Phonetic Cues to Stress and Accent in Spanish

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1. Introduction

The significance of pitch, duration and intensity cues to lexical stress in Spanish was first discussed in 1964 (Contreras 1964, Navarro Tomás 1964). While duration and intensity measurements were easy to correlate with tonic syllables, the challenge was to explain the pitch variation displayed by stressed syllables spoken in different intonational contexts. For example, the stressed syllable "le" in "Ma**le**na" has a rising pitch accent in "Malena miraba la luna" (Figure 1). However, in "¿Malena?", "le" displays a falling pitch accent, and in "Mira la luna – dijo Malena", "le" shows a flat pitch contour. Yet, the syllable "le" is always perceived as the stressed syllable.

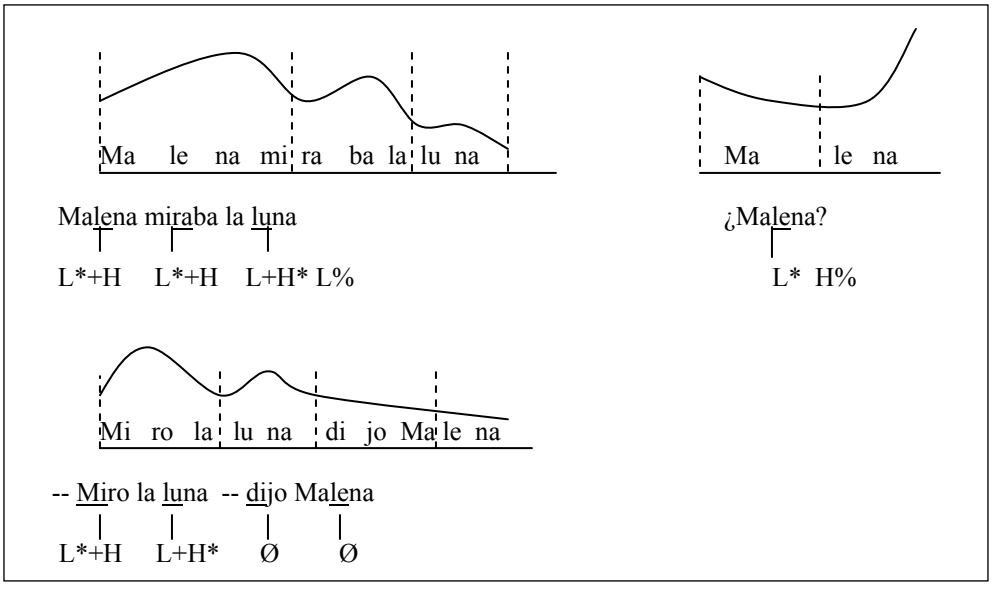

Figure 1. The name "Malena" produced in three different intonational contexts. The top left is a declarative sentence where "le" in "Malena" has a rising pitch accent. On the right, "Malena" is a question and "le" has a low pitch accent. At the bottom, "Malena" is part of a parenthetic phrase produced with flat intonation and no accents.

Navarro Tomás (1964) chose the radical solution of dissociating pitch cues from stress. He argued that pitch variation was related to the accents of sentence intonation, while intensity and duration cues prompted stress[1]. In fact, he defined stress as "acento de intensidad" (Navarro Tomás 1964), which correlated with the higher intensity values displayed by stressed vowels in comparison to the intensity values shown in unstressed vowels. Thus, since pitch and accent were determined by different phonetic

[1] In this paper, stress refers to the most prominent syllable in a word, like /ó/ in /kantó/, while accent refers to the most prominent word in a sentence, i.e. 'No, María la CANTÓ' *No, Mary sang it* as an answer to the question '¿María la bailó? *Did Mary dance it?*

cues, he considered them to be two different linguistic units, so he did not address any possible interaction between cues that prompted different linguistic units.

On the other hand, Contreras (1964) did relate pitch to stress but, following Bolinger's (1961) acoustic study of Spanish stress, he limited the pitch variation induced by sentence intonation by assuming that the acoustic cue relevant to lexical stress was the break from the pitch melody, not the rising or falling pattern of the contour itself. Moreover, in his experimental materials, he only included isolated words and words in short declarative sentences elicited by reading from a list. In this way, stressed syllables always displayed a rising pitch accent such as that of the syllable "le", "mi", or "lu" in "Ma**le**na **mi**ra la **lu**na". As a result of these limitations in the materials, Contreras found pitch to be the main cue to lexical stress, followed by duration and, in the last place, intensity, thus reaching the conclusion that pitch prompted both lexical stress and the accents of sentence intonation.

Later studies have provided further evidence for pitch being the main cue to lexical stress (Gili Gaya 1981, Quilis 1971, 1981, Llisterri et al. 2003) while refuting Navarro Tomás' (1964) theory of stress being cued by intensity. Yet, to my knowledge, researchers have continued limiting the pitch variation brought on by sentence intonation. Like in Contreras' (1964) materials, these studies included only words in isolation or in short carrier sentences read with declarative intonation. For example, in his 1971 experiment, Quilis measured the duration, pitch, and intensity of stressed syllables in word triplets such as "h**á**bito, hab**i**to, and habit**ó**" in three contexts, namely, words in isolation, and within the carrier sentences "Digo la palabra_____", and "Digo la palabra _____ otra vez". In words spoken in isolation or within the first carrier sentence, the stressed syllable also had a nuclear accent. For instance, in "Digo la palabra habitó", the syllable "tó" has both stress and a rising nuclear accent. Similarly, words uttered within the second carrier sentence, like "Digo la palabra habi**tó** otra vez" displayed stress and a pre-nuclear accent on the same syllable, i.e. the "tó". Whether in nuclear or pre-nuclear position, stressed syllables were always accented and displayed a rising pitch contour. Consequently, the phonetic cues related to stress could not be separated from those related to accent.

