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What Makes Spanish-Accented English Sound Spanish-Accented? Acoustic Measures and Listener Cues

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Abstract

This study aimed to understand which acoustic parameters of Spanish-accented English are correlated with listeners' perception of Spanish-accentedness. Temporal differences were analyzed in multisyllabic target words spoken in sentences by 22 Spanish speakers of English and five native speakers of American English (AE). Recordings were presented to AE listeners who judged the degree of accentedness on a 9-point scale. Spearman rank order correlation showed that the listeners' ratings of degree of accentedness in sentences correlated strongly (ρ= +0.82) with those in words. Listeners' ratings of accentedness correlated in varying degrees with various temporal measures, namely Overall word durations (+0.04 to +0.56), Stressed/unstressed vowel duration ratios (–0.01 to +0.35), Voice Onset Time of stops (+0.26 to +0.36), and, closure duration (+0.29 to +0.59). Results suggest that Spanish-accented English is characterized by systematic temporal differences from native AE, and that these temporal differences contribute to the perception of accentedness. Implications of findings in improving theoretical understanding and applied practices are discussed.

Keywords: Spanish, Accent, Acoustics, Perception, Listener cues

1. Introduction

Foreign-accented speech is defined as "non-pathological speech produced by second language learners that differs in partially systematic ways from the speech characteristics of native speakers of a given dialect" (Munro, 1998). As foreign accent is ultimately a phenomenon dependent on the listener, it is especially crucial to understand the variables that

influence listeners' processing and judgment of accented speech. Studies have found that listeners can and do attend to, and encode the surface indexical details of the foreign accent in their ongoing linguistic processing (e.g., map-drawing tasks: Preston, 1986; card-sorting tasks: Tamasi, 2003; accent and dialect labeling and categorizing tasks: Shah, 2007; Clopper & Bradlow, 2007). Attitude-judgment studies have shown that listeners use their long-term stored surface representations to form opinions, stereotypes, biases, and/or judgments about extra-linguistic, psychological traits of individual speakers and their particular dialects and/or accents (Ryan, Giles & Sebastian, 1982; Brennan & Brennan, 1981; Preston, 1989). Thus, it is clear that listeners attend to surface variability represented through accented speech. While these studies clearly demonstrate how listeners are influenced by the presence of a foreign accent in their speech and linguistic processing, very few studies have actually addressed the question of which attributes of the accent directly influence listeners' overt perception of a foreign accent. As a result of these studies, the salient attributes that are most distinctive of the accent to listeners are now known for a variety of languages/accents: Arabic (Flege & Port, 1981), French (Hazan & Boulakia, 1993), Dutch (Elsendoorn, 1985), German (Olson & Samuels, 1973), Italian (Flege, Munro, & Mackay, 1995), Mandarin/Taiwanese (Flege, 1988b), Korean (Flege, Yeni-Komshian, & Liu, 1999), Russian (Thompson, 1991), and Polish (Neufeld, 1980).

In keeping with the above-mentioned direct acoustic-perceptual comparison-based approach, the present paper attempts to extend and add to the available information to help uncover the production attributes that are most directly related to the identity of an accent. In particular, this paper addresses the distinct speech characteristics of Spanish-accented speakers of English that may be related to native listeners' perception of accentedness. Among the various immigrant languages in the United States, Spanish is one of the most widely spoken ones. Recent US Census data (Census, 2010) show that the Hispanic population represents the largest number of individuals in the United States whose native language is not English, and that Spanish is the most common form of accented English in the United States. Because of the high influx of Spanish-speaking people to the United States and their regional and occupational spread, the study Spanish-accented English to determine what speech characteristics make Spanish speakers sound "foreign-accented." offers both, theoretical and clinical applications as discussed in this paper.

1.1 Theoretical Framework

1.1.1 Spanish-Accented English Phonological Characteristics

The purpose of this paper was to address the distinct speech characteristics of Spanish-accented speakers of English that may be related to native listeners' perception of accentedness. While variables predictive of intelligibility are frequently studied and reported on, the question of the relationship between the production differences and their influence on listeners' perception of *foreign-accentedness* remains unanswered. Findings about the variables that correlate with lowered intelligibility cannot be used to make inferences about perceived accentedness (e.g., Munro & Derwing, 1995).

In order to understand the characteristics of Spanish-accented speech, contrastive phonological analyses have been done of speech characteristics as they related to perceived Spanish-accentedness (MacDonald, 1989; Ortega-Llebaria, 1997). MacDonald (1989) published a compilation of studies of Spanish phonology as well as Spanish-accented English phonology. MacDonald's description of Spanish-accented English was based on groups of studies in three dialects of Spanish: Mexican-American, Puerto-Rican-American, and Cuban-American. Overlapping features of phonological variations found across all studies were used to draw conclusions about characteristics of Spanish-accented English. A later study by Ortega-Llebaria (1997) reported a hierarchy of frequency of occurrence of a set of phonological characteristics for Spanish-accented speech. Table 1 shows 21 phonological processes, with examples and corresponding frequencies of occurrence.On the basis of these, Ortega-Llebaria inferred a hierarchy of production difficulties and their influence on intelligibility for native listeners.

In a study correlating production deviations of nonnative speakers and accentedness ratings by native speakers, the predictor variables must be quantifiable characteristics. Phonological deviations derived from impressionistic transcriptions do not lend themselves to quantitative analyses. The only study that directly addresses the causal relationship between production differences and listeners' perception of Spanish-accentedness is a study by Magen (1998). Magen edited Spanish-accented utterances to make them acoustically more similar to native English utterances and tested the influence of these modifications on listeners' perception. The results indicated that the edited forms were perceived to be less accented than the unedited forms. Listeners' judgments of foreign-accentedness were affected significantly by modifications in epenthesis, final /s/ deletion, and consonant manner substitution. By contrast, vowel reduction, tenseness-laxness, and voicing errors did not significantly affect listeners' judgments of foreign-accentedness.

