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Production of English Lexical Stress by Persian EFL Learners

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Abstract

This study examines the phonetic properties of lexical stress in English produced by Persian speakers learning English as a foreign language. The four most reliable phonetic correlates of English lexical stress, namely fundamental frequency, duration, intensity, and vowel quality were measured across Persian speakers' production of the stressed and unstressed syllables of five English disyllabic stress pairs which differed only in the location of stress, such as *contract* (noun)/ *contract* (verb). Results showed that Persian speakers' use of the prosodic cues to lexical stress, that is fundamental frequency, duration, and intensity was comparable to the use of the same cues by American English speakers for both the stressed and unstressed syllables. There were, however, significant differences in formant frequency patterns (as the phonetic correlates of vowel quality) across the two language groups, such that Persian speakers did not manage to approximate the target native-like productions of the majority of the vowels in the experimental data both in the stressed or unstressed conditions. This observation supports the proposal made by Flege and Bohn (1989), namely that L2 learners acquire L1 patterns of vowel reduction only after they have acquired English-like patterns of prosodic cues to stress (F0, duration and intensity), and that their inability to reduce vowels in unstressed syllables does not influence their ability to employ prosodic cues to lexical stress contrast. As will be discussed at the end, the results shall have implications for material developers and EFL teachers.

Keywords: lexical stress, vowel quality, vowel reduction, vowel space, formant frequency patterns, prosodic cues

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1. Introduction

A large number of the languages of the world employ a structural parameter called stress that specifies which syllable in the word is, in some sense, stronger than any of the others. However, the properties of lexical stress can vary dramatically from one language to another (Beckman, 1986; Beckman & Edwards, 1994) . One source of variation is that languages encode stress differently in their phonological representations of words. In some languages like English and Spanish, stress is contrastive in that words can vary in only the location of stress, such as object/object, while stress in other languages like French and Finnish is positionally fixed (occurring on the last syllable in case of French and the first syllable in case of Finnish) (Dupoux, Pallier, Sebastian, & Mehler, 1997; Dupoux, Peperkamp, & Sebastian-Galles, 2001). Another source of variation is the phonetic properties by which the stressed syllable distinguishes itself from the surrounding unstressed syllables, as well as from the unstressed realization of the same syllable. Lexical stress is generally cued by multiple acoustic features such as fundamental frequency (F0), intensity, vowel quality, and duration (Beckman, 1986; Beckman & Edwards, 1994; Fry, 1955, 1958). However, languages differ as to what degree each acoustic cue contributes to the phonetic realization of stress. In languages like English and Dutch, stress is cued not only by pitch[1] movement (F0 excursions) but also by intensity and duration (Fry, 1955, 1958; Sluijter & Van Heuven, 1996), while in the so-called tonal languages like Chinese and Japanese stress is mainly realized by F0 variation (Chen, Robb, Gilbert, & Lerman, 2001; Flege & Hillerbrand, 1987; Hung, 1993; Juffs, 1990; Zhang & Francis, 2010).

Native experience with a particular stress pattern can result in difficulties when trying to learn the stress pattern of a different language. For example, in a series of stress studies, it was found that French listeners had difficulties in discriminating Spanish stress contrast and claimed that native listeners of languages with a positional stress system could experience “stress deafness” when exposed to a contrastive stress language (Dupoux et al., 1997; Dupoux et al., 2001). As suggested subsequently by Dupoux, Sebastian-Galles, Navarete, and Peperkamp (2008), non-native listeners’ stress deafness results from their inability to encode contrastive stress in their phonological representation, that is, the problem may be fundamentally linguistic. Nevertheless, phonetic factors may play a significant role in explaining the problem of native-like stress production and perception (Chen et al., 2001; Dupoux, et al., 2001; Zhang & Francis, 2010). The interference of native phonetics on the acquisition of non-native segmental as well as suprasegmental features has been studied extensively, and results typically suggest that L2 learners have relatively greater difficulty producing and perceiving non-native contrasts that involve phonetic features dissimilar to those used in their native language (Flege & Bohn, 1989; Zhang & Francis, 2010; Zhang, Nissen, & Francis, 2008). For example, although English and Spanish both possess contrastive stress, vowel quality differences are associated with stress in English, but not Spanish, and native Spanish speakers have been found to have problems using vowel quality to signal English lexical stress (Flege & Bohn, 1989). Also, Mandarin speakers learning English as a second language have been reportedly shown to have difficulties producing English lexical and/or sentential stress, and it has been argued that this difficulty results, in large part, from the influence of native suprasegmental (tonal) categories (Archibald, 1997; Chen, et al., 2001; Hung, 1993; Juffs, 1990; Zhang, et al., 2008). In Zhang et al. (2008), native Mandarin speakers were asked to produce two-syllable English words differing only in stress position, e.g. *record/record* and *contract/contract*. Results showed that participants either did not reduce the vowel or did not use an appropriate reduced vowel in many unstressed syllables, although they were relatively good at manipulating the other acoustic correlates of stress (F0, duration, and intensity). Zhang et al. (2008) argued that Mandarin speakers' problems with reducing vowels might lie in the differences in vowel space between the two languages. For example, they observed that Mandarin speakers apparently aimed at producing the high lax vowel [ɪ] for the unstressed syllable *de* in *desert* (verb), but their production of [ɪ] was not close to that of their native English counterparts. That is, although their production was acoustically most similar to a canonical native English [ɪ], it was not sufficiently close to [ɪ] to be clearly identified as such by native speakers of English. This brought further evidence for previous findings in the literature that acoustic features used in the L2 phonological system, but not in the L1 might be under-attended (Chen, et al., 2001; Flege, Bohn, & Jang, 1997; Francis & Nusbaum, 2002).

