1. Introduction

This paper presents the results of an acoustic analysis of the voiceless posterior fricative /h/ in Puerto Rican Spanish based on data from a naturalistic linguistic task. Caribbean Spanish is known for many innovative features at the segmental level including coda s-aspiration, trill variation, lateralization of /l/, fortition of the palatal approximant, etc. Previous characterizations of the posterior voiceless fricative report a realization that is best characterized as a [h].

Lipski characterizes the realization as “in practice a posterior fricative (voiced or voiceless)” (1994:333). Some researchers of Caribbean dialects of Spanish have noted that phoneme /h/ may have a voiced realization (Hualde 2013 Jiménez Sabater 1975, Sosa 1980), but there are no reports of a systematic variation between voiced and voiceless variants.

This posterior realization of /h/ has the potential to overlap phonetically, i.e., as an aspiration, with at least two other phonemes in Puerto Rican Spanish; the aspirated /s/ in coda position and the phonemic trill. The IPA symbol [h] is used to characterize the phonetic realization of three separate phonemes in Puerto Rican Spanish, in addition to other varieties. First, the IPA symbol [h] corresponds to the phoneme /h/ which is a posterior realization of the phoneme /x/, or voiceless velar fricative in most varieties of Spanish. Secondly, a posterior or glottal fricative is regularly used to describe the aspiration of coda /s/ in Puerto Rico, as well as many dialects of Spanish, and is typically represented with the IPA symbol [h] or [h]. The phonemic trill /r/ is often produced as a velar or uvular fricative in many Puerto Rican dialects, or described as aspiration (Graml 2009, López-Morales 1979, Navarro-Tomás, 1948, Sosa 1980, Vaquero and Quilis 1989). On the potential for neutralization between /x/ and /r/, Lipski notes that some Puerto Ricans will joke about the potential neutralization between the /x/ and /r/ phonemes as in Ramón ‘Ramond’ and jamón ‘jam’ (333), though he notes that this rarely occurs. Dillard (1962), on the contrary, claimed this neutralization occurs more frequently, but see Delgado-Díaz and Galarza (this volume) for more on this topic.

To our knowledge there are no acoustic studies that examine /h/ in Puerto Rican Spanish. Given the similar phonetic characterization of [h] for three distinct phonemes it seemed like a better understanding of the phonetic details based on an acoustic study could contribute to our understanding of the actual phonetics and the patterns that may not always be easily perceived with the ear. The second section of this paper will review the literature on the /x/ and /h/ in Spanish followed by the methodology in Section 3 used to examine /h/ in Puerto Rican Spanish. Section 4 presents the results of the experiment and a discussion of the results is covered in Section 5. The conclusions are reviewed in Section 6.

* Indiana University. We are grateful to the comments of two anonymous reviewers and the audience at the Laboratory Approaches to Romance Phonology held at El Colegio de México, Mexico City, October 3-5, 2012.

1 We will use both /x/ and /h/ in reference to the posterior voiceless fricative while recognizing that they are not contrastive and that the phonemic status reflects traditional characterizations. We will refer to /x/ when characterizing dialects with a reported velar realization and /h/ for those dialects claimed to have a laryngeal production. However, the purpose of the paper is not to argue the phonemic status of either symbol, but rather demonstrate regular patterns of contextualized voicing.

2. Literature review

The current voiceless velar fricative /x/ in modern Spanish evolved from two phonemes /ʃ/ and /ʒ/ in medieval Spanish that were distinguished by voicing (Penny 2002, Pharies 1997). After the merger of the voiced variant to the voiceless, this sound retracted from an alveo-palatal to a velar place of articulation.

The majority of reference materials on dialectal variation in Spanish report that the phonemic voiceless velar or posterior fricative in the Caribbean region is produced as a weak glottal fricative and is typically represented with the IPA symbol [h] (cf. Canfield 1981, Navarro Tomás 1948, Quilis 1993, Zamora and Guitart 1988). The previous dialectal descriptions often characterize a distinct phonemic specification; /x/ for those dialects with a velar voiceless fricative and /h/ for those with a laryngeal production. Hualde (2013) reports that in Latin American Spanish there are two main realizations of /x/; one is a velar fricative [x] that is predominant in Mexico, Peru, Chile and Argentina, and which is both less strident and less retracted than the Castilian variant [χ]. He also described a laryngeal voiceless fricative [h], which is found in Caribbean, Central American, Canary Islands and Colombian varieties of Spanish. These three main variants of the velar or posterior fricative are presented in Figure 1.

