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THE ACOUSTIC CORRELATES OF STRESS-SHIFTING SUFFIXES IN NATIVE AND NONNATIVE ENGLISH: SOME PRELIMINARY FINDINGS

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Although laboratory phonology techniques have been widely used 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. 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. 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 relative salience hierarchy of the three acoustic correlates of stress. The results support the notion that differences in lexical stress production in varieties of L2 English can be directly attributed to differences in the L1 sound system; hence, nonnative ratios of the acoustic cues lead to accented speech. Furthermore, the findings suggest that native-like command of ELS can be acquired by proficient L2 learners via increased L2 input.

INTRODUCTION

Certain suffixes in English cause a shift in stress in the root morpheme to the syllable directly preceding the suffix, and have hence been labeled *stress-shifting suffixes* by pronunciation experts (e.g., Celce-Murcia, Brinton, and Goodwin, 1996, Kreidler, 2004). They have claimed that the resultant shift in stress in turn causes a change in the neutralization or vowel reduction in the unstressed syllable. However, these claims about lexical stress shifts have not yet been supported quantitatively by laboratory phonology. Furthermore, quantification of stress shifts in suffixal derivations has scarcely been utilized as a tool in the acoustic phonetic characterization of accentedness in the speech of second language (L2) English speakers from different first language (L1) backgrounds.

Background and Need for the Study

The acoustic correlates of lexical stress are fundamental frequency (hereinafter F0), duration, and intensity[(9)]. Although various laboratory phonology studies have analyzed these cues in the

(1) According to Ladefoged (2006), for all intents and purposes, F_0 is synonymous with pitch (measured in Hertz, Hz), duration means vowel length (measured in milliseconds, ms), and intensity equates to loudness (measured in Decibels, db). Frequency is the number of cycles of variations in air pressure in one second, and pitch is the auditory feature that allows listeners to

context of English Lexical Stress (ELS) in general, they have not explored the acoustic properties of the full range of stress-shifting suffixes in the lexicon. In fact, studies on ELS in *polysyllabic* words in general have largely been ignored in favor of disyllabic minimal stress pairs, as in Fry's seminal works (1955, 1958).

Moreover, there are few studies comparing the productions of stress-shifting suffixes by native speakers of English (NSE) and nonnative speakers of English (NNSE), and the effects of L1 background and amount of L2 exposure/input on pronunciation accuracy have not been fully explored. Munro and Derwing (1995) have emphasized the need for further studies on the features of L2 pronunciation that have the most significant effect on intelligibility in English. Similarly, 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.

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 NNESs, 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 of interest to investigate whether Arabic L1 NNSE typically produce the acoustic correlates of stress more accurately than Mandarin L1 NNSE. Notwithstanding, Shemshadsara (2011) has provided statistical empirical evidence that Iranian Persian speakers have more difficulty placing stress in words with stress-shifting suffixes than words with neutral-suffixes (Burzio, 1994). Thus, these data further necessitate the need for a thorough acoustic analysis of stress-shifting suffixes.

Purpose of the Study

First, this project aims to quantify lexical stress shifts and provide insight into the relative salience hierarchy of the acoustic correlates of ELS. To do this, vocalic F_0, duration, and intensity productions by native speakers of Midwestern American English (MWAE) dialect are analyzed in words containing stress-shifting suffixes.

From a second language acquisition (SLA) research perspective, the other purpose of this study is to identify problematic acoustic correlates for NNSE and observe whether there is a correlation between exposure to the L2, amount of L2 input, and/or L1 background and production accuracy of words containing stress-shifting suffixes. As Zhang et al. (2008) have succinctly noted, most

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perceive a sound on a low-high spectrum where a sound with high frequency is realized as high pitched (Ladefoged, 2006).

research in the area of ELS "confound the phonological issue of stress placement with the phonetic problem of native-like stress production" (p. 4498). Thus, production accuracy here implies a twofold distinction:

1) L2 knowledge of where to place the stress in derived words
2) Native-like production of the acoustic correlates of stress.

Specifically, this study examines the acoustic correlates of ELS in productions of English words containing stress-shifting suffixes by Arabic L1 and Mandarin L1 NNSE.

Research questions

Q1. Do English 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 F_0, duration, and intensity?

