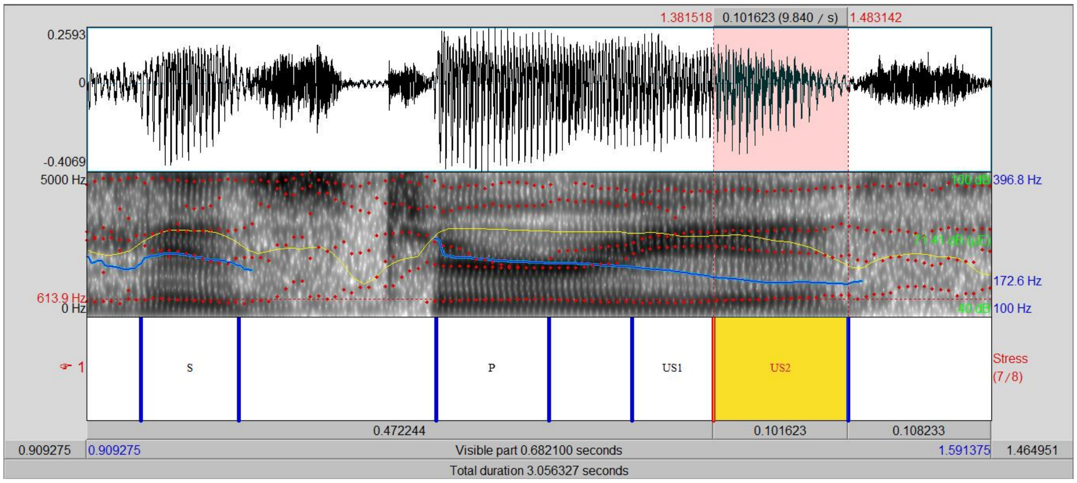

Figure F3. <Historious> Produced by a Midwest American Female as [hɪstɔ́riəs] *without* an Epenthetic /j/ in the Onset of the Ultima

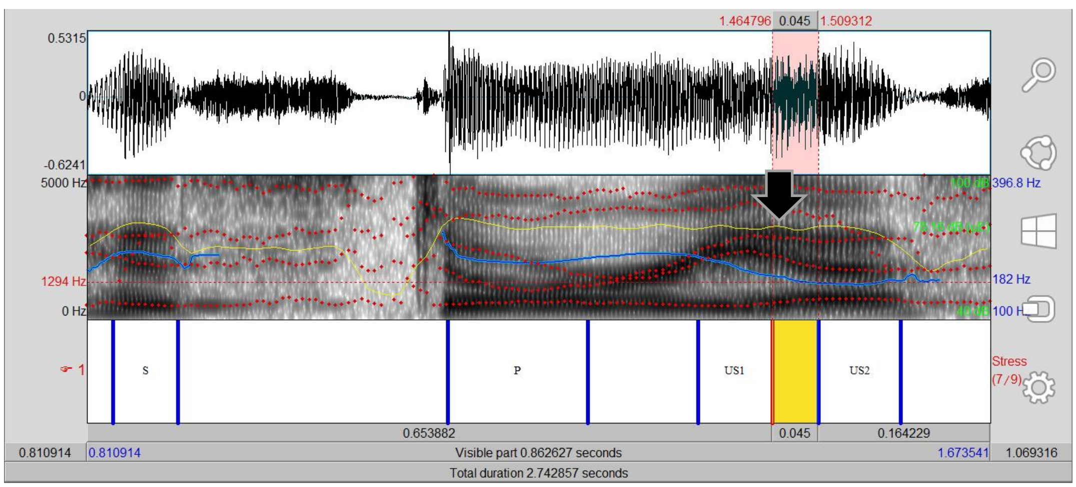

Figure F4. <Historious> Produced by a Midwest American Female as [hɪstɔ́rijəs] *with* an Epenthetic /j/ in the Onset of the Ultima