![Figure 1. Allophonic examples of the dialectal variation of the Spanish phonemic voiceless velar fricative in intervocalic position, all in unstressed syllables.](image)

2 The example in cajas ‘boxes’ is actually produced with voicing.
There are several research accounts that indicate voicing of phonemic voiceless posterior fricatives occurs in Spanish. These accounts are limited in number and are primarily based on impressionistic characterizations of the data (see for example, Sosa, 1980); and for Peninsular Spanish, Marrero (1990) and Torreira and Ernestus (2011) are the exceptions. We will review these works to motivate our current study.

Sosa (1980) is an impressionistic study of the realization of /h/ and is based on recorded interviews of 12 Venezuelan speakers based on auditory analysis. This author generalized his findings and suggested that the normal pronunciation of the phonemic voiceless posterior fricative in Caribbean Spanish is in fact a voiced fricative. He reports that 93% of the tokens observed in his data were produced with voicing. These voiced realizations are divided into two types, breathy and relaxed, though there are no acoustic cues or descriptions to distinguish these two realizations, and he claims the place of articulation ranges from the palatal region to a glottal articulation. Sosa reported that these two voiced realizations of breathy and relaxed vary by speaker sex and socioeconomic level, though no clear report of characteristics are provided to explain these claims. Furthermore, the voicing assimilation observed in the phonemic voiceless velar fricative is posited as a lenition process; however, he claims that this rarely results in complete elision of the sound. Sosa also reported a few productions (1.8%) that he characterizes as “non-aspirated” (136), meaning that their place of articulation was uvular, velar and palatal. He indicated that these “non-aspirated” tokens were invariably produced as voiceless.

The study by Marrero (1990) is an acoustic examination of the different realizations of the aspiration of implosive /s/ and /h/ produced by 2 men and 2 women from Tenerife, Canary Island. She found that the two phonemes share the same aspirated variants but differ in their allophonic distributions. Marrero found that the most frequent allophone of /h/ was a pharyngeal realization, whereas the most frequent allophone of implosive /s/ was a laryngeal variant. In addition, /s/ variants evidenced higher voicing rates than /h/ variants. Thus, /s/ laryngeal variants were produced with voicing in 90.4% of the cases, whereas /h/ laryngeals showed lower voicing rates (around 50%). Similarly, /s/ pharyngeals observed a greater number of voiced tokens (51.2%), than /h/ pharyngeal productions, which tended to be voiceless (60%). The most frequent /s/ velar variants were also inclined to be produced with voicing, but only during the first half of the segment, leading Marrero to characterize them as partially-voiced tokens (60.4%). In contrast, /h/ velar variants were produced mainly as voiceless segments in more than 90% of the cases. This study shows that in this variety, place of articulation and voicing patterns play an important role in the distribution of the aspiration coming from /h/ and implosive /s/.

Torreira and Ernestus (2011) documented the application of voicing of the phonemic voiceless fricatives in a corpus of spontaneous speech from Madrid and they reported intervocalic voicing at the following rates,

- /s/  -- 34%
- /f/  -- 25.9%
- /θ/  -- 28.7%
- /χ/  -- 15.5%

In their corpus, the phonemic voiceless posterior fricative was typically produced phonetically as a uvular variant with a strong frication. The relevant facts of the Torreira and Ernestus study for the current study is the documentation of another variety of Spanish with voicing of a phonemically voiceless segment and further indicates the possibility of dialectal variation of voicing for fricatives.

The preceding review which indicated variation in the voicing status among several dialects of Spanish and the possibility of sociolinguistic variables led us to the following questions that guided this experimental research.
1. Is there a systematic allophonic variation in the production of Spanish phonemic /h/ in Puerto Rican Spanish, described as a voiceless fricative in general Spanish?  
2. What is the role of voicing in the allophonic variation of the phonemic posterior fricative in Puerto Rican Spanish?  
3. Is speaker sex a predictive sociolinguistic variable in the realization of the /h/?

3. Methodology

In order to address the research questions we followed an experimental design to elicit and examine multiple realizations of the /h/ in a variety of contexts.

3.1. Participants

We selected the speech of 12 participants to report in the current study. These participants were primarily from the town of Caguas, Puerto Rico, although we did have two speakers that were native to San Juan, Puerto Rico. We recorded 16 informants for the study but discarded four due to disfluencies in their speech production such as extensive creaky voice or devoicing. As we sought to keep the numbers of male and female speakers even, we used all of the analyzable male informants and the first six female informants that met our criteria for fluency with the task. We also first selected speakers that came from Caguas, n = 10, and the additional 2 were from San Juan. The number of informants was not completely balanced for age and sex of speaker in this corpus. Six informants were in the 60-80 age range (4 women and 2 men) and six were in the 20-40 range (4 men and 2 women). We did not examine socio-economic level. This socio-economic limitation was not addressed as this is an initial survey to see what types of patterns are present in the speech of Puerto Ricans.