Q2. Which acoustic correlates are problematic for Arabic L1 and Mandarin L1 speakers when producing lexical stress contrasts in words containing stress-shifting suffixes?

Q3. 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 lexical stress in stress-shifting suffixal derivations.
b) Native-like production of the acoustic correlates in stress-shifting suffixed words.

METHOD

Participants

One hundred participants including 29 MWAE NSE (male n = 15; female n = 14), 38 Arabic L1 NNSE (male n = 15; female n = 23) from the Kingdom of Saudi Arabia (KSA), and 33 Mandarin L1 NNSE (male n = 15; female n = 18) from the People's Republic of China (PRC) participated in the experiment. Subjects were recruited primarily 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. This study only used NNSE who grew up speaking MWAE dialect. Prior to acoustic data elicitation, each participant completed a short "factual" (Dörnyei, 2003, p.8) sociometric questionnaire. Figure 1 shows the total number of subjects by language and gender.

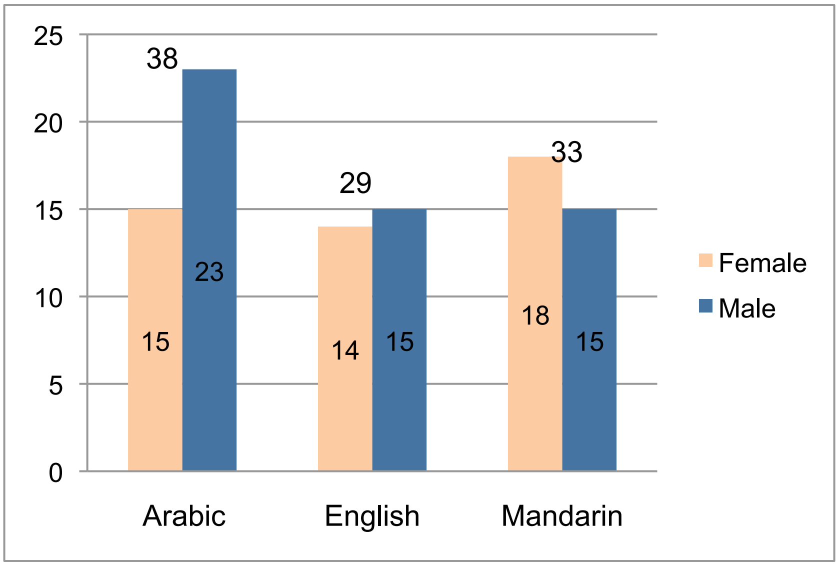

Figure 1. Participants by language and gender.

Materials
Stimuli

The procedure involved digitally recording (sampling rate of 44.1 kHz and quantization of 16 bits) productions of eight tokens, which included 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>.

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. In this case, *"Say"* carries the onset rise, and *"again"* carries the pitch accent.

Procedure
Data collection

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. Prior to recording, the participants did not receive any training in pronunciation of the words so that they would have to rely upon their own phonological knowledge of where to shift the primary stress.

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, 2001; See Appendix A). 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). First, the grid-maker script was run and vowel segments were defined in the series of spectrograms (Appendix B).

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. Thus, each individual production was measured for the mean F0/intensity/duration of the primary stressed vowel and the mean of the mean F0/intensity/duration values for all the other vowels (i.e., secondary stressed and unstressed).

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 $F_{0.}$ This concurs with the methodologies of McClean and Tiffany (1973), Flege and Bohn (1989), and Lee and Cho (2011).

In order to answer *Research Question 2, and 3b,* 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 might also include stress placement errors but was deemed more serious with regards to intelligibility as it (also) included a deletion, and/or addition, and /or substitution of a segment or cluster of segments. Naturally, any productions containing errors had to be excluded from the main dataset; however, this data was useful to answer *Research Question 3a*. Pearson Product-Moment Correlations were used to determine the strength of relations and effect sizes (r values) for the operationalized variables of L2 exposure and L2 input.

RESULTS

Pronunciation and Stress Placement Errors

Figure 2 shows the percentage of errors for each language group. As one would expect, the NES made far fewer errors.

