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The Phonetic Manifestation of Secondary Stress in Spanish

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0. Introduction

In this paper, I investigate the acoustic correlates of secondary stress in Spanish. These included duration, pitch, and intensity. According to Navarro-Tomás (1957), Spanish has rhythmic stress, since native speakers perceive alternations between stressed and unstressed syllables at the level of the phrase. Navarro-Tomás suggests that these alternations are due to intensity changes. This observation has been formalized by Roca (1986) and Harris (1983, 1991). Harris (1991) claims that secondary stress is located in alternate syllables at the right or left of the primary lexically assigned stressed syllable. Secondary stress, according to this phonological account, is a different level of prominence from primary stress and lack of stress. Nonetheless, these phonological descriptions do not give any phonetic definition of the type of acoustic prominence expected. The derivation of secondary stress can be described as in (1):

(1) estimulo 'I stimulate'	word
(* *)(* *)	foot
* *	stress
*	primary stress

In the word *estimulo* 'I stimulate', primary stress is assigned to the syllable *mu*, whereas secondary stress is expected in the syllable *es*. The traditional description presented by Navarro-Tomas (1957) and the formal studies (Roca 1986 and Harris 1983, 1991) have not been evaluated from a phonetic perspective using materials specially designed to test the rhythmic hypothesis. Thus, the aim of this research is to analyze the phonetic correlates of secondary stress in Spanish.

1. Previous research

Research completed by Navarro-Tomás (1957), Harris (1983 & 1991), Roca (1986), and Prieto & Van Santen (1996) is presented in this section in order to offer a general perspective on secondary stress in Spanish.

 Hispanic Linguistics at the Turn of the Millennium, ed. Héctor Campos et al., 49-65. Somerville, MA: Cascadilla Press.

In regard to rhythmic stress, Navarro-Tomás points out that Spanish speakers perceive increased and decreased differences in intensity in syllabic groups of more than three syllables. The author maintains that, besides intensity, there are other factors contributing to the increase-decrease effect, though he does not mention any specific factor. Some examples of secondary stress from Navarro-Tomás (1957:196) are presented in (2). The numbers indicate stress prominence: 3 represents the highest prominence, 1 the lowest.

(2) a. repetir
2-1-3
b. rápido
3-1-2
c. abadesa
2-1-3-1

The examples in (2) show alternations in prominence among syllables, taking lexical stress as the point of reference. Navarro's observations indicate the necessity of carrying out research in order to understand the nature of the rhythmic stress. In Navarro's words (1957:195): "No conocemos suficientemente la naturaleza del acento rítmico, ni los principios porque éste se rige en la lengua española." (We do not know the nature of rhythmic stress sufficiently, nor the principles which govern it in Spanish). Harris (1983:85) maintains that there are two patterns of non-primary stress (secondary stress) at the word internal level.

(3) a. gènerativo, Pànamá
'generative', 'Panama'
b. genèrativo, gramàticàlidád, àntigèneràtivísta
'generative', 'grammaticality', 'anti-generative'

According to Harris, secondary stress can be located in the word-initial syllable as is the case in the words in (3a) or in alternate syllables, counting from the primary stressed syllable at the right edge of the word, as presented in (3b). Secondary stress is deleted whenever there is a clash with a primary or secondary stress syllable adjacent (e.g., *decisión contraproducente* 'contrariwise decision'. In this case, the expected secondary stress in the syllable *con* is deleted because of the clash with the primary stressed syllable *sión*.) The pattern in (3a) is found in colloquial speech, whereas the pattern in (3b) is found in formal speech (e.g., reading, news broadcasting, etc.).

Roca (1986) studies the interaction between post-lexical prosodic phenomena and stress rhythm to provide evidence supporting the view that secondary stress is assigned post-lexically. Roca (1986) distinguishes three types of stress: i.) a principal stress in the phonic group located at the one

rightmost word within that unit, ii.) a primary stress lexically assigned to each word, and iii.) a secondary stress assigned post-lexically to alternate syllables to the left and right of primary stress (e.g, còstantìnopléño).
According to Roca, secondary stress is assigned to right-headed binary feet. In (4) and (5), the algorithm proposed by Roca (1986:353) is presented.