With regard to the question of what contributes to the perception of accentedness, the Magen (1998) study is an important contribution to the relationship between acoustic deviations and listeners' ratings of accentedness. However, a number of issues remain and would need to be addressed in order to arrive at a complete account of production variables as they affect perception, as is attempted in the present study. For example, Magen (1998) tested only a few phonological/acoustic deviations and did not account for all deviations of Spanish-accented English. Thus far, a database of acoustic measures of the production deviations of Spanish-accented speakers, such as the database of phonological deviations by Ortega-Llebaria (1997) is unavailable. Also, Magen (1998) attempted to correlate production and perception after acoustic editing. No attempt was made to correlate the production measures with the perception before doing any editing, as a means of exploring the baseline production-perception relationship. Therefore, there remains the need for a study of the relationship between production deviations and perceived accentedness, as attempted in the present paper.

1.1.2 Temporal Deviations in Nonnative Speakers' Utterances are Relevant to Native Listeners' Perception

Temporal properties vary across different languages (Flege, 1988 a; Mack, 1982) and similar phonemes across different languages are reported to have quite different patterns of temporal implementation (Port, Al-ani, & Maeda, 1980). First-language (L1) temporal properties are reported to carry over to the second-language (L2), thus affecting listeners' perceptions and making the L2 speech sound accented (Flege, 1984). Additional evidence (Flege & Port, 1981) reveals that durational differences in vowels preceding obstruents are smaller for Arabic speakers of English than those produced by native speakers. Mack (1982) showed a similar effect for French speakers of English. Elsendoorn (1985) examined duration of vowels preceding obstruents in speakers of Dutch while they spoke Dutch as well as English. Acoustic analysis showed Dutch speakers of English, on average, produced shorter vowel durations preceding obstruents compared to native English speakers. Perceptual results showed that foreign vowel duration influenced the acceptability of the speech as perceived by native listeners. Port and Mitleb (1983) showed that English timing patterns were more difficult to acquire than spectral characteristics for Arabic speakers of English.

These findings collectively support the notion that nonnative speakers have different temporal patterns of production compared to native English speakers, and that measuring duration for nonnative speakers may tap into production differences that affect perception of accentedness. Furthermore, there is substantial evidence that listeners use temporal cues in the perception of words, phrases and sentences. Deviations in temporal patterns are related to judgments of accentedness by native listeners. Flege (1993) showed that degree of perceived foreign accent, as judged by native listeners, correlated significantly with vowel duration differences preceding final voiced versus voiceless obstruents for Chinese-accented English speakers. Hutchinson (1973) reported that Spanish speakers of English who showed a relatively smaller difference in vowel durations in stressed vs. unstressed syllables were given lower accentedness ratings by native American English (AE) listeners. All of the above studies indicate that native listeners are sensitive to durational deviations in nonnative utterances and that these temporal differences are significant contributors to perceived accentedness.

With regards to Spanish-accented English, the pattern of findings described earlier in the studies by MacDonald (1989) and Ortega-Llebaria (1997) add to the above support for the importance of temporal features to the perception of accentedness. These phonological studies have described several processes which are related to vowel identity and voicing of stops. Many of the phonological deviations they reported have temporal/durational correlates, e.g., stopping of fricatives, neutralization of aspirates, deletion of word-final consonants, simplification of word-final clusters, devoicing of obstruents, addition of epenthetic vowels, and spirantization of medial voiced stops. The vowel production differences also have a temporal component in addition to the more marked spectral component for vowel changes related to /æ, ɔ, ʌ/ and /i-I/. These phonological findings are used in the selection of the acoustic measures in the present study as will be described later.

Two studies are presented here to address the following hypotheses:

1) The temporal structure of Spanish-accented speakers' productions of multisyllabic words will differ from that of native American English (AE) speakers, and

2) Temporal deviations in nonnative speakers' productions of multisyllabic words will be correlated with native AE listeners' perception of accentedness.

In order to address these two hypotheses, the following two studies were designed.

Study 1 (the perception study) established the relative accentedness of a set of 22 native Spanish speakers of English as compared with five native AE speakers. Two sets of materials were presented to a panel of ten native AE listeners: 1) eight short sentences each containing a multisyllabic target word, and 2) the target words excised from the sentences and presented in isolation. The purpose of this study was to establish the extent to which the perceived accentedness of the isolated target words was predictive of the listeners' judgments of speakers' "global accentedness," derived from their ratings of the sentences. If the ratings of the target words were highly predictive of global accentedness, then a detailed analysis of their temporal structure and its relationship to accentedness ratings would be justified.

Study 2 (the production study) included detailed acoustic analysis of the productions of the eight multisyllabic target words. Overall word durations (used as a measure of speaking rate), relative vowel duration, stressed to unstressed vowel ratios (a measure of lexical stress), VOT of initial voiceless stops, and intervocal /t/ flap/closure duration were the temporal measures examined. Each of these measures was predicted to deviate from native AE speaker patterns for the Spanish speakers' productions. Finally, each temporal measure of the nonnative speakers' productions was correlated with native listeners' judgments of accentedness of the words to establish the extent to which each temporal deviation was predictive of accentedness.

