Spanish lexical stress produced by proficient Mandarin learners of Spanish

Peng Li [1], Xiaotong Xi [2]

[1] Center for Multilingualism in Society across the Lifespan (MultiLing), University of Oslo, Norway,
[2] Department of Translation and Language Sciences, Universitat Pompeu Fabra, Spain,
[1]*peng.li@iln.uio.no*, [2]*xiaotong.xi@upf.edu*

Abstract

L2 learners produce the Spanish lexical stress differently from native speakers in various aspects. However, relatively fewer studies have focused on how Mandarin learners of Spanish produce lexical stress and how it influences vowel quality. In this study, ten Mandarin students with advanced Spanish proficiency and six Spanish native speakers completed text-reading and word-reading tasks in Spanish. The results revealed that (a) Mandarin students encoded Spanish lexical stress with pitch contrast more than duration or intensity, which added positive evidence for the *phonetic approaches* to L2 lexical stress acquisition because only pitch is relevant to Mandarin lexical tones. (b) Moreover, lexical stress enhanced the mouth aperture of /a, o/ for Spanish natives but that of /e, i, o/ for Mandarin students, which suggests that L2 learners still differ from native speakers in speech production, even at a high proficiency level.

Keywords: Lexical stress, Vowel, Spanish, Mandarin student, Second language acquisition

1. Introduction

Late adult learners of a second language (L2) may still have a non-native accent even after achieving advanced L2 proficiency [1]. Prosodic elements such as lexical stress [2] and segmental features like vowel quality [3] can largely affect the perceived foreign accent by native speakers. Crucially, errors in these features may contribute to accentedness even for advanced learners [4]. Traditional *phonological approaches* predicted that successful L2 lexical stress acquisition would be subject to the similarities between learners' L1 and L2 in terms of the existence of lexical stress contrast and the stress assignment rules. However, recent research shows that the *phonetic approaches* are more predictive. Particularly for late L2 learners, the functional relevance of a certain phonetic property may determine the extent to which they attend in their L2 speech production [5]. For example, since vowel length is relevant for encoding Thai lexical tones, vowel length could

affect the Thai speakers' stress placement in L2 English production [6] but this is not the case of Korean speakers to whom vowel length is not relevant [7].

Turning to Spanish as foreign language research, lexical stress is an important prosodic feature since it connects to orthography and sentence rhythm [7] and affects vowel quality [8]. Spanish lexical stress is assigned to words. Generally, stressed syllables show a higher pitch, longer duration, and greater intensity than unstressed ones in isolated words [9]. Vowels in stressed syllables are longer [10], more open [11], and less centralized [12] than in unstressed syllables.

Previous studies have investigated Spanish lexical stress and vowel quality in speech production by learners with various L1 backgrounds [13]–[17] and heritage speakers [18], [19], but only a few of them have dealt with tonal language speakers, such as Mandarin [20]. Mandarin assigns lexical tones on syllable level, and the lexical tones differ mainly in pitch. Moreover, Mandarin shows a five-to-six vowel inventory /i, y, a, ə, (ɚ), u/ [21], which is quite different from the Spanish five-vowel system /i, e, a, o, u/. When interacting with vowel quality, the Spanish lexical stress is challenging for Mandarin-speaking learners. As for lexical stress production, Mandarin students may assimilate the Spanish lexical stress to Mandarin lexical tones (e.g., realizing the stressed syllables as Tone 2, a rising tone) [20]. However, it is unclear how Mandarin learners produce Spanish vowels in different stress conditions and speech styles (e.g., isolated words vs. running speech). Some found that Mandarin students produced the Spanish /a, o/ with lower F2 than Spanish speakers [22]. Others showed that Mandarin students produced all five vowels with higher F1 and only back vowels with higher F2 than native speakers, while lexical stress only affected the production of /i/ [23].

Based on the literature review, we ask the following two research questions:

RQ1: How do Mandarin students encode Spanish lexical stress contrasts in speech production? Based on previous research [5], we hypothesize that

Mandarin students may manipulate pitch for lexical stress contrasts to a larger extent than Spanish natives.

