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Persian Sentence Stress Production by Mandarin Chinese Speakers

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ABSTRACT

This study examined the phonetic characteristics of Persian sentence stress produced by native Mandarin Chinese speakers. We compared the phonetic correlates of sentence stress, namely fundamental frequency (F0), vowel duration, and vowel intensity in the production of 8 Mandarin Chinese speakers and 8 native Persian speakers. Results indicated that Mandarin Chinese speakers of Persian could differentiate stressed and unstressed words in Persian sentences based on F0, duration, and intensity. However, the two groups of speakers differed as to the extent to which they varied the acoustic parameters to signal sentence-level prominence. In particular, Mandarin Chinese speakers produced stressed words in Persian sentences with a significantly higher F0 and shorter vowel duration compared to native Persian speakers. It is argued that these differences may best be accounted for as prosodic interference from Mandarin Chinese in the production of sentence stress in L2 Persian.

Keywords: Mandarin Chinese, sentence stress, F0, duration, intensity

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1. Introduction

The importance of L1 transfer, the incorporation of features of the L1 into the linguistic system of the L2 has been, and still is one of the main research questions in language teaching, applied linguistics and second language acquisition (Ellis, 1994: 28; Odlin, 1989). Various studies in the past few decades have attempted to identify the role of L1 in the L2 acquisition (Ellis, 1994; Kohn, 1986; Odlin, 1989). Their principle finding was that L1 transfer is one of the most important factors shaping the learner's inter-language competence and performance (Flege & Hillenbrand, 1987; Lord, 2005; Raiser & Hiligsmann, 2007; Raiser & Hiligsmann, 2009).

Despite intensive transfer studies over the past few decades, there still remains substantial uncertainty concerning the exact nature of transfer, the circumstances in which it occurs, and psychological processes it relies on. For instance, there has been accumulating cross-linguistic evidence that L1 influences L2 in the area of phonology, resulting in a so-called foreign accent, which is probably an indication of the difficulty adults face when learning speech sounds in a non-native language (Archibald, 1997; Flege & Hillenbrand, 1987; Lord, 2005; Piske, Mackay, & Flege, 2001). However, most research on the acquisition of phonology has predominantly dealt with segmental issues, paying insufficient attention to prosody or supra-segmental features of speech (such as stress, rhythm and intonation).

The present paper sets out to examine the phonological and phonetic properties of sentence stress in Persian produced by Mandarin Chinese speakers learning Persian as a second language. Work on the acquisition of Persian phonetics and phonology as a second language is less documented, and no specific study, thus far, has been directed towards the phonetic realization of stress in the production of L2 learners of Persian. Native speakers of tonal languages, specifically Mandarin Chinese, are assumed to have some difficulty in producing sentence stress in intonational languages. There are substantial differences between Mandarin Chinese and Persian in the segmental and supra-segmental characteristics of speech (as we will mention later). The primary purpose of the present paper was to explore to what extent the prosodic system of L1 Mandarin Chinese language would interfere with the production of sentence stress in L2 Persian. The questions specifically asked in the present production experiment were as follows: Can the acoustic correlates of sentence stress in native Persian, namely F0, duration and intensity, reliably differentiate stressed from unstressed syllables in the production of Mandarin Chinese learners? If so, are these correlates of sentence stress implemented in the same way (with similar ranges of variation) in the production of native Persian and Mandarin Chinese speakers?

2. Literature Review: Sentence Stress in Persian and Mandarin Chinese

Persian is a polysyllabic language with three types of syllable structure, namely CV, CVC and CVCC. Two forms of stress occur in the production of the Persian language: lexical stress and sentence stress. Lexical stress, or prominence at the word level, specifies which syllable in the polysyllabic word is, in some sense, stronger than any of the others. Sentence stress, or prominence at the sentence level, on the other hand, signals the communicative importance of a word in relation to other words in a sentence. Persian is often described as a stress-timed language, whereby the sentence prominence or speech rhythm of Persian involves an interplay of longer (more prominent) syllables and shorter (less prominent) syllables. Persian is also an intonational, or non-tonal, language whereby the meaning of a word is derived from the phonetic composition of the word, rather than the tonal properties of syllables/words. In fact, in a language like Persian, tones are part of what is usually called intonation, and can be spread across any number of syllables. Tones are described as pitch accents in intonational languages. The primary acoustic correlate of a tone, or pitch accent, is the F0 contour or movement. The most prominent tone in a sentence is called a nuclear tone or accent, which in Persian, is normally placed on the last word of an utterance to convey either a statement or a question. However, tones can also be placed on virtually any syllable within a sentence to alter the sentence stress pattern. In such cases, tones are assumed to bear a contrastive function.

Previous examinations of the phonetic correlates of stress in Persian have shown the salience of F0 contour in cueing stress in minimal stress word pairs (Abolhasani Zadeh, Bijankhan, & Gussenhoven, 2012; Rahmani, Rietveld, & Gussenhoven, 2015). More recent research, however, suggests that lexical stress in Persian, as a stress-accent language like English (Beckman & Edwards, 1994), is multidimensional involving consistent variation in F0, duration, and intensity (overall intensity and spectral tilt) (Sadeghi, 2011). Sadeghi, in particular, has found that although F0 is the primary acoustic correlate of stress in Persian, duration and intensity cues can also serve reliably to distinguish Persian stress contrast, with stressed syllables being both longer and louder than unstressed syllables. 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.