(4)a. stressable elements are rhymes (equivalent for our purposes here, [+syllabic] segments)
b. line 0 constituents are right-headed
c. on line 0 construct bounded constituents from right to left

The rule in (4b) clashes with the alternator stress rule for Spanish:

(5)a. line 0 constituents are left-headed
b. on line 0 construct from right to left bounded constituents

This proposal generates iambic feet combining the algorithm above with two rules (stress clash and initial stress shift). Even though the output in Roca's proposal is the same as previous work supporting trochaic feet in Spanish, it can be characterized as more complex.

Based on Roca's observations, Harris (1991) discusses secondary stress in Spanish. Harris maintains that Roca's evidence to support the idea of iambic feet in Spanish is not sufficient. In some dialects, as Roca explains in his paper, words like *cántaro* 'pitcher' and *cántalo* 'sing it' have certain prominence in the final syllable. Roca interprets this as primary stress due to a reinforcement explained by the stress shift rule. Nonetheless, according to Harris, this final prominence can be explained by means of a rule that assigns final stress to the final syllable at the right edge of the intonational phrase in the dialect analyzed by Roca (1986). Harris maintains that, when the final syllable does not correspond to the end of the intonational phrase, there is no secondary stress (e.g., *cántalò* 'sing it' vs. *cántalo hòy* 'sing it today').

Harris' second argument against Roca's stress shift rule is that in words like *cántalò* 'sing it', *cántamelò* 'sing it for me', *cantándosemelò* 'it being sung for me', in which primary stress is found in *tán*, secondary stress is located at a distance of one, two, and three syllables, respectively. This fact demonstrates that it is not a matter of considering right-headed feet, but a rule that assigns stress to the final syllable of the intonational phrase. Harris maintains that secondary stress in Spanish is assigned to left-headed binary feet. This is consistent with the idea that Spanish has trochaic rhythm as described by the traditional literature (Navarro-Tomás 1957).

Prieto & van Santen (1996) analyze the acoustic correlates (duration, intensity, and pitch) of secondary stress. They review three proposals: i. the rhythmic hypothesis as supported by Roca (1986) and Harris (1983 & 1991); ii.

the non-rhythmic hypothesis according to which secondary stress is located at the beginning of the word, and iii. the null hypothesis according to which there is no secondary stress. Their experimental results show that there is no acoustic or perceptual evidence to support the rhythmic hypothesis. Nevertheless, Prieto & van Santen found a positive correlation showing that secondary stress is located word-initially in terms of intensity and pitch. They claim that word-initial secondary stress is associated with the amplitude peak and a F_0 downward slope.

The primary purpose of this paper is to test the rhythmic hypothesis using materials that enable us to compare the same syllable when three different kinds of prominence are expected (no stress, secondary stress, and primary stress) and to analyze the phonetic correlates of secondary stress in the case where evidence to support that hypothesis is found. Even though Prieto & van Santen present results concerning the rhythmic hypothesis, it is not clear from their methodology how they manage to differentiate the predictions of the word initial hypothesis from those of the rhythmic hypothesis. In summary, the aim of this research is to test the rhythmic hypothesis and to observe, in the case that positive evidence is found, what the phonetic correlates of secondary stressed syllables are.

2. Methodology

2.1 Material

As is explained below, the materials contained two target syllables under two conditions (unstressed and secondary stress) and two target syllables under three conditions (unstressed, secondary stress, and primary stress). The four target syllables are [es] and [ti] in the words *estímulo* 'stimulus', *estimulo* 'I stimulate', and *estimuló* 'he/she stimulated'; and the syllables [de] and [po] in the words *depósito* 'deposit', *deposito* 'I deposit', and *depositó* 'he/she deposited'. Following Arvaniti (1994), the four-syllable target words were embedded in carrier sentences, the target words within the six sentences in the corpus having different stress patterns.