Table 1. Phonological processes with potential to affect intelligibility and their frequency of occurrence (%) in native Spanish speakers' English (Ortega-Llebaria, 1997)

Phonological Process	Example	(%)
Target lax vowels become tense	[lɪft]→[lift] "lift"	44.95
Target /ɑ/ is produced as /ɔ/ and /ʌ/	[klɔk] or [klʌk]"clock"	27.82
Final position: Target voiced obstruents become voiceless	[tʌb̲]→[tʌp] "tub"	24.82
Final position: Deletion of a consonant of a target cluster	[lɑkt]→[lɑk] / [lɑt] "locked"	17.73
Target /ʌ/ is produced as /ɑ/ and /ɔ/	[trʌk]→[trɑk]/[trak] "truck"	15.33
Target /æ/ is produced as /ɑ/	[kæt] →[kɑt] "cat"	12.07
Addition of an epenthetic vowel in the word-initial position	[snoʊ]→[əsnoʊ] "snow"	8.88
Target /z/ becomes voiceless /s/	[zɪpɚ]→[sɪpɚ] "zipper"	6.43
Target medial voiced stops are perceived as voiced fricatives, and the affricate as a glide	[rʌbɚ]→[rʌvɚ] "rubber"	5.70
Target voiced stops deleted in final position	[tʌb̲]→[tʌ] "tub"	3.07
Target nasals neutralize to the point of articulation	[drʌm]→[drʌn] "drum"	2.96
Target initial voiceless stops are perceived as voiced	[pʰɑɪ]→[bɑɪ] "pie"	2.74
Final position: Target voiceless fricatives become voiced	[skarf]→[skarv] "scarf"	2.56
Target /tʃ/ becomes /ʃ/	[skrætʃ]→[skræʃ] "scratch"	2.08
Target /dʒ/ becomes continuant	[keɪdʒ]→[keɪʒ] "cage"	2.04
Target /ʃ/ becomes /tʃ/	[ʃɑrp]→[tʃɑrp] "sharp"	1.97
Target /ʒ/ devoices	[gərɑʒ]→[gərɑʃ] "garage"	1.86
Target glides become noncontinuant segment	[jɛlo]→[dʒɛlo] "yellow"	1.68
Target /θ/ becomes /t/ or /f/	[θʌm]→[tʌm] "thumb"	1.57
Target /ð/ becomes /d/	[ðɛr]→[dɛr] "there"	1.50
Target /v/ becomes /b/	[vælʌntɑɪn]→[bælʌntɑɪn] "valentine"	1.35

2. Methodology

2.1 Study 1: Rating of Accentedness (Perception Study)

This study had two objectives: first, to provide perceptual ratings of relative "global" accentedness of Spanish speakers uttering English sentences, as judged by native listeners of English; second, to determine the relation between judged accentedness of the multisyllabic words used in this study and the speakers' overall level of global accentedness, as judged by native listeners' assessment of the sentences. This comparison revealed the extent to which the accentedness of the target words was predictive of "global accentedness" of sentences.

2.1.1 Participants

a. Nonnative speakers (NN). Twenty-two (7 males, 15 females) native Spanish speakers of English as a second language served as the nonnative speakers. They were fluent speakers of English with a substantial degree of Spanish (Dominican-Republic) accent (as judged by native listeners in pilot testing). They were between the ages of 18-47 years and had arrived in the United States after 12 years of age. Age of Arrival to the United States (AOA) was used to represent the age of second language learning. The Length of Residence (LOR) was at least two years. All nonnative speakers had a minimum of a high-school level of education. Subjects were recruited by posting advertisements in graduate school programs and organizational e-mail postings.

b. Native speakers (AE). Five (2 males, 3 females) monolingual AE speakers served as control subjects. The discrepancy between the group size of the native and nonnative speakers followed other studies (Flege, 1993; Flege, 1984). These speakers ranged in age from 26-50 years. They were all born and raised in the Greater New York metropolitan area. They all had a minimum of a high-school education.

c. Listeners. Ten listeners were drawn from the same population as the native AE speakers. Criteria for inclusion were: 1) ages between 18-45 years, 2) a minimum of a high-school education, and 3) born and raised in the Greater New York metropolitan area. Additionally, on the basis of self-report, none of the listeners had any formal training in Spanish or any extensive experience listening to Spanish-accented English (e.g. living or working every day with a native Spanish speaker). They were all required to pass a hearing screening. History of speech and language therapy or speech/language or hearing problems were ruled out for all three speaker and listener participant groups.

2.1.2 Stimuli

a. Stimuli for global accent-judgment (sentence-rating) task. Eight sentences, each containing a high-frequency multisyllabic target word, were used as the stimuli in this study. These target words were selected from 98 multisyllabic, two- to five-syllable words appearing in the Francis and Kucera (1982) word lists, with frequency of occurrence between 53 and 729. These words were embedded in sentences with well-defined semantic contexts for the presence of the target words. In a pilot experiment the Spanish speakers recorded the

sentences. The speakers had no knowledge of which words in the sentences were target words.

These 98 sentences were then presented to two trained phoneticians for analysis regarding production deviations and accentedness. On the basis of these judgments, 16 words were identified in which the lexical stress was shifted and/or vowel production was perceptibly accented, but in which such consonantal problems as cluster reduction or consonant omission were not minimized. These 16 words were considered representative of those that elicit temporal deviations from Spanish-accented speakers. Table 2 shows a list of these 16 words in their sentence contexts. The list was shortened to eight words that were acoustically segmentable, and made the final corpus. This final list of eight words chosen varied in morphological status, as well as in the distribution of primary stress in the word (See Table 3).