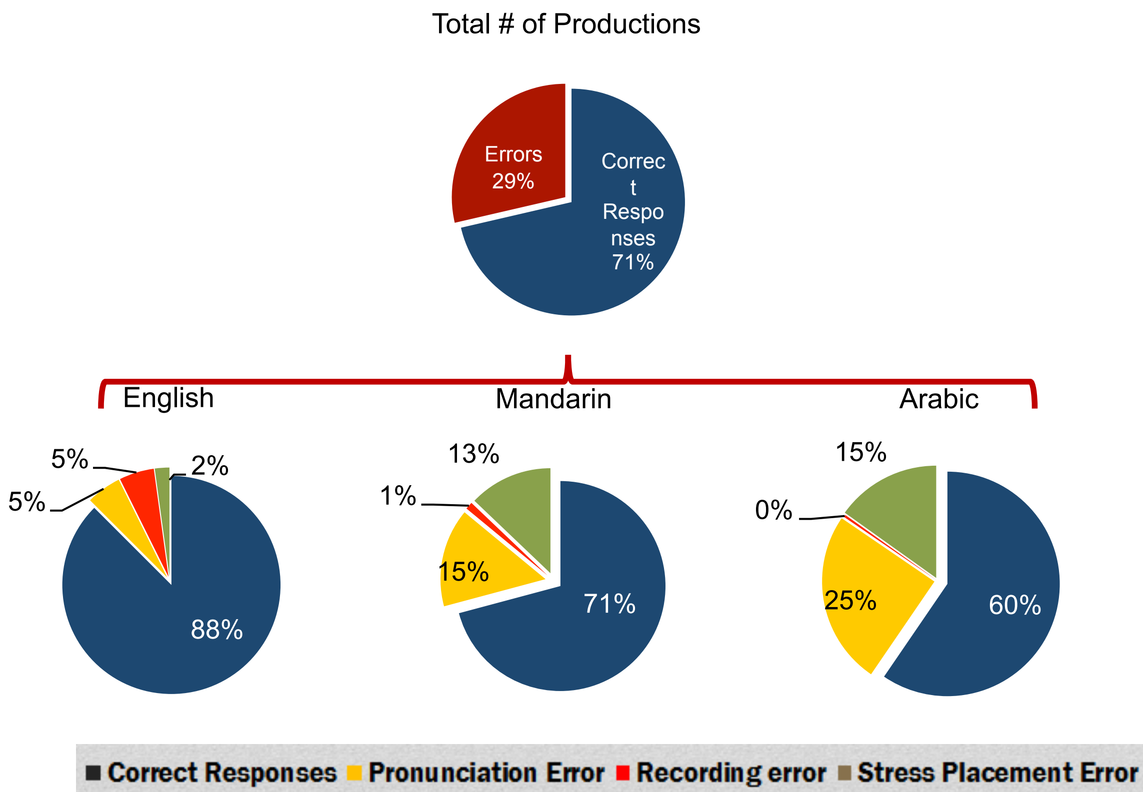

Figure 2. Proportion of error types for each language group.

Figure 3 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 are able to use the stress-shifting rules that are stored in their lexicons.