The difficulty of finding test materials that will separate syllables bearing stress from those bearing an accent comes from the fact that stressed syllables in Spanish behave as the anchors or "landing sites" for the pitch accents that configure the intonation of a sentence[2]. The accent's shape, however, is related to the intonation of a sentence, not to the stressed syllable. Beckman (1986) classified languages like Spanish as Stress Accent languages and hypothesized that they use duration patterns in addition to pitch in order to signal accents. She wrote: "Since stress-accent systems associate the same accent within an accent pattern with several pitch shapes for different intonation contours, might they not then compensate for this phonetic uncertainty by using other phonetic cues more? Might there not be, for example, an accompanying durational pattern to ensure that the tonal pattern of an utterance is correctly interpreted for its particular accentual organization?" (Beckman 1986:10). The question this raises for our purposes is the following: If accents in Spanish are cued by pitch and duration, and previous studies of stress in Spanish examined materials where the stressed syllable always bore an accent, could it be that their results indicating pitch and duration as the main phonetic cues to stress were mistaken, and that in fact, pitch and duration were more related to accent than they were to stress?

The huge phonetic variation observed in phonological units, argued Pierrehumbert (2003), stems from the interaction of phonetics with other levels of language. She stated "A bit of speech signal which counts as voiced in one language might count as unvoiced in another, and a bit which counts as stressed in one language might count as unstressed in another. These observations point to the conclusion that categories are acquired from statistics of the speech signal (as opposed to being available a priori by universal grammar)". Statistics of the speech signal include two processes. First, bottom-up statistics which analyze all the variation displayed by the relevant cues as a source of useful information in finding distinct modes for each phonetic category. Secondly, they must include a refining process of the phonetic categories, which implies the computing of type statistics over the

[2] For a review on sentence intonation in Spanish, readers are referred to Beckman et al. (2002), Hualde (2003), Sosa (1999), Quilis (1987) and references therein.

lexicon. Thus, phonetic categories such as stress, in order to be learnable, should be context sensitive and language specific.

The phonetic descriptions of lexical stress in Spanish to date might not be very useful when computing the bottom-up statistics on the acoustic characteristics of "le" in Malena from sentences with different intonation patterns in order to identify this syllable as a stressed syllable. The problem comes from the fact that studies have eliminated the variation induced by sentence intonation and defined stress by generalizing the results obtained from isolated words or short declarative sentences to any possible context. All the target syllables measured in those experiments were both stressed and accented. Cues to stress were not measured in syllables such as "le" in the sentence "Mira la luna – dijo Ma**l**ena", where "le" bears only stress, not an accent. Consequently, in the literature on stress in Spanish, the phonetic cues of stress were not disentangled from those of accent, nor were their possible interactions addressed. The assumption that phonetic cues to stress could be examined without taking into consideration different intonation contexts led to misleading conclusions. Thus precisely, the objective of this paper is to disentangle the phonetic cues of stress from those of accent.

In order to do so, I examined the phonetic cues of pitch, duration and intensity in oxytone words in two types of sentences. The first type included declarative sentences where stressed syllables were also accented. In some instances, subjects produced an Intermediate Phrase (IP) boundary after the stressed accented syllable. Parenthetic phrases constituted the second type of sentence. Their flat intonation and low pitch register prevented any stressed syllables from bearing an accent. No IP boundaries were produced in this type of sentences. Two sets of independent variables were examined. First, by comparing how the above phonetic cues patterned in accented stressed syllables, unaccented stressed syllables, and unstressed syllables, the phonetic cues to stress and accent were disentangled. Second, accented stressed syllables followed by an IP boundary were compared with accented stressed syllables and unaccented stressed syllables without IP boundaries in order to examine the effect of IP boundaries on the phonetic cues of stress and accent.

2. Methodology

2.1. Subjects

Five native speakers of Spanish, two male and three female, participated in the experiment. Four of them were from Spain (Valencia, Barcelona, Bilbao, Santiago de Compostela), and the fifth subject was from Mexico (Veracruz). Their ages ranged from 26 to 42 years old. All subjects had university degrees and spoke an educated variety of their Spanish dialect. They spoke English as their second language, which they learned as adults. They had lived in English speaking countries for at least three years while maintaining a frequent use of Spanish on a daily basis with their family and within their work environment. No subject reported having speech or hearing problems.

Subject	*Sex*	*Origin*	*Age*
1	female	Barcelona	38
2	male	Veracruz	42
3	female	Bilbao	26
4	female	Valencia	28
5	male	Santiago	32

Table 1. Description of subjects

2.2. Materials

Materials consisted of thirty sentences written on separate index cards. Each sentence contained an underlined four syllable verb, conjugated in third person singular of the preterit tense, and placed in pre-nuclear position. Fifteen of these sentences were statements, such as "El diputado les manifestó su opinión sobre el proyecto de ley" and "El guardia les amonestó con energía su imprudencia".

The other fifteen sentences were made up of a main sentence plus a parenthetic phrase. For example, in "—El acusado no hará declaraciones a la prensa – les manifestó su abogado", "El acusado

no hará declaraciones a la prensa" is the main sentence, while "les manifestó su abogado" is the parenthetic phrase. The complete list of sentences can be found in the Appendix.

2.3. Task

After shuffling the 30 index cards, the experimenter read each sentence aloud. The subjects' task was to repeat the sentence replacing the underlined verb with "agagagó", the preterit form of the nonce verb "agagagar", while keeping the same intonation patterns modeled by the experimenter. Similar techniques have been successfully used in Nakatani et al.'s (1981) study of English rhythm with reiterant speech.