In this study, we will be concerned with whether (and how) differences in the characterization of linguistic stress in English and Persian might lead to Persian learners' inability to correctly produce the phonetic properties of linguistic stress in English. Persian is a "stress-accent" language, as is English (Abolhasani Zadeh, Gussenhoven, & Bijankhan, 2010; Sadeghi, 2011). Stress-accent languages differ from nonstress-accent languages such as Japanese in that stress is not only characterized by a pitch movement, or F0 excursions but also by other phonetic correlates such as greater duration and loudness (intensity) as well as full vowel quality (Beckman, 1986), but stress-accent languages vary as to what cues other than F0 they employ to signal stress. In both English and Persian, the stressed syllable can be distinguished both acoustically and perceptually by a combination of longer duration and greater intensity in addition to F0 excursions (Abolhasani Zadeh, et al., 2010; Campell & Beckman, 1997; Sadeghi, 2011; Sluijter & Van Heuven, 1996). However, while English has a phonological pattern of vowel reduction related to stress (Beckman, 1986; Campell & Beckman, 1997; Sluijter & Van Heuven, 1996), Persian is claimed to be less sensitive to vowel reduction than English (Sadeghi, 2011). Thus, while English vowels exhibit spectral differences in stressed and unstressed syllables, Persian vowels always have full vowel quality (i.e. absence of spectral reduction) irrespective of stress contrast.

There are contrasting findings in the literature as to what extent native phonetic and phonological categories interfere with the acquisition of nonnative categories. Regarding the phonetic categories related to stress, Flege and Bohn (1989) argue that L2 learners of English whose native language lacks a phonological pattern of vowel reduction related to stress first learn to produce stressed and unstressed syllables contrasting in F0, duration, and intensity, and only later learn (or fail to learn) to reduce the vowels in unstressed syllables. They argue that patterns of prosodic cues to stress contrast (F0, duration, and intensity) are less likely to be affected by L2 learners' inability to employ vowel quality in English. In contrast, Fokes, Bond, and Steinberg (1984) suggest that the inability of L2 learners to reduce the vowels in unstressed syllables may influence their ability to manipulate other phonetic correlates of English lexical stress, resulting in poorer performance on lexical stress production tasks.

This research is motivated to explore how the patterns of stress-related phonetic categories in Persian may influence Persian learners' ability to produce the patterns of stress-related cues in English. Thus, we may ask whether F0, duration and overall intensity, which are associated with stress both in English and Persian, would still prove as reliable acoustic correlates of stress in English if they were produced by Persian EFL learners, and whether, and to what degree, vowel reduction, which is associated with stress in English but not in Persian, might pattern differently in Persian learners' productions of English stress and influence the production of other acoustic cues. Given that the phonological issue of stress placement may have a confounding effect on the phonetic problem of native-like stress production, we attempt to dissociate the question of whether 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. Thus, the question is whether, or to what degree, Persian EFL learners are capable of producing native-like patterns of fundamental frequency, duration, intensity, and vowel formant frequency associated with English stressed and unstressed syllables when there is no question of stress placement. Inability to produce these acoustic correlates of stress would suggest that their native language experience with producing the specific acoustic cue patterns related to Persian phonetic categories (segmental and suprasegmental) interferes with their ability to produce qualitatively different patterns of these same cues for the purpose of producing English stress distinctions.

2. Lexical Stress in English and Persian

Stress in English is lexically contrastive in that words may vary in only the location of stress, such as <u>ob</u>ject/ob<u>ject</u>. A great deal of research has been directed towards the acoustical representation of stress in American English (Beckman, 1986; Campell & Beckman, 1997; Fry, 1955, 1958; Sluijter & Van Heuven, 1996). Most of these studies have focused on lexical stress in disyllabic words in which the stress location on the first or the second syllable leads the word to be identified as either a noun or a verb respectively. Results of such studies consistently suggest that stress in English is correlated with average fundamental frequency (F0), intensity, syllable duration, and vowel quality: stressed syllables have higher F0, greater intensity, longer duration, and unreduced vowel quality.

In English, as well as other stress-accent languages, a speaker may present a word as communicatively important by realizing a pitch accent on the prosodic head of the word, i.e. the stressed syllable. For this reason pitch movement has always been advanced as the most important correlate of stress in English (Beckman & Edwards, 1994; Huss, 1977). In addition, vowel quality, intensity, and duration have been consistently reported as other correlates of stress in English that produce additive effects for a robust differentiation between stressed and unstressed syllables (Beckman, 1986; Beckman & Edwards, 1994). Beckman and Edwards (1994) suggest that F0 and vowel quality are the most prominent acoustic cues to stress in English and present English prominence as a two-correlate system with four qualitative levels: the highest stress occurs on a syllable with a full vowel bearing a nuclear pitch accent[2]; the second highest stressed syllables contain a full vowel with a nonnuclear pitch accent; the next highest stressed syllables contain a full vowel with no pitch movement; and the lowest level (i.e., unstressed) syllables are reduced. Changes of vowel quality are identified using patterns of spectral frequencies (usually F1 and F2) (Beckman, 1986; Campell & Beckman, 1997; Fry, 1955, 1958; Sluijter & Van Heuven, 1996). Although vowel quality has not been extensively studied in cross-language studies, many researchers have discussed its importance in general terms. For example, the use of unreduced vowels in unstressed syllables has been argued to contribute importantly to foreign accent (Flege & Bohn, 1989), and is a strongly typical phenomenon in Spanish-accented English (Hammond, 1986). Either way, vowel quality is clearly an important acoustic correlate of stress in English (Beckman, 1986; Fry, 1965), and failure to appropriately produce an unstressed vowel may contribute to the perception of non-native accent (Flege & Bohn, 1989; Fokes, et al., 1984).

Intensity and duration have also been shown to correlate with stress both in the presence and absence of prominence-lending pitch movement (i.e. both when the target words are accented and unaccented). However, unlike duration, the precise measure of computing intensity is debated. Beckman (1986) and Fry (1955, 1958) identify average intensity over the syllable as a possible acoustic correlate of stress differences, while others (Sluijter & Van Heuven, 1996) argue that spectral tilt (i.e. difference in intensity over the frequency spectrum of a given vowel) is a more appropriate measure.

Stress in Persian, unlike English, is positionally fixed: The majority of lexical words in Persian are stressed on the final syllables (Fergusen, 1957; Kahnemuyipour, 2003). Word-final stress pattern applies to nouns, adjectives, most adverbs, and simple verbs. However, prefixes in inflected verbs attract stress, resulting in a recessive stress pattern (Kahnemuyipour, 2003). In addition, right-edge clitics (like “aʃ” in “cetɑbaʃ” ’his book’), unlike suffixes, do not attract stress, leaving the stress pattern of the stem unaffected (Abolhasani Zadeh, et al., 2010; Fergusen, 1957).