3.2. Production task

Because we wanted to identify the contextual variables potentially responsible for voicing variation in /h/ we developed an information task data elicitation instrument that allowed us to control the contextual variables in question in a somewhat naturalistic speech task. The context of the information task was a birthday party in which people (inviters) invite others to a party (the invitees). The invitees in turn were asked to bring different presents and food items. The names of many of the invitees and inviters, as well as most of the presents and food items had the target sound. At the beginning of the task there was a familiarization component in which the participants were taught and practiced the names of the invitees, the gifts and the food items. This was done to encourage the participants to produce the experimental words and that they would get used to the task.

After reviewing all of the people, foods and gifts, the participants were shown two pictures of people and instructed to identify who invited whom (as in 1a). The next step in the task was to identify the food and gifts that each invitee brought to the party based on the picture prompts, without any text, resulting in target utterances shown in 1b-c.

1. (a) /h/ulieta invitó a /h/osefina
   Ramón invitó a An/h/el
   ‘Julieta invited Josephine’
   ‘Ramon invited Angel’

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3 We will refer to this phoneme as a posterior fricative. This phone to our judgement most resembles the phonetic characterization of a glottal fricative (Ladefoged and Maddieson 1996)
4 Caguas is a medium-sized municipality in the Central Valley of Puerto Rico. It is approximately 20 miles from San Juan and there is constant interaction between these two communities facilitated by a multilane highway. Caguas can be considered a bedroom community of San Juan. In addition to being an extension of the San Juan Metropolitan area, Caguas was used as a data collection site because two of the researchers had extensive social networks in the area, including the more mature age group.
5 An anonymous reviewer noted that not controlling for age and education is a drawback to the study. Our choice to not control for educational level was deliberate as explained.
(b) /h/osé trajo un espe/h/o
   ‘José brought a mirror’
An/h/el trajo un cuadro de /h/ibaros
   ‘Angel brought a picture of Jíbaros’
Olga trajo un cone/h/o
   ‘Olga brought a rabbit’

(c) /h/uan trajo pollo con ajo
   ‘Juan brought chicken with garlic
Susana trajo a/h/on/h/olí
   ‘Susana brought sesame seeds’
/h/ulieta trajo /h/elatina
   ‘Julieta brought jello’

The final step in the task was to review once again the names of the inviters and the invitees. This was done by showing a picture associated with an invitee, a food item or a present and then listing three possible names on the right-hand side. The informant said the name aloud and clicked the right answer they received a brief applause, and when they clicked the wrong answer it slowly faded away allowing them to choose again until they said the correct name.

There was a total of 1,147 tokens analyzed out of a potential 1,212 intended tokens. These tokens included 14 inviters/invitees, invitees and the number of objects brought is 32, and the final review of items 26 for a total of 101 intended tokens for each of the informants. The contexts included phrase initial or post pause and phrase internal positions. The intended contexts are shown in Table 1 were:

<table>
<thead>
<tr>
<th>Phonological context</th>
<th>In tonic syllable</th>
<th>In atonic syllable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phrase initial or initial pause</td>
<td>/h/uan /h/orge</td>
<td>/h/osé /h/ulieta</td>
</tr>
<tr>
<td>Phrase internal across word boundary</td>
<td>…trajo /h/ente</td>
<td></td>
</tr>
<tr>
<td>Phrase internal with preceding /h/ across word boundary</td>
<td>…un /h/ugo de…</td>
<td>trajo un /h/ amón</td>
</tr>
<tr>
<td>Phrase internal with preceding vowel across word boundary</td>
<td>trajo /h/ente</td>
<td>trajo una /h/elatina/</td>
</tr>
<tr>
<td>Word internal with preceding /s/</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Word internal with preceding /n/</td>
<td>--</td>
<td>An/h/el ajon/h/olí</td>
</tr>
<tr>
<td>Word internal/vowel</td>
<td>va/h/illa espe/h/o</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Token and context examples by linguistic independent variables.