Statement sentences were spoken in a declarative intonation with three pre-nuclear accents before the nuclear accent. The word "agagagó" always bore the second pitch accent from the left (Figure 2). In some instances, subjects produced a pause and/or an extra High tone after "agagagó", indicating the presence of an Intermediate Boundary Phrase.

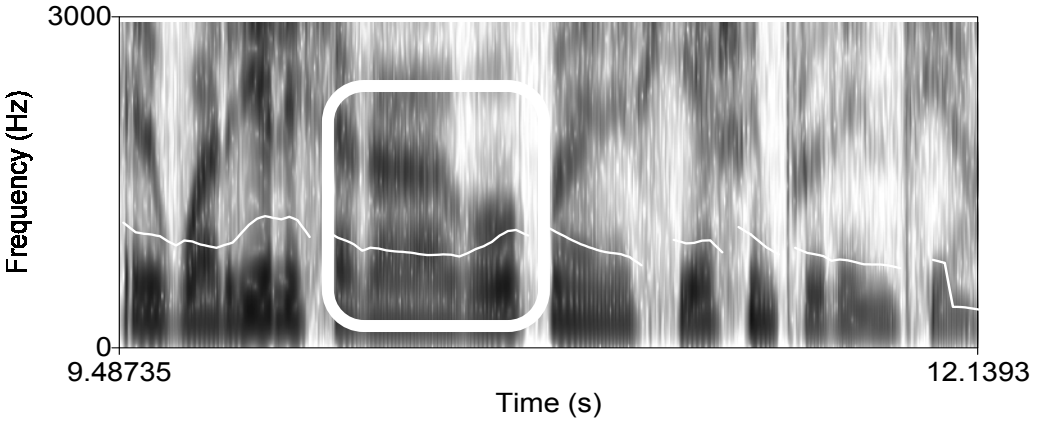

Figure 2. Spectrogram and pitch contour of the sentence "El guardia les agagagó con energía su imprudencia". The word "agagagó" falls inside the squared section. Notice the rising pitch accent on [ó].

In order to avoid any noticeable pitch accents, parenthetic phrases were uttered in a low register with a deliberate flat intonation. Consequently, in this context no pitch accents stood out either in the parenthetic phrase or in the word "agagagó" (Figure 3). To facilitate the segmentation of the verb "agagagó" from its context sentence, the preceding word ended in [s] and the first consonant of the following word was either a voiceless obstruent, a trill, or an [l] as in "El guardia le**s** agagagó **c**on energía su imprudencia".

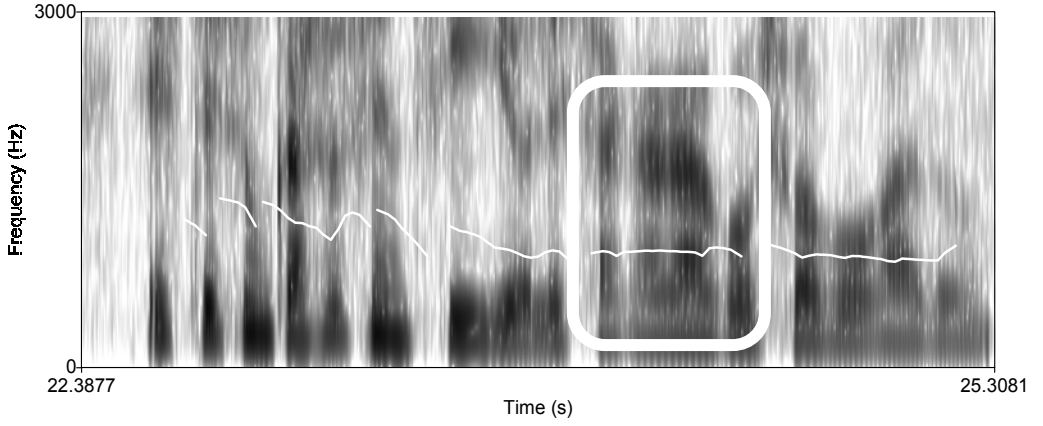

Figure 3. Spectrogram and pitch contour of the sentence "—Este es un caso sencillo – les agagagó su abogado". The word "agagagó" falls inside the squared section. Notice that [ó] displays a flat pitch contour.

2.4. Measurements

A total of one hundred and fifty repetitions of the word "agagagó" (30 sentences * 5 subjects) were obtained. Each repetition was divided into four syllables, i.e. a-ga-ga-gó, and syllables 2, 3 and 4 were measured for pitch, duration, and intensity.

In order to emphasize within-subjects variation over between-subjects differences, pitch measurements were based on standard deviations, and duration and intensity measurements on ratios. For example, pitch was measured as the standard deviation of the subject's pitch variation along each vowel in each spoken item. Large standard deviations showed the presence of a pitch accent on that vowel, while small standard deviations represented a vowel spoken in a flat intonation.

There were two sets of measurements for duration. The ratio of the consonant's duration to that of the vowel constituted the first set. Ratios closer to 1 indicated that tautosyllabic consonants and vowels displayed similar durations, while ratios closer to 0 represented consonants with shorter durations than their tautosyllabic vowels. The second set of measurements included syllable and segment durations in milliseconds.

Intensity was estimated as the ratio of the consonant's Root Mean Square to that of the vowel. This ratio measured the degree of consonant lenition as a continuum that ranged from 0 to 1. Ratios closer to 0 designated consonants produced as stops, while ratios closer to 1 indicated a high degree of consonant lenition.

3. Results

3.1. Group patterns

A Repeated Measures ANOVA with two within-subjects' factors, i.e. syllable (2^{nd} syllable, 3rd syllable, and 4^{th} syllable) and intonation (declarative versus parenthetic), was performed on the pitch, duration, and intensity measurements of the pseudo-word "agagagó". Recall that this word was always stressed on the last syllable /gó/ and that this syllable was accented only in declarative sentences. Therefore, the effect of syllable on pitch, duration and intensity will reflect cues to stress, if the stressed /gó/ maintains different patterns from the unstressed syllables 2 and 3 across declarative and parenthetic sentences. On the other hand, any difference between accented /gó/ in declarative sentences and unaccented /gó/ in parenthetic sentences will provide us with phonetic evidence for accent.