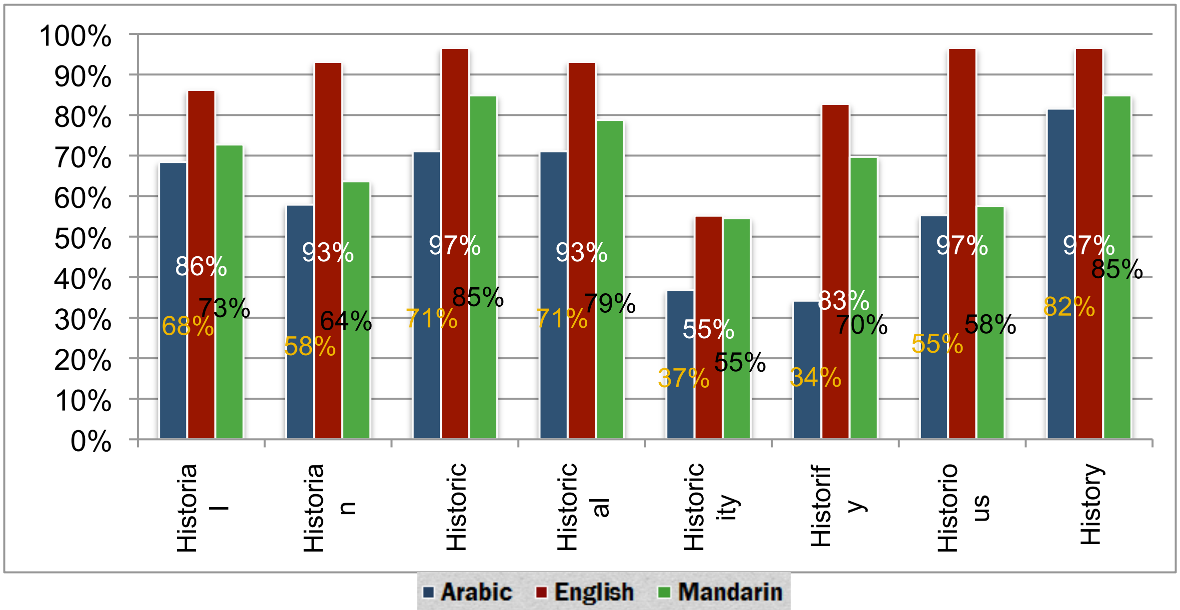

Figure 3. Proportion of correct responses by token and language group.

In Figure 4, the frequency of errors (pronunciation and stress placement) for all NNESs (Arabic and Mandarin L1 speakers) 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 participants had only spent between 0 and 1.5 years in an English-speaking country.

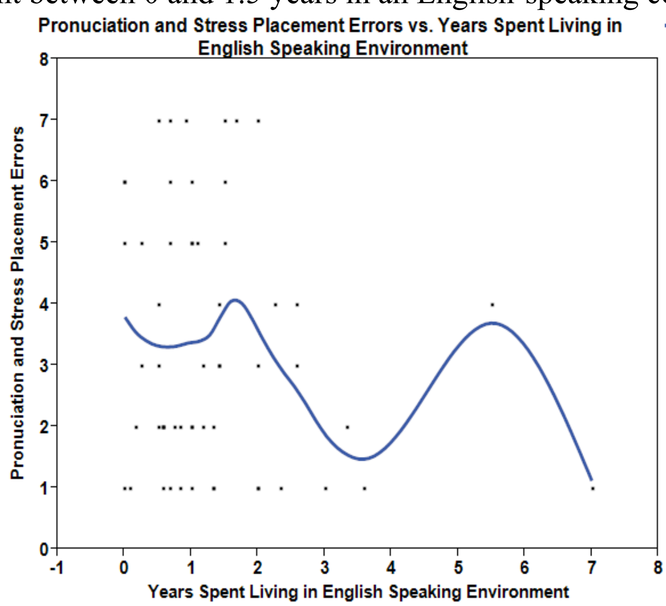

Figure 4. Frequency of pronunciation and stress-placement errors vs. years in L2 environment.

However, the smooth curve in Figure 5 shows that a significant correlation was found (r= - .26, p< .05.) for years of English language study and frequency of errors.

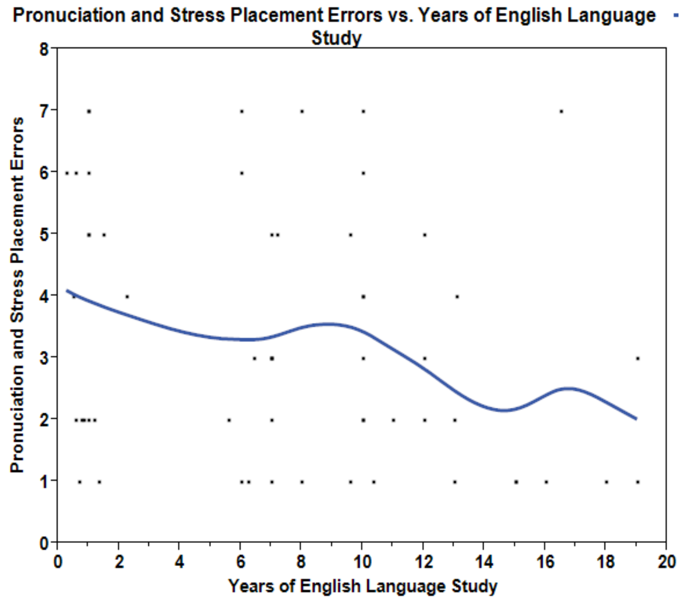

Figure 5. Frequency of pronunciation and stress-placement errors vs. years of L2 study.

Main Dataset

Table 1 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 NNESs were differentiating the stress in suffixed words, they did not do so to such a great extent as NES.