Mandarin Chinese, unlike Persian, is a mono-syllabic language with primarily a CV word template (Chen, Robb, Gilbert, & Lerman, 2001). Mandarin Chinese syllables consist of both segmental and suprasegmental features (Shih, 1986). Regarding segmental features, a vocalic nucleus in a word may be optionally preceded and/or followed by a single consonant (Xu, 2005; Xu & Liu, 2006). As concerning suprasegmental features, there are four “basic” tones in Mandarin Chinese which can be superimposed on any syllable (word) in a sentence (Cheng, 1987). When the tone of a syllable (i.e., a word) changes in Mandarin Chinese, the lexical meaning changes too (Cheng, 1987; Chun, 1982). It is generally believed that Mandarin Chinese is a syllable-timed language, in which there is no pattern of word-level prominence, and syllable duration remains relatively constant throughout the production of a sentence (van Santen & Shih, 2000).

A number of perceptual and acoustic studies have been directed towards the acoustical representation of stress in Mandarin Chinese (Chun, 1982; Shen, 1993; Xu, 1999; Xu & Liu, 2006). Results of such studies consistently indicate that sentence stress in Mandarin Chinese is signaled by differences in F0 and duration; stressed syllables are realized by greater pitch excursion (larger F0 values) and longer duration than unstressed syllables. For example, Cao (1986), and Shen (1993) have reported that stressed words are lengthened compared to unstressed syllables. In addition, it has been shown that variation in F0 is a reliable acoustical correlate of stress and is consistently used in the production of Mandarin Chinese speakers to distinguish between stressed from unstressed words. In addition, the acoustic studies conducted by Shen (1993), Xu (2005) and Zhang, Nissen and Francis (2008) found Mandarin Chinese speakers to produce stressed words with higher intensity compared to unstressed words. Perceptual research has shown that these non-pitch cues can also function as acoustic cues to Mandarin Chinese tones in the absence of F0 information (Liu & Samuel, 2004). Thus, from a purely phonetic perspective, it can be argued that since Mandarin Chinese speakers have experience with controlling the F0, duration, and intensity of individual syllables to express lexical tone distinctions, they may be able to control these same acoustic properties to produce native Persian-like lexical stress contrasts.

Based on previous findings in the literature concerning the characteristics of sentence stress in the Persian and Mandarin Chinese languages, a number of hypotheses were formulated regarding the production of Persian sentence stress by native speakers of Mandarin Chinese. The hypotheses were developed with reference to the acoustic parameters for the realization of sentence stress, namely F0, duration, and intensity. We generally hypothesized that the way Mandarin Chinese speakers vary F0, duration and intensity to signal prominence contrast at the sentence level in Persian would not be significantly different from native Persian speakers. In particular, we hypothesized that (1) there is no significant difference between Mandarin Chinese speakers and native Persian speakers in their use of F0 to signal stress in the production of Persian sentences. It is generally assumed that in a tonal language such as Mandarin Chinese, variation in F0 is exclusively used to signal a change in word meaning rather than communicative function (Chen et al., 2001). However, more recent results suggest that Mandarin Chinese speakers employ F0 to signal prominence at sentence level, most specifically for pragmatic purposes (Xu, 1999; Xu, 2005); (2) differences of duration as a cue to signal stress contrast in Mandarin Chinese and Persian are not significantly different from each other. This prediction is based on results from previous studies by Chen et al. (2001), Shen (1993) and Xu (2005) which have revealed that although Mandarin Chinese is a syllable-timed language, speakers of this language use patterns of durational differences to differentiate stressed from unstressed syllables; (3) Mandarin Chinese speakers will vary intensity in a manner similar to native Persian speakers to cue stress in Persian sentences. Earlier studies suggested that Mandarin Chinese speakers manipulate intensity to indicate stress in their own native language (Shen, 1993), and in English as a second language (Chen et al., 2001).

3. Methods

3.1. Participants

Two groups of speakers participated in this experiment: 8 native speakers of Persian (all men) and 8 native speakers of Mandarin Chinese (all men). All participants were undergraduate students of English at Imam Khomeini International University (IKIU) in Qazvin, Iran. Persian participants ranged in age from 19 to 24 (M=21), while Mandarin Chinese speakers were 20-31 (M=25). The Persian speakers were all native residents of Iran, while the Mandarin Chinese speakers were all originally from the People’s Republic of China, and had lived in Iran for at least 9 months prior to participating in the experiment. The Mandarin Chinese group had all passed introductory and intermediate courses of formal instruction in Persian, were able to orally read Persian fluently, and would speak Persian for at least 30% of their daily conversation. 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.

3.2. Speech Materials and Recordings

Following the methodology of Chen, et al. (2001), we evaluated patterns of sentence stress production with one single sentence with different stress patterns. The target sentence was ‘sɑm bɑ ʔɑb ɢors χord’ (Sam took a pill with water). All the words in the sentence were monosyllabic, consistent with syllable structure in Mandarin Chinese. The sentence was produced three different ways with primary stress placed on ‘sɑm’,‘ʔɑb’, and ‘ɢors’. The three sentences with varying stress (indicated in boldface) were: ‘**sɑm** bɑ ʔɑb ɢors χord’, ‘sɑm bɑ **ʔɑb** ɢors χord’ and‘sɑm bɑ ʔɑb **ɢors** χ ord’. Each of the three sentences was read three times by each speaker. Thus, the materials under study consisted of 144 utterances (3 target sentence/stress conditions × 2 groups × 8 speakers × 3 repetitions). The target sentences were recorded on DAT recorder using a high quality unidirectional head-mounted microphone in a sound proof booth. Speakers were instructed to read each sentence naturally and at a normal speed, and were given some time to familiarize themselves with the task by practicing with a small number of random examples from the data. The sentences were presented in random order. After recording, the sentences were examined to ensure that the test words were produced with correct intonation pattern.