There was some variation in the actual number of tokens produced by each speaker. Several informants produced additional tokens of /h/ as they were trying to perform the tasks. For example in the person identification and invitation, one speaker produced five word forms in order to produce the target token of José. A sample utterance was as follows, “Ángel, Ángel, ¿no es Ángel? ¿Carlos será?, ¿Tampoco?, pues José, que no es Pedro” ‘Angel, Angel, no it is not Angel. Is it Carlos? Not him either, well maybe José, it is certainly not Pedro’. Since these forms were all natural productions of the target segment, these additional tokens were included in the analysis and were coded for their phonological context, including the presence of a pause or previous sound. Other informants did not produce as many extra target tokens and there were several speakers that did not say the names of the people or the objects until the actual information gap part of the Powerpoint, which resulted in some variation in number of tokens per speaker.

6 We did not have any tokens of word final/phrase final /h/ as in reloj ‘watch’.
7 The number of intended contexts varies from the actual realizations documented in the results section due to variable realization of the /s/ and /r/ in addition to the inclusion of vocalization prior to the post-pausal realization of the sound. There were also a few occasional speaker improvisations of lexical choice which changed the preceding context to a different segment.
8 This data collection methodology, a modified information gap task of a laboratory approach, resulted in far more tokens than a normal laboratory phonology experiment. This instrument/task however, also produced far more tokens with a controlled context than usually occur in a spontaneous sociolinguistic interview.
3.3. Recording

The participants were recorded in a quiet room at the second author’s home in Caguas, or in a quiet classroom in San Juan. The speakers were recorded using a head mounted microphone (Shure WH 20) and a USBpre external soundcard connected to a computer. The PowerPoint presentation was presented on a separate computer.

3.4. Acoustic analysis

The acoustic analysis was performed with Praat (Boersma and Weenink 2014). We measured the segment duration and determined the voicing status of the /h/. The voiced/voiceless categorization was based on the pulse analysis; pitch tracking, periodicity of the waveform, and presence of the voicing bar. The presence of continuous formant structure in the case of the voiced tokens was also considered.

Figure 2. Sample spectrogram with cues used for identification of /h/ segment and voicing, José ‘Joseph’.

In Figure 2 on the first level point 1 indicates the onset of waveform perturbations and energy in the spectrogram. Number two on the first level marks the beginning of the vowel which can be observed in the increase in waveform amplitude and the increased energy in the spectrogram by the darker bands of the first two formants. Voiced tokens were similarly segmented by visual inspection of
variations in amplitude of the waveform and with the spectrogram we used variations in formant structure and intensity.

Our examination of the voicing of /h/ did not find the same type of incremental voicing or partial voicing as has been reported for /s/ in studies that examine assimilation processes (Campos-Astorkiza 2011, Schmidt and Willis 2011, Sedó 2015). This lack of partial voicing may be due to the place of articulation difference, whereas /s/ is typically alveolar the /h/ is glottal. We have limited our characterization to a categorical voiced/voiceless distinction based on the acoustic evidence stated.

4. Results

Our findings indicate that voicing of /h/ varies systematically by context. We will use the symbol typically utilized by Spanish dialectologists [h] in the case of voiceless variants and the [ɦ] to represent the voiced variant.

Figure 3. Initial voiceless posterior fricative with examples of the other two voiceless fricatives in Spanish, /s/ and /f/, Josefina ‘Josephine’.

9 While the place of articulation specifications for different fricatives are reported to be associated with particular frequency heights, we could not consistently identify an objective measures for consistent identification of place of articulation for the phoneme that corresponds to the voiceless posterior fricative /h/. As we do not have a metric for consistent identification we will refer to them as a posterior fricative as opposed to the velar and uvular variants in other varieties of Spanish.

10 Torreira and Ernestus (2011) find that phonemically voiceless fricatives can be produced with voicing in spontaneous conversation.
4.1. Token types

There were several different token types in our corpus. Because we relied on specific acoustic criteria and evidence for each of the characterizations, the current token descriptions may not be directly comparable with previous accounts. For example Sosa’s claim of *breathy* versus *relaxed* are perceptual characterizations without clearly identified corresponding acoustic cues. We provide several spectrograms of variant productions though we are unwilling to make claims regarding their exact place of articulation.

In Figure 3 we can see a representative example in post-pausal position illustrating a posterior fricative without voicing. Interestingly, the other two fricatives /s/ and /f/, despite being in intervocalic position, are produced without voicing. Figure 4 shows a representative example of the posterior fricative in intervocalic position that is produced with voicing.

![Waveform and spectrogram](image)

**Figure 4. Voiced posterior fricative in Puerto Rican Spanish, *cinco jamones* ‘five hams’.

One of the claims made by Sosa is that the phonemic posterior fricative is never reduced to the point of total elision. We found 70 tokens in our corpus that were reduced to the point of no identifiable acoustic cues. Figure 5 is an example of a reduced token in the word *vegetales* ‘vegetables’.