RQ2: Does lexical stress affect Spanish vowel quality produced by Mandarin and Spanish speakers? We hypothesize that lexical stress would have different effects on vowel quality in Mandarin and Spanish speakers because Mandarin has different vowel inventories than Spanish.

2. Method

2.1. Participants

Ten Mandarin learners of Spanish (female = 5, aged 24-33 years, M_{age} = 27.30, SD = 3.13) and six Spanish native speakers (female = 3, aged 24-28 years, M_{age} = 24.83, SD = 1.94) were recruited from Spain. On average, the Mandarin students reported starting learning Spanish after 18 years old and having learned Spanish for 4.10 years (SD = 1.20). They have studied in Spanish-speaking countries for 5.53 years (SD = 3.13). As for their proficiency, they have passed the DELE (Diploma of Spanish as a Foreign Language) examination of B2 (advanced, n = 4) or C1 (high advanced, n = 6) level. Therefore, the Mandarin students were considered late adult learners with advanced proficiency and intensive exposure to Spanish. All the participants, including the six native speakers, reported having normal hearing and no speech disorder. They gave written permission to the researchers allowing them to process their speech data.

2.2. Materials

The test materials consisted of a short Spanish text and 30 Spanish $C_1V_1C_2V_2$ words. The short text was the standard testing material for eliciting the pronunciation of different languages, "*El viento norte y el sol*" (*North Wind and the Sun*) [24].

In the word list, 15 of the words were oxytones (e.g., *tapó*, 'she/he/it covered'), while the other 15 paroxytones (e.g., *tapo*, 'I cover'). We set the target vowel as V_1, so half of the vowels were tonic while the other half were atonic. To create clear syllabic boundaries [25] and avoid potential errors caused by non-native phonemes, C_1 and C_2 were chosen from the three voiceless plosives /p, t, k/, given that these three consonants are shared phonemes in both Mandarin and Spanish. Each of the three voiceless plosives cooccurred with each of the five vowels twice, once in oxytone and once in paroxytone, resulting in 30 C_1V_1 syllables: 3 plosives /p, t, k/ × 5 vowels /i, e, a, o, u/ × 2 stress conditions (stressed vs. unstressed). We selected real Spanish words to avoid unnatural speech. Consequently, the non-target C_2V_2 syllables were not strictly controlled, although it was ensured that C_2 was one of the three plosives and V_2, one of the five vowels. In addition, we added 146 words for testing Spanish consonants which are fillers for the current study. Accordingly, the final word list contained 176 words organized in random order.

2.3. Procedure

Participants were tested individually in a quiet room. Before starting the experiment, the participants were given a short period to get familiar with the reading materials. Then they were instructed to read the words at a natural and comfortable speech rate. Upon finishing reading the word list, they proceeded with reading the short text. If they mispronounced a certain word, they would correct it immediately. The word list was read twice, and the text was read once. In total, the experiment took around 10 minutes. The computer automatically recorded participants' speech outcomes.

2.4. Data coding

We obtained 2592 and 960 vowels from the text-reading task (162 vowels × 16 participants) and the word-reading task (30 words × 16 participants × 2 repetitions). We annotated the target vowels using Praat [26]. The annotation was done by visually checking the tokens' spectrogram, waveform, and auditory judgment. The onset and offset of each vowel were determined by the presence and absence of the energy of the second formant [25].

After annotation, for each target vowel, we extracted the following acoustic data from Praat: (a) duration, (b) mean pitch, (c) mean intensity, (d) the mid-point of the first formant, and (e) the mid-point of the second formant. For statistical analyses, the first two formant values were transformed from Hertz to bark to account for the potential impact of individual vocal tract length [27] (hereafter F1 and F2, respectively). However, the descriptive data reported in the "Results" section are in Hertz.