Table 1
Mean Ratios of Primary Stressed [+tonic acc.] to Non-primary Vowels [-tonic acc.] for the Three Acoustic Correlates by Language Groups

Language Group	F0	Intensity	Duration
Arabic	1.07	1.05	1.29
English	1.13	1.06	1.61
Mandarin	1.08	1.04	1.57

The mean ratios for each factor were entered into ANOVAs. The results are shown in Table 2.

Table 2
ANOVA Results for the Three Acoustic Correlates

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 6).

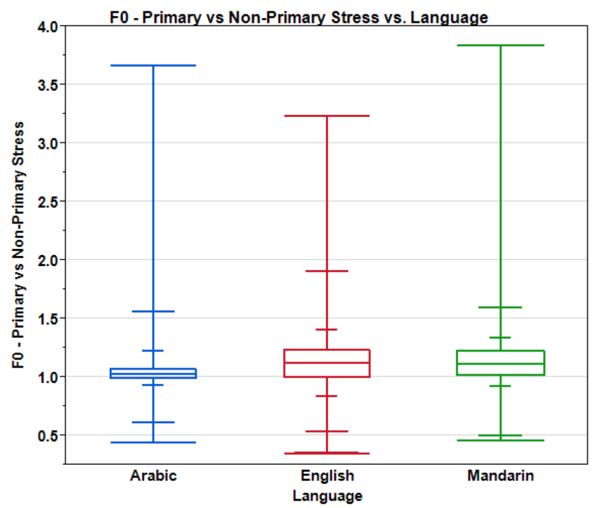

Figure 6. Comparative usage of F0 as a cue to ELS in stress-shifting suffixed words.

One-way ANOVA tests showed that there were significant differences between the language groups with regards to intensity as a prosodic cue, $F(2, 481) = 5.25$, $p < .01$. The Tukey HSD post hoc comparison revealed that Mandarin L1 NNES ($M = 1.04$, $SD = .05$) were statistically different from NES ($M = 1.06$, $SD = .04$) as they used a significantly lower ratio of intensity in stress contrasts (Figure 7).

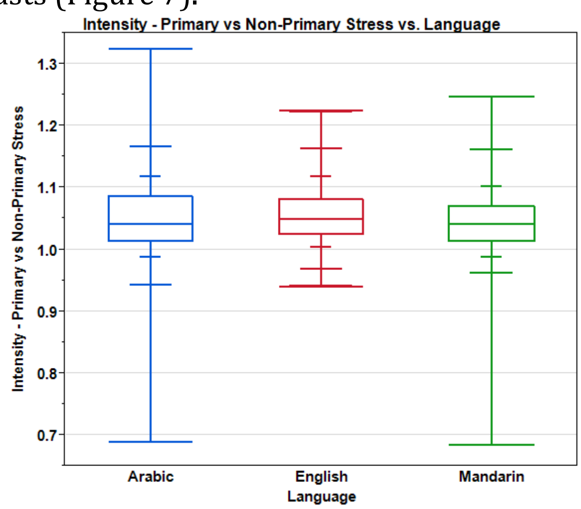

Figure 7. Comparative usage of intensity a cue to ELS in stress-shifting suffixed words.

Conversely, Figure 8 shows that it was Arabic L1 speakers who were statistically different from both Mandarin L1 speakers and NESs with respect to duration ratios of stressed to unstressed vowels. One-way ANOVA tests showed that there were significant differences between the language groups with regards to duration as a prosodic cue, $F(2, 481) = 11.90$, $p < .01$. The Tukey HSD post hoc comparison revealed that Arabic L1 NNES ($M = 1.29$, $SD = .70$) were statistically different from both NES ($M = 1.61$, $SD = .63$) and Mandarin L1 NNES

(M = 1.57, SD = .58) in their usage of durational stress contrasts (Figure 4); i.e., their relative vocalic stress ratios were much smaller.