Earlier studies on the phonetic correlates of stress in Persian have shown the salience of F0 contour in cueing stress in minimal stress word pairs (Abolhasani Zadeh, et al., 2010). Results of a more recent study, however, suggest that lexical stress in Persian, as a stress-accent language like English, is multidimensional, involving consistent variation in F0, duration, and intensity (overall intensity and spectral tilt) (Sadeghi, 2011). Sadeghi (2011) has shown that though F0 is the primary acoustic cue for stress in Persian, duration and intensity cues can also serve reliably to distinguish Persian stress contrast. Among these two non-pitch cues, duration is stronger, as it functions as an acoustic cue to stress even in the absence of F0 information. In addition, it has been shown that vowel quality is the poorest cue to stress in Persian as differences for this measure between stressed and unstressed syllables are highly variable across speakers and vowels (Sadeghi, 2011). Thus, Persian differs from English in having considerably fewer words in which unstressed syllables are reduced. That is, unlike English, lexical stress in Persian is acoustically instantiated primarily in terms of pitch, then duration and intensity, and vowel quality is not an acoustic cue to Persian stress. Furthermore, assuming that Persian speakers employ many of the same acoustic correlates of stress as English speakers, including duration, intensity and F0, it is possible that their use of these correlates is significantly different from English speakers.

The present study addresses three main factors in the production of stress: (1) the acoustic cues used by English and Persian speakers to signal lexical stress, including F0, duration and vowel quality; (2) differences between the two groups in terms of their use of these features; and (3) the degree to which Persian speakers' pattern of English stress production can be explained by the structure of their native language phonetics and phonology (segmental and super-segmental).

3. Methods

3.1 Materials

Following Beckman (1986), Beckman and Edwards (1994), Fry (1955, 1958), Huss (1977), and Zhang, et al. (2008), five pairs of disyllabic words were selected. Each word pair consisted of a noun and a verb that had identical spelling forms and differed only in terms of stress position where the initial and final syllables were stressed in the noun and verb respectively. These pairs were formed from the following set of word forms: *contract*, *desert*, *subject*, *permit*, and *record*. These words are most commonly used in L2 stress production and perception experiments; thus we also selected the same words to provide for cross-language comparisons of our results. Each target word was embedded in the pre-final position in the carrier sentence [3] *I said — this time*, and was accompanied by associated context sentences created especially for each word, which are shown in Table 1. Pre-final position helps avoid the confounding effects of boundary tones (rising and

falling tones) on segmental structures (Sluijter and Van Heuven, 1996; Zhang et al., 2008).
To identify the quality of vowels in the target words as produced by Persian speakers, a vowel mapping production task was first conducted. In this task, based on Chen et al. (2001) and Zhang et al. (2010), 9 familiar English words *beat, bet, bit, bat, bought, butt, put, boot,* and *father* were used to match English vowel space as produced by Persian speakers with that of native American English speakers. Similarly, a list of six Persian words was selected for the comparison of the Persian vowel space with those of English (as produced by Persian and American English speakers) to find possible cases of interference on an item-by-item basis.

Table 1: Stimuli and context sentences to aid in establishing the stressed syllable

Target word	*Noun/verb*	*Context sentence*
contract	noun	They have agreed to sign the new *contract*.
	verb	Steel will *contract* when it is cooled.
desert	noun	They got lost in the *desert*.
	verb	Will he *desert* his team?
subject	noun	What is the *subject* of the text?
	verb	He may *subject* me to this boring practice.
Permit	noun	In order to park here, you need a *permit*.
	verb	Would you *permit* to stay longer?
	noun	I got a copy of my health *record*.
record	verb	He may *record* all songs you are going to sing today.

3.2 Participants

The participants were undergraduate students of English at Imam Khomeini International University (IKIU) in Qazvin, Iran. Their ages ranged from 21 to 26. They were all senior students (6th and 7th semester) majoring in English translation, or TEFL. None of the subjects was resident of an English speaking country. To select a homogeneous sample group for the research, initially 106 students took a TOEFL English language proficiency test. Then, based on the result, 54 students (31 female and 23 men) scored two standard deviations above and two standard deviations below the mean of 72.6 were selected. Finally, the 54 students were individually interviewed by the author, from whom 30 students (15 male and 15 female) with generally good productive skill were selected as the final participants. None of the participants reported any speech or hearing problems. They were all naïve as to the purpose of the experiment. Their participation was voluntary and did not imply any kind of compensation.

3.3 Procedure

The stimuli were presented to speakers in two sets on a computer screen. The first set of stimuli was the English and Persian words of the vowel space mapping task. For this set of recordings, participants were asked to read the target words twice in isolation displayed on the computer screen. The second set included the stress pairs on the top of the screen together with a pair of corresponding context sentences and the carrier sentence below. The context sentences were used to familiarize the participants with the task (Table 1).

Participants were asked to read the context sentence first and then the carrier sentence twice for each stimulus. In the instructions, it was pointed out that stress needs to be shifted between syllables when words shift from nouns to verbs. The rule should be familiar to the participants, because it is part of the phonetics and contrastive analysis course syllabuses in Iran. They were also instructed to speak naturally at a typical rate and loudness level. The recordings yielded 900 tokens (15 words (9 English and 6 Persian) × 2 repetitions × 30 participants) for the first set and 600 tokens (5 words × 2 stress positions × 2 repetitions × 30 participants) for the second set. Moreover, eight productions from the first set and 5 productions from the second set could not be analyzed, leaving a total of 892 vowel space mapping tokens and a total of 595 stress-contrasting tokens. The speakers were individually recorded in a quiet room using a digital audio recorder (Sound Blaster X-Fi 5.1) and a Shure directional condenser microphone (SM 58). The microphone was placed approximately 20 cm from the speaker's mouth when recoding. The 1115 stimulus tokens were sampled at a rate of 22.05 KHz and low-pass filtered at 4.8 KHz. The output amplitude levels for each individual speaker were normalized to the maximum amplitude range using Praat version 5.1.2 (Boersma and Weenink, 2004).

