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When *hat* Becomes *rat*: The Perception of English /h/ and /ɹ/ by Brazilian Portuguese Speakers

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Abstract

This study investigates how speakers who have Brazilian Portuguese (BP) as their L1 and English as their L2 perceive the phonetic distance of English /h/ and /ɹ/, and how they and monolingual BP speakers map these phonemes onto BP sound categories. 32 native BP learners of English participated in three consecutive experiments: the AXB discrimination test, the identification test and the assimilation test. In addition, 18 monolingual BP speakers participated in the same assimilation test. Lower and higher proficiency groups were able to hear the distinction acoustically. Only the higher proficiency group used the distinction to identify English words. Monolingual BP speakers and the higher proficiency group assimilate English /h/ primary to BP /h/. However, the phonological environment had an effect for monolinguals, but not for the higher proficiency group. The lower proficiency group, which one might expect to fall in between these two groups, showed a failure to assimilate L2 sounds to their L1 BP categories.

Phonetic segments that are considered phonemically distinct in L2, but not in L1, are not easily perceived as separate phonemes by L2 learners (Aoyama, Flege, Guion, Akahane-Yamada, & Yamada, 2004). Brazilian Portuguese (BP) learners of English, for example, have difficulties in

differentiating between initial English retroflex [ɹ] and glottal fricative [h], even though similar phonetic segments to both phonemes occur in BP (e.g., Osborne, 2010; Zimmer, Silveira, & Alves, 2009). These two phonemes are allophones when they occur in syllable-final and word-final positions in PB. The BP rhotic sound in these positions can also be pronounced as a velar fricative [x] (e.g., Marta may be pronounced as [mah.ta], [maɹ.ta] or [max.ta]). In word-initial position, the BP rhotic sound can be pronounced allophonically as a glottal fricative [h], a velar fricative [x], and a trill [r], but not as a retroflex (Cristófaro Silva, 2007). The variation on pronunciation of the BP rhotic sound is related to both linguistic (e.g., position of the rhotic sound in the syllable) and extralinguistic factors, such as regional dialect and age (e.g., Botassini, 2009). Whereas the BP [h] sound is considered standard, the production of retroflex is a variant.

There is an important cross-linguistic phonological difference: In Portuguese, [h] is considered a rhotic sound (Cristófaro Silva, 2007), whereas in English it is not. The primary goal of this study is to investigate how BP learners of English and monolingual BP speakers perceive the English /ɹ/ and /h/ word-initially, and how they map them onto BP categories over the trajectory of language learning. Considerations on assimilation when familiar non-standard varieties and L1 restriction on environment are involved are discussed.

THE PRESENT STUDY

The main goal of this study is to investigate the perceived phonetic distance of English /h/ and /ɹ/ by Brazilian Portuguese (BP) speakers, both monolinguals and English learners. This study was conducted as follow: First, participants were asked to answer a background questionnaire and read some English sentences, which were later used to define their level of proficiency more objectively. After that, they took part in three consecutive experiments. In an AXB discrimination test (experiment 1), the L2 perceptual phonological competence between English /h/ and /ɹ/ was assessed. In an identification test (experiment 2), word recognition was investigated. In an assimilation test (experiment 3), participants classified and judged the similarities between L2 sounds according to their first language. A separate group of monolingual BP participated only in the assimilation test (experiment 4). All the experiments were done in PRAAT version 5.2.23 (Boersma & Weenink, 2011) and the instructions for the experiments were in Portuguese.

This study aims to answer the following research questions:

1. Can BP learners of English distinguish acoustically English /h/ and /ɹ/ word-initially?
2. Are BP learners of English able to distinguish the target segments in words?
3. How are English /h/ and /ɹ/ categorized in BP by L2 learners and monolinguals?