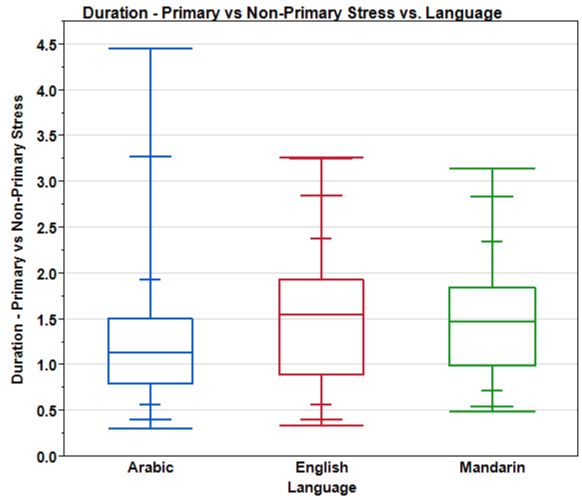

Figure 8. Comparative usage of duration as a cue to ELS in stress-shifting suffixed words.

Figures 9 and 10 show years of English L2 study versus native-like production of F0 (i.e., difference from the mean NES ratio) in lexical stress contrasts. While there was no significant correlation for Arabic L1 speakers, there was a significant correlation for Mandarin L1 speakers (r= - .49, p< .05). Therefore, the longer 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.

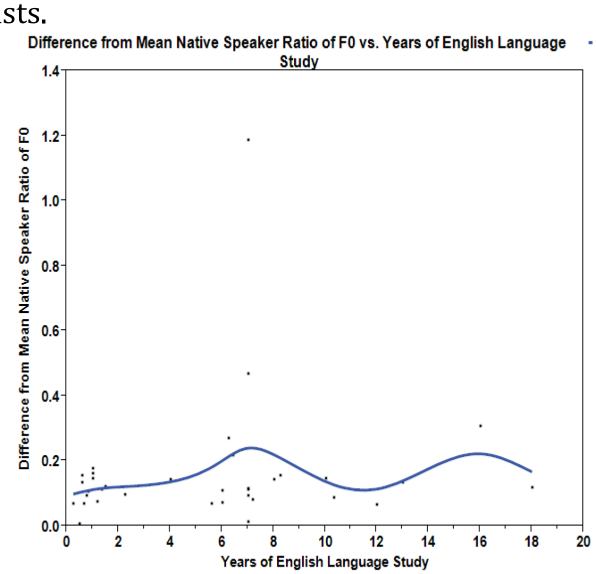

Figure 9. Difference of mean Arabic L1 speaker ratio of F0 from mean native speaker ratio of F0 vs. Years of L2 English study.

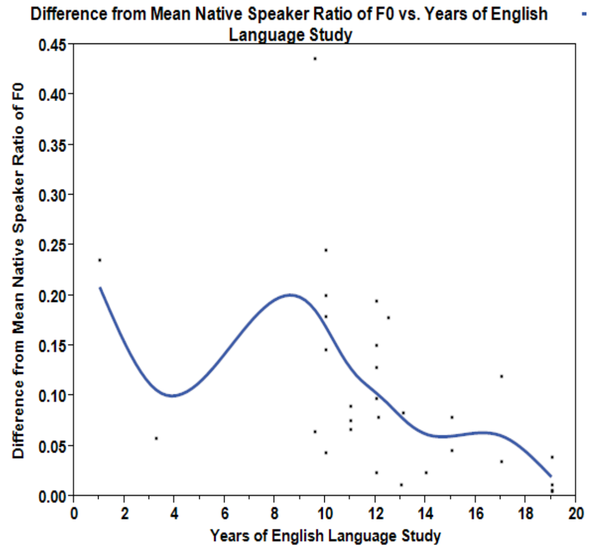

Figure 10. Difference of mean Mandarin L1 speaker ratio of F0 from mean native speaker ratio of F0 vs. Years of L2 English study.

Meanwhile, it was Arabic, not Mandarin L1 speakers, whose pronunciation improved with respect to duration usage as a result of increased English language study (Figures 11-12). Figure 11 shows that difference from mean NEs ratio of duration and years of English L2 study were significantly correlated for Arabic speakers, r= - .28, $p < .05$.