3. Results

We built a series of Linear Mixed-Effects Models (LMM) using the *lmer()* function in the *lme4* package [28] in R [29]. For the duration, pitch, and intensity, the fixed factors were stress (stressed vs. unstressed), speaker (Mandarin learners vs. Spanish natives), and their interaction; for F1 and F2, we added a three-way interaction of Stress × Speaker × Vowel. For each model, we added participant and item as random intercepts. Since pitch and formant are largely affected by gender, but gender difference is not involved in our research questions, we nested participant by gender to analyze pitch and formants.

We calculated the significance using the Type II Wald *chi*-squared tests in the *car* package [30] and performed post-hoc pairwise comparisons in the *emmeans* package [31], with the significance adjusted using the Bonferroni method.

3.1. The effects of stress on duration, pitch, and intensity in Spanish produced by Mandarin-speaking learners and Spanish natives

The descriptive data of duration, pitch, and intensity are summarized in Table 1.

Table 1: Means (standard deviation) of the duration (ms), mean pitch (Hz), and mean intensity (dB) of the target vowels across stress conditions and speakers (CHN=Mandarin students, ESP=Spanish natives) in the text and word reading tasks.

	Duration		Pitch		Intensity	
	CHN	ESP	CHN	ESP	CHN	ESP
Text reading task						
Str	127.7	85.5	169.2	160.0	68.9	70.4
	(40.2)	(23.8)	(42.6)	(58.0)	(4.3)	(6.7)
Unstr	99.9	62.8	159.6	162.1	67.3	69.7
	(41.2)	(25.7)	(43.5)	(58.3)	(4.8)	(6.9)
Word-reading task						
Str	140.0	118.3	193.3	164.0	70.7	71.7
	(35.2)	(22.2)	(46.0)	(49.7)	(4.1)	(7.0)
Unstr	123.5	84.4	150.3	151.3	67.4	69.4
	(34.6)	(19.7)	(40.3)	(47.8)	(4.1)	(6.9)

3.1.1. Duration

The text-reading task did not show significant interaction of Speaker $\times$ Stress ($p = .397$) for the duration, although both groups of speakers produced longer vowels in stressed syllables than in unstressed ones (all $p < .001$). By contrast, the word-reading task revealed a significant interaction of Stress $\times$ Speaker for the duration ($p < .001$). Post-hoc comparisons showed that both Mandarin students and Spanish natives produced the target vowels with a longer duration in stressed syllables than in unstressed ones (all $p < .05$). In addition, Mandarin students produced significantly longer vowels than Spanish natives in unstressed syllables ($p = .002$). These results suggest that Mandarin students and Spanish natives marked stress with duration similarly. Figure 1 visually plots the results of duration.
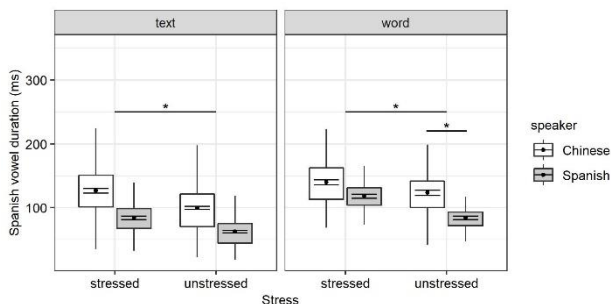

Figure 1: Boxplot of the duration of the target vowels across speakers and stress conditions in the text and

word reading tasks. The solid point indicates the mean value, and error bars show 95% CI. Asterisks mark significant contrasts.

3.1.2. Mean pitch

There was a significant interaction of Stress $\times$ Speaker for pitch in both text-reading ($p < .001$) and word-reading ($p < .001$) tasks. Post-hoc comparisons showed that Mandarin students produced stressed vowels with a higher pitch than unstressed ones when reading words and text, but Spanish natives revealed the same pattern only when reading isolated words (all $p < .05$). That is, although pitch is relevant to mark Spanish stress, Mandarin students used pitch to a larger degree than Spanish natives. Figure 2 visually plots the results of the mean pitch.
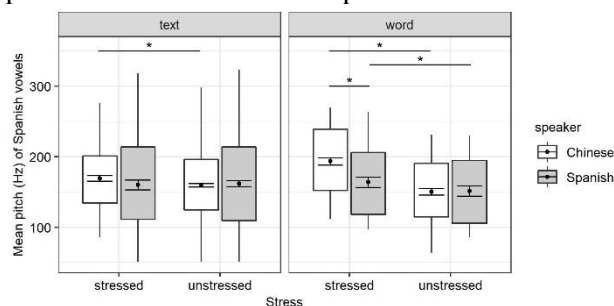