Speech Materials

The speech materials used in all experiments were produced by a male native speaker of English (age = 59) from New York City. The speaker read a list of words with initial /h/ or /ɹ/, followed by the /ɪ/, /æ/, and /o/ (e.g., *hick/rick; hat/rat; hole/role*). The words were inserted in a carrier phase (_____ *is a word*) in order to ensure similar intonation. The recording was made in a sound-proof booth at the University of Arizona. The speaker was asked to produce these sentences at a natural speech rate. Only the words with the target phonemes were used as stimuli. They were spliced off from the frame sentence at the onset of voicing of the following vowel for 'is'. There were a total of 30 pairs (60 words), divided into three groups according to the subsequent vowel.

Accent Rating

Brazilian Portuguese learners of English were asked to read a series of eight sentences, extracted from a beginner ESL book (*Let's Talk 2,* Jones, 2008). These sentences were then used as stimuli for an accent rating task, and a comparison with self-reporting proficiency was conducted. The recordings were done using the software PRAAT version 5.2.23 (Boersma & Weenink, 2011), a headmounted microphone, and a Shure FP23 Battery Powered Microphone Preamplifier, and they were done directly to the researcher's computer in a quiet room.

The accent rating data was collected using the ALVIN experiment presentation software version 1.27 (Hillenbrand, 2007). Only the four middle sentences produced by the participants were used for rating (the first two and last two sentences were not used). A total of 21 raters (monolingual speakers of English) judged the participants' accent in a continuing scale from 'no accent' (1) to 'heavy accent' (7).

Cronbach's alpha, used to calculate the inter-rater consistency, was 0.976, which shows a strong reliability. The measurement error, or error

variance, was only 2.4%, whereas the result was 97.6% consistent. To determine which groups differ from each other, pair-wise comparisons of basic to intermediate and intermediate to advance were conducted. There was a significant difference between beginners and the intermediate and advanced groups ($F(2,29) = 35.254$, $p < 0.001$), but no significant difference was found between intermediate and advanced groups ($F(<1)$. In order to divide participants into two groups of proficiency (lower and higher), the cut-off was set at 4.5, so that the two groups would have a relatively equal number of participants (13 lower, 19 higher). This division (based on accent ratings rather than self-rating) was used for data analyses of all experiments in which BP learners of English participated.

Experiment 1 – AXB Discrimination Test of BP Learners of English

The AXB discrimination test aims to assess L2 perceptual phonological competence between English /h/ and /ɹ/. It aims to answer the following question: Can BP learners of English acoustically perceive English /h/ and /ɹ/ as the same sound?

Participants heard a sequence of three English tokens (e.g., *hat*/*hat*/*rat*) (see Speech Materials section for details). Using a mouse-click response, they chose a word that was more similar to the word in the middle. If they found the word in the middle more similar to the first word, they clicked number 1 in a box on the left; if they found it more similar to the third word, they clicked number 3 in a box on the right. The stimuli were organized into randomized trials of 3 tokens, in which either the first token or the third token was the same as the on in the middle. The experiment was run in a quiet room either at an English school or at home. There were 32 participants and 120 randomized triads for a total of 3,840 responses.

Results and discussion of the AXB discrimination test

The data on discrimination of English /h/ and /ɹ/ by BP learners of English were analyzed using a 2-factor mixed ANOVA, with with phonological environment (target phoneme followed by the vowels /ɪ/, /æ/, /o/), and direction of match (left, right) as the within-subject factor, and proficiency (lower, higher) as the between-subject factor. The proportion of correct responses was the dependent variable.

The main effect of following phoneme ($F(2,60) = 6.76$, $p < 0.05$) was significant, with higher accuracy for leftward matches than rightward

matches before /æ/ and /o/ vowels than before the high vowel /ɪ/. Main effect of proficiency was not significant ($F(1,30) = 2.09$, $p > 0.05$). There was no significant interaction between proficiency and the following phoneme ($F<1$). The following phoneme /ɪ/ seems to be the most difficult phonological environment for the lower group, whereas /æ/ and /o/ look more similar, suggesting that high front vowels could be the hardest environment for discrimination. Although there was a main effect of following phoneme, the primary finding of this experiment is that both groups of listeners were rather successful at discriminating English /h/ and /ɹ/ (see Figure 1). Participants did well, reaching a ceiling effect (both listener groups scored above 90% correct in almost all conditions, despite their difference in accentedness). Therefore, the main conclusion about the AXB discrimination test is that BP learners of English are able to auditorily discern the English /h/ and /ɹ/ contrast.