The measurements were made on simultaneous visual displays of waveform, wideband spectrogram and F0 tracks. Figure 1 displays the waveforms, spectrographs and F0 contour of the target sentences, namely **sɑm** bɑ ʔɑb ɢors χord’ (top), ‘sɑm bɑ **ʔɑb** ɢors χord’ (middle) and‘sɑm bɑ ʔɑb **ɢors** χord’ (below), produced by one native Persian (left), and one Mandarin Chinese (right) participant.

3.3. Acoustic Analysis

The three target words in each sentence recitation were measured for average fundamental frequency (F0), average vowel duration and average intensity. Segmentation boundaries for measuring syllable/word boundaries were determined in a straightforward fashion using the visual criteria described by Zanten, van Damen and van Houten (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. The procedure for measuring the acoustical parameters was as follows:

Average F0 measure was calculated as the average value computed across three points over the course of the vowel segment, namely at beginning, midpoint and end locations of the vowel. During F0 measurements, the pitch range was set to 75-300 Hz for all speakers (note that all speakers were male). The beginning of the vowel was defined as the point coinciding with the beginning of the second formant frequency (F2), which roughly corresponded to the periodic activity following the third glottal pulse. The end of the vowel was defined as the point where F2 clearly disappeared, which coincided with the periodic activity preceding the last three glottal pulses. The middle point between the beginning and end points was identified as the vowel midpoint. For each vowel point, we extracted the center frequency of the first harmonic peak to indicate the F0 for the point concerned. Average F0 was determined for each vowel based on the mean of the F0 values across the three vocalic locations, namely vowel beginning point, midpoint and ending point.

Based on segmentation criteria explained above, vowel duration was directly obtained from the length of the measurement interval of each stressed and unstressed vowel under investigation. Thus, vertical cursors were manually placed at the beginning and the end of the second format frequency of the vowel to demarcate its onset and offset points. The time interval between the two cursors was taken to be the vowel duration.

The measure of average intensity was defined as the overall intensity of the vowel and was computed as the mean of multiple intensity values extracted over the entire length of the vowel of each target word. The measure used five Hamming mid-pass filters across the frequency for each