	Main Effects		Interaction
Measures	intonation	syllable	intonation* syllable
pitch	F(1,73)=226.629; p<.0001	F(2,146)=217.663; p<.0001	F(2,146)=170.136; p<.0001
duration ratios	F(1,73)=15.104; p<.0001	F(2,146)=86.392; p<.0001	F(2,146)=22.224; p<.0001
duration in milliseconds	F(1,73)=108.406; p<.0001	F(2,146)=120.222; p<.0001	F(2,146)=45.925; p<.0001
intensity	F(1,73)=21.978; p<.0001	F(2,146)=61.189; p<.0001	F(2,146)=7.773; p=.001

Table 2. Repeated Measures ANOVA. Main effects and the interaction "syllable * intonation" were statistically significant for all three measures.

The repeated measures ANOVAS showed that the main effects and the interaction "syllable * intonation" were statistically significant for all three measures (Table 2). The main effects proved that pitch, duration, and intensity patterned differently according to each experimental variable. Interactions, as expected, indicated that the relationship of the criterion variables with accent depended on stress.

Moreover, subjects produced some declarative sentences with an Intermediate Phrase Boundary (IP) after "agagagó". This IP also had an effect on the pitch, duration, and intensity of the syllable /gó/. Therefore, Multiple Comparisons with the Bonferroni adjustment were performed on pitch, duration and intensity measurements with the independent variable of IP (IP in declaratives, no-IP in declaratives, and no-IP in parenthetic sentences) in order to disentangle the effects of accent from those of IP boundaries.

		pitch			duration			intensity		
		Mean Diff	*Sta. Error*	*Sig*	*Mean Diff*	*Sta. Error*	*Sig*	*Mean Diff*	*Sta. Error*	*Sig*
IP, declaratives	*no-IP, declaratives*	3.41	0.801	.0001	0.04	0.005	.0000	-0.02	0.044	1.00
	no-IP, parenthetic	9.86	0.656	.0000	0.06	0.004	.0000	-0.10	0.036	.011
no-IP, declaratives	*IP, declaratives*	-3.41	0.801	.0001	-0.04	0.005	.0000	0.02	0.044	1.00
	no-IP, parenthetic	6.45	0.724	.0000	0.02	0.005	.0001	-0.07	0.040	.164
no-IP, parenthetic	*IP, declaratives*	-9.86	0.656	.0000	-0.06	0.004	.0000	0.10	0.036	.011
	no-IP, declaratives	-6.45	0.724	.0000	-0.02	0.005	.0001	0.07	0.040	.164

Table 3. Multiple Comparisons with Bonferroni adjustment. Comparisons were significant for pitch and duration, and non-significant for intensity. All Mean Differences were statistically significant for pitch and duration at the .05 level.

The Multiple Comparisons demonstrated that the vowel /ó/ spoken in declarative sentences with an IP boundary patterned differently from /ó/ in declarative sentences with no IP boundary, and those in turn differed from /ó/ in parenthetic sentences with regards to pitch and duration. However, for intensity measurements, there were no significant differences among these groups. Let us now examine in detail the interactions from the ANOVAs and the results from the Multiple Comparisons.

3.1.1. Pitch

As Figure 4 illustrates, pitch variation took place only on the vowel /ó/ in declarative sentences. While the second and third vowels in a-g**a**-g**a**-gó obtained a standard deviation close to 0, the value of the standard deviation in /ó/ increased dramatically showing that there was pitch variation on this vowel. This F0 variation was displayed as a steep rising pitch trajectory that reached its peak at the end of the vowel (Figure 2). In contrast, in the parenthetic sentences, none of the measured vowels

presented significant F0 variation, indicating that they were produced with a flat intonation contour (Figure 3). Post-hoc tests revealed that accented /ó/ in declarative sentences was significantly different from any other vowel, and that the unstressed vowels and the unaccented /ó/ in parenthetic phrases did not display any significant differences. Since /ó/ in declarative sentences and /ó/ in parenthetic phrases differed with regards to accent, not stress, this rise in pitch on the declarative /ó/ must be related to accent. Thus the accented stressed syllable was the only one to display a rising pitch accent, whereas the unstressed syllables and the unaccented stressed syllable displayed a flat intonation contour.

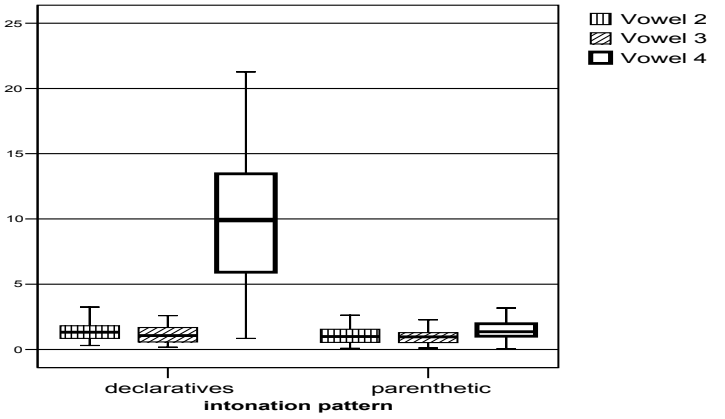

Figure 4. Pitch patterns. The X axis displays vowels 2, 3, and 4 of the word “agagagó” in declarative and parenthetic sentences. The Y axis shows the standard deviation of the pitch contour within each vowel. Only the vowel [ó] in declarative sentences displays a large standard deviation, indicating the presence of a pitch accent.