Table 1: Stimulus sentences

Set 1	Set 2	Initial syllable	Antepenultimate Syllable.
Necesitas *estímulo* grande. 'You need a great stimulus'	Necesitas *depósito* grande. 'You need a big deposit'	Unstressed	Primary stress
A Campos *estimulo* en la tarde. 'I stimulate Campos in the afternoon'	A Campos *deposito* en la tarde. 'I deposit (the money) for Campos in the afternoon'	Potential secondary stress	Unstressed
Casas *estimuló* confianza. 'Casas stimulated confidence'	Casas *depositó* confianza. 'Casas deposited confidence'	Unstressed	Potential secondary stress

The first pair of test words has antepenultimate primary stress (*Necesitas estímulo grande* 'You need a great stimulus'; *necesitas depósito grande* 'You need a big deposit'). The second pair of test words has penultimate stress (*A Campos estimulo en la tarde* 'I stimulate Campos in the afternoon'; *A Campos deposito en la tarde* 'I deposit (the money) for Campos in the afternoon'). The third pair of test words has final stress (*Casas estimuló confianza* 'Casas stimulated confidence'; *Casas depositó confianza* 'Casas deposited confidence'). In the first syllable of each pair, we would expect no stress in the syllables *es* and *de*. In the second pair, we would expect secondary stress in the first syllables of the words ***es**timulo* and ***de**posito*. Finally, in the third pair, we would predict no stress in *es* and *de*.

On the other hand, the second syllable of each word enables us to compare syllable units bearing primary stress, secondary stress, and no stress. In the first pair (*Necesitas estímulo grande* 'You need a great stimulus'; *necesitas depósito grande* 'You need a big deposit'), the target syllables [ti] and [po] bear primary stress. In the second pair (*A Campos estimulo en la tarde* 'I stimulate Campos in the afternoon'; *A Campos deposito en la tarde* 'I deposit (the money) for Campos in the afternoon') the target syllables [ti] and [po] are predicted to have no stress. In the third pair (*Casas estimuló confianza* 'Casas stimulated confidence'; *Casas depositó confianza* 'Casas deposited confidence'), the target syllables [ti] and [po] are predicted to have secondary stress. With these four target syllables, not only can the analysis predicted by phonological accounts be examined, but also the phonetic correlates of syllables bearing potential

secondary stress can be analyzed. In other words, we will be able to observe if the duration, intensity, and pitch of potentially secondary stressed syllables are similar to stressed syllables or unstressed syllables.

Three carrier phrases were constructed using the same units for each of the three stress patterns represented by the target words. This design was useful to compare sentences with similar stress patterns, and to test phonological accounts regarding secondary stress. Even though some target sentences seem to be unnatural, (e.g., *A Campos estimulo en la tarde* 'I stimulate Campos in the afternoon') they have the prosodic structure required to test the rhythmic hypothesis. Six additional sentences were also included in the list of stimulus sentences to create a semantic context for the targets. The complete set of sentences (target sentences and carrier phrases) are presented in (6).

(6) a. Creo que has estado deprimida últimamente
'I believe that you have been depressed lately'
b. Necesitas estímulo grande
'You need a big stimulus'
c. Comprarás una casa muy grande este año
'You will buy a very big house this year'
d. Necesitas depósito grande
'You need a big deposit'
e. Entrego un estímulo a los mejores trabajadores hoy
'I give a stimulus to the best workers today'
f. A Campos estimulo en la tarde
'I stimulate Campos in the afternoon'
g. Campos me ha llamado muchas veces para cobrar su dinero
'Campos has called me requesting his money many times'
h. A Campos deposito en la tarde
'I deposit (the money) for Campos in the afternoon'
i. Nombraron a Casas como el nuevo presidente del Banco Central
'They named Casas as the new president of the Central Bank'
j. Casas estimuló confianza
'Casas stimulated confidence'
k. Casas confía en el nuevo gobierno
'Casas has confidence in the new government'
l. Casas depositó confianza
'Casas deposited confidence'

2.2. Speakers

Five female speakers of Peninsular Spanish were recorded in a sound-attenuated room located in Cunz Hall of Languages at The Ohio State University. Each informant read twelve sentences in Spanish after being instructed to read as carefully and clearly as possible. The informants practiced the reading before recording and when they felt comfortable with the material, two repetitions were recorded.

2.3. Measurements and statistical analysis

The material recorded was digitized in order to obtain measurements of duration, intensity, and F_0 for each syllable. From the two repetitions, the one of best acoustic quality was selected. Durational measurements of the nuclear vowel were obtained from digital spectrograms using the PCquirer acoustical analysis software package. The intensity and F_0 were measured by means of the same program. For intensity, the highest RMS measurement corresponding to the syllable nucleus was chosen. In the case of pitch, F_0 tracks were plotted and an F_0 value occurring without segmental perturbation within the mid-portion of the target syllable was selected for analysis. Statistical analysis was applied to the data obtained from the five speakers using Analyses of Variance (ANOVA).