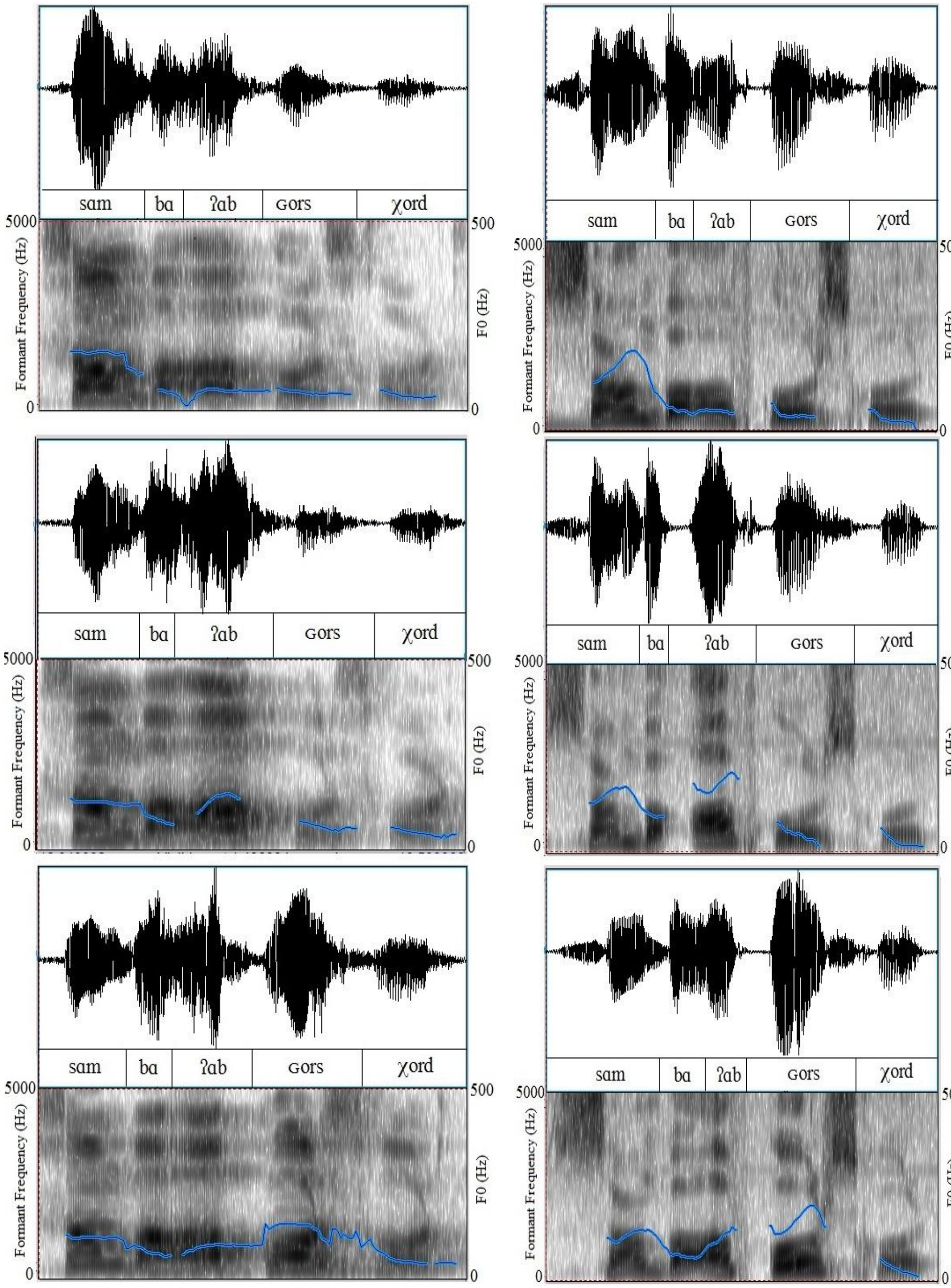


Fig. 1: waveforms, spectrographs and F0 contour of the target sentences, i.e., **sɑm** bɑ ʔɑb ɢors χord' (top), 'sɑm bɑ **ʔɑb** ɢors χord' (middle)and'sɑm bɑ ʔɑb **ɢors** χord' (below), produced by one native Persian (left), and one Mandarin Chinese (right) participant.

filter were as follows: 0 and 1000 Hz for the first filter, 1000 and 2000 Hz for the second filter, 2000 and 3000 Hz for the third filter, 3000 and 4000 Hz for the fourth filter and 4000 and 5000 Hz for the fifth filter. The intensity values computed for these five filters were then averaged to yield the intensity value for the vowel segment.

3.4. Computation of Sentence Stress

Following Chen et al. (2001), we analyzed the acoustic data of each speaker's production of sentence stress in two different ways to compute sentence stress. The first method was *average* sentence stress, according to which we computed mean values of acoustic parameters, namely F0, intensity, and duration for stressed words only. This method of computing sentence stress yielded values of the acoustic features involved across the two groups of speakers for stressed words.

However, this analysis alone does not provide a comprehensive evaluation tool for the comparison of the productions of sentence stress in the two groups of speakers. It has been suggested that one needs to evaluate differentiated stress, i.e., differences in F0, duration and intensity between stressed and unstressed syllables/words, in order to have a complete account of cross-linguistic differences of prominence contrast (Chen et al., 2001; Zhang et al., 2008). Thus, we analyzed and compared the acoustic characteristics of stressed and unstressed words in the two groups of speakers to evaluate the differentiated production of sentence stress, and to explore comprehensively to what extent Mandarin speakers produced Persian sentence stress in a manner similar to Persian speakers. This method was referred to as *across-sentence* stress (Chen et al., 2001). The evaluation of differentiated stress, as applied to the data of the current study, meant to compare the acoustic characteristics of a stressed word (e.g., stressed 'ɢors') to the same but unstressed words (e.g., the other two unstressed 'ɢors' productions) produced across the three different sentences. Thus, this method of computation ensured that a "difference" value for each acoustic parameter (F0, intensity, or duration) was obtained which would show the magnitude of the difference between the stressed word and the remaining unstressed words (Chen et al., 2001). For example, the following formulae represents how the across-sentence duration (Δ*duration*) for the word ‘ɢors’ across the three sentences: ‘**sɑm** bɑ ʔɑb ɢors χord’, ‘sɑm bɑ **ʔɑb** ɢors χord’ and ‘sɑm bɑ ʔɑb **ɢors** χord’ is computed:

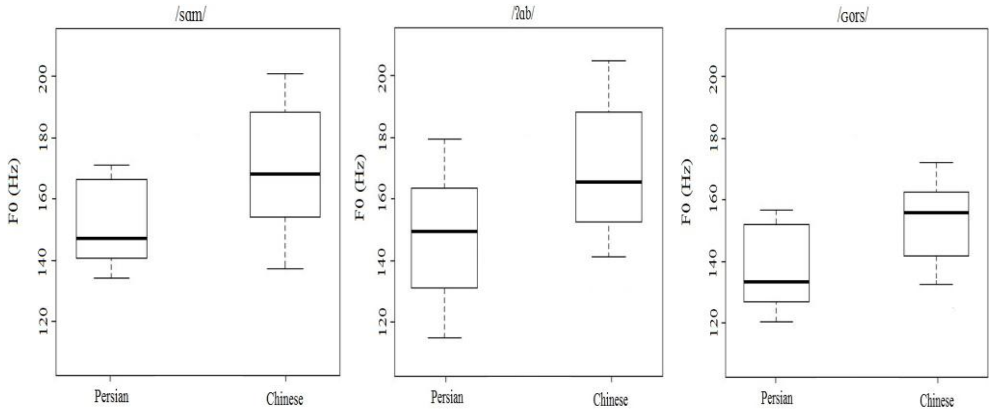
$$\Delta duration = duration_{\mathbf{Gors}} - (duration_{Gors} + duration_{Gors})/2.$$

4. Results

4.1. Average Sentence Stress

The graphs in Figures 2-4 plot the mean F0, duration, and intensity values for average sentence stress across the two language groups for each of the three target words. The results are presented below separately for each acoustic measure.