Table 2. List of target multisyllabic words within their sentence contexts

Final Corpus selected for further analyses

1. The telephone company closed down
2. They formed a committee to solve this problem
3. Her sister will move to California soon
4. He makes automobile spare parts
5. Mexico's economic situation is slowly improving
6. We have a new political candidate
7. The new student association seems active
8. The congress representative changed his vote

Stimuli excluded from the final corpus

1. I live right next to the community center
2. Read the material carefully
3. I cannot recognize any of these pictures
4. He has apparently stopped working
5. She enjoyed Bill's literature paper
6. I am presenting in a conference next week
7. The fresh atmosphere calms us
8. I want Governor Smith to win again

Table 3. List of the Eight words, transcription of acoustic segments, and morphemic and stress status of target words

Word	Phonetic transcription	No. of syllables	Syllable with primary stress	No. of morphemes	Stress Change
Company	/kʰʌ́mpəni/	3	1st	1	No change
Committee	/kʰəmíri/	3	2nd	1	No change
California	/kʰæ̀ləfórnjə/	4	3rd	1	No change
Automobile	/ɔ́ɾəməbiə̀l/	4	1st	2	Difference in stress from related morpheme "automotive"
Economic	/ɛ̀kənɑ́mɪk/	4	3rd	2	Change of stress from "economy"
Political	/pʰəlíɾɪkəl/	4	2nd	2	Change of stress from "politics"
Association	/əsòsiéʃən/	5	4th	2	Change of stress from "associate"
Representative	/rɛ̀prəzɛ́nɾəɾɪv/	5	3rd	3	No change from "represent" or "present"

b. Recording procedure. All speakers who responded to the advertisement were audio recorded if they met the inclusion criteria. Each speaker filled out a language background questionnaire. Instructions during recording were for the speakers to read each sentence aloud "at a normal speaking rate, as naturally as you speak in your everyday conversation, and avoid using over-careful pronunciation." The sentences were recorded at a sampling rate of 44.1K, using a dynamic microphone (Electrovoice Shure SM 48). Recordings were made in a quiet room, with the microphone placed on a stand, and positioned directly in front of the speaker at a distance of approximately 14 cm. For each of the 27 (22 nonnative and 5 native) speakers, the eight sentences were digitized at 16 bit resolution and a 22.05 kHz sampling using the Sound Forge speech-editing program (Sonic Foundry, Inc., 1991-1998). These sentence-files were then played to the listeners for rating of global accentedness.

c. Stimuli for word-rating task. The target words were excised from their sentence contexts and saved as separate files using the Sound Forge speech-editing program. Each target word either a) began with a silent closure and was therefore easily separable from the upper formants of the preceding vocalic segment, or b) began with a vocalic segment that could be separated from the upper formants of the preceding fricative. These target word files were then played to listeners for rating of accentedness.

2.1.3 Procedure for Rating Tasks: Global Accentedness (Sentences) and Target Words

Ten listeners rated eight blocks of sentences (as a measure of global accentedness) and eight blocks of words. Within each block, the sentence/word was the same utterance, produced by all 27 speakers. Thus, each block of sentences/words consisted of 27 (22 nonnative and five native versions) sentences or 27 words, respectively, which were presented in random order of four sets. Each of the eight blocks of sentences/words was randomized (without replacement) differently for each listener. The order of Blocks 1-2 and Blocks 3-4 was also randomized differently across listeners; however, for all listeners, sentence blocks preceded word blocks so that the listeners would not know which words in the sentences were the target words. The stimuli were presented binaurally through headphones. The presentation of the stimuli was self-paced, i.e., the listeners controlled the response-time, and each new sentence/word was played 750 ms after the listener had made a response. A rest period (5-10 minutes) was provided between each of the four sets.

The productions of the native speakers of AE in the corpus were used as a baseline for comparison of the degree of relative foreign accent of nonnative speakers. Listeners were given instructions for the sentences or words rating tasks to decide whether each sentence/word sounded foreign-accented and to rate it from 1 to 9, where 1=Least accented (among these speakers) and 9=Most accented (among these speakers), by clicking on the rating scale on the computer screen. They were alerted to use the entire rating scale to make their judgments, and to not limit themselves to using the extreme ends of the scale.

3. Results of Study 1

3.1 Reliability of Accentedness Judgments

3.1.1 Intrajudge Reliability

Medians and ranges were compared across the sentence and word conditions of each stimulus word for each listener as a measure of intrajudge reliability. All the listeners used nearly the full range on the 9-point rating scale. Each listener displayed internal reliability in his/her ratings across sentences and words, as demonstrated by the roughly comparable medians (medians of corresponding word and sentence condition for each stimulus differed no more than 2 points on the scale) and ranges for sentence and word conditions.

3.1.2 Interjudge Reliability

Interjudge reliability across the 10 listeners was fairly high. Median and range of accentedness ratings were calculated by collapsing across all speakers (including the native speakers) and all eight words in both sentence and word conditions. Comparison of medians within each condition across different listeners showed high consistency, with median ratings varying only 0.5 steps for the sentence condition, and 1.5 steps for the word condition.

Each of the listener's ratings was also examined by separating his/her performance on only the native speakers (AE) from those of the nonnative speakers (NN), in the sentence and word conditions. All the listeners gave a modal rating of 1 for all the AE sentences; the ranges of the ratings for AE sentences and for AE words were consistent across listeners,

ranging from 1 to 3. In contrast, for the NN data, modes ranged from 6 to 9 across the listeners. The range in ratings of NN production varied across listeners from 9 steps (1 to 9) for Listener 4 to only 5 steps (5 to 9) for Listener 3.

Frequency distributions for the listeners' ratings of the nonnative (NN) speakers' sentence and word productions showed more variability in range and shapes of distribution than the AE data.