Moreover, the pitch variation displayed by /ó/ in declarative sentences varied according to the presence of an IP boundary. Figure 5 shows that F0 displayed greater variation in IP declarative sentences than in non-IP declarative sentences, while /ó/ in parenthetic sentences, which was spoken without an IP boundary, showed an F0 variation close to 0. The differences amongst these three groups were significant in the Multiple Comparisons analysis. Thus, these results further confirmed that only declarative sentences displayed a pitch-accent in the syllable /gó/. Moreover, it showed that the steepness of the accent’s F0 trajectory was influenced by the presence of an IP boundary. The F0 of a pitch-accent followed by an IP boundary displayed a steeper ascendant trajectory than that of an accent without an IP boundary.

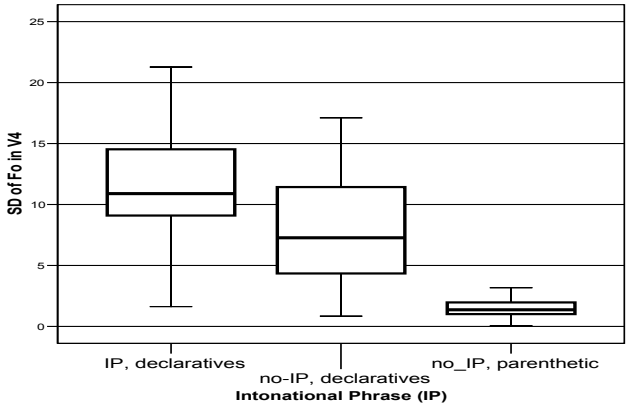

Figure 5. Pitch and Intonational Phrase Boundaries (IP) in stressed /gó/. The X-axis displays declarative sentences with an IP after “agagagó”, declarative sentences without an IP, and parenthetic sentences, which were never produced with an IP. The Y-axis shows the F0 variation in stressed /ó/. Only parenthetic sentences show no variation, indicating a flat F0 contour, while declarative sentences display F0 variation, indicating the presence of a pitch accent. The range of the pitch-accent increases with the presence of an IP boundary.

3.1.2. Duration

In contrast to pitch, duration measures displayed similar patterns across intonational contexts. The graph on the left in Figure 6 shows the durations in milliseconds of syllables 2, 3, and 4 in the word "a-ga-ga-gó". Post-hoc tests indicated that stressed /gó/ was significantly longer than the preceding unstressed syllables within each intonation context.

The graph on the right in Figure 6 displays the C/V duration ratios for syllables 2, 3, and 4 of the word "a-ga-ga-gó". All syllables obtained values smaller than 1.00, indicating that within each syllable the vowel was longer than the consonant. Moreover, post-hoc tests showed that subjects produced a significantly smaller ratio in the third syllable in comparison to the ratios of the second and fourth syllables, yielding the alternating pattern of long-short-long ratios in both intonation contexts.

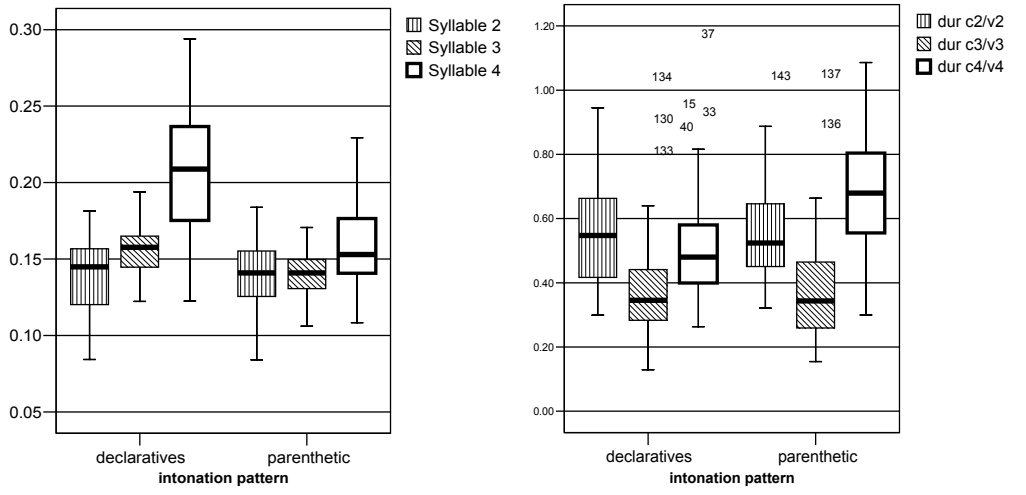

Figure 6. Duration patterns. The left figure displays the duration in milliseconds of the second, third and fourth syllables of "agagagó" in declarative and in parenthetic sentences. The syllable /gó/ is the longest in both sentence types. The right figure shows C/V duration ratios for each syllable in declarative and parenthetic sentences. The difference between the third and fourth syllable ratios increases in parenthetic contexts.

These similarities were then related to stress, since they differentiated stressed syllables from unstressed syllables regardless of accent. Stressed syllables were longer than unstressed syllables, and they had a higher C/V ratio than their preceding unstressed syllables. However, the first pattern was more salient in declarative sentences, i.e. /gó/ in declarative sentences was significantly longer than /gó/ in parenthetic sentences, and the second pattern was enhanced in parenthetic phrases by raising the C/V ratio in the fourth syllable. These differences were related to accent and IP boundaries.

Figure 7 shows that the vowel in /gó/ was longer in the accented syllables in declarative sentences than in the unaccented syllable of parenthetic sentences, and that within declarative sentences, the accented syllable with an IP boundary was in turn longer than the accented syllable with no-IP boundary. These differences were all significant according to a Multiple Comparison analysis with a Bonferroni adjustment. Therefore, duration not only related to stress, but also to accent and IP

boundaries in a cumulative fashion. The more of these phonological units a vowel bore, i.e. stress, accent, IP boundary, the longer the vowel became.