The graphs plotting mean F0 (see Figure 2) reveal that Mandarin Chinese speakers produce stressed words with a higher mean pitch than Persian speakers across all three target words. It can also be observed that the word ‘ɢors’ has a lower mean F0 than the other two stressed words (namely, ‘sɑm’, ‘ʔɑb’) both in the production of Persian and Mandarin Chinese speakers. This difference in pitch is due to an automatic physiological phenomenon called pitch declination (Ladd, 1992, 1993; Lieberman & Pierrehumbert, 1984; Pierrehumbert, 1980; Prieto, 1998; Prieto & Shih, 1995; Prieto, Shih, & Nibert, 1996). Declination refers to the downward trend of F0 over the course of an utterance (due to the reduction of subglottal pressure, and the activity of laryngeal muscles), causing the words towards the end of an utterance to be produced with lower F0 height or pitch excursion than those located earlier. Results of a two-way repeated measures ANOVA with “native language” (Persian vs. Mandarin Chinese) as the between groups factor, “stressed words” (‘sɑm’,‘ʔɑb’, ‘ɢors’) as the



within groups factor, and F0 as the dependent factor revealed a main significant

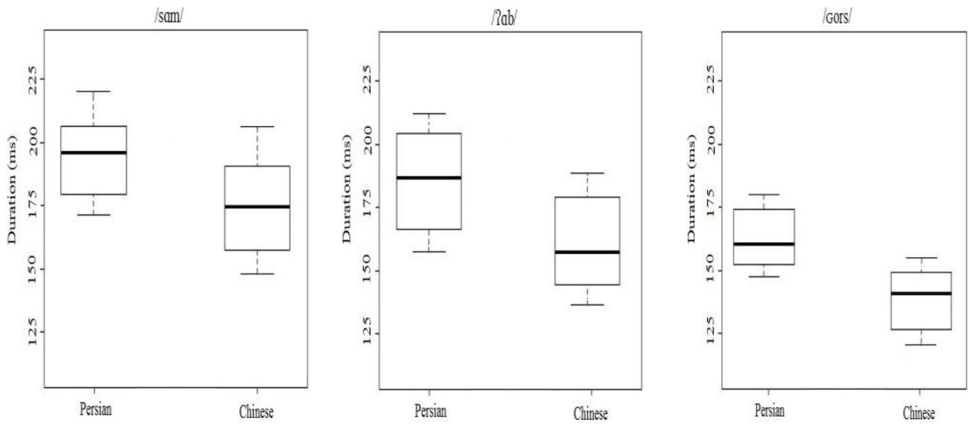
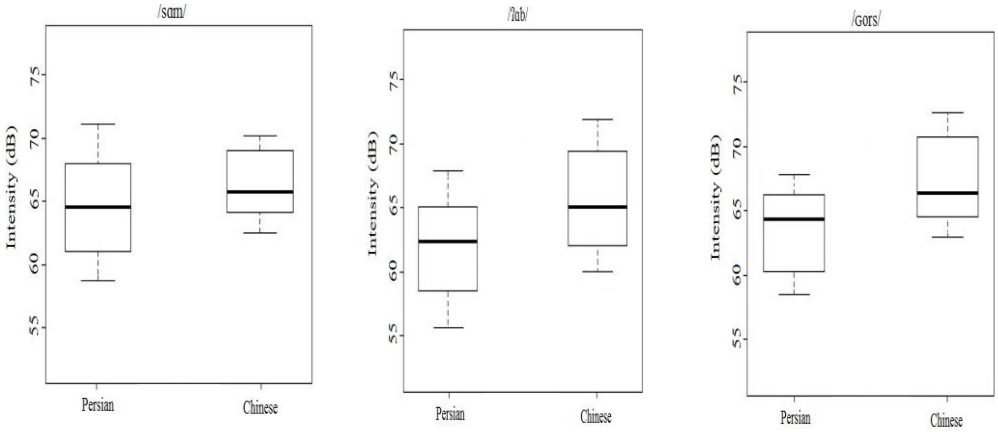


Figure 2. Mean and standard error values of F0 for average sentence stress across the two language groups (Persian and Mandarin Chinese) for each of the three target words.

Figure 3. Mean and standard error values of duration (ms) for average sentence stress across the two language groups (Persian and Mandarin Chinese) for each of the three target words.

effect of “language group” ($F(1, 142)= 141.31$, $p<0.001$), with Mandarin Chinese speakers producing stressed words with a higher F0 compared to Persian speakers. There was also a significant main effect for ‘stressed words' (F(1, 142)= 14.72, p<0.001). Post hoc Scheffe comparisons found



'Gors' to be produced with a significantly lower F0 compared to the

Figure 4. Mean and standard error values of intensity (dB) for average sentence stress across the two language groups (Persian and Mandarin Chinese) for each of the three target words.

remaining two stressed words ('sɑm', 'ʔɑb') (p<0.001). There was no significant interaction between language group and stressed words (F<1).