Figure 2: Boxplot of the mean pitch of the target vowels across speaker and stress condition in the text and word reading tasks. The solid point indicates the mean value, and error bars show 95% CI. Asterisks mark significant contrasts.

3.1.3. Mean intensity

We only found a significant main effect of stress for intensity in both text-reading ($p = .001$) and word-reading ($p < .001$) tasks, with stressed vowels showing greater intensity than unstressed ones. This means that both Mandarin students and Spanish natives made Spanish stress contrast with intensity in a similar way. Figure 3 visually plots the results of mean intensity.
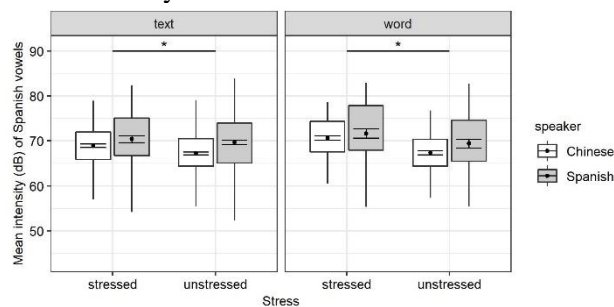

Figure 3: Boxplot of mean intensity of the target vowels across speaker and condition in the text and word reading tasks. The solid point indicates the mean value,

3.2. The effects of lexical stress on vowel quality in Spanish produced by the Mandarin-speaking students and Spanish native speakers

Regarding the F1, in the text-reading task, there was a significant interaction of Stress × Speaker × Vowel ($p = .012$). Briefly, the Mandarin students produced stressed /e, i, o/ more openly than unstressed ones, while the Spanish natives did so with /a, o/. In addition, Mandarin students produced stressed /e/ and unstressed /a/ with larger F1 than did Spanish natives. By contrast, in the word-reading task, we only found two significant main effects for F1: vowel and stress (both $p < .001$). The post-hoc results showed that in both L1 and L2 speech, the five Spanish vowels had different degrees of openness and that stressed vowels were more open than unstressed ones. Taken together, stress influenced the mouth aperture of Spanish vowels, and its impact varied across speakers (Mandarin students vs. Spanish natives) and speech types (isolated words vs. running speech).

The analysis of F2 revealed a significant interaction of Vowel × Speaker in both text-reading ($p < .001$) and word-reading ($p = .04$) tasks. Since the significance was adjusted, we could not find any significant contrast in F2 between the two groups of speakers in the text-reading task. Regarding the word-reading task, Mandarin students produced /u/ with significantly higher F2 than L1 speakers ($p = .006$). In short, stress did not significantly affect the tongue position in either L1 or L2 speech, but the Mandarin students centralized /u/ when reading isolated words.

To sum up, lexical stress only affected the F1 of the Spanish vowels produced by Mandarin students and Spanish natives in both isolated words and running speech. Stressed vowels were more open than unstressed vowels. By contrast, lexical stress showed no effect on F2. As for the production of specific vowels, Mandarin students showed more open /a, e, i, o/ in running speech and more centralized /u/ in isolated words than Spanish natives. See Table 2 for the descriptive data of all five Spanish vowels across stress conditions, speaker groups and tasks.

Table 2: Means (standard deviation) of F1 mid-point (Hz) and F2 mid-point (Hz) of the target vowels across stress conditions and speakers (CHN=Mandarin students, ESP=Spanish natives) in word and text reading tasks.