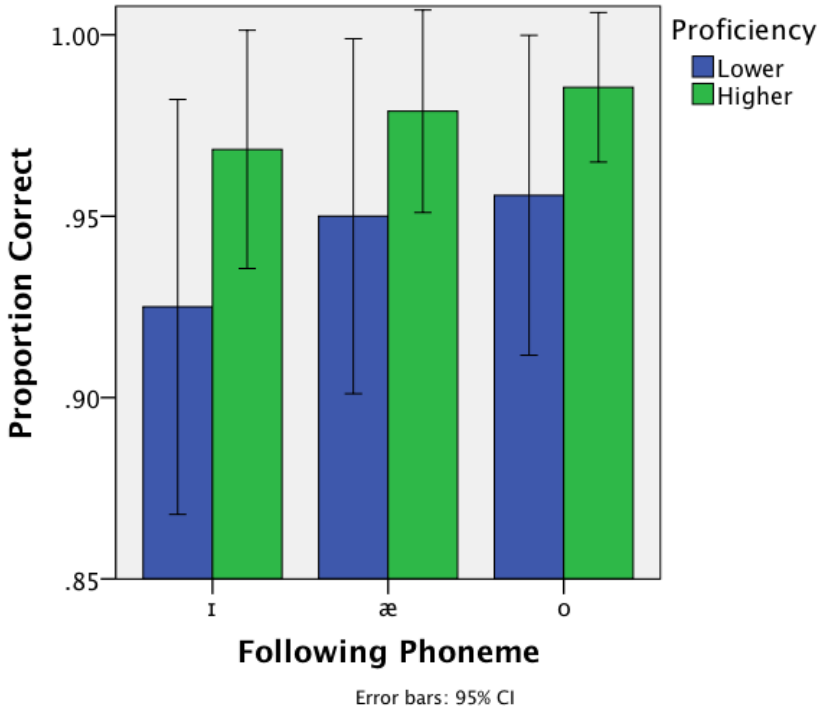

Figure 1. Results of Experiment 1: Brazilian Portuguese learners of English, accuracy on AXB discrimination of English /h/ and /ɹ/, by English proficiency level and following vowel.

Experiment 2 – Identification Test of BP Learners of English

In order to investigate word recognition with the target phonemes, an identification task was conducted. The task aims to answer the following

question: Can BP learners of English identify words with the target segments?

The same participants from experiment 1 participated in experiment 2, except one whose data was lost due to computer error. The words used in experiment 2 were the same ones used in experiment 1 (see Speech Material section for details). The experiment was run in a quiet room either at an English school or at home, and it was done after the completion of experiment 1. Using a mouse-click response, participants were asked to click on the word they heard by choosing from six written words on the screen (e.g., *hick, him, hip, rick, rim, rip*). The words displayed on the screen were blocked by the following vowel (/ɪ/, /æ/, /o/). In each of the three blocks, there were 12 trials, making a total of 36 randomized trials. There were 31 participants (13 lower and 18 higher) in this experiment, resulting in 1,116 responses.

Results and Discussion of the Identification Test

The data on the identification experiment was analyzed using a 3-factor mixed design ANOVA, with target phoneme (/h/, /ɹ/) and following phoneme /ɪ/, /æ/, /o/) as the within-subject factors, and proficiency (lower, higher) as the between-subject factor. The proportion of correct responses was the dependent variable.