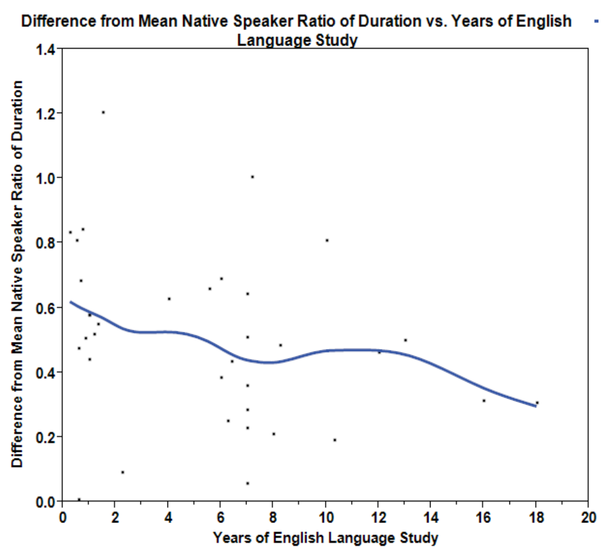

Figure 11. Difference of mean Arabic L1 speaker ratio of duration from mean native speaker ratio of duration vs. Years of L2 English study.

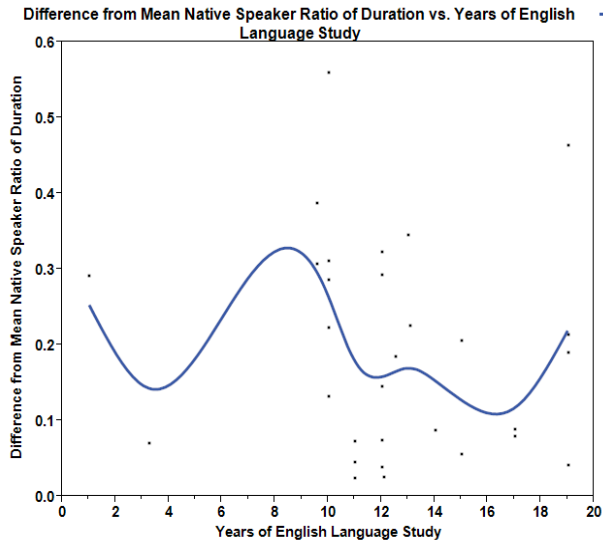

Figure 12. Difference of mean Mandarin L1 speaker ratio of duration from mean native speaker ratio of duration vs. Years of L2 English study.

DISCUSSION

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

Q1. Quantitative observation of lexical stress-shifts in derivations containing stress-shifting suffixes.

In accordance with the pronunciations stated in common textbooks and dictionaries, at least 90% of native speakers of MWAE placed the primary stress either on the vowel preceding the suffix in the derivations or on the first vowel in <history>. 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. Thus, we can conclude that stress-shifts in words containing stress-shifting suffixes *can* be observed quantitatively.

Q2. Problematic acoustic correlates for Arabic L1 and Mandarin L1 speakers

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 1). However, 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, further statistical tests were necessary in order to determine problematic features of L2 speech. One-way ANOVAs revealed that Mandarin L1 speakers did not use intensity in a native-like manner while Arabic L1 speakers tended to *underuse* duration as an acoustic cue to ELS in stress-shifting suffixed words. The latter phenomenon is most likely caused by Saudi speakers not fully reducing vowels in stress-shifts which is a result of L1 transfer from the predictable stress-system of Arabic as suggested by several researchers (Zuraiq, 2005; Altmann, 2006; Bouchhioua, 2008).

Q3. Correlation between amount of L2 exposure and/or amount of L2 input and

a) Accurate placement of stress in stress-shifting suffixal derivations.

Figure 5 suggests that the longer learners of English have spent studying the language, the fewer pronunciation and stress-placement errors they make in stress-suffixed words. As mentioned, although amount of L2 exposure (i.e., years of residence in L2 country) did not yield statistical correlations, a study with a larger range of values for this variable may produce significant results.

b) Native-like production of the acoustic correlates of stress in stress-shifting suffixal derivations.

Mandarin L1 speakers used pitch more accurately (in a more native-like manner) as an acoustic cue to ELS, the longer they claimed to have spent learning English. Meanwhile, Arabic L1 speakers used duration more accurately (by reducing unstressed vowels), the longer they claimed to have spent studying English. Thus, it seems that through increased L2 acquisition, Saudi learners are able to overcome the detrimental effects of negative transfer.