3.1.3 Rationale for Pooling Listeners

All listeners separated the native from the nonnative speakers in both word and sentence conditions. Moreover, pooling all medians across all words and listeners, the median ratings assigned to each speaker showed that some speakers were identified as "least" accented, and some as "most" accented. Given the above trends, inter-rater reliability was judged to be high enough to warrant pooling judgments across listeners. Therefore, ratings of the listeners are henceforth pooled and the typical (median) native listener judgments of accentedness of the speakers are used as the speakers' scores in correlational analyses.

3.2 Correlation of Accentedness on Words vs. Sentences

Spearman rank-order correlations of median accentedness ratings for sentence and word conditions were computed for each of the eight stimuli. In addition, an overall correlation was performed in which the overall median ratings on all eight words/sentences for each speaker were calculated (Note 1). The overall sentence and word correlations were computed first including all 27 speakers (AE and NN. All five AE speakers were assigned (tied) ranks of 1. The correlation coefficient (re-calculated with the AE speakers excluded) was +0.82. This positive coefficient is indicative of a high correlation between the word and sentence conditions across all stimuli. In general then, the excised multisyllabic target words were highly predictive of global (sentence) accentedness.

Each of the eight isolated words was examined for differences in its predictability of global accentedness. Correlations across the eight words ranged from +0.50 to +0.82. These correlations were all statistically significant with p-values ranging from <0.02 to <0.001. These results indicate that each target word was predictive of the speakers' judged accentedness from sentence productions (variance accounted for [ρ2] ranged from 0.25% to 0.64%), albeit with some variability in the strength of the correlations.

4. Discussion of Study 1

The objectives of this study were to a) establish the relative global accentedness of the NN speakers in the study, and b) to determine the correlation between ratings of accentedness in word and sentence conditions. Results showed that intra- and inter-judge reliability was adequate to warrant pooling of listeners' responses. Correlations of accentedness ratings on words and sentences showed that the isolated multisyllabic target words were good predictors of the overall accentedness of the sentences, although some words were better predictors than others.

The present results have a few methodological as well as theoretical implications. Consistent performance across the listeners indicates that native listeners are reliably able to detect the presence of, and rate the degree of, foreign accent. Moreover, listeners' reliability helps validate the use of the accent rating scale as a suitable measure of listeners' perceptions of range of foreign-accentedness. This finding adds to evidence from prior research validating use of rating scales (cf. Southwood & Flege, 1999).

Multisyllabic words were found to be moderately predictive of overall accentedness. Hence, it appears that multisyllabic words have properties that contribute significantly to overall sentence accentedness. The acoustic properties of these productions of multisyllabic words need to be studied in order to narrow down those that underlie the perception of accentedness by native listeners. Therefore, Study 2 involved measuring the acoustic durations of segments of these multisyllabic words, and correlating selected temporal parameters with listeners' ratings of accentedness of the words.

5. Study 2: Acoustic Analysis (Production Study) and Correlation of Acoustic Parameters With Accentedness Ratings

Study 2 was designed to yield several measures of temporal deviations of Spanish-accented productions that could be correlated with listeners' ratings to establish the relationship between production and perception of Spanish-accented English. Based on previous phonetic and phonological findings, the following temporal deviations were expected. Overall word duration for the target words was expected to be greater for NN speakers than AE speakers. Relative vowel durations were also expected to be different between the speaker groups, especially those that might be associated with the distinction between stressed and unstressed vowels within a word. Voice Onset Time (VOT) values for NN initial voiceless stops were expected to be smaller compared to those for AE stops because Spanish (L1) phonological rules generate voiceless stops that are unaspirated. The duration of flapped allophones of /t/ was expected to be greater in NN speakers, approximating the duration of stops, because Spanish phonology does not include a flapping rule for intervocalic alveolar stops.

The above-mentioned acoustic segments were measured using the Multispeech waveform editing software.(Kay Elemetrics Corp. 1999). Displays of waveforms and wideband spectrograms were used in combination to arrive at decisions regarding the acoustic segments. Spectrogram settings were: analysis size of 125 points, frequency range 0-4000 Hz, pre-emphasis of 0.8, Nyquist frequency OFF. The formant analysis settings were: filter of 24 points, frame advance at 5 ms, bandwidth of 500 Hz, frequency range of 0-4000 Hz, autocorrelation ON, and Nyquist frequency OFF.

5.1 Segmentation Methodology

Each of the eight target word productions by the native (n=5) and nonnative speakers (n=22) in Study 1 was segmented using systematic criteria following Shah (2002), and the duration of each segment was computed for each of the 216 words (27 speakers x 8 words). The following temporal segments were measured: 1) closure duration for stops, 2) VOT of stops,

3) duration of flapped /t/, 4) noise duration for fricatives, 5) nasal murmur duration for /m,n/, 6) steady-state formant duration for liquids, and 7) vowel duration.

6. Results

Following the segmentation of words and the measurement of durations of each acoustic segment within the words, group differences in segmental durations were compared and temporal deviations of NN productions from those of AE productions were tested for their relations to perceived accentedness. Only the nonnative speakers' scores were considered in the correlation analyses. Table 4 shows a summary of all the acoustic measures described below and mean differences between the native and nonnative groups for each measure. Table 5 shows a summary of the correlation coefficients for each of the acoustic measure with accentedness ratings.