The main effect of target phoneme was significant ($F(1,29) = 73.57$, $p < 0.001$), whereas the main effect of following phoneme and proficiency were not significant (following phoneme: $F<1$; proficiency: $F(1,29) = 3.98$, $p > 0.05$). All the 2-way interactions were significant (target by proficiency: $F(1,29) = 89.81$, $p < 0.001$; following phoneme by proficiency: $F(2,58) = 5.28$, $p < 0.05$; following phoneme by target: $F(2,58) = 3.20$, $p < 0.05$). The 3-way interaction was not significant (following phoneme by target by proficiency: $F(2,58) = 2.90$, $p > 0.05$). Because of the interaction, the 2-factor design of target phoneme and following phoneme were analyzed for each proficiency level (lower, higher). For the lower level, no effects were significant (target: ($F<1$); following phoneme: $F(2,24) = 1.36$, $p > 0.05$); following phoneme by target: $F(2,24) = 2.93$, $p > 0.05$. For the higher level group, the two main effects were significant: target: ($F(1,17) = 284.62$, $p < 0.001$) and following phoneme ($F(2,34) = 5.87$, $p < 0.05$). The 2-way interaction, however, was not significant ($F<1$). The results showed that the higher proficiency group could identify the distinction between /h/ and /ɹ/ in words, whereas the lower proficiency group could not (see Figure 2), since they could not map what they heard onto the correct

English word. It is, however, more difficult for the higher group to identify the target phoneme in words when they occur before /æ/, since both target phonemes seem to sound more like as an English retroflex for listeners.

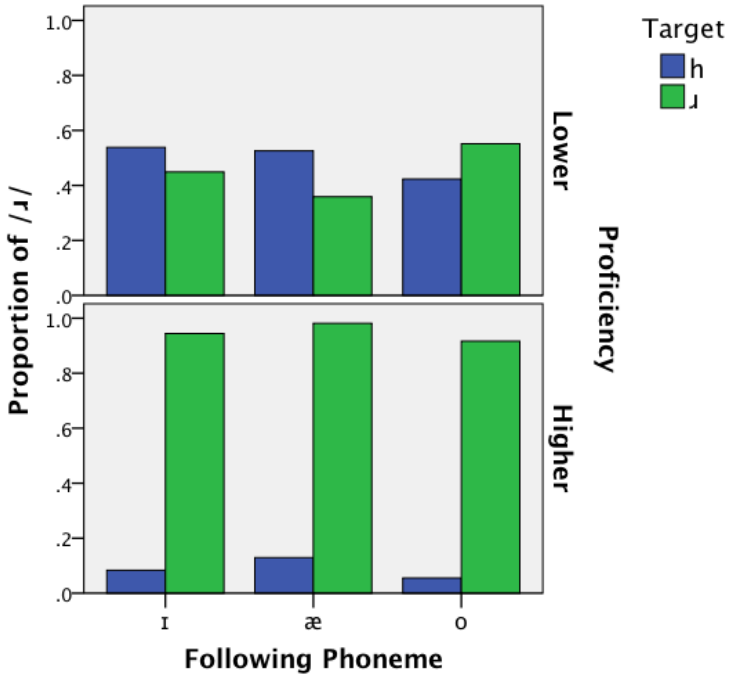

Figure 2. Results of Experiment 2: Brazilian Portuguese learners of English, proportion of English /ɹ/ identified in words, by English proficiency level and following vowel.

Experiment 3 – Assimilation Test of BP Learners of English

It is not clear how BP speakers would map these sounds according to the Portuguese category. An assimilation test for BP learners of English was then conducted. The goal was to answer the following question: How do BP learners of English classify and judge the similarities between the English phonemes /h/ and /ɹ/ according to the Portuguese category?

The same participants who took part in experiments 1 and 2 also participated in the assimilation test. However, only 28 participant responses were considered due to missing data (12 lower, 16 higher). The same words used in experiment 1 and 2 were also used in experiment 3 (see Speech Materials section for details). The experiment was run in a quiet room either at an English school or at home, and it was done after the completion of experiments 1 and 2. There were18 trials, which means that, from the total of 60 words used in the experiment, each participant

heard 18 words. The words were randomly assigned and participants heard them only once. Participants were asked to match the initial sound of the English words they heard with one of the two Portuguese categories: BP /h/, represented on the screen by the word foRRó ('a Brazilian dance'), or BP /ɹ/, represented on the screen by the word poRta ('door'). Participants were asked to choose between the two BP rhotic categories according to their perception of similarities between them and the English /h/ and /ɹ/. The responses that participants gave when choosing BP /h/ or BP /ɹ/ were the dependent factors in this analysis. Immediately after mapping the sounds, the participants rated the identification for goodness-of-fit to the Portuguese category, using a scale from 1 (not similar) to 5 (very similar). There were 18 trials in this experiment; the total of responses from all participants was 558 for mapping and 558 for goodness.