3.4 Data analysis

All acoustic measurements were made using Praat acoustic software**.** The acoustic parameters computed for each token of the first set of stimuli were the values of the first and the second formant frequencies (F1 and F2 in Hz), while those for the second set of stimuli included syllable duration (in ms), average intensity (in dB), average F0 (in Hz), and F1 and F2 measures in Hz). Segmentation boundaries for measuring syllable boundaries were determined in a straightforward fashion using the visual criteria described by Zanten et al. (1991): (1) First syllable onset (or word onset): the first zero crossing going upward at the beginning of the waveform; (2) second syllable offset (word offset): the last downward going zero crossing at the end of the sound waveform; (3) boundary between the first and second syllable: when a stop consonant occurs at the onset of the second syllable (like *contract*), the boundary is defined at the beginning of the silence of the stop gap. In words with no medial stop (like *permit, desert*), the boundary is marked as the transition between the spectral pattern of the initial consonant of the second syllable and the segment preceding it. Average F0 measure was calculated as the average value over the entire syllable using a hamming window of 25 ms. During F0 measurements, the pitch range was set to 75-300 Hz for male speakers and 100-500 Hz for female speakers. The average intensity measure was computed as the mean of multiple intensity values extracted over the entire length of the vowel of each target word. Formant frequencies were determined by locating the strongest harmonic of the formants in a fast Fourier transform (FFT) spectrum. All vowel quality and intensity measurements were determined at the point where F1 reached its maximum. In some cases, it was impossible to determine a reliable value for F1, mostly for female speakers due to interference of F0 with F1. Unreliable F1 measurements were excluded from further data processing.

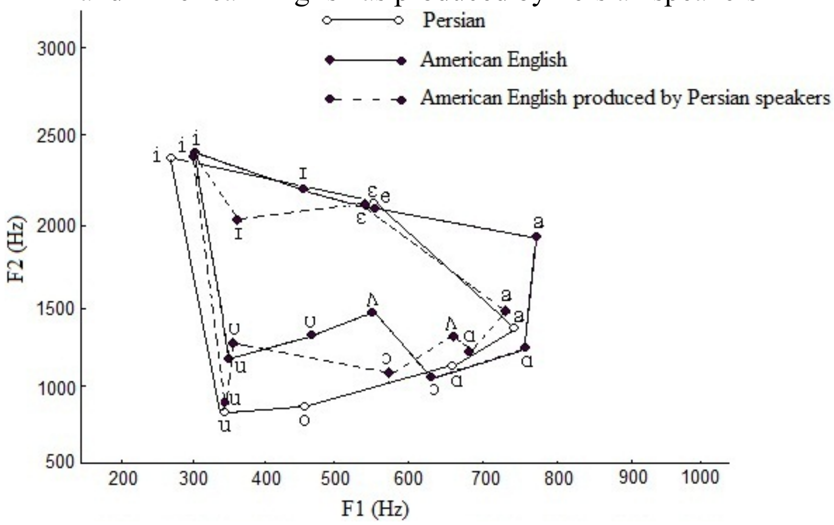
3.5 Results

3.5.1 Vowel space mapping task

There is little variation and inconsistency in previous findings of the American English vowel space measurements. The vowel spaces computed by Chen, et al. (2001), Hillerbrand, Getty, Clark, & Wheeler (1995), Ladefoged and Maddison (1996), and Zhang, et al. (2008), all based on the measure F1×F2 are roughly quadrilateral, though there are slight differences in the location of specific vowels due to inter-individual and dialectal variations. In the present study, Ladefoged and Maddison’s F1×F2 measurements for the American English vowel space were used as reference values to be compared with Persian and English vowel spaces produced by Persian speakers. Many studies on cross-language production and perception of vowels have used Ladefoged and Maddison’s data as reference measurements (Chen et al., 2001; Francis and Nusbaum, 2002). It is assumed that the adoption of a similar reference vowel space in L2 acoustical studies allows for cross-language comparisons of results obtained for the acquisition of non-native vowel spaces (Chen et al., 2001; Zhang et al., 2008).

Figure 1 shows the American English vowel space (adopted from Ladefoged and Maddison's study (1996)) as well as Persian and English vowel spaces produced by Persian speakers, i.e. the participants of this study, averaged across both male and female speakers. As can be seen, the overall structure of the vowel space of American English is quite different from that of Persian.

Figure 1: Comparison of three vowel spaces of American English, Persian and American English as produced by Persian speakers



First, while English employs five vowels in the more central area, namely ɪ, ɛ, ʊ, ʌ, and ɔ, Persian employs only two, e and o. Second, even when the two languages employ the same vowel categories, their qualities seem to be quite different due to the great magnitude of the distance between them. The production of Persian [u], for example, is farther back (in the sense of having lower F2) compared to the American English [u]. It has been documented that the American English Production of [u] is considerably higher than similar phoneme productions in many other languages (For examples, compare vowel charts for various languages presented in IPA, 1999), which may be the result of a more advanced tongue placement (Ladefoged and Maddison, 1996). English [a] and [ɑ] are considerably lower (in the sense of having higher F1) than Persian [a] and [ɑ]. The lower productions of [a] and [ɑ] in American English compared to similar vowel productions in other languages have also been reported in Ladefoged and Maddison's study (1996). In addition, [i] in Persian is further front (having lower F1) than [i] in English, though the magnitude of the distance is smaller than those for [a], [ɑ] and [u]. Furthermore, Persian [o] and English [ɔ], though both considered as the mid-back vowels, are sharply different in that [ɔ] is considerably lower (having higher F1) than [o]. Indeed, English [ɔ] is considerably closer to Persian [ɑ] than [o], and is more likely to be identified as a vowel more similar to [ɑ] than [o] by Persian speakers. In contrast, the mid-front vowels [e] and [ɛ] are quite close, with [ɛ] being to a very small extent lower than [e]. Thus, unlike the back equivalents, these two front vowels seem sufficiently close to be identified as the same vowel in the two languages.