The data for duration in Figure 3 reveal consistent effect of language group on vowel duration: stressed vowels in the production of Mandarin Chinese speakers are consistently shorter than those in the production of Persian speakers. The data further reveal that both groups of participants produce the word 'Gors' with a lower mean vowel duration than the other two stressed words (namely, 'sɑm', 'ʔɑb'). The results of a two-way ANOVA revealed a significant main effect of 'language group' on vowel duration (F(1,142)= 36.47, p<0.001). The results also showed a clear main effect of stressed words on vowel duration (F(1,142)= 11.38, p<0.001). Post hoc Scheffe tests found 'Gors' to be significantly different in duration compared to the other stressed words (both comparisons, p<0.01). There was no significant interaction between language group and stressed words (F<1).

As concerning intensity, it can be observed that (see Figure 4) none of the target words display a considerable difference of mean intensity between Mandarin Chinese and native Persian speakers. In addition, values of mean intensity are fairly stable across different target words for both language groups. The results of a two-way repeated measures ANOVA revealed non-significant main effects for both language group ($F(1,142)= 2.48$, $P= 0.11$) and 'stressed words' ($F(1,142)= 1.14$, $P= 0.21$). Furthermore, there was no significant interaction between language group and intensity of stressed words ($F<1$).

4.2. Across-Sentence Stress

The bar graphs in Figures 5-7 plot the mean differences in F0, duration, and intensity values between stressed and unstressed words across sentences using *across-sentence* stress calculation. The results are presented below separately for each acoustic measure.

Results of the F0 analysis are displayed in Figure 5. As can be observed, both Persian and Mandarin Chinese speakers produced stressed words with a higher F0 compared to unstressed words (all values of F0 differences are positive). The graph further reveals that Mandarin Chinese speakers differentiated stressed from unstressed words with a higher F0 compared to Persian speakers. Results of a two-way ANOVA for the F0 differences revealed a significant main effect for language group ($F(1,142)= 86.18$, $p<0.001$). In addition, the F0 of stressed words produced a significant effect ($F(1,142)= 17.32$, $p<0.001$). Post hoc testing found the word 'sɑm' to have a higher differentiated F0 compared to the other words ($p<0.001$). There was no significant interaction between language group and stressed words ($F<1$).

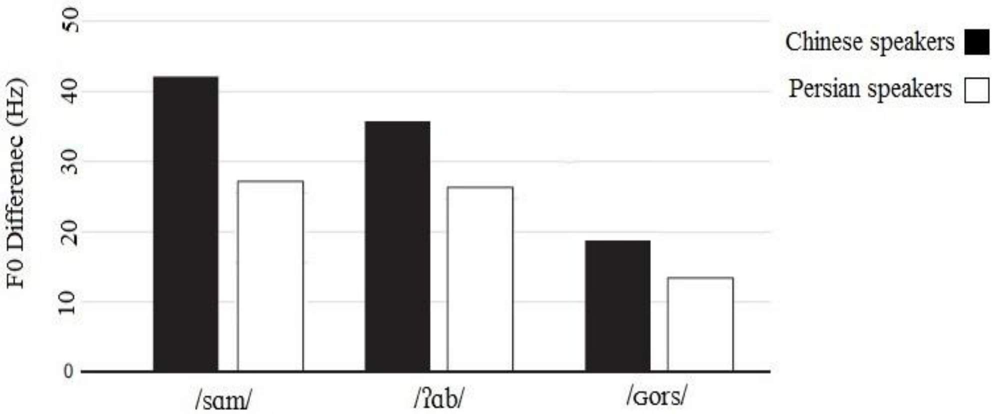


Figure 5. Values of F0 difference between stressed and unstressed words across sentences for Persian and Mandarin Chinese speakers.

Results of the durational differences are displayed in Figure 6. It can be seen that stressed words are longer than unstressed words both in the productions of Persian and Mandarin Chinese speakers. Results of a two-way ANOVA for vowel durational differences between stressed and unstressed words revealed a significant main effect for language group ($F(1,142)= 33.41$, $p<0.001$): Mandarin Chinese speakers produced differentiated stress with shorter vowel durations than Persian speakers. Stressed words also exerted a significant effect on duration ($F(1,142)= 10.36$, $p<0.001$). Post hoc testing revealed that the word 'ɢors' had longer stress-based durational difference than the other two words ($p<0.001$). There was no significant interaction between language groups and stressed words ($F<1$).

Figure 7 shows the results of the intensity analysis. The figure shows that the intensity of stressed words in the productions of both groups of speakers is greater than unstressed words. A two-way ANOVA analysis

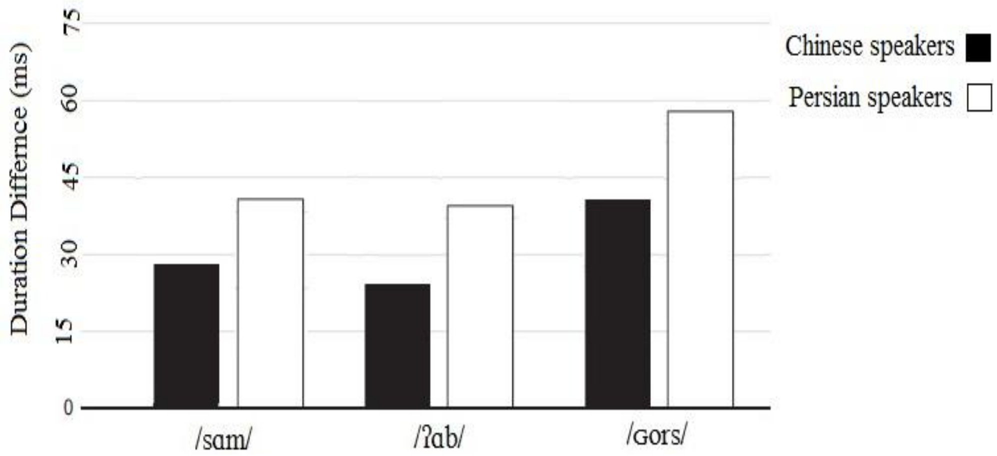


Figure 6. Values of duration difference between stressed and unstressed words across sentences for Persian and Mandarin Chinese speakers.