Results and Discussion of the Assimilation Test of BP Learners of English

The data on the assimilation test were analyzed using the same statistical design as experiment 2. There was a significant main effect of target phoneme ($F(1, 26) = 29.142$, $p < 0.001$) and the other main effects were not significant (following phoneme: $F(2, 52) = 1.810$, $p > 0.05$; proficiency: $F(1, 26) = 2.717$, $p > 0.05$). Only one of the 2-way interactions was significant (target by proficiency: $F(1, 26) = 14.301$, $p < 0.05$). The other 2-way interactions (following phoneme by proficiency: $F(2, 52) = 2.559$, $p > 0.05$; target by following phoneme: $F<1$) and the 3-way interaction (target by following phoneme by proficiency: $F<1$) were not significant. In the follow-up tests, the simple effect of target phoneme was checked for each proficiency level (lower, higher), collapsed across phonological environment, since phonological environment did not participate in any significant interaction. The result showed that there was a significant simple effect of target phoneme for the higher group only ($F(1, 15) = 61.332$, $p < 0.001$), but no simple effect of target phoneme for the lower group ($F<1$).

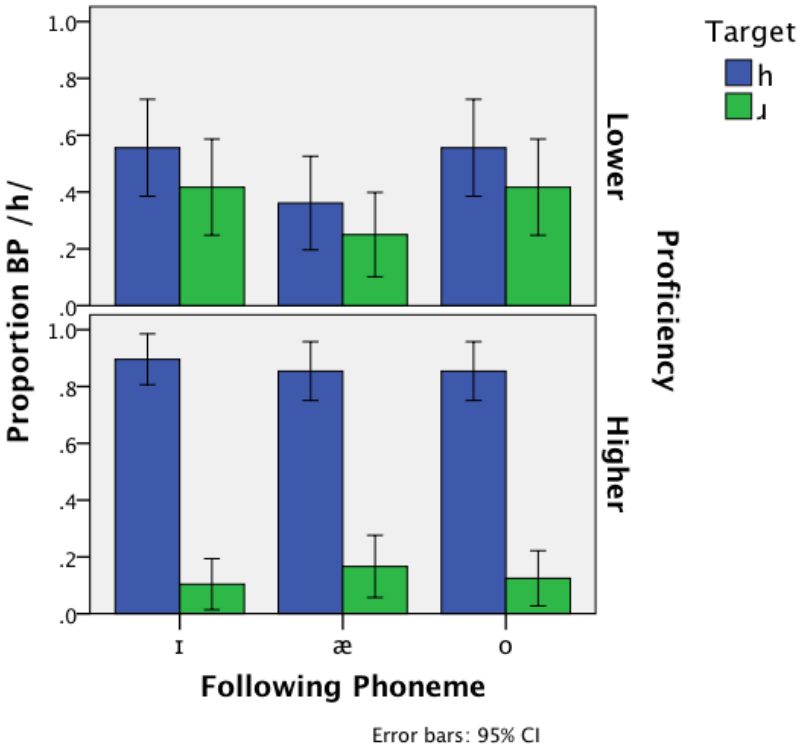

Figure 3. Results of Experiment 3: Brazilian Portuguese learners of English, proportion of responses on mapping of English /h/ and /ɹ/ to Brazilian Portuguese /h/, by English proficiency and following vowel.