Table 4. Summary table of acoustic measures (and the related phonological sources they were based upon

Acoustic Measure	Stimuli words	Related phonological source	Native measures		Nonnative measures	
			Mean	S.D.	Mean	S.D.
Overall word duration	7 words (see Table II for complete list; *representative* omitted)	Slower speaking rate in nonnative speakers (Riggenbach, 1991)	609 ms	165.44	702 ms	195.05
			* significant on average			
Vowel durations	7 words (*political* omitted)	Tense-lax vowel substitutions (e.g. Ortega-Llebaria, 1997). Lack of neutralization for unstressed vowels (e.g., Pike, 1945).	S:17.54 U:9.41	S:4.94 U:5.37	S: 14.63 U: 12.75	S: 5.41 U:3.67
			Pooled vowel Mean & S.D.: 13.30; 6.46		Pooled vowel Mean & S.D.: 13.65; 4.38	
			* significant for 8 of 12 unstressed vowels			
S/U ratio	7 words (*political* omitted)	Equal vowel durations for stressed and unstressed vowels in Spanish, related to its syllable-timed stress property (e.g., Pike, 1945)	2.80	1.56	1.75	1.07
			* significant for 5 of 7 words			
VOT	california, committee, company, political	Spanish voiceless stops are unaspirated (e.g., Flege, 1991)	56.04	13.67	31.89	12.05
			* significant for 3 of 4 words			
Flap/ Closure duration	Automobile, Committee, Political, Representative (t_1 and t_2)	Spanish does not does not include a flapping rule for intervocalic alveolar stops (e.g., Harris, 1969).	18.72	12.91	40.23	38.93
			* significant for 4 of 5 instances			

S= stressed vowel U= Unstressed vowel
S/U ratio: Stressed to unstressed vowel ratio VOT: Voice Onset Time
t1 & t2: flap/closure durations of the 1st and 2nd "t" in *representative*

Table 5. Summary table of all correlations of acoustic parameters and accentedness ratings

Word	Whole word duration (ρ)	S/U ratio (ρ)	VOT (ρ)	Flap/ Closure duration (ρ)
Association	0.08	-0.01		
Automobile	0.04	0.09		0.46*
California	0.36	0.15	0.36	
Committee	0.56**	0.35	0.29	0.35
Company	0.23	0.02	0.26	
Economic	0.23	0.80**		
Political	0.39		-0.01	0.59**
Representative	CND	0.11		t_1= 0.58** t_2= 0.29

CND = Could Not Determine
* p <.05
** p <.01

6.1 Comparison of Acoustic Data of American English vs Nonnative Speakers and Correlation with Accentedness Ratings

6.1.1 Overall Word Duration

It was predicted that the overall duration of target words would be longer for NN speakers than for AE speakers, reflecting a slower production rate, which could have an effect on judgments of accentedness. The NN speakers produced each of the seven words with longer durations, on average, than AE speakers (Note 2). Due to unequal group sizes (5 AE vs. 22 NN speakers), and differences in variances, group differences were compared using t'-tests that corrected for unequal variances ("Welch t'-test" (Note 3) or "t'-test with separate variance estimate") for all temporal measures. The NN speakers' productions, averaged over all seven words, were significantly longer in duration than AE speakers' productions [t (56) = -2.15, p<0.04)]. For all seven words, the upper end of the NN range exceeded the AE range, since some of the NN speakers spoke considerably slower than others. It was of interest to test whether this variability in word duration among the NN speakers correlated with accentedness ratings. To assess this, overall word durations were rank-ordered and correlated with ranked median ratings of accentedness on words, using a Spearman rank-order correlation. All words involved 22 NN speakers in the correlation, except for "automobile" (n = 20). Correlations of word duration and accentedness ratings ranged from very low to moderate (ρ = +0.04 to + 0.56). No significant correlations of overall duration and accentedness were found, except for the word "committee" (ρ= +0.56, p<0.01). Thus, in most

cases overall duration probably did not affect ratings of accentedness. Since overall word duration was not found to correlate significantly with accentedness ratings, the individual acoustic segments within the word were examined for specific differences in temporal structure that were predictive of perceived accentedness.

6.1.2 Vocalic Segment Duration

For each word, the duration of the vocalic segments was measured and the averages of corresponding vocalic segments for the native and nonnative speaker groups were compared. Ten of the 12 unstressed vowels were, on average, proportionally longer for the NN group than the native group. The t'-tests revealed a significant effect of speaker group for 8 of the 12 unstressed vowels. That is, NN speakers, as a group, failed to produce reduced schwa vowels in syllables that AE speakers produced as unstressed.

6.1.3 Stressed/Unstressed (S/U) Vowel Ratio

The ratio of the stressed to the unstressed vowels (S/U ratio) in each of the seven measurable words was computed as a measure of lexical stress. It was predicted that for the NN speakers the ratio of durations of stressed to unstressed vowels within each word would be close to 1.0, reflecting the syllable-timed stress pattern of Spanish. In contrast, the AE speakers were predicted to have an S/U ratio greater than 1.0 (due to reduction of vowel duration in unstressed syllables). As predicted, the native speakers made a temporal distinction between stressed and unstressed vowels, with ratios greater than 2 except for "California" (S/U ratio = 1.53) and "representative" (S/U ratio = 1.55). In contrast, for the NN group, average ratios varied from less than 1.00 to 2.05, with standard deviations ranging from 0.20 to 1.53, indicating marked variability in this group. The t'-tests of group differences showed that AE and NN groups differed significantly in S/U ratio for five of the seven words. Spearman rank-order correlations were performed between ranked S/U ratios and ranked median ratings of accentedness for each of the seven words analyzed. As can be seen in Table 5, correlations of S/U ratios with accentedness ratings yielded very low coefficients (ρ = -0.01 to +0.35) for six of the seven words, while the relation was highly significant for "economic" (ρ = +0.80 ; $p<0.001$) (Note 4). It was concluded that lexical stress, as measured by the S/U vowel ratio, varied systematically across groups, with many NN speakers failing to reduce vowels in syllables that AE speakers produced as unstressed.