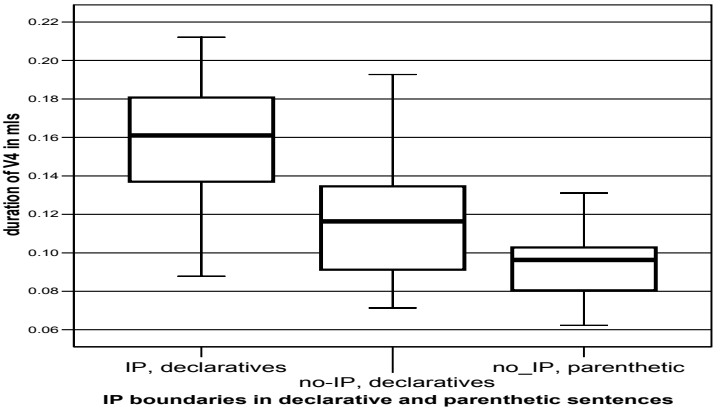

Figure 7. Duration of vowel /ó/ in mls. in declarative sentences where the verb 'agagagó' is followed by an IP boundary, in declarative sentences with no-IP, and in parenthetic sentences with no-IP.

3.1.3. Intensity

Like duration, intensity cues displayed similar patterns across intonation contexts. The third syllable of "aga**ga**gó" showed a higher RMS C/V ratio than syllables two and four (Figure 8). Post-hoc tests signaled this difference as significant, indicating that the consonant /g/ in the pre-stressed syllable was more lenited than the other two consonants. Therefore, a lenited consonant in an unstressed syllable preceding a stop-like consonant indicated the presence of stress on the second syllable.

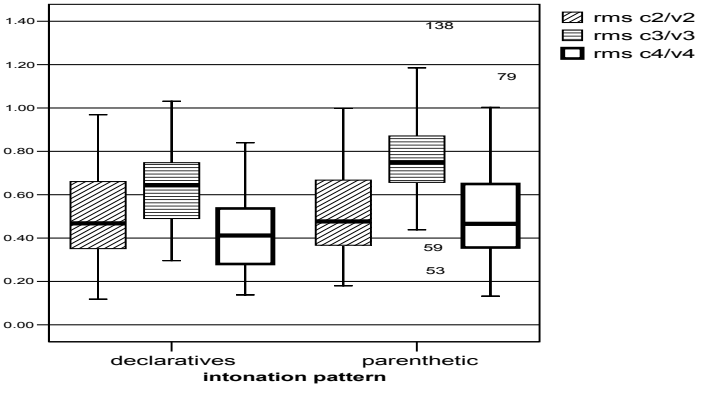

Figure 8. Intonation patterns. Root Mean Square C/V ratios for each syllable in declarative and parenthetic sentences.

Multiple Comparisons analysis yielded no significant results. Thus, IP boundaries had no effect in the way intensity patterned in relation to stress and accent.

In summary, a raising F0 trajectory cued a pitch accent, not stress, since it appeared only on accented syllables. This F0 trajectory became steeper when the accented syllable was followed by an IP boundary. Duration cued stress, accent and IP boundaries. Syllables with accent and stress that were followed by an IP boundary were longer than accented stressed syllables with no-IP. The latter were longer than unaccented stressed syllables, and in turn, unaccented stressed syllables were longer than unaccented and unstressed syllables. Regarding intensity, a lenited consonant in a syllable placed before a stop-like consonant indicated the presence of stress on the second syllable. Neither accent nor IP boundaries had an effect on consonant lenition.

3.2. Across-subject variation

The interactions between 'intonation type and syllable' for pitch, duration and intensity measurements were examined for each subject. Pitch and duration patterns were extremely consistent across subjects. In declarative sentences, the five participants produced a significantly higher F0 variation in the last vowel of "agagag**ó**" in comparison to the pre-stressed vowels, while in parenthetic phrases no subject produced significant F0 variations in any syllable.

As for duration, the stressed syllable was the longest one in both intonational contexts for all subjects. The duration of the stressed vowel was longer than that of the unstressed vowels regardless of whether it bore an accent. Moreover, the accented stressed syllables were also longer than the unaccented stressed syllables. Subjects maintained a "long-short-long" alternating pattern in the C/V ratios, and increased the C/V ratio differences between the pre-stressed and the stressed syllables in parenthetic sentences.

Unlike pitch and duration, results for intensity displayed variation across subjects. For example, subjects 3, 4, and 5 produced lenited consonants in pre-stressed syllables and stop-like consonants in stressed syllables in both declarative sentences (Figure 9, left graph) and parenthetic sentences (Figure 9, graph on the right), but these differences only reached significance for subjects 4 and 5. Subject 2 showed significant differences between pre-stressed and stressed consonants only in parenthetic contexts. On the other hand, subject 1's consonants did not show any significant difference in any context.

Speech rate could have affected the above variation across subjects. Subjects with faster speech rates and therefore with shorter consonants, would produce consonants with more lenition. The degree of consonant lenition in the stressed syllable was correlated with the duration in milliseconds of that consonant. The Pearson's correlation coefficient (0.506) was significant at the 0.01 level.

Thus, there is a general tendency to produce the stressed syllable with a stop-like consonant and the pre-stressed syllable with a lenited consonant. However, not all subjects produced this pattern, and those that did, diverged in the strength of this difference and the contexts in which it was present. At least, part of this variation could be related to speech rate.