Following Guion, Flege, Akahane-Yamada, and Pruitt (2000), the responses from the goodness-of-fit of experiment 3 were analyzed in terms of overall fit to the Portuguese categories in order to obtain the fit indices. According to Guion et al., the fit index is derived from multiplying the proportion of responses to a modal identification (the most frequent category used for the classification) by the goodness-of-fit rating. Relatively high fit indices would represent instances of BP categories, whereas low fit indices would represent deviant instances of BP categories.

For the lower proficiency group, both English phonemes are equally good exemplars of BP /ɹ/ (fit index for /h/ is 1.65 and for /ɹ/ is 1.63). Only /h/ is a good exemplar of BP /h/ (fit index is 1.71), whereas /ɹ/ is a poor exemplar for BP /h/ (fit index is 0.9). For the higher proficiency group, both English phonemes are assimilated to two different BP categories: /h/ is a good exemplar of BP /h/ (fit index is 3.61), whereas /ɹ/ is a good exemplar for BP /ɹ/ (fit index is 2.47). Although the lower proficiency group mapped both English target phonemes onto both BP categories

without distinction, the goodness-of-fit results showed that they perceive /h/ as being a better instance of the BP /h/. The high proficiency group classified and rated /h/ and /ɹ/ as being good instances of BP /h/ and BP /ɹ/ respectively.

Although the lower group matched both target phonemes to the BP /h/ about equally often, the goodness-of-fit analysis showed that only English /h/ is considered a good exemplar of BP /h/. On the other hand, the higher group mostly matched English /h/ with the BP /h/, showing that they assimilated the English /h/ sound to the BP /h/ most of the time. This result is supported by the goodness-of-fit analysis, which shows that the English /h/ and /ɹ/ are good exemplars of BP /h/ and /ɹ/ respectively.

The assimilation test for BP learners of English shows that the lower and higher groups behave differently regarding mapping the target phonemes to the BP phonemes (see Figure 3). Whereas the higher group assimilates both target phonemes to two different BP phonemes, the lower group assimilates both sounds to both BP phonemes without distinction.

Experiment 4 – Assimilation Test of Monolingual BP Speakers

The same assimilation test taken by BP learners of English (see Experiment 3 section for details) was also conducted with monolingual BP speakers, who had very little or no experience with English. The goal was to make a cross-language mapping experiment in which participants were asked to identify English sounds in terms of Portuguese category, and then rate the identification for goodness-of-fit to the Portuguese category. There were 18 participants, which resulted in324 responses for mapping and 324 responses for goodness.

Results and Discussion of the Assimilation Test of Monolingual BP Speakers

The classification data on assimilation test of monolingual BP were analyzed using a (3)x(2) 2-factor within-subject design ANOVA, with phonological environment (/ɪ/, /æ/, /o/) and target phoneme (/h/, /ɹ/) as the within-subject factors. The result showed that there was a main effect of following phoneme ($F(2, 34) = 6.722$, $p < 0.05$) and target phoneme ($F(1,17) = 31.730$, $p < 0.001$). The 2-way interaction was also significant (target by following phoneme: $F(2, 34) = 4.705$, $p < 0.05$). In the follow-up tests, the simple effect of target phoneme was checked for each phonological environment (/ɪ/, /æ/, /o/). The result showed that there was a significant

simple effect of target phoneme for all 3 phonological environments (environment /ɪ/: $F(1, 17) = 11.102$, $p < 0.05$; environment /æ/: $F(1, 17) = 43.456$, $p < 0.001$; environment /o/: $F(1, 17) = 8.768$, $p < 0.05$), with higher accuracy when target phonemes were followed by /æ/.

In order to confirm the assumption that monolingual BP speakers seem to make a greater distinction before /æ/ environment than before the other two environments, an interaction comparison - a (2)x(2) 2-factor within-subject design -, considering only /ɪ/ and /o/ environment, was conducted. The result showed that there was a main effect of phonological environment and target phoneme (environment: $F(1, 17) = 8.566$, $p < 0.05$; target phoneme: $F(1, 17) = 15.179$, $p < 0.05$). The 2-way interaction was not significant (phonological environment by target: $F<1$). This indicates that the simple effects of /ɪ/ and /o/ environment do not differ significantly, that is, they are equally harder for monolingual BP speakers to make the distinction between the two English phonemes (see Figure 4). The main effect of the following phoneme is, therefore, due to the /æ/ environment, which was the environment which monolingual BP speakers made more distinction.