Another observation is that the structure of the English vowel space produced by Persian speakers is, to a large extent, different from that produced by American English speakers. The observations are summarized as follows: First, Persian speakers' productions of the class of high tense vowels, [i] and [u] are clearly close to those of English speakers, though [i] is slightly further front, and [u] is slightly further back in the direction of the native Persian vowels' locations; Second, Persian speakers' productions of English [a] and [ɑ] are significantly closer to Persian [a] and [ɑ] than their English counterparts. Just like Persian [a], Persian speakers' productions of English [a] are considerably higher and more central than American English [a], and similar to Persian [ɑ], Persian speakers' productions of [ɑ] are considerably higher than American English [ɑ]; Third, interestingly, Persian speakers produced the vowel [ɔ] quite close to the native productions of the vowel, though, to some extent, higher to make it sufficiently distinct from their productions of English [ɑ]; and Fourth, Persian speakers' productions of the high lax vowels, [ɪ] and [ʊ], and the central vowel, [ʌ] are sharply different from their native English productions, mainly due to the lack of the corresponding vowels in the Persian system. The high lax vowels [ɪ] and [ʊ], which are clearly more central than their tense counterparts in the English vowel space, are produced by Persian speakers close to the high tense vowels. Similarly, the productions of the central vowel [ʌ] are directed toward their [ɑ] productions.

3.5.2 Stress pairs experiment

3.5.2.1 Prosodic cues

Using the originally measured values for each of the prosodic acoustic variables, i.e., average F0, duration and intensity, a two-way analysis of variance (ANOVA) was performed with stress (stressed and unstressed) and gender as the independent factors. All *post hoc* (LSD) tests were performed with a critical ρ value of 0.05. The means for each gender and stress condition are given in Table 2.

Average F0: Results of analysis of average F0 showed significant main effects of stress [F(1, 26)= 97.66, ρ<0.001] and gender [F(1, 26)= 183.54, ρ<0.001]. The F0 of stressed syllables, averaged across males and females, was significantly higher than that of the unstressed syllables (stressed: 170, unstressed: 139). In addition, female speakers produced significantly higher F0 than male speakers averaged across stressed and unstressed conditions, as expected (females: 186, males: 124). There was a significant interaction between stress and gender [F(1, 26) = 16.38, ρ<0.001].

The difference between the stressed and unstressed syllables was greater for female than male speakers.

Table 2: Mean values and standard deviations for all prosodic parameters for English stressed and unstressed syllables produced by Persian speakers. Note: STR = stressed, UNSTR = unstressed. Standard deviations are given in parentheses.

Prosodic cues	*Male*		*Female*	
	STR	UNSTR	STR	UNSTR
F0 (Hz)	138 (21)	110 (14)	203 (18)	169 (15)
Syll duration (ms)	279 (27)	241 (33)	285 (22)	246 (38)
Intensity (dB)	69.53 (2)	65.07 (1)	70.31 (3)	65.89 (2)

Duration: Results of analysis of syllable duration showed a significant effect of stress [F(1, 26)= 119.75, ρ<0.001], but no effect of gender [F(1, 26)= 2.89, ρ<0.093], and no significant interaction [F(1, 26)= 2.37, ρ<0.158]. *Post hoc* tests showed that for both gender groups' stressed syllables had a significantly longer duration (females: 285 , males: 279) than unstressed syllables (females: 246 , males: 241). In addition, although gender showed no significant main effect for Persian speakers, the differences followed the same trend as female speakers, on average, produced longer syllables than male speakers.

Intensity: Analysis of average intensity showed a significant effect of stress [F(1, 26)= 12.48, ρ<0.005]. Gender did not show a main effect [F(1, 26)= 3.27, ρ<0.074], and the interaction of stress and gender was not statistically significant [F(1, 26)= 1.29, ρ<0.241]. *Post hoc* tests showed that stressed syllables had a significant higher intensity than unstressed syllables for both male and female speakers. The results generally agree with those for American speakers in that the intensity of speech produced by both language groups was, on average, 4 to 5 dB higher for stressed than unstressed syllables (see Hillerbrand et al. (1995) and Zhang et al. (2010) for American English data).

3.5.2.2 Vowel reduction

For each syllable in each word, F1 and F2 values were measured and averaged across male and female participants. The average formant values for each vowel were then converted to bark scale values. These values were used to compute Euclidean distances for each stressed and unstressed vowel produced in the experimental words and those from the vowel space mapping task (English and Persian productions of the vowels in the vowel space mapping task). In other words, the vowel in each stressed and unstressed syllable was interpreted in terms of the magnitude of the distance from the English and Persian speakers' productions of the mapping vowels. The results were compared with those of Hillerbrand et al. (1995) and Zhang et al. (2010) for the American English speakers' productions of the same stressed and unstressed syllables in the same disyllabic words to show if Persian speakers' productions of stressed and unstressed vowels pattern significantly and unambiguously with those of native American English speakers.

Table 3: Euclidean distance in F1×F2 space (measured in Bark) between Persian speakers' stressed and unstressed vowels in the stress pairs production task and English speakers' productions of English vowels in the vowel space production task, adopted from Ladefoged and Maddison (1996). Note: smallest distance is indicated in bold.

		i	ɪ	ɛ	a	ɑ	ɔ	ʊ	u	ʌ
Con	STR	5.49	3.08	2.09	1.36	**0.32**	0.46	1.63	3.76	1.11
	UNSTR	2.81	0.87	**0.31**	1.61	1.68	1.42	0.85	2.65	0.61
tract	STR	5.47	2.45	1.43	**0.52**	0.59	1.29	1.97	4.63	1.27
	UNSTR	5.36	2.38	1.30	**0.49**	0.77	1.36	1.93	4.60	1.31