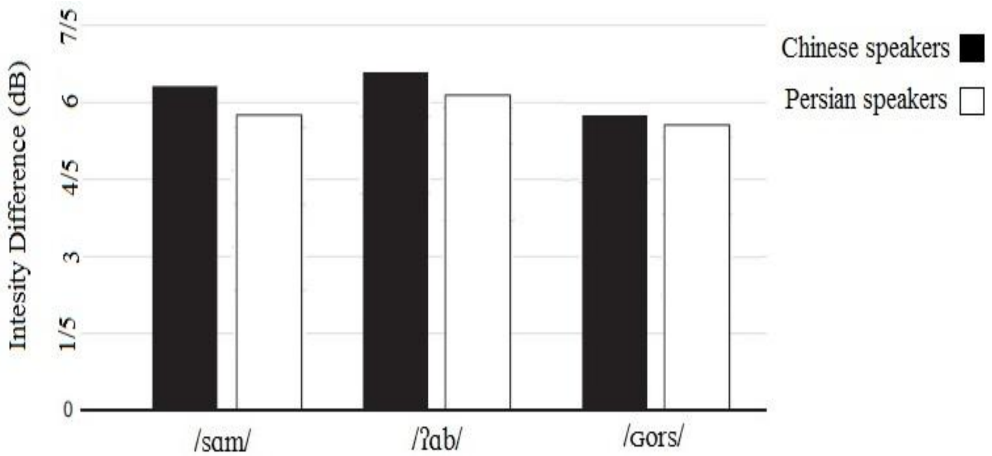


Figure 7. Values of intensity difference between stressed and unstressed words across sentences for Persian and Mandarin Chinese speakers.

showed that the effect of language group on intensity was non-significant ($F(1,142)= 0.84$, $p<0.36$). There was also a non-significant effect for the intensity of stressed words ($F(1,94)= 0.52$, $p<0.47$). In addition, the interaction between language group and stressed words was not significant ($F<1$).

5. Discussion and Conclusion

This study was motivated by issues concerning the phonetic realization of Persian sentence stress in the production of speakers of Persian as a second language. We investigated the acoustical correlates of sentence stress in Persian produced by Mandarin Chinese speakers of Persian as a second language. We were interested to explore to what extent F0, duration and intensity as three most reliable acoustical correlates of stress in Persian would still prove reliable cues to stress when Persian sentences are produced by Mandarin Chinese speakers.

The measurements of F0 revealed that the F0 of syllables/words is sensitive to the stress condition of the target syllable in the production of Mandarin Chinese speakers, suggesting that like native Persian speakers, Mandarin Chinese speakers are able to use F0 variation in Persian to differentiate stressed from unstressed words. Our findings indicated that stressed words are consistently produced with higher pitch than unstressed words by both groups of speakers. Thus, our first hypothesis, namely that Mandarin Chinese speakers are capable of altering F0 to differentiate stressed from unstressed words in the production of Persian sentences, is generally confirmed. However, one important difference between Mandarin Chinese speakers and native Persian speakers, as indicated by the results obtained from the average stress analysis, was that Mandarin Chinese speakers produced stressed words with a significantly higher F0 than their native Persian counterparts.

The use of higher F0 by Mandarin speakers to signal Persian sentence stress may be explained in terms of prosodic transfer from the L1 system to L2. As noted by Mennen (2006), prosodic transfer can take the form of both phonological and/or phonetic interference. Phonological influence results from differences in the inventory of phonological tones, their form, and the meaning assigned to them. By contrast, a phonetic influence is due to a difference in the phonetic realization of an identical phonological tone. As explained in the introduction, the prosodic systems of Persian and Chinese are significantly different from one another at both the phonological (the existence of tones to express lexical meaning in Chinese and the lack of a tonal system in Persian) and phonetic level (the way stress-based fundamental frequency pattern is implemented in the speech signal is different in the two languages). One possible explanation for the differences of F0 between the two groups of speakers may be that since Chinese is a tonal language, it contains significantly greater F0 fluctuations at the syllable-level compared to the continuous speech of Persian. Since every syllable in Mandarin Chinese has its own tonal specification, F0 changes drastically from syllable to syllable in the course of the production of a sentence (Xu, 1999; Xu, 2005). The pattern of greater F0 fluctuations has also been reported for Chinese L2 speakers of other languages such as English (Eady, 1982) and French (Shen, 1990). Thus, the findings of F0 as reported in the present study may be interpreted as suggesting that though Mandarin Chinese speakers can use variation in F0 to signal prominence contrast at the sentence level in Persian, they produce stressed and unstressed words in Persian sentences with higher F0 due to prosodic interference from their L1 system. This prosodic interference results specifically from the interaction between sentence intonation and lexical tones in Mandarin Chinese, which leads to a higher overall pitch level in the course of the production of a sentence, irrespective of whether the sentence is from L1 Mandarin Chinese or L2 Persian.