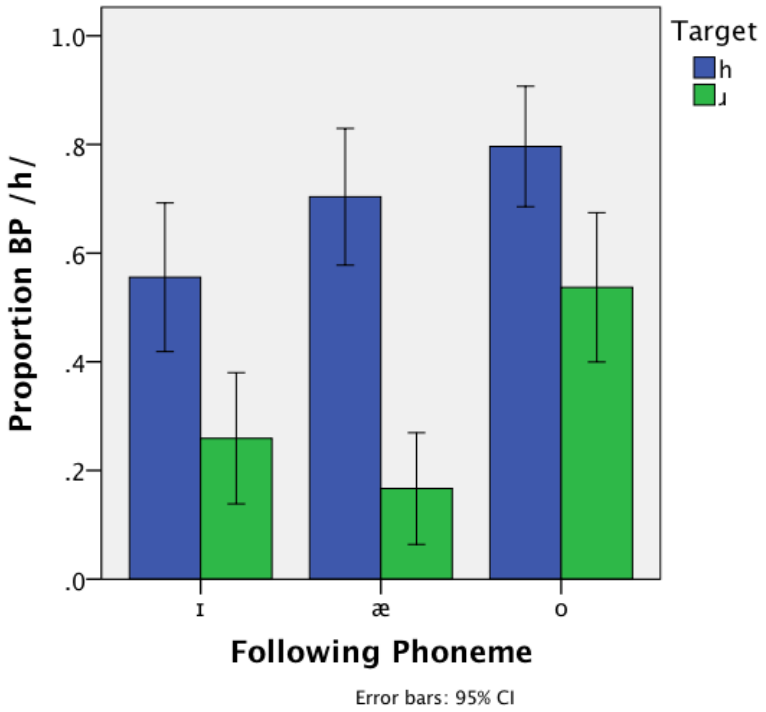

Figure 4. Results of Experiment 4: Monolingual Brazilian Portuguese, proportion of responses on mapping of English /h/ and /ɹ/ to Brazilian Portuguese /h/ by following vowel.

Following Guion et al. (2000), the responses from the goodness-of-fit of Experiment 4 were also analyzed in order to obtain the fit indices. The results show that monolingual BP speakers consider English /h/ as being a good exemplar of BP /h/ (fit index was 2.29) and English /ɹ/ as a good exemplar of BP /ɹ/ (fit index was 2.17). On the other hand, English /h/ was rated as a poorer instance of BP /ɹ/ (fit index was 1.03) and English /ɹ/ was considered a poorer instance of BP /h/ (fit index was 0.96). This result supports the monolingual BP speakers' classification of the English target phonemes as two different BP phonemes

General Discussion of the 4 Experiments and Conclusion

The results of this study showed that BP learners of English can acoustically distinguish the English glottal fricative and retroflex in word-initial position, independent of their proficiency level (Exp. 1). The fact that the lower proficiency group can distinguish acoustically the target phonemes might not have come as a surprise, since these two sounds are acoustically very different: /h/ is an aperiodic turbulent noise produced at the glottis, and the American English retroflex is produced with three vocal tract constrictions: labial, coronal, and pharyngeal, and it has an uncommonly low frequency for F3 (e.g., Johnson, 2012). Moreover, although these two sounds are allophones of the same phonemes in BP, sociolinguistically they are perceived as different sounds by native speakers. Whereas glottal fricative is considered standard, retroflex is mainly considered a stigmatized pronunciation (e.g., native speakers tend to relate retroflex to less-educated speakers) (Taylor and Eddington, 2006). Therefore, as expected, participants did well in experiment 1, independent of their level of proficiency.