6.1.4 Voice Onset Time (VOT)

The word-initial, voiceless, aspirated stops [k^h, p^h] in the words "company", "committee", "California", and "political" were used to compare AE and NN productions of VOT. As was predicted from previous studies, the averages showed consistent group differences, with NN speakers producing shorter VOT (less aspiration) for all four stops. The t'-tests showed that these group differences were reliable for three out of four words (all containing [k^h] stops).

Spearman rank-order correlation coefficients for ranked VOT and ranked accentedness ratings ranged from -0.01 to +0.36; none was statistically significant. Lack of significant correlations suggests that deviation from native-like production of voiceless aspirated stops

by NN speakers, contrary to expectations, was not reliably associated with perceived accentedness of these multisyllabic words.

Table 6. Summary table of all stepwise multiple regressions of acoustic parameters (predictors) and accentedness ratings

	Predictors: Standardized Regression Weights				
Word	**Whole word duration**	**S/U ratio**	**VOT**	**Flap/ Closure duration**	**R^2**
	(b)	(b)	(b)	(b)	(b)
Association	0.08_{ns}	-0.01_{ns}			0.07_{ns}
Automobile	-0.07_{ns}	-0.03_{ns}		0.44*	0.19*
California	0.29**	-0.25_{ns}	-0.84**		0.80**
Committee	$0.34_{(ns; p=0.06)}$	-0.14_{ns}	-0.16_{ns}	0.49*	0.24*
Company	0.29_{ns}	-0.64**	-0.25_{ns}		0.42**
Economic	0.16_{ns}	-0.86**			0.73**
Political	0.51**		-0.24_{ns}	-0.11_{ns}	0.26**
Representative	CND	-0.02		t_1= 0.51* t_2= 0.16_{ns}	0.26*

CND = Could Not Determine
b = beta (standardized)
* p <.05
** p <.01
ns = not significant

6.1.5 Closure Duration for Medial /t/

Closure durations of five intervocalic /t/s in positions where a flap is expected in AE were considered: "committee", "automobile", "political", and two in "representative" (target segment underlined). The two flaps in "representative" are henceforth differentiated as "t_1" and "t_2". Flap/closure durations showed consistent average group differences, with NN speakers producing longer closure duration (i.e. stops rather than flaps) in all five cases. The t'-tests showed that these differences were significant for four of the five realizations. Greater variability was noted in the NN group (NN standard deviations from 12.82 to 38.16) compared to the AE group (AE standard deviations from 1.82 to 8.43). Correlation coefficients ranged from +0.29 to +0.59. Three of the five correlations ("political," "automobile" and t_1 in "representative") were statistically significant. It can be concluded that flap/closure duration was, on average, longer for the NN group than for the AE group and that differences in flap/closure durations in the NN speakers may have affected perceived accentedness of these words.

While the above data show that temporal deviations may indeed be related to perceived accentedness of NN speakers' productions of multisyllabic words, each of the temporal

parameters alone do not appear to relate strongly to perceived accentedness of the whole word. It may be possible that a combination of deviations in some or all of the temporal parameters would yield stronger correlations with native listener ratings of accentedness. Thus, a final analysis was conducted as described below to address whether a combination of the temporal parameters can be attributed to foreign accent.

6.2 Stepwise Multiple Regressions to Identify Predictors of Accentedness

Stepwise multiple regressions were performed to identify acoustic predictors of perceived accentedness. These regression analyses were performed separately for each of the eight individual words due to the different numbers of dependent variables for each word. Table 6 shows the regression coefficients for each of the predictor variables as well as the overall R^2 for each word. Except for the word "association" all the analyses yielded significant R^2 coefficients, indicating that the predictor variable(s) accounted for significant variance in accentedness. Among the words with significant R^2, the variance accounted ranges from 0.19 to 0.80. Thus, the temporal measures addressed in this study collectively appear to be highly predictive of listeners' ratings of accentedness. No individual independent variable stood out across the words as a dominant and consistent predictor of accentedness. These predictor variables hold different degrees of weight in a given word and appear to interact with each other differently therein. For example, flap/closure duration appears to be a stronger predictor of accentedness, relative to S/U ratio or whole word duration, in "automobile," "committee," and "representative," but not in "political." VOT appears to a relatively stronger predictor in "california" and no other word. S/U ratio accounts for the large proportion of the variance in "economic." Whole word duration appears to account for a moderate variance in "political" and to a lesser extent in "california."

7. General Discussion

The purpose of this paper was to examine temporal speech characteristics of native Spanish speakers of English as an L2 that relate to native English listeners' perception of accentedness. The present study analyzed several temporal characteristics of multisyllabic words as they related to a measure of perceived accentedness. Temporal measures were selected based on predictions made from previous phonological descriptions of Spanish-accented speech. Duration differences were expected to underlie several features of interlanguage phonology of Spanish-accented speakers (Macdonald, 1989; Ortega-Llebaria, 1997), e.g., lack of differentiation of long vs. short vowels (/ɪ/ vs. /i/) and initial voiceless stops perceived as voiced. Lexical stress was also expected to be deviant in the production of Spanish-accented multisyllabic words (Mairs, 1989).

Results from Study 1 showed that perceived accentedness ratings of the multisyllabic words were, in general, good predictors of global accentedness, as overall correlation of words and sentences (pooled over listeners and stimulus words) yielded a strong relationship (ρ=+0.82). Therefore, it was concluded that multisyllabic words had properties that were representative of overall sentence accentedness.