3. Results and discussion

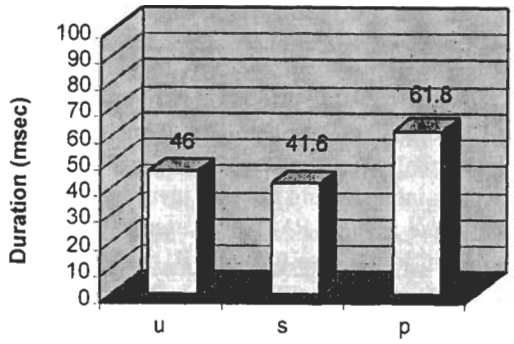
This section is organized by target syllable. As displayed in table 1, six words with different stress patterns are the target of the analysis. The first set consists of the words *estímulo* 'stimulus'; *estimulo* 'I stimulate'; *estimuló* 'he/she stimulated'. The second set consists of the words *depósito* 'deposit'; *deposito* 'I deposit'; *depositó* 'he/she deposited'. Four target syllables are the focus of the study, namely [ti], [po], [es], and [de]. The different environments created for [ti] and [po] allow us to test three levels of prominence: primary stressed, secondary stressed, and unstressed syllables, whereas in the case of [es] and [de], two levels of prominence are observed (secondary stressed and unstressed syllables).

3.1 Duration

3.1.1. The target syllables [ti] and [po]

Figure 1 shows the results for the target syllable [ti] with three different levels of prominence (u: unstressed, s: secondary stress, and p: primary stress).

Figure 1: Mean of duration by type of syllable

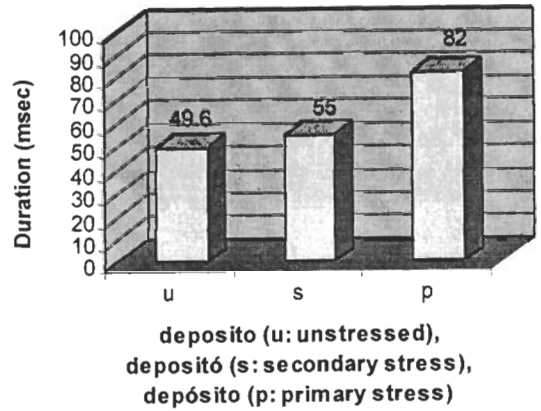


The mean values represented in Figure 1 reveal that stressed syllables are longer than unstressed and secondary stressed syllables. In the case of unstressed syllables in comparison to stressed syllables, there is a difference of 15.8 milliseconds, whereas comparing secondary stressed syllables to stressed ones there is a difference of 20.2 milliseconds. These differences were significant [F (2, 12) = 7.4, $p < 0.01$)] indicating that duration is a phonetic correlate separating primary stressed syllables from unstressed and secondary stressed syllables.

In order to observe if there was a significant difference between unstressed and secondary stressed syllables, the Tukey-Kramer test was applied. The Tukey-Kramer test allows us to observe the interaction among all pairs of syllables. In other words, a comparison among unstressed, secondary stress, and primary stress syllables in all possible combinations was obtained by applying this statistical test. The purpose of this was to analyze the status of secondary stressed syllables in a pairwise comparison with unstressed and with primary stressed syllables. The findings show that the only significant difference is between primary stress versus no stress and secondary stress. This means that there is not a significant duration value that creates a distinction between unstressed syllables and secondary stressed syllables.

In Figure 2, the results for the target syllable [po] are presented. Three levels of prominence are compared (u: unstressed, s: secondary stress, and p: primary stress).

Figure 2: Mean of



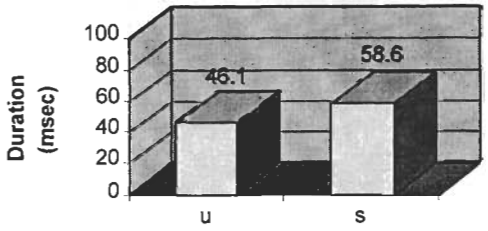
The mean duration values show that stressed syllables are longer than unstressed and secondary stressed syllables. There is a difference of 32.4 milliseconds between stressed and unstressed syllables, whereas the difference is 27 milliseconds when comparing stressed versus secondary stressed syllables. The ANOVA test indicates that these differences were significant [F (2, 12) = 14.3, $p < 0.01$)].