		i	ɪ	ɛ	a	ɑ	ɔ	ʊ	u	ʌ
De	STR	4.32	0.57	**0.21**	1.84	2.37	1.95	1.26	2.76	0.86
	UNSTR	0.76	**0.60**	1.62	4.18	4.51	3.36	1.54	1.71	1.62
Sert	STR	2.33	0.60	**0.26**	1.84	2.32	1.76	1.12	2.56	0.84
	UNSTR	2.27	0.54	**0.36**	1.96	2.38	1.72	0.94	2.47	0.73
Sub	STR	5.18	2.38	1.54	1.51	0.64	**0.40**	1.35	3.32	0.67
	UNSTR	4.19	1.80	1.22	1.60	1.11	0.51	0.91	2.74	**0.39**
Ject	STR	2.39	0.69	**0.12**	1.70	2.26	1.76	1.23	2.80	0.79
	UNSTR	2.46	0.74	**0.11**	1.66	1.95	1.71	1.17	2.76	0.66
Per	STR	2.32	0.62	**0.18**	1.80	2.33	1.84	1.22	2.77	0.87
	UNSTR	2.47	0.72	**0.22**	1.72	1.96	1.67	1.10	2.56	0.62
Mit	STR	0.80	**0.55**	1.53	4.13	4.29	3.20	1.51	1.62	1.80
	UNSTR	0.75	**0.60**	1.50	4.04	4.12	3.03	1.30	1.53	1.55
Re	STR	2.40	0.70	**0.19**	1.72	2.29	1.80	1.24	2.82	0.90
	UNSTR	1.13	**0.44**	1.36	3.77	3.97	2.82	1.22	1.66	1.59
cord	STR	3.35	1.77	1.81	3.55	2.44	1.26	**0.29**	1.23	1.12
	UNSTR	2.49	0.86	0.60	2.01	1.87	1.35	0.50	1.96	**0.27**

The distance measures in F1×F2 space between Persian speakers' productions of the stressed and unstressed vowels and American (Ladefoged and Maddison, 1996) as well as Persian speakers' productions of English vowels in the mapping task are shown in table 3 and 4 respectively. In other words these tables show the distance between the vowel in a given syllable and each of the English speakers' (Table 3) mapping vowels and Persian speakers' mapping vowels (Table 4).

Comparison of the distance between Persian speakers' productions and English and Persian speakers' mapping vowels as well as the results from Hillerbrand et al.'s (1995) and Zhang et al.'s (2010) studies on native productions of similar stressed and unstressed syllables suggests that although Persian speakers employ nearly the same vowel categories as the English speakers, their productions of the target syllables do not pattern with those of native English speakers in that they fail to produce the majority of the vowels with the expected F1 and F2 values in the same way that they failed to produce in the vowel space mapping condition. The pattern of results for each syllable is discussed below:

Con- (contract): For the stressed *con-*, American English speakers, recorded in Hillerbrand et al.'s (1995) and Zhang et al.'s (2010) studies, used a vowel very close to [ɑ]and Persian speakers recorded here used the same vowel category. However, Persian speakers' productions were, to a

Table 4: Euclidean distance in F1×F2 space (measured in Bark) between Persian speakers' stressed and unstressed vowels in the stress pairs

production task and Persian speakers' productions of English vowels in the vowel space production task. Note: smallest distance is indicated in bold.

		i	ɪ	ɛ	a	ɑ	ɔ	ʊ	u	ʌ
con	STR	5.41	4.12	2.13	0.46	**0.21**	0.63	3.73	3.75	0.32
	UNSTR	2.76	2.27	**0.42**	1.34	1.49	1.33	2.46	2.75	1.33
tract	STR	5.39	4.59	1.56	**0.16**	0.78	1.43	4.48	4.71	0.43
	UNSTR	5.32	4.44	1.43	**0.28**	0.89	1.48	4.44	4.70	0.69
de	STR	2.27	1.72	**0.13**	1.73	2.08	1.78	2.54	3.13	1.66
	UNSTR	0.71	**0.39**	1.52	3.82	3.86	2.91	1.61	2.26	3.19
sert	STR	2.34	1.71	**0.21**	1.66	1.82	1.64	2.44	2.87	1.68
	UNSTR	2.27	1.65	**0.33**	1.70	1.84	1.59	2.34	2.77	1.70
sub	STR	4.83	3.91	1.66	0.64	0.28	0.49	3.24	3.26	**0.11**
	UNSTR	4.06	3.14	1.30	0.85	0.59	**0.43**	2.65	2.74	0.47
ject	STR	2.36	1.80	**0.09**	1.62	1.84	1.65	2.55	3.14	1.66
	UNSTR	2.42	1.84	**0.17**	1.56	1.76	1.59	2.51	3.08	1.63
per	STR	2.29	1.77	**0.14**	1.66	1.92	1.96	2.53	3.11	1.68
	UNSTR	2.47	1.81	**0.23**	1.53	1.69	1.54	2.44	2.98	1.57
mit	STR	0.74	**0.41**	1.49	3.78	3.81	2.86	1.53	1.96	3.39
	UNSTR	0.93	**0.46**	1.47	3.59	3.56	2.50	1.42	1.81	3.12
re	STR	2.35	1.79	**0.07**	1.63	1.84	1.70	2.56	3.22	1.66
	UNSTR	0.98	**0.53**	1.27	3.20	3.31	2.45	1.54	1.96	3.07
cord	STR	2.94	2.21	1.88	2.36	1.71	**0.96**	1.18	1.22	1.67
	UNSTR	2.41	1.72	0.84	1.07	1.52	**0.78**	1.83	1.83	1.36

large extent, closer to Persian speakers' [ɑ] mapping vowel (Table 4) than English speakers' (Table 3), in a manner consistent with the result of the mapping task experiment. In other words, Persian speakers' inaccurate productions of stressed *con-* seem to be related to their inaccuracy in the production of the same vowel in the vowel space mapping experiment. For the unstressed *con-*, while Persian speakers produced a vowel very similar to their own [ɛ] or English [ɛ] mapping vowels, English speakers have been recorded to produce a vowel most similar to their [ʌ] mapping production. The inaccuracy in the production of unstressed *con-* can be explained by the lack of a central vowel corresponding to [ʌ] in the Persian system that causes the vowel to be substituted by a vowel from the Persian central region most similar to it. Despite the sharp difference between the two vowels, however, it seems that Persian speakers knew that they needed to employ vowel change as a cue to lexical stress, but their productions lacked sufficient accuracy to be identified as native-like unstressed *con-* productions.