	F1 mid-point		F2 mid-point	
	CHN	ESP	CHN	ESP
Text-reading task				
Stressed vowels				
/a/	771 (142)	703 (169)	1497 (212)	1403 (215)
/e/	552 (95)	482 (93)	1924 (251)	1981 (319)
/i/	434 (166)	359 (46)	2229 (352)	2195 (384)
/o/	554 (89)	533 (96)	1067 (157)	1191 (202)
/u/	379 (70)	380 (53)	848 (286)	803 (128)
Unstressed vowels				
/a/	744 (147)	663 (175)	1482 (235)	1438 (236)
/e/	509 (90)	487 (97)	1953 (306)	1895 (330)
/i/	352 (53)	365 (62)	2298 (383)	2313 (359)
/o/	514 (95)	505 (103)	1106 (214)	1169 (227)
/u/	396 (138)	369 (77)	1047 (380)	952 (229)
Word-reading task				
Stressed vowels				
/a/	811 (149)	758 (158)	1404 (222)	1401 (159)
/e/	513 (82)	481 (66)	2060 (274)	2164 (345)
/i/	329 (58)	320 (61)	2490 (379)	2446 (387)
/o/	533 (104)	473 (70)	981 (169)	922 (111)
/u/	398 (80)	364 (51)	878 (206)	780 (146)
Unstressed vowels				
/a/	825 (169)	750 (156)	1414 (185)	1284 (191)
/e/	482 (83)	452 (61)	2100 (311)	2103 (243)
/i/	312 (50)	317 (57)	2342 (502)	2408 (388)
/o/	499 (85)	468 (66)	955 (120)	969 (152)
/u/	358 (63)	360 (65)	905 (256)	842 (180)

4. Discussion

This study compared the production of Spanish lexical stress by Mandarin- and Spanish- speakers in isolated words and running speech. The results showed that although with advanced proficiency and intense exposure to the target language, L2 learners still performed differently from native speakers. Although Mandarin students could make clear lexical stress contrast by manipulating pitch, duration, and intensity, they seemed to rely more on the pitch than did the Spanish natives. Moreover, lexical stress influenced vowel quality differently in L1 and L2 speech, especially in running speech. The main difference lay in the mouth aperture, with stressed vowels being more open. Finally, even for advanced learners, their vowel quality was still different from native speakers.

Our first research question is how Mandarin speakers encode Spanish lexical stress in speech production. In general, the Mandarin students produced stressed vowels with longer duration, higher pitch, and greater intensity, as did the native speakers. This means that they have acquired the Spanish lexical stress on the phonological level after long exposure to the target language. However, the Mandarin students did not encode the lexical stress the same way as Spanish natives did. As hypothesized, the pitch was more important for Mandarin speakers to make the lexical stress when speaking Spanish than duration or intensity. This finding is consistent with [20], which showed that Mandarin students produced stressed Spanish syllables as a rising tone but unstressed ones as a falling tone. The results suggest that learners may transfer the prosodic characteristics from their L1 to L2 when learning prosody.

The second research question is whether lexical stress has different effects on vowel quality produced

by Mandarin students and Spanish natives. The formant analysis of the target vowels confirmed that lexical stress significantly affected the mouth aperture of four Spanish vowels /a, e, i, o/ in both L1 and L2 running speech (text-reading), but the effects were different. Among them, /o/ was the only vowel that both groups of learners produced more openly in stressed syllables than in unstressed syllables. Despite the effects of lexical stress, Mandarin students and Spanish natives did not pronounce the Spanish vowels in the same way. We found that Mandarin students produced the back vowel /u/ in isolated words more fronted than Spanish natives. In conjunction with previous findings, it can be safely concluded that the Spanish vowel system is not as easy to acquire as it seemed. Even at an advanced acquisition stage, Mandarin students still showed a non-native pronunciation fashion.

In conclusion, our findings provided new evidence for the *phonetic approach* [5] to L2 lexical stress production: Even proficient L2 learners transferred the prosodic features from L1 to L2 in speech production (e.g., prefer pitch more than duration or intensity in stress contrast) and showed different formant patterns in producing vowels than Spanish natives.

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