![Waveform and spectrogram](image)
4.2. Distribution of tokens

For the purposes of characterizing the distribution of tokens, we have limited ourselves to the distinction between voiced and voiceless realizations due to the difficulty in identifying exact places of articulation. The bar graph in figure 6 presents the distribution of voiced and voiceless allophones by all speakers according to the post-pausal or phrase medial context. In the post-pausal context\textsuperscript{11} we can clearly see a preference for a voiceless realization of phonemic /h/ similar in voicing quality to the standard Spanish voiceless velar fricative and corresponds to the canonical characterization of voicelessness of this phone.

The post-pausal context was consistently produced as voiceless, whereas phrase internal the realization is consistently produced with vocal fold vibration in 90.4% of the cases. Figure 6 provides clear evidence of the near categorical nature for allophonic variation based on voicing.

\textsuperscript{11} This also includes those realizations produced with a previous pause despite the intention of being phrase medial. Additionally, we also had a few cases in which the speakers would vocalize prior to beginning the target utterance. For example they might say something such as \textit{y y y y Juan invitó a Olga} ‘aaannnnnnnd Juan invited Olga’. The cases in which there was vocalization up to the point of the first target word were considered as no longer a post-pausal context.
Figure 6. Distribution of allophones by voicing according to context.

In figure 7 we present the distributions of voiced and voiceless variants by context and by sex of the speaker. We can see that the distribution of variants is consistent for the two sexes with variation between the contexts and realizations.

Figure 7. Allophones by phrase position context and by speaker sex.

We found a total of 61 tokens of elided /h/ in both contextual positions: 10.7% when there was a preceding pause and 2.8% when there was a preceding segment (figure 6). To determine if the elisions were the result of unique or a particular speaker that may influence the distribution of tokens we examined the rate of elision for all speakers. Figure 8 shows the distribution of /h/ deletion by speaker. Most of the participants deleted /h/, except for participants f-01, f-07 and m-08 who were from San
Juan and were language teachers, and speaker F01 who worked in a university office setting prior to retirement. In terms of the words in which /h/ was deleted we found that the most common one was Juanito, with 20 tokens and Julieta with 14 tokens; however, /h/ was also deleted in other words, such as the names Angel, Josefina, Julia, Jorge, José and the words jugos, vegetales, ajonjoli, cajas, toronja and ajo. The two speakers that produced the larger number of elisions came from the higher age range. Most speakers produced some tokens of /h/ that were completely elided which demonstrates that the phenomena of deletion is not uncommon, even in a more formal speech act compared to spontaneous conversation. These results of, primarily in phrase initial position, may be due to lexical frequency; however, further investigation is needed taking into account this factor.

Figure 8. Distribution of /h/ deletion by speakers.

4.3. Linguistic and extra-linguistic variables

In order to identify the linguistic and extra-linguistic variables that significantly predicted /h/ voicing in our data, we performed a Generalized Estimating Equations (GEE) using SPSS. The GEE can perform a binary logistic regression while accounting for multiple responses per participant (Ziegler, 2011). The dependent variable was the voicing quality of /h/: (a) voiced, (b) voiceless. The three variables included in the regression were (1) preceding context, (2) stress, and (3) sex of the speaker. For the preceding context, we wanted to examine if a preceding voiced segment would predict the voicing of /h/. Thus, this variable was composed of the following levels: (a) voiced consonant, (b) vowel, (c) sibilant /s/, which was always produced as a voiceless segment in our data, and (d) pause. The following context was not analyzed in the statistical analysis because all of the tokens had a following vowel. The second variable examined was the stress of the syllable in which /h/ was produced: (a) unstressed syllable, and (b) stressed syllable. Finally, the last variable analyzed was a sociolinguistic variable, and had to do with the sex of the speaker: (a) male, and (b) female. In

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12 A possible explanation is that as language teachers they are more conscientious in their articulation with the result of fewer elisions.
13 Figure 8 shows the actual number of tokens in which /h/ was deleted by the speakers.
14 We did not include the deleted tokens in the statistical analysis due to the few cases in our data set.
Table 2 we can see that the only predictor selected as significant by the GEE in the regression was preceding context (p=0).