CONCLUSION

This investigation supports the view that the relative salience hierarchy of the acoustic correlates of lexical stress is an important feature of English L2 accentedness. Clearly, the precise ratios of the three acoustic cues play an integral role in differentiating lexical stress patterns, and there does indeed appear to be a *native-norm* for ordering these acoustic signals as evidenced by the significant correlations. Although speakers with different L1 sound systems encounter different problems when trying to acquire native-like stress production, encouragingly, it appears that they may be able to learn through increased L2 input. Not only do experienced learners produce fewer pronunciation errors, they also produce ELS in a more native-like manner. For example, although Saudi speakers inherently under-use duration as an acoustic cue to ELS by not fully reducing unstressed 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 employing pitch in a more native-like manner as they advance in their studies.

While this project has already yielded interesting results, it is a work in progress for my Master's thesis, and there are still many more research questions that can potentially be answered using the current dataset. These include issues relating to conflicts with standard dictionary pronunciations, the role of tonic accent shift, the idiosyncrasies of individual suffixes, and L1-specific acoustic correlates of stress salience hierarchies.

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Appendix A

Table A1

Ladefogedian stress-pattern values of the stimuli

Token/ Variable	CV					Stress-pattern Value
1.<history>	[hɪ́s]	[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]	[rɪ́s]	[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 P. Ladefoged, 2001, p97.

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

Appendix B

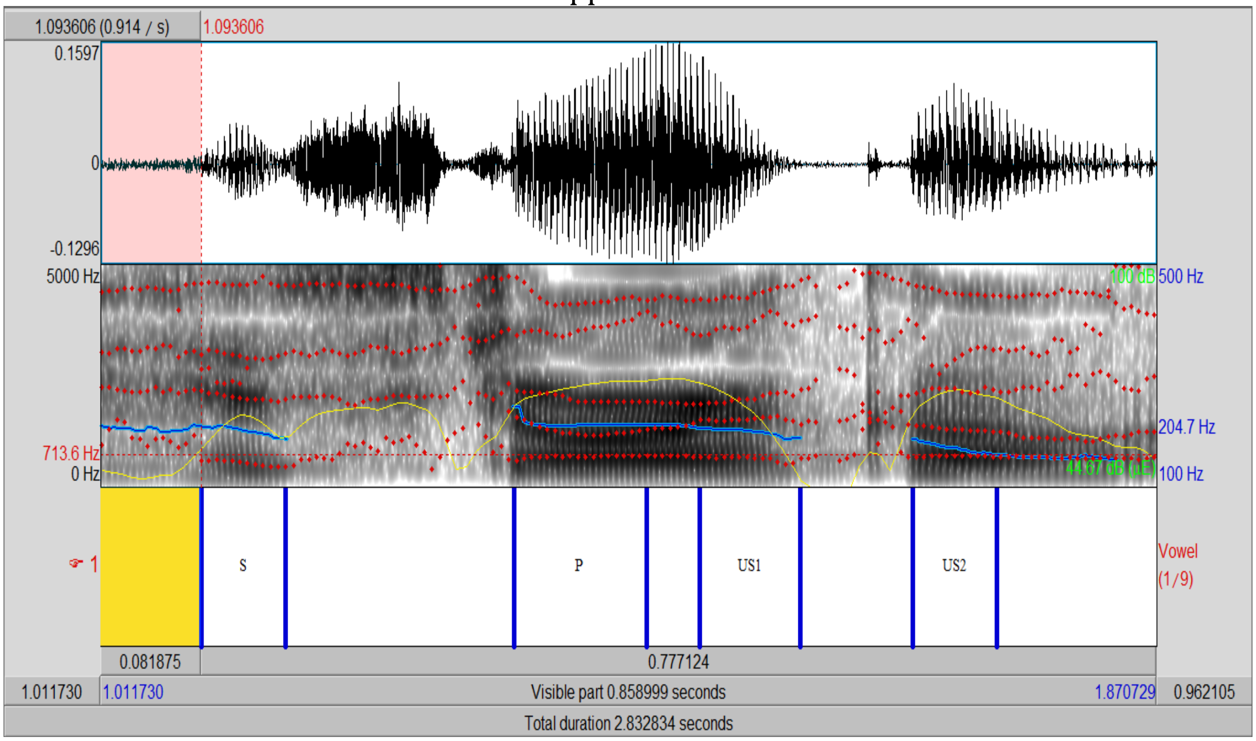

Figure B1. <Historical> as spoken by a Midwest American female.

P = primary-stressed vowel *S* = secondary-stressed vowel *US* = unstressed vowel