We may also note that differences in F0 between speakers of tonal languages (most specifically in the Eastern Asia) and speakers of intonational languages (like Persian) result from discrepancies in laryngeal anatomy. For example, Chen et al. (2001) studied patterns of sentence stress production in Mandarin speakers of American English, and found Mandarin Chinese speakers to produce stressed words with a significantly higher F0 compared to the American speakers. They argued that the higher F0 values in Mandarin Chinese speakers compared to American English speakers may be related to differences in the anatomic measures of the larynx.

Concerning duration, the Persian word duration patterns as a function of stress produced by non-native speakers of Mandarin Chinese generally matched those produced by native Persian speakers, as both groups of speakers pronounced stressed words with longer duration than unstressed words. Thus, our findings for duration generally confirmed the hypothesis stated earlier, namely, there is no significant difference between Mandarin Chinese speakers and native Persian speakers in the use of duration to cue Persian sentence prominence. However, as shown by the results from the *across-sentence* analysis, the patterns of differentiated duration were different in the two groups of speakers as differences in duration between stressed and unstressed syllables in the production of Mandarin Chinese speakers were significantly shorter than those of native Persian speakers. This difference in the native and non-native speakers' use of durational cues to sentence-level prominence may be reasonably accounted for if we consider the prosodic systems of the two languages. As stated earlier, Mandarin Chinese has been classified as a syllable-timed language, in which differences of duration between stressed and unstressed syllables/words are very small. As such, when Mandarin Chinese speakers produce sentence stress in Persian (which is a stress-timed language), they would pronounce words with relatively constant duration, and find it hard to regulate duration based on sentence prominence pattern in a manner similar to native speakers of Persian.

Our results are consistent with earlier findings in the literature in relation to syllable and/or word duration in non-native speech. For example, studies on syllable and vowel duration have shown that there is less within-speaker durational variance in the speech of non-native English speakers than native speakers. Anderson-Hsieh and Horabail (1994) have shown that low-proficient Mandarin Chinese learners of English produced a smaller durational difference between stressed and unstressed syllables than native English speakers. In addition, non-proficient Japanese learners of English have been found to produce less syllable reduction than native English speakers as the number of syllables in a foot increases (Chen, 2010; Mochizuki-Sudo & Kiritani, 1991). Also, Studies by Fokes and Bond (1989) have revealed that non-native speakers of English with five different language backgrounds (Farsi, Japanese, Spanish, Hausa, and Mandarin

Chinese) reduce the durational differences between stressed and unstressed vowels, relative to native English speakers. A similar pattern of results has been reported for Korean learners of English (Lee, Guion, & Harada, 2006) and Spanish learners of English (Flege & Bohn, 1989).

With respect to intensity, our findings confirmed the hypothesis developed previously, showing that the patterns of intensity differences between stressed and unstressed words are not significantly different between Mandarin Chinese and native Persian speakers. Similar findings have been reported for Mandarin Chinese speakers of English as a second language. For example, Chen et al. (2001) showed that Mandarin Chinese speakers produced English stressed and unstressed vowels with native-like intensity patterns. Our results agree with previous findings in the literature which suggested that intensity is an acoustical correlate of prominence in both Mandarin and Persian languages (Sadeghi, 2011; Shen, 1993). Thus, intensity cues to sentence stress in Persian were the most comparable acoustic measures across Mandarin and Persian speakers, though earlier research has revealed that intensity is the least salient and less consistent acoustic parameter to differentiate stress from unstressed words (Sluijter &i van Heuven, 1996).

In sum, the outcome of this study confirmed the hypotheses that Mandarin Chinese speakers of Persian would be capable of manipulating acoustical parameters of sentence stress, namely F0, duration, and intensity to distinguish stressed from unstressed syllables/words. Our findings, further indicated that L2 Mandarin and native Persian speakers differ in the way they use variations of F0, duration, and intensity to implement sentence stress in Persian, and the differences involved can best be explained as an interference from the prosodic system of the Mandarin Chinese language into that of the Persian language.

6. Implications for L2 Learners and Teachers

Since speaking a language with a wrong sentence stress pattern can cause communication errors and problems in dialogues, it is important that second language learners and teachers have knowledge about prosodic features of speech. As suggested by Zhang and Francis (2010), the incorporation of L2 phonetic and phonological patterns into course materials contributes to improving learners' pronunciation skills. Thus, the results of the study might be specifically worthy of attention for curriculum developers who produce Persian materials for non-Persian learners to adequately and thoughtfully incorporate Persian native patterns of sentence stress in some exercises and tasks that are intended for learning pronunciation, specifically the features dissimilar to the ones used in the L1 (Mandarin Chinese), like patterns of F0 or duration variation. It is further suggested that teachers explicitly make students aware of the importance of suprasegmental (F0, duration and intensity) cues to sentence stress in Persian employing some relevant pedagogical activities and tasks. Careful listening to Persian sentences spoken by native speakers might also be a successful pedagogical method to reach awareness of the differences in prosodic minimal pairs (Cauldwell, 2013).

In summary, it is believed that if guided practice and spontaneous speech is incorporated in the instructional planning of pronunciation courses for Mandarin Chinese learners of Persian, they will be 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.

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