A difference of 5.4 milliseconds was found when comparing unstressed versus secondary stressed syllables. This slight distinction is not significant according to the Tukey-Kramer test. The findings of this test reveal that the only significant difference is between stressed syllables as opposed to syllables that are unstressed or carry secondary stress.

3.1.2. The target syllables [es] and [de]

Figure 3 presents the mean duration values for the target syllable [es]. Two degrees of prominence are compared in this case (u: unstressed, and s: secondary stressed).

Figure 3: Mean of duration by type of syllable.

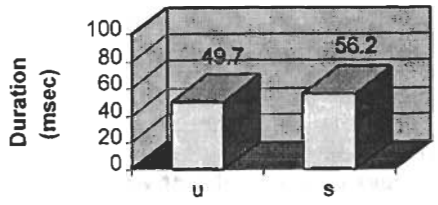


estímulo, estimuló (u: unstressed), estimulo (s: secondary stress).

The data in this case indicate that there is a contrast of 12.5 milliseconds between unstressed and secondary stressed syllables. The ANOVA test shows that this difference in duration is significant [F (1, 13) = 7.4, $p < 0.05$)]. This means that when unstressed syllables are compared to potential secondary stressed syllables there is a difference in duration, possibly confirming the rhythmic hypothesis in these environments.

Figure 4 presents the mean duration values for the target syllable [de]. Two degrees of prominence are compared (u: unstressed, and s: secondary stressed).

Figure 4: Mean of duration by type of syllable



depósito depositó (u: unstressed), deposito (s: secondary stress)

As can be seen, there is a difference of 6.5 milliseconds between unstressed and secondary stressed syllables. Nevertheless, the ANOVA test did not show a significant correlation between duration and type of syllable [F (1, 13) = 1.6, p = 0.22)]. These findings do not match the previous observations regarding the target syllable [es]. In the case of [es], the results were significant. These results could be explained taking into account the possible effect of vowels in open

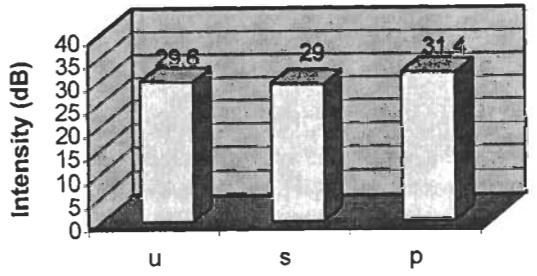
syllables versus vowels in closed syllables. Future research will need to take into consideration syllable structure.

3.2 Intensity

3.2.1. The target syllables [ti] and [po].

Figure 5 presents the results measuring mean of intensity by type of syllable for the target [ti] where three prominence levels are compared (u: unstressed, s: secondary stress, and p: primary stressed).

Figure 5: Mean of intensity by type of syllable

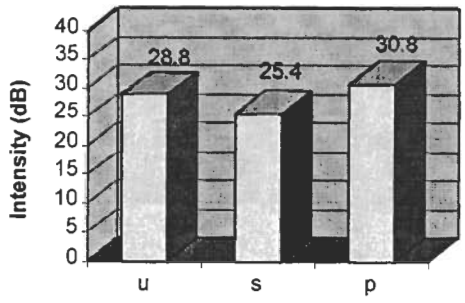


estimulo (u: unstressed), estimuló (s: secondary stress), and estímulo (p: primary stress)

As can be seen in Figure 5, there is a difference of 1.8 dB between stressed and unstressed syllables, and 2.4 dB between stressed and secondary stressed syllables. The ANOVA test indicates that there is not a significant correlation between the type of syllable (unstressed, secondary stress, and primary stress) and intensity [F (1, 13) = 0.02, p = 0.8)].

Figure 6 shows the mean values of intensity by type of syllable for the target syllable [po] comparing three levels of prominence (u: unstressed, s: secondary stress, and p: primary stress).