-tract (contract): As reported by Hillerbrand et al. (1995) and Zhang et al. (2010), American English speakers employed the same target vowel for the stressed and unstressed conditions, meaning that they did not reduce the vowel in the unstressed production of the syllable. As shown in Tables 3 and 4, Persian speakers, too, used a vowel very similar to Persian and English [a] mapping vowels in both the stressed and unstressed versions of the syllable, though their productions were noticeably closer to Persian speakers' productions of [a] than English speakers'.

de- (desert): Both the American English speakers (as recorded in Hillerbrand et al.'s (1995) and Zhang et al.'s (2010) studies and Persian speakers in the present study chose the same target vowels for the stressed and unstressed productions of *de-*, i.e. [ɛ] and [ɪ] respectively. While the Persian speakers' stressed *de-* productions were rather equally close to Persian and English [ɛ] mapping vowels, their productions of the unstressed token *de-* were closer to Persian [ɪ] than English [ɪ] in the vowel space mapping productions. However, their productions were still, different from their [ɪ] mapping vowel (see the distance measures in Table 4), as they clearly moved in the expected direction of native-like [ɪ] production, though they did not manage to produce it with sufficient accuracy. This suggests that Persian speakers knew they needed to produce clearly different vowel qualities for the stressed and unstressed productions of *de-*; however, their productions involved insufficient spectral accuracy mainly because it was an unfamiliar vowel to Persian speakers.

-sert (desert): Persian speakers' productions of *–sert* in both the stressed and unstressed conditions were clearly closest to Persian and English speakers' [ɛ] mapping vowel that was considerably farther front compared to the more central productions of the native English speakers, i.e., a vowel closest to [ʌ], reported by Hillerbrand et al. (1995) and Zhang et al. (2010) for both the stressed and unstressed conditions. As in the case of unstressed *con-*, Persian speakers, having failed to approximate the target central position for [ʌ] due to the lack of a sufficiently similar vowel in the Persian system, have replaced it with the native short front mid vowel [ɛ] that seems to be closest to it in F1 and F2 values.

sub- (subject): As reported by Hillerbrand et al. (1995) and Zhang et al. (2010), native English productions of stressed and unstressed *sub-* were almost equidistant between [ʌ] and [ʊ], with the vowel in the stressed condition being closer to [ʌ], and the one in the unstressed condition closer to [ʊ]. Persian speakers' productions of stressed *sub-* were considerably lower and farther back, compared to the English productions, being closest to their own [ʌ] and English speakers' [ɔ] mapping vowels. As was shown in Fig. 1, Persian speakers produced English central vowel [ʌ] considerably lower and farther back, closest to, but somewhat more central, than their mapping vowel [ɑ]. For unstressed *sub*-, Persian speakers produced a vowel clearly more central than their stressed productions of *sub*-, mistakenly assuming that the vowel needed to be reduced in unstressed *sub*-, just like the unstressed *con*- and *sert*-, yet they did not manage to attain the native-like central target position as described by Hillerbrand et al. (1995) and Zhang et al. (2010). Thus, unlike English speakers, Persian speakers showed considerable differences between the stressed and unstressed productions of *sub*-.

***-ject* (*subject*):** For *-ject*, both the Persian and English speakers' productions of the stressed and unstressed conditions were closest to their productions of [ɛ] in the mapping experiment. Given the very small distance between Persian and English productions of the vowel [ɛ] in the vowel space mapping task, Persian speakers' productions of *-ject* (stressed and unstressed) seem to be quite similar to English speakers' productions which suggests that this syllable is produced by Persian speakers in both the stressed and unstressed conditions with a vowel that would clearly be identified by English speakers as an acceptable native-like [ɛ] production.

***per-* (*permit*):** For *per*-, just like *-sert*, Persian speakers used different target vowels than did the English speakers for both the stressed and unstressed conditions, where Persian speakers produced a vowel most similar to their own [ɛ] or English speakers' [ɛ] mapping vowel, but English speakers produced a vowel very similar to their mapping vowel productions of [ʌ]. Again, the inability to produce a central target vowel for the stressed and unstressed productions of *per*- may be explained by the lack of a vowel with sufficiently similar F1 and F2 values in the Persian system leading to particularly incorrect productions where the native central vowel [ʌ] is substituted by a vowel from the Persian system with different spectral property, but still closest to it among other vowels.

***-mit* (*permit*):** Both groups produced *-mit* in the stressed and unstressed conditions with a vowel most similar to their [ɪ] mapping vowel productions. Due to the great magnitude of the distance between Persian and English speakers' productions of [ɪ] in the mapping experiment, the Persian productions would not be clearly identifiable to English speakers as accurate native-like [ɪ] productions. However, their productions, though closer to Persian [ɪ] mapping vowel, were clearly different from it (see the distance measures in Table 4), being directed in the expected region of the native English vowel [ɪ], suggesting that Persian speakers were aware of, and attempted to make use of, formant frequency differences to approximate a native-like [ɪ] production.

***re-* (*record*):** The stressed productions of *re-* by both the American and Persian speakers were quite close to their [ɛ] mapping vowels. Thus, as mentioned earlier, given the very small magnitude of the distance between English and Persian speakers' pronunciations of [ɛ] in the mapping experiment, Persian speakers seem to have achieved a native-like pronunciation of the stressed syllable *re-*. For the unstressed *re-*, although both groups chose the same vowel category, i.e., [ɪ], as shown in the Table 3 and 4, the productions differed in that while English speakers produced the vowel at a region roughly equidistant between [ɪ] and [ʌ], being directed more in the direction of [ɪ], Persian speakers produced the vowel at a region equidistant between Persian and English [ɪ] mapping vowels. Thus, again, like the unstressed *de-* and the stressed and unstressed *-mit*, Persian speakers did not successfully attain a native-like central target for the unstressed vowel in question; however, they clearly moved away from the more front toward the more central region appropriate to a native-like unstressed [ɪ] pronunciation, which suggests that they knew they needed to produce a vowel different from their [ɪ] mapping vowel for the unstressed token [ɪ] but they failed to realize it with sufficient spectral accuracy.