Identification test (Exp. 2) investigates the L2 perception of the target phonemes when lexical components are added. The two groups of L2 learners (lower and higher) behaved differently. Although the lower group can distinguish the target phonemes acoustically, as demonstrated in Exp. 1, they cannot identify the sounds in words; on the other hand, the higher group can. However, phonological environment has an effect: It is harder for the higher group to identify the phonemes after /æ/. In the absence of lexical information, L2 leaners perform in a similar way across the target phonemes, regardless of their level of proficiency. However, when lexical components are added, the lower and higher groups perform asymmetrically.

In the assimilation test of BP learners of English (Exp. 3), the high proficiency group assimilates the English /h/ to BP /h/, and the English /ɹ/ to BP /ɹ/ most of the time. The goodness-of-fit rating confirms that the English phonemes are good exemplars of these two BP categories. On the other hand, the lower proficiency group assimilates both /h/ and /ɹ/ to BP /h/ and BP /ɹ/ without distinction, although there is a non-significant tendency to perceive the glottal sound more as a BP /h/. The goodness-of-fit rating shows that in fact /h/ is a better BP /h/, whereas /ɹ/ is a good exemplar for both BP /h/ and /ɹ/.

The same assimilation test was also conducted with monolingual BP speakers (Exp. 4). Monolinguals assimilate both English phonemes /h/ and /ɹ/ to two different BP phonemes. Results from the goodness-of-fit rating confirm English /h/ as a good exemplar of BP /h/, and English /ɹ/ as a good exemplar of BP /ɹ/. Phonological environment has a significant effect for monolingual BP speakers: It is easier for them to distinguish the target phonemes when they occur before /æ/, and it is harder before /o/ and /ɪ/.

Although both monolingual BP speakers and the higher group (but not the lower group) performed in a similar fashion in the assimilation test (assimilating the two English target phonemes to two different BP phonemes), monolinguals and the L2 learners do not seem to be using the same resources for mapping non-native sounds to the L1 phonemes. For monolinguals, the preceding vowel matters, whereas for the higher group, the phonological context does not make a difference in their performance of the task. Monolinguals, who do not know any English, seem to use phonetic cues as their primarily resource, whereas the higher group might be demonstrating effects of learning from instruction (e.g., in a formal setting, they could have learned to map the phonemes to the corresponding graphemes).

The phonetic knowledge exhibited by monolinguals is not demonstrated by the lower group. There is an apparent sense that L2 learners "lose" this ability when they start studying English. There are some issues to consider that might help explain this behavior. For instance, learners have to learn to associate a familiar sound with a new phonetic environment (e.g., in BP, /ɹ/ is not pronounced word-initially, whereas in English it is). "The main obstacles for learners to utilize familiar L2 sounds in a new system are due to their different distributions in the two languages in question" (Zybert, 1997, p. 103). Best and Tyler (2007) cite the example of English L2 learners of French. Although English /r/ is phonetically different from French /r/, L2 learners recognize the French /r/ as being phonologically equivalent to English /r/. Orthography

may contribute to the bias; however, "different phonetic realizations may be learned for the phonological /r/ of each language" (p. 28).

In order to help learners overcome this challenge, teacher intervention can be beneficial (e.g., Zybert, 1997; Zimmer, Silveira, & Alves, 2009). In this study, the higher group seems to show effects of training and of pedagogical intervention. Therefore, the apparent lack of positive transfer of this phonetic knowledge might be linked to the difference in their proficiency, since the higher group is able to assimilate the target sounds as two different phonemes.

Another possible reason for L2 learner difficulties might be related to the influence of the orthographic knowledge. English phonemes /h/ and /ɹ/ are considered rhotic sounds in BP, that is, they are linked to the orthographic 'r', whereas the orthographic 'h' is silent. Although this study does not investigate the influence of orthography, a number of studies have shown that L1 orthographic knowledge can have an effect on both perception and production of a second language (e.g., Silveira, 2009; Escudero & Wanrooij, 2010; Simon, Chambless, & Alves, 2010). For instance, Hayes-Harb, Nicol, and Barker (2010) showed evidence that learning new phonological forms in another language is affected by orthographic information that learners have from their L1.

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