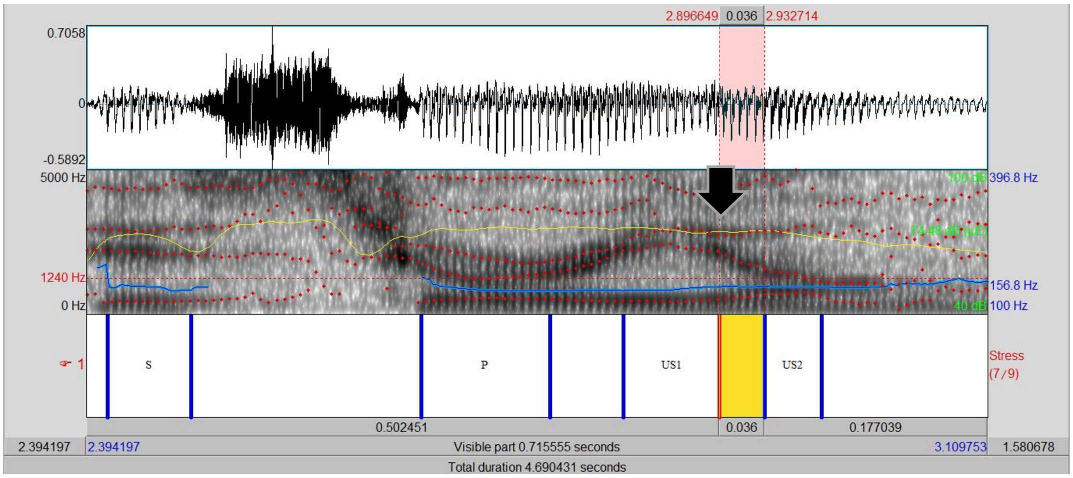

Figure F5. <Historial> Produced by a Midwest American Female as [hɪstɔ́rijəl]
with an Epenthetic /j/

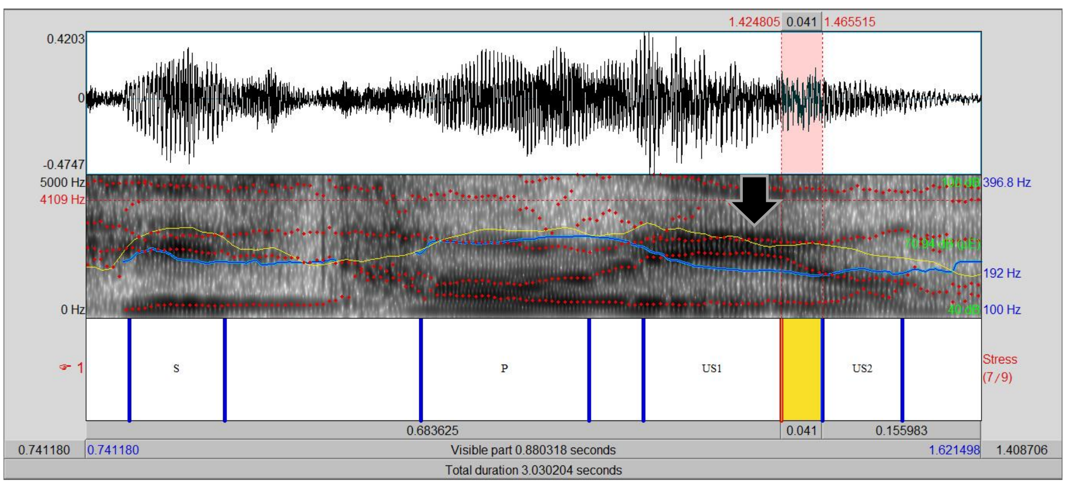

Figure F6. <Historial> Produced by a Chinese Female Graduate Student as [hɪstɔ́rijəl]
with an Epenthetic /j/

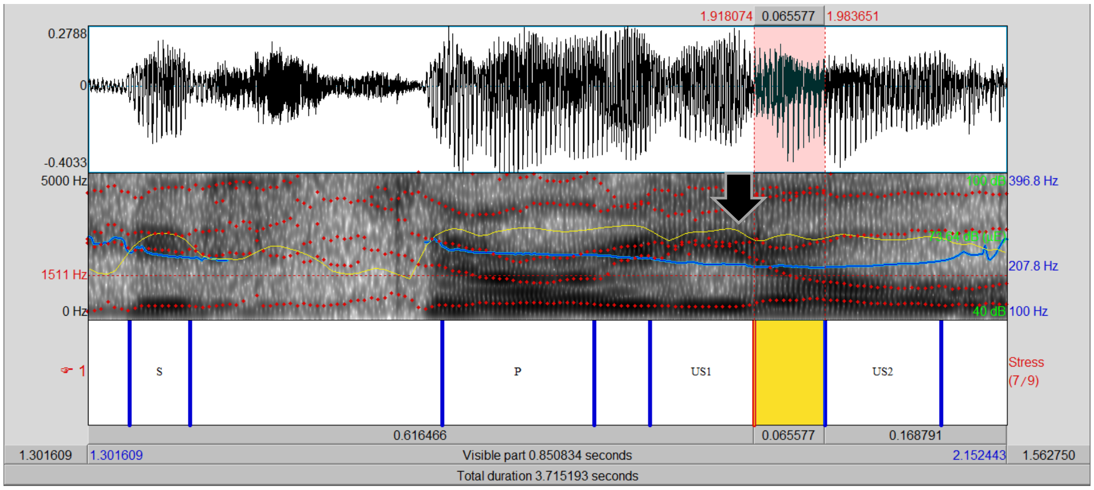

Figure F7. <Historial> Produced by a Saudi Female Graduate Student as [hɪstɔ́rijəl] *with* an Epenthetic /j/