Figure 6: Mean of intensity by type of syllable



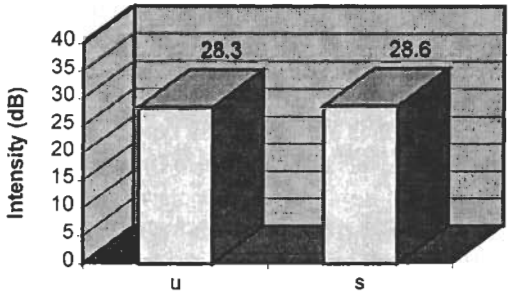
depósito (u: unstressed), depositó (s: secondary stress), and depósito (p: primary stress)

In Figure 6, a difference of 2 dB is found between stressed [po] and unstressed [po], while a difference of 5.8 decibels is found between stressed [po] and secondary stressed [po]. The ANOVA test shows that there is not a significant correlation between the type of syllable (no stress, secondary stress, and stress) and intensity [F (2, 12) = 1.9, p = 0.18)]. In other words, intensity does not seem to be a cue distinguishing between any level of stress.

3.2.2. The target syllables [es] and [de]

Figure 7 presents the mean intensity values for the target syllable [es] comparing two levels of prominence (u: unstressed, and s: secondary stress).

Figure 7: Mean of intensity by type of syllable

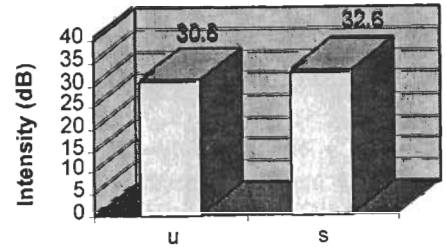


estímulo, estimuló (u: unstressed), and estimulo (s: secondary stress)

Figure 7 indicates that there is a 0.3 dB difference between unstressed and secondary stressed syllables, the latter being higher. Again, the ANOVA analysis reveals that there is no correlation between intensity and stress [F (1, 13) = 0.01, p = 0.89)]. These results coincide with the previous data regarding the target syllables [ti] and [po]. Thus, there is no evidence to support the hypothesis that intensity is a phonetic correlate of secondary stress.

Figure 8 presents the mean intensity values obtained for the target syllable [de] where two levels of prominence are compared (u: unstressed, and s: secondary stress).

Figure 8: Mean of intensity by type of syllable



depósito, depositó (u: unstressed), deposito (s: secondary stress)

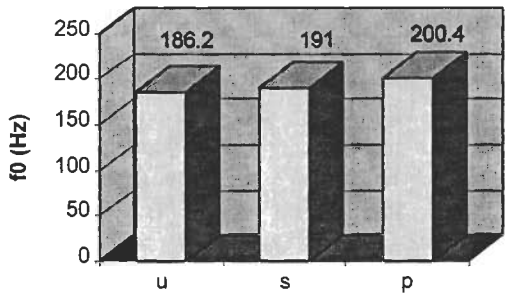
As can be seen in Figure 8, secondary stressed syllables average 2 dB higher that unstressed syllables. The ANOVA test shows that this difference is not significant [F (1, 13) = 1.5, p = 0.23)]. These findings do not support previous work (e.g. Navarro-Tomás 1957) where it is suggested that stress in Spanish phonetically correlates to intensity. Furthermore, there is no evidence to claim that secondary stress correlates to intensity.

3.3. Fundamental Frequency

3.3.1. The target syllables [ti] and [po]

Figure 9 presents the mean fundamental frequency (F_0) values for the target syllable [ti] comparing three levels of prominence (u: unstressed, s: secondary stress, and p: primary stress).

Figure 9: Mean of F_0 by type of syllable

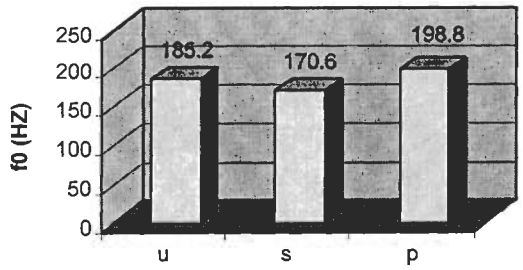


estimulo (u: unstressed), estimuló (s: secondary stress), estímulo (p: primary stress)

A difference of 14.2 Hz is observed between unstressed and stressed syllables, whereas between secondary stressed and stressed syllables the difference is of 9.4 Hz. The ANOVA test reveals that this difference is not significant [F (2, 12) = 0.6, p = 0.54)]. This suggests F_0 does not constitute a phonetic cue to identify the type of syllable (unstressed, secondary stress, and primary stress).