Study 2 compared differences across the native and nonnative groups for each of the following acoustic variables: overall word duration, relative vowel durations as well as ratios of relative durations of stressed and unstressed vowels, initial voiceless stop VOT, and intervocalic /t/ closure duration. Overall word duration was, on average, longer for NN speakers than AE speakers, for all eight words, implying a reduced rate of speech in the NN group. Unstressed vowels were longer (relative to total word duration) for NN speakers, indicating that the Spanish speakers did not reduce unstressed vowels. The S/U vowel ratio of the AE speakers was considerably greater than 1.0 (1.53 to 4.65) for all eight words, indicating the temporal reduction of unstressed vowels in a stress-timed language. NN speakers, conversely, showed ratios much closer to 1.0 (0.93 to 2.05), indicating the minimal temporal distinction between stressed and unstressed vowels typical of Spanish. The VOT of voiceless, initial stops was, on average, consistently shorter for the NN speakers compared to the AE speakers, a pattern expected from phonological transfer from Spanish, which has unaspirated stops. As predicted, the durations of intervocalic /t/, realized as a flap in AE productions, was on average longer in NN than AE productions.

Correlations of each of these temporal variables with accentedness ratings on words from Study 1 were low to moderate. Differences in overall word duration yielded low to moderate correlations with perceived accentedness (ρ ranged from +0.04 to +0.56). S/U ratios correlated only weakly with native perception of accentedness (ρ = -0.01 to +0.35) except for the word “economic,” whose S/U ratio was highly correlated with accentedness (ρ =+0.80). VOT values for nonnative productions of initial /k/ were moderately correlated with accentedness ratings in three words (ρ =+0.26 to +0.36); initial /p/ VOT values were not related to accentedness in "political" (ρ =-0.01). Nonnative intervocalic /t/ closure durations showed moderate correlations with perceived accentedness in all five words (ρ = +0.29 to +0.58). Thus, results showed that each of the temporal parameters alone did not relate strongly to perceived accentedness of the whole word.

Regression analyses including all predictor variables were conducted to determine their combined weight in prediction of accentedness. Regression coefficients ranged from 0.07 to 0.80; 7 of the 8 coefficients were significant. These results show that a combination of temporal variables does account for the ratings of accentedness assigned by listeners. However, no individual variable appears to generalize across the words as a predictor of accentedness. Each of the predictor variables differentially influences perceived accentedness in different words. It is likely that underlying characteristics related to the structure of these stimuli words, not measured in this study, mediate the impact of the predictor variables. Future research will focus on better understanding the nature and structure of words to the extent that they drive the effect of predictor variable(s) differently across different words. The interaction between predictor variables will be also examined in other contexts.

The range in regression coefficients suggests that while these selected temporal variables are important to the prediction of accentedness, they are not sufficient to completely account for accentedness. For example, spectral differences and/or other suprasegmental components, such as fundamental frequency contour and relative syllable intensity, may also contribute to

perceived accentedness of multisyllabic words and need to be analyzed in future correlation studies.

8. Conclusion and Implications

In conclusion, temporal differences in acoustic segments of native Spanish speakers of English are correlated with native listeners' perception of accentedness on multisyllabic words. The present findings bear important clinical and theoretical implications. Clinical practice dealing with accent-related concerns is severely lacking in research-based findings of the parameters to address in accent modification interventions (e.g., Behrman, Ferguson, Akhund, & Moeyaert, 2019; Chan & Hall, 2019; Shah & Gu, 2019; Shah, 2009 a, 2009b). Therefore, the information presented here about the proportion of the role temporal variables play in the perception of accentedness will help systematically target and address these temporal deviations in speech and English-as-Second-Language (ESL) interventions. Furthermore, ESL teaching and accent management programs are typically geared towards addressing only those speech characteristics that affect intelligibility by native listeners. Accented speech, even when free of errors affecting intelligibility, may still be stigmatized. Therefore, it may pose difficulties in L2 speakers' personal and professional interaction with native speakers. Issues of accentedness should be addressed using a measure other than intelligibility scores. Global accent rating by native listeners is a more valid measure of accentedness according to several of the studies mentioned above.

Concurrently, the findings of the present study help inform theories of speech perception to help understand variables that help cue listeners' perception of accentedness as an important but understudied form of surface variability in perceived speech (e.g., Shah & McClennan, 2008). Recent interest in understanding the mechanisms and processes underlying listeners' perceptual adaptation to accented speech (e.g., Bradlow & Bent, 2008) as well as intelligibility (Kang, Thomson & Moran, 2018) can similarly benefit from a better understanding of the characteristics of accented speech that cue listeners. Similarly, another accent-related phenomenon, the Interlanguage Speech Intelligibility Benefit (e.g., Bent & Bradlow, 2003; Shah & Vavva, 2005), and other intelligibility factors (e.g., Munro, Derwing & Morton, 2006) that explore the interaction of speaker and listener language backgrounds in the intelligibility of speech, can also benefit from a better understanding of the characteristics of the accented speech as they influence perceived intelligibility. Ongoing development of technologies can benefit from deepening the understanding about factors that influence perception of foreign accents (de Mareüil & Vieru-Dimulescu 2006).

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Notes

Note 1. Rank-ordered correlation was required in this study since an interval scale assumption for the 9-point accentedness rating scale could not be assumed.

Note 2. The word "representative" was not included in this analysis due to a final-syllable segmentation problem.

Note 3. Tomarken & Serlin (1986), Glass & Hopkins (1996).

Note 4. Note that "economic" also yielded a more robust significant difference ($p<0.01$) in means of S/U ratio compared to the other words ($p<0.05$).

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