<table>
<thead>
<tr>
<th>Results of the GEE</th>
<th>( \chi^2 )</th>
<th>df</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preceding context</td>
<td>160.968</td>
<td>3</td>
<td>.0</td>
</tr>
<tr>
<td>Stress</td>
<td>0.213</td>
<td>1</td>
<td>.644</td>
</tr>
<tr>
<td>Sex</td>
<td>1.83</td>
<td>1</td>
<td>.176</td>
</tr>
</tbody>
</table>

Table 2. Factors predicting the voicing of /h/

4.4. Duration

Overall the durations of the phonemic voiceless posterior fricative were relatively consistent. Figure 9 shows the durations of the voiced and voiceless variant by phrase position.

![Figure 9: Duration of the phonemic voiceless posterior fricative by voicing quality and phrase position.](image)

We also analyzed the duration of the /h/ segment according to the position in the utterance (Figure 9). The mean duration of the voiceless allophone [h] was longer than the voiced [ɦ] in both post-pausal and phrase-medial position. We performed a two-way ANOVA in order to test if voicing (voiceless/voiced) and the position of the segment (post-pausal/phrase medial) had a significant effect on the mean duration of /h/ in our data. The results of this analysis first showed a partially significant interaction between voicing and position with a low effect size (\( f=(1) \) 5.019, \( p=.025, \eta^2=.005 \)).

This analysis also found that voicing had a significant main effect on duration (\( f=(1) \) 8.544, \( p=.004, \eta^2=.008 \)), which indicates that [h] had a significantly longer duration than [ɦ]. Position did not have a significant main effect on duration. The main effect found for voicing may also explain the significant interaction between voicing and position since this difference in duration according to

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15 The partial eta square (\( \eta^2 \)) measures the effect size. A small effect size is considered \( \eta^2<.01 \). This value reflects how much the independent variable affects the dependent variable (Larson-Hall 2010: 119).
voicing was more pronounced in phrase-medial position than in post-pausal position (figure 9). What is clear from this analysis is that voiceless realizations of /h/ are significantly longer than voiced productions. This result agrees with Marrero’s finding (1990) that voiced segments were shorter than voiceless realizations of [h] in Tenerife, Canary Islands.

4.5. Phonetic overlap between /h/ and /s/

While the current experiment was not designed to test the variable realizations of phonemic /s/, there were a number of the elicitation contexts that yielded an aspirated fricative realization that was both posterior and voiced. Our literature review found that the symbol [h] is used to represent the Puerto Rican posterior voiceless fricative, a voiceless velar fricative /x/ in other dialects of Spanish, and [h] is also the symbol used represent the aspirated form of the phonemic voiceless alveolar fricative /s/ → [h]. The specific context that was often produced with a voiced posterior fricative for the phonemic /s/ was when a coda /s/ was followed by a vowel in the next word as in dos espejos [do. fie.pe.fio] ‘two mirrors’ or illustrated in Figure 10.

We note that the amplitude of the waveform for the /s/ segment is far greater than that typically associated with a voiced alveolar fricative [z] and suggest that this realization is a variant of a voiced glottal fricative [ɦ] similar to the phonetic realization of /h/ in non-initial position. Concerning rates of /s/ aspiration in the pre-vocalic context, Alba (1990) provides data from Terrell (1978) for Dominican Spanish at a rate of 31% and López Morales (1983) for Puerto Rico at a rate of 40.7%. While we do not provide rates of aspiration for the resyllabified /s/ in this corpus of Puerto Rican Spanish, we do wish to make note of the fact that the examples in our corpus were regularly produced with voicing as illustrated in figure 10.

Figure 10. Sample waveform and spectrogram of voiced aspiration for phonemic /s/ and /h/ in the phrase camarones al ajillo ‘shrimp with garlic sauce’.
5. Discussion

5.1. Research questions

The first research question examined the possibility of systematic allophonic variation in the production of the Puerto Rican voiceless posterior fricative. Sosa assumed that the phonemic voiceless velar fricative in Caribbean Spanish was uniformly produced as a voiced posterior fricative with only 2% of his Venezuelan corpus being realized as velar and voiceless. Our data indicate that the realization of phonemic /h/ is conditioned by context. When preceded by a pause it is regularly produced as voiceless, and when preceded by some other speech sound, including consonants, it is regularly voiced. Through the use of an experimental elicitation task we were able to confirm the importance of preceding context on the realization of this phone.

The second research question dealt with the role of voicing as part of the allophonic distribution. We found that voicing plays a significant role in the allophonic variation exhibited for the voiceless posterior fricative in Puerto Rican Spanish. This variable allophonic voicing is similar to another fricative voicing assimilation rule commonly accepted in Spanish phonology, namely, the voicing of /s/ when followed by a voiced consonant. While this rule of assimilatory voicing is not categorical, most reports recognize the process as highly productive (see Schmidt and Willis 2011 and Sedó this volume for further discussion of variation).