Figure 10 shows the mean F_0 values for the target syllable [po] where three levels of prominence are compared (u: unstressed, s: secondary stress, and p: primary stress).

Figure 10: Mean of F0 by type of syllable



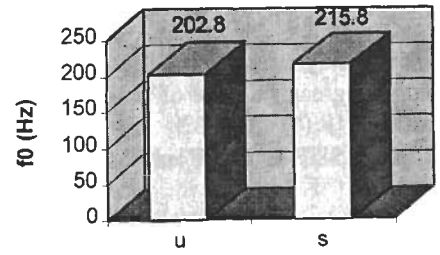
deposito (u: unstressed), depositó (s: secondary stress), depósito (p: primary stress)

As can be seen in Figure 10, there is a difference of 13.6 Hz between unstressed and stressed syllables. The difference is 28.2 Hz between secondary stressed and stressed syllables. The difference when comparing unstressed [po] to secondary stressed [po] is 14.6 Hz, the former being higher. The ANOVA test again found this difference not to be significant [F (2, 12) = 2.05, p = 0.17)], indicating that F_0 may not be an acoustic correlate of secondary stress.

3.3.2 The target syllables [es] and [de]

Figure 11 presents the mean F_0 values for the target syllable [es] where two levels of prominence are compared (u: unstressed, and s: secondary stress).

Figure 11: Mean of F_0 by type of syllable

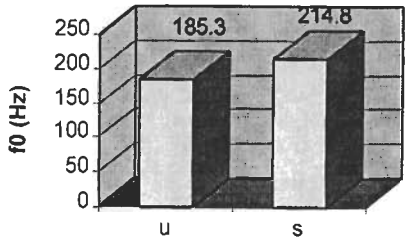


estímulo, estimuló (u: unstressed), deposito (s: secondary stress)

A difference of 13 Hz is found between unstressed and secondary stressed syllables. The ANOVA test shows that this difference is not significant [F (1, 13) = 0.46, p = 0.50)]. These results are consistent with those found when analyzing the target syllables [ti] and [po].

Figure 12 presents the mean F_0 values obtained for the target syllable [de] where two levels of prominence are compared (u: unstressed, and s: secondary stress).

Figure 12: Mean of F_0 by type of syllable



depósito, depositó (u: unstressed), deposito (s: secondary stress)

According to these results, secondary stressed syllables are 29.5 Hz higher than unstressed syllables. Despite this greater degree of difference, the ANOVA test indicates that it is not significant [$F(1, 13) = 3.1$, $p = 0.10$)]. The conclusion that can be drawn from Figures 9-12 is that F_0 is not a phonetic correlate of secondary stress.

4. Conclusion

The findings of this research show that duration constitutes an acoustic correlate of stress that distinguishes primary stressed syllables from other syllable types. Primary stressed syllables are longer than secondary stressed and unstressed syllables.

The results for the target syllable [es], where two levels of prominence are compared (u: unstressed, and s: secondary stress), show that duration is a significant factor [$F(1, 13) = 7.4$, $p < 0.05$)]. Nonetheless, in the case of the target syllable [de], where the same conditions of the target syllable [es] applied, the results are not significant [$F(1, 13) = 1.6$, $p = 0.22$)]. These findings do not support the view that duration is a phonetic correlate separating secondary stressed syllables from unstressed syllables. Future investigations will have to address this issue by measuring the duration of the entire syllable instead of only the nuclear vowels. Since the material used here was designed to test the rhythmic hypothesis, future work should compare other perspectives like the word initial hypothesis.

The results concerning fundamental frequency show that F_0 values are not significant when considering differences in stress prominence (unstressed, secondary stress, and primary stress).

Finally, with regard to intensity, no significant difference was found. The differences found in syllables produced with different levels of prominence clearly indicate that intensity is not a phonetic cue separating any level of stress.

Contrary to what is claimed in the traditional literature, the research presented here shows that duration is more relevant than intensity when considering stress. This is consistent with findings in more recent work (Enríquez, Casado & Santos 1989) where duration has been found to play an important role in conveying stress.

Notes

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