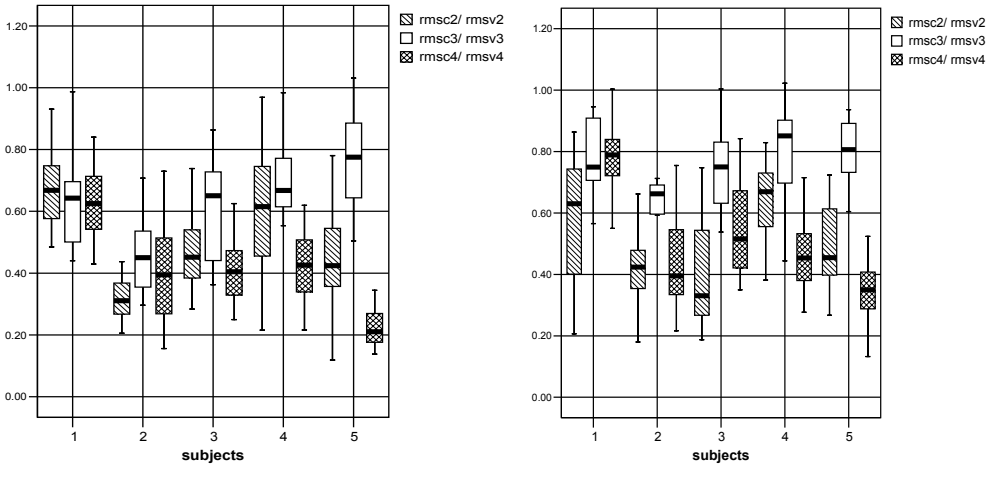

Figure 9. Intensity ratios in declarative sentences (left graph) and parenthetic phrases (right graph) across subjects.

In summary, patterns of pitch and duration were consistent across subjects. The 5 subjects produced a rise in pitch only in the accented stressed syllables. As for duration, all subjects produced

patterns that differentiated stressed from unstressed syllables regardless of accent. The last syllable was the longest in the word, and the C/V ratio of this syllable was closer to 1.00 than the ratio of the preceding unstressed syllable. Moreover accented stressed syllables displayed longer durations and higher C/V ratios than unaccented stressed syllables. In contrast, results for intensity were inconsistent across subjects. Although stressed syllables tended to display more stop-like consonants than those in the preceding unstressed syllable regardless of accent, this pattern was not significant for all subjects in both contexts.

4. Discussion

Results indicated that, on the one hand, a single phonetic cue acquired different values according to the phonological units it was cueing. For example, vowel duration took different values in accordance with the number of phonological units related to that vowel. Thus, an accented stressed vowel was longer than an unaccented stressed vowel, and the latter was longer than an unaccented unstressed vowel.

On the other hand, stress and accent were related to different phonetic cues, i.e., pitch cued accent and intensity was related to stress. Only accented syllables displayed pitch accent by showing a rising F0 trajectory on the vowel of that syllable. Unaccented syllables, regardless of being stressed or unstressed, never had a pitch accent. As for intensity, stressed syllables were produced with a stop-like consonant whereas their preceding unstressed syllable contained a lenited consonant; while the degree of consonant lenition did not change in relation to accent. Similar results were also obtained for /g/ by Cole et al. (1998) and Ortega-Llebaria (2003). However, results from this experiment showed that intensity patterns were not as consistent across subjects as pitch and duration patterns were. Therefore, intensity may be an optional cue to stress that is used in conjunction with other cues.

Moreover, an IP boundary placed after a vowel bearing a pitch accent modified the duration and the pitch range of that vowel. It became longer and displayed a steeper F0 trajectory than accented vowels without IP boundaries. Previous research has shown that IP boundaries have this type of effects on unstressed and/or unaccented vowels (Hualde 2002, Nirbert 2000).

The picture that emerges from these results is that, as far as production goes, the same phonetic material, i.e. pitch and duration, consistently cued different linguistic units in Spanish, namely stress, accent and IP boundaries. What makes these units different in terms of their phonetic content is the relationship between these two cues. In this study, unstressed and unaccented vowels displayed the shortest durations together with a flat pitch contour (Figure 10). If the vowel maintained the flat pitch contour, but displayed longer durations, it bore a stress. An accent was always placed on a stressed vowel, which made the vowel become longer and changed the F0 to a rising trajectory. Adding an IP boundary after an accented stressed vowel increased its duration further and made the ascendant F0 trajectory steeper. Thus, the production on a segment of different supra-segmental units, such as stress or accent, was related to the speaker's control of the interaction between that segment's duration and F0 trajectory in relation to the duration- F0 interaction of the surrounding segments.

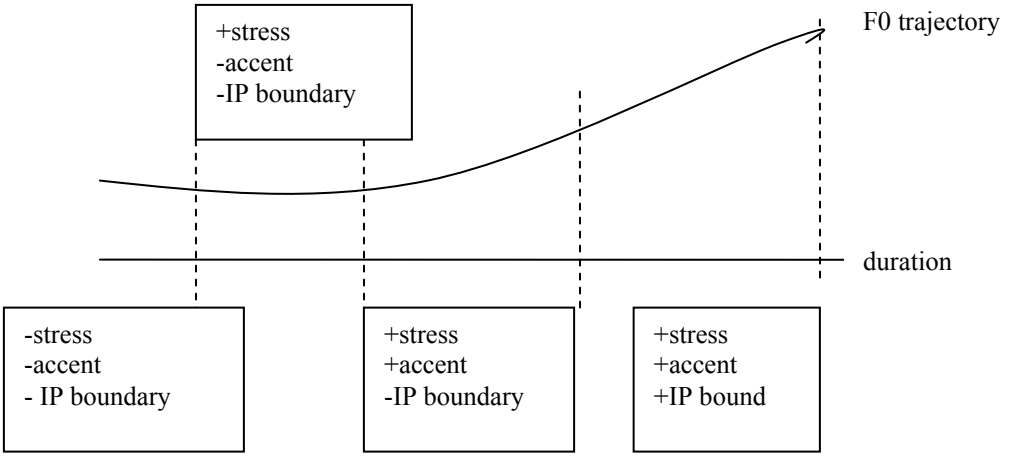

Figure 10. F0 trajectory and duration patterns for segments bearing stress, accent, and IP boundaries.