Our data indicate that there is some degree of variability in the realization of these voicing patterns as we saw a reduction in the selection of a voiced variant following the voiceless alveolar fricative /s/. This finding may be unremarkable due to the high rates of /s/-aspiration and general coda consonant elision in this dialect. It is likely that the reductive processes involved in /s/-aspiration contribute to the variable nature of the posterior fricative voicing patterns which can also be seen as a reductive process. It is interesting to note that voicing of the voiceless posterior fricative is produced in the cases of a preceding voiced consonant. Sosa claimed that the voicing of the /h/ was due to assimilation in the voicing quality of the context.16

If the voicing of /h/ is indeed the result of an assimilation of the voicing quality of the previous segment, it does not follow normal patterns reported in Spanish17 as it appears to be a progressive assimilation being realized as voiced when the preceding segment is voiced, be that a vowel or consonant. Another possibility is that this phoneme is now best characterized as voiced and that this voicing is allophonically inhibited or stopped when it occurs in post-pausal position without invoking an assimilation process. Future tests of these claims can include a phrase final /h/ to determine voicing patterns in the forward direction of assimilation if present, as in reloj ‘watch’, although the potential set of test tokens is severely limited and the common pattern in Puerto Rican Spanish is to elide this phone.

Our next question considered whether speaker sex was a predictive sociolinguistic variable in the voicing of /h/. This question addressed Sosa’s (1980) claim that speaker sex played a role in voicing of this phoneme with middle class women producing more voiced tokens. However, our results indicate that gender is not a significant predictor of the production of [h] or [ɦ] since this variable was not selected as significant by the binary logistic regression. These results suggest that the voicing pattern observed might be generalized in this dialect since it is systematically associated with the context in which it appears. Nonetheless, more data is needed to confirm this claim of generalizability.

We note that there are dialects of Spanish that vary considerably in the voicing patterns of fricatives. For example, the Spanish voiced palatal fricative /j/ in Argentine Spanish has a consistent fricative realization. The voicing quality of this post alveolar fricative is correlated with several sociolinguistic variables, including sex (Chang, 2008, Fontanella de Weinberg, 1978). In our data, the lack of evidence of sociolinguistic variation by sex, and to a limited degree age, could be due to the fact that this voicing process is now generalized throughout this dialectal variety. We note that the ages of our informants ranged from 18 to 65 and that there was no variation by generation such as is

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16 Sosa does not clearly define what constitutes a voicing context.
17 The majority of the assimilations in Spanish are characterized as regressive assimilations as in nasal place assimilation and coda sibilant voicing (i.e. Hualde 2013, Quilis 1993).
reported in Argentine Spanish (Chang 2008, Rohena Madrazo 2011, Wolf and Jiménez 1979). Additional data controlling for a greater number of sociolinguistic variables is necessary before concluding that sociolinguistic variables play no role in the voicing of /h/ in Puerto Rican Spanish.

The role of dialectal variation in the realization of the /x/ or /h/ will have to wait for additional data and comparison with other dialects. However, the current study provides a baseline of allophonic patterning with which to compare. It would be useful to examine dialects that have also been characterized as having a voiceless glottal fricative as the primary variant as well as a dialect in which dialectal characterizations correspond to traditional Spanish norms. Nonetheless, we can compare a portion of our dataset with the results of Torreira and Ernestus and their corpus of Madrid conversational Spanish (2011). They found that the intervocalic voiceless fricatives in Madrid Spanish were often realized as voiced in spontaneous speech. Their characterization of voicing was 100% of the segment. Our speech corpus with over 1000 tokens indicates much higher rates of voicing of the velar fricative compared to voicing of all the fricative segments in their corpus, namely, /f, θ, s, x/, which at most reached voicing rates of 34% for the alveolar fricative /s/. Whereas the Madrid corpus exhibits voicing in a subset of intervocalic tokens, our Puerto Rico dataset indicates that 95% of the /h/ tokens in intervocalic position were realized as fully voiced variants. Regardless of the actual fricative place of articulation for the phonemic /h/ in Puerto Rican Spanish, these differences indicate a substantial variation from peninsular Spanish and the limited characterizations from other varieties.

Another point that can be considered with the current data is the characterization of this phone in Puerto Rican Spanish as a “weak aspiration” by Lipski (1994: 333). This characterization by Lipski likely captures the posterior realization and the presence of voicing which makes the segment more similar to adjacent sounds which are typically vowels. Increased intensity of the waveform combined with voicing contributes to a more vowel-like production (Carrasco et al 2012) which may cause the aspiration to be perceived as “weak”. Whereas the perceptual awareness of this phone as different is correct, our current data and analysis can now suggest that this perceptual characterization is due to the presence of voicing.