***-cord* (*record*):** The two groups chose different categories for the stressed and unstressed productions of *–cord*. English speakers produced the syllable both in the stressed and unstressed conditions with a central vowel most similar to their [ʊ] mapping vowel productions (Hillerbrand et al., 1995; Zhang et al., 2010). However, Persian speakers produced the syllable in the stressed condition with a vowel in the mid back region most similar to their own [ɔ] and English speakers' [ʊ] mapping vowels, and the syllable in the unstressed condition with a vowel in the more central region, roughly equidistant between their own [ɛ] and [ɔ] mapping vowels (but a little closer to [ɔ], as shown in Table 4), and closest to English speakers' [ʌ] mapping vowel. Thus, Persian speakers' productions of both the stressed and unstressed *–cord* were inappropriate as they substituted the clearly central native target vowel (close to English [ʊ]) with a mid back vowel (very close to [o] in the Persian system) in the stressed and a inaccurate central vowel (closer to [ʌ] than [ʊ]) in the unstressed conditions. In addition, unlike English speakers, Persian speakers showed considerable differences between the stressed and unstressed productions of *–cord.*

4. Conclusion and Discussion

The acoustic analyses of prosodic cues indicated that just like English speakers, Persian speakers used the acoustic correlates of F0, duration and intensity to cue lexical stress in English. Previous results reported for native speakers' productions of English lexical stress pairs suggest that English speakers produce stressed syllables with a significantly overall higher average F0, longer duration and greater intensity than unstressed ones (Beckman, 1986; Fry, 1965; Zhang et al., 2010); similarly, Persian speakers produced stressed syllables with a higher F0, longer duration and greater intensity than unstressed syllables. Quite interestingly, the quantitative variations of average F0, duration and intensity across the stressed and unstressed syllables of the target stress pairs produced by the Persian speakers were almost comparable to those produced by English speakers.The similarity may be explained by the fact that lexical contrasts in Persian are cued by the same properties as average F0, duration and intensity with similar quantitative variations across the stressed and unstressed syllables, and that Persian speakers are able to transfer the use of these prosodic properties from the lexical stress domain in Persian to the lexical stress domain in English. This suggests that Persian speakers are able to produce English stress contrasts without a discernable accent so far as prosodic cues to lexical stress are concerned.

To examine vowel reduction, productions of vowels in the stressed and unstressed syllables were referenced against productions of monosyllabic (stressed) vowels in the vowel space mapping task, and then compared against the data for the American English speakers (Hillerbrand et al., 1995; Zhang et al., 2010). Based on these comparisons, it seems that Persian speakers are not able to correctly control acoustic correlates of vowel quality (F1 and F2 frequencies) in an English-like manner due to interference from their native vowel system. The observations showed that except for the vowel [ɛ] in stressed and unstressed productions of *-ject*, and the unstressed productions of *de-* and *re-*, Persian speakers failed to achieve the target vowel qualities required for the productions of other syllables (stressed or unstressed). Indeed, for the majority of the vowels in the target stress pairs, they did not manage to attain the formant values comparable to those used by the native English speakers. In all these cases, in which Persian speakers showed considerable differences in formant frequencies from the native-like formant patterns, the vowels concerned were either missing from the Persian system, as the central vowels in the unstressed syllables *-con, de-*, and *re-*, and the stressed and unstressed *per-*, *-mit*, *-sert*, *sub-,* and *–cord* or they had different qualities (different frequency patterns) in the Persian system as the vowel [a] in the stressed and unstressed *–tract*, and the vowel [ɑ]. in the stressed *con-*. In spite of this inaccuracy in the production of the target syllables, Persian speakers appeared to be close to the appropriate vowel targets, but missed producing them with the expected F1 and F2 formant values in the same way that they missed producing the target vowels in the stressed monosyllabic vowel space mapping condition. In other words, difficulties with native-like production of English vowels seem to be characteristic of Persian speakers' production of English vowel space, in a manner independent of the issue of lexical stress production. With respect to the observed group differences in vowel qualities, the present results are consistent with the results of Chen, et al. (2001), Flege, et al. (1997), and Zhang, et al. (2010) who have found that unfamiliar vowels to Mandarin speakers were pronounced less accurately than the vowels that were familiar to them. As found by Flege et al. (1997) and Zhang et al. (2010), Mandarin speakers showed the least spectral accuracy when producing English vowels, including [ɪ], [ʊ] and [ʌ], that were not found in Mandarin. They argue that one explanation for discrepancies in the vowel spaces produced by native and non-native speakers of a given language is interference from the native vowel system or, more properly, the lack of sufficiently similar vowels in the native system leading to particularly incorrect or inaccurate productions of non-native target vowels.

Thus, it appears that Persian speakers are able to successfully approximate English-like patterns of F0, duration and intensity when producing stress contrast. In contrast, Persian speakers, although clearly aware of the importance of vowel reduction as a cue to stress, systematically fail to produce English-like vowel targets across different words and vowel categories, in a manner consistent with the transfer of properties characteristic of the Persian vowel space. This observation is consistent with the proposal of Flege and Bohn (1989), who suggested that L2 learners acquire L1 patterns of vowel reduction only after they have acquired English-like patterns of prosodic cues to stress (F0, duration and intensity), and that their inability to reduce vowels in unstressed syllables does not influence their ability to employ prosodic cues to lexical stress contrast.

Since Persian speakers were successful at producing English-like patterns of F0, duration and intensity, it is difficult to determine whether they learned to produce these cues systematically, whether they have simply learned these cues for the specific words examined here, or whether transfer from their native suprasegmental phonological system was sufficient to achieve native-like patterns in the L2. Further research is needed to examine the relative contribution of the various cues examined in this study to the perception of stress in English.

As to the implications of the study, Zhang, et al. (2010) suggest that the incorporation of L2 patterns of phonetic and phonological categories into course materials contributes to improving learners' pronunciation skills. Thus, the results of the study might be specifically worthy of attention for material developers to adequately and thoughtfully incorporate native-like patterns of phonetic categories of stress in some exercises and tasks that are intended for learning pronunciation, specifically the features dissimilar to the ones used in the L1 like the process of vowel reduction. It is further suggested that teachers explicitly make students aware of the importance of segmental (vowel quality) and suprasemental (F0, duration and intensity) cues to lexical stress in English employing some relevant pedagogical activities and tasks.

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Notes:

[1] Pitch is the perceptual correlate of F0 variation

[2] A pitch accent that carries the greatest F0 excursion in a sentence is a nuclear accent. In an unmarked sentence, it is usually the final word that receives the major pitch change. A pitch accent that receives a less prominent F0 movement in a position preceding the nuclear accent is a nonnuclear pitch accent.

[3] A carrier sentence is a sentence that is used to present test words in production experiments in a way that all segmental and supra-segmental effects on the test words are controlled.