Since stress and accent were mainly cued by duration and pitch, and what made them different was the value that these cues displayed in a segment in relation to the value they acquired in the surrounding segments, the overall phonetic variation observed in these data was in agreement with the long-standing idea that phonetic properties of linguistic units are determined by prosodic structure, intonation, and the system of contrasts of a language (Firth 1948, Ogden & Local 1994, Pierrehumbert 2003). The corollary that follows from this hypothesis is that autonomous and abstract linguistic units, such as stress or accent, are untenable objects. Therefore, stress must be studied in relation to all the factors that shape its phonetic content and the phonetic correlates of stress inferred from isolated words should be reconsidered.

Up to this point, we have mainly discussed the cues of pitch and duration. How do other cues, such as intensity, fit into this interpretation? Recall that subjects tended to produce stop-like consonants in stressed syllables regardless of whether or not they bore an accent, and lenited consonants in the preceding unstressed syllable; however, this pattern was not as consistent across subjects as those of duration and pitch. While this general tendency is in agreement with the theories that explain phonetic variation by considering stress a trigger for increased speaker activity in the production of speech distinctions (Lindblom 1990, de Jong et al. 1993, de Jong to appear), we still need to explain the lack of consistency across subjects.

Relating speech rate to the degree of consonant lenition could in part motivate this variation (Piñeros 2002, Kirchner 1998). The shorter the consonant was, the less time the subject had to move the articulators into the closure target. Therefore, higher degrees of lenition would correlate with shorter consonants and smaller degrees of lenition would take place in consonants with longer durations. This hypothesis was partially confirmed by the correlation between the duration of the consonant in the stressed syllable and the C/V RMS ratio of the stressed syllable. Although the correlation was significant, it only reached a coefficient of .506. Consequently, consonant duration accounted for some of the variation in the degree of consonant lenition, but there must have been other factors that influenced this variation as well.

These conclusions, however, were tested only in oxytone words. In future experiments, I plan to extend these results to new contexts and test them in perception tasks. For example, paroxytone and proparoxytone words need to be examined as well. It would also be interesting to add one intonational context, such as that of emphatic discourse, where the beginnings of words are marked with an accent

regardless of whether or not they bear stress. The resulting accented unstressed syllables could be compared to accented stressed syllables, and this would confirm whether duration alone cued stress. Finally, the impact of these production patterns on the perception of stress and accent will be assessed in perception experiments.

5. Conclusion

The goal of this paper was to disentangle the phonetic cues of stress from those of accent in Spanish by measuring pitch, duration, and intensity in unstressed syllables, accented stressed syllables, and unaccented stressed syllables. The effect of IP boundaries was also examined by measuring pitch, duration and intensity on accented stressed syllables with and without IP boundaries.

Results indicated that pitch and duration were the two cues that were used consistently across subjects. Both cues were used to signal stress, accent, and IP boundaries. What made these units different in terms of their phonetic material was, on the one hand, the interaction between the values of these two cues. For example, unstressed and unaccented vowels with a flat pitch contour were the shortest segments. When vowels bore stress, they maintained a flat pitch contour but increased in duration. Vowels with an accent increased their duration and changed the flat F0 into a rising trajectory. Overall, however, the duration increments and the changes in F0 trajectories that defined stress and/or accent in a segment were relative to the duration and F0 values of their neighboring segments.

This type of phonetic variation strongly supports the hypothesis that stress or accent could not be studied without taking into consideration the prosodic structure, intonation, and system of contrasts of a language. Therefore, past studies on the phonetic cues to stress in Spanish based on materials that excluded relevant contexts, such as different intonational contexts, should be reconsidered.

Appendix

List of sentences: Declarative sentences

El cantante les agradeció su calurosa ovación.
El diputado les manifestó su opinión sobre el proyecto.
La contable les asesoró sobre la declaración de renta.
Su amiga les aconsejó la dieta de su doctor.
La profesora les recomendó la lectura del capítulo.
Manuela les acompañó con su perro a la estación.
Manolo les abandonó repentinamente.
El director les notificó su decisión sobre el aumento.
El bedel agasajó constantemente a los ministros.
El hombre del tiempo nos pronosticó tormentas para mañana.
La portavoz les comunicó las conclusiones de la conferencia.
Manolo les interesó por el sindicato de la empresa.
El guardia les amonestó con energía su imprudencia.
El abogado les garantizó su éxito en el pleito.
Mamá les acomodó precisamente esa habitación.

Parenthetic phrases

-- Este puesto es suyo – les aseguró su director.
-- Veinte años compartidos con mi querido público – les agradeció Sebastián.
-- Vuelvan a leer este capítulo – les recomendó la profesora.
-- Voy con Uds. a la estación – les acompañó Clarita.
-- El acusado no hará declaraciones a la prensa – les manifestó su abogado.
-- Estos son los impresos para la declaración de renta – les asesoró su contable.

-- No puedo seguir en la carrera – les abandonó Roberto.
-- Les subo el sueldo con gusto – les notificó su director.
-- Su presencia nos honra – les agasajó Constantino.
-- Mañana lloverá en las regiones del interior – nos pronosticó Carlitos García.
-- Se llegó a las siguientes conclusiones – les comunicó la portavoz.
-- Pregunten por el sindicato – les interesó Pablito.
-- Aparcar aquí está prohibido – les amonestó con energía.
-- Este es un caso sencillo – les garantizó su abogado.
-- Siéntense en el sofá – les acomodó Paquita.

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