5.2. Implications for the system

As previously noted in the review of literature, Spanish /s/ is often produced as aspiration in coda position. Puerto Rican Spanish is claimed to regularly aspirate in coda position and this /s/ aspiration is repeatedly described as an [h]. There are also several accounts of a morphological coda /s/ that resyllabifies into a syllable onset resulting in an [h] allophone, as in, los otros [lo.ho.tɾoh] ‘the others’ (see also Figure 10). The phonetic symbol for this sound realization is the same symbol that is regularly used for characterizing the phonemic voiceless posterior fricative /h/.

Another phoneme with a posterior fricative realization in Puerto Rican Spanish is /ɾ/. Current work (this volume) on the perception of the posterior fricative associated with /ɾ/ by Delgado-Díaz and Galarza suggest that variations in voicing patterns serve to distinguish between the phonemic voiceless posterior fricative /h/ and the retracted phonemic trill of Puerto Rican Spanish that is typically realized as a velar or uvular fricative. However, this voicing distinction only occurs in intervocalic position, where /h/ is regularly produced as voiced and the retracted /ɾ/ is produced as voiceless. In post-pausal contexts, where both are realized as voiceless, native Puerto-Rican listeners distinguish between them at chance-level. Therefore, in specific contexts the presence of voicing serves to distinguish between /ɾ/ and /h/. Similar phonetic realizations for intervocalic /h/, posterior /ɾ/ and coda /s/ provides evidence of potential challenges for non-Puerto Ricans to distinguish between specific variants of /ɾ/, /h/, and intervocalic /s/ and underscores the role and importance of voicing as a cue for contrast within

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18 We did not investigate generational groups explicitly as we did not have a balanced distribution of members due to challenges in recruiting older speakers and time limitations. However, and most importantly, we did find the described voicing patterns among all speakers.
19 We acknowledge that several recent papers have suggested that the realization of the /s/ in Puerto Rican Spanish in intervocalic position can also be produced as a glottal stop (Valentín-Márquez 2006).
20 This is often derived from cases of coda /s/ and the process of resyllabification as in camarones al ajillo ‘shrimp with garlic sauce’ shown in Figure 10.
the fricative system of Puerto Rican Spanish. The potential for neutralization and contrast maintenance between the /r/ and /h/ in Puerto Rican Spanish, both with fricative allophones, indicates another area of overlap between manner and place of articulation that can partially be resolved by voicing.

Based on the IPA symbols used to characterize the allophones of the previously described phonemes of /s/, /h/, and /r/, the potential phonetic mappings and resultant overlaps/neutralizations include:

![Phonemic mappings to fricative allophones](image)

Figure 11. Phonemic mappings to fricative allophones

The use of an identical phonetic symbol for two, and sometimes three, supposedly distinctive phonemes raises two specific questions. The first question is whether or not these two sounds exhibit a contextual neutralization as in nasal place of articulation assimilation in coda position, and the second, does the symbol usage [h] accurately represent the phonetic reality of these two phones. As shown in figure 11, an intervocalic /s/ produced with voiced aspiration (voiced glottal fricative) due to resyllabification can be produced as a variant that looks remarkably similar to the voiced variant of /h/ in intervocalic position. The current finding suggest that there may be contextual neutralizations in Puerto Rican Spanish between /s/ and /h/ in intervocalic position, similar to that argued for /r/ and /h/ in phrase initial position proposed by Delgado-Díaz and Galarza (this volume) based on perceptional research.

6. Conclusions

Our findings indicate a clear allophonic distribution for the posterior voiceless fricative in Puerto Rican Spanish; [h] occurs in post-pausal contexts and [ɦ] occurs between voiced segments. Although we do not characterize the exact point of articulation of the /h/ we draw particular attention to the allophonic patterns and variation in voicing of /h/ in Puerto Rican Spanish and note that the IPA symbols [h] and [ɦ] should be used to reflect voicing patterns present in San Juan and Caguas.

We found the same voicing allophonic pattern in men and females which suggests that this voicing allophony is widely diffused in this dialect. We hypothesize that this voicing process, or variation in voicing, may be employed to avoid possible neutralizations with other phonemes that share a similar posterior place and manner of articulation in certain contexts with other segments. Finally, our research demonstrates the role that voicing can play in allophonic distributions that have been typically characterized as voiceless and highlights the importance of considering this feature in variationist studies of Spanish.

References


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