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Perception of English Word-Final Unreleased Consonants by Brazilian EFL Learners

Reiner Vinicius Perozzo
Federal University of Rio Grande do Sul

Ubiratã Kickhöfel Alves
Federal University of Rio Grande do Sul

Abstract

This study investigates how Southern Brazilian EFL learners perceive the distinctions concerning place of articulation in unreleased voiceless stops [p̚], [t̚], and [k̚] in word-final position in English. Thirty-two undergraduate students of English in two levels of proficiency (basic and intermediate), from the Federal University of Rio Grande do Sul, Brazil, participated in this research study. In order to determine the perceptual accuracy regarding the place of articulation of the three consonants, we carried out two perceptual tasks with CVC words, equally distributed according to the vowels [i], [ɪ], and [æ]. The results show that: (a) the final segments [p̚] and [k̚] are perceived more accurately than the final segment [t̚]; (b) there were greater levels of accuracy in both tasks when the nuclear vowel was lax; and (c) the level of proficiency of the participants was not crucial to ascertain perceptual accuracy.

In Brazilian Portuguese, stop consonants are not allowed in final position. In English, on the other hand, not only are final stops allowed, but they may also be produced without an audible release. In fact, unreleased final stops constitute one of the most common patterns found in English phonology (Selkirk, 1982; Yavaş, 2006; Celce-Murcia, Brinton, & Goodwin, 2010; Davidson, 2011). In order to distinguish the places of articulation of final unreleased consonants (i.e., *sip* – *sit* – *sick*), speakers have to rely on a very important acoustic cue: formant transitions in the preceding vowel, which occur at the final portion of the production of the vowel segment, right before the stop closure (Abramson & Tingsabadh, 1999; Lisker, 1999).

Regarding the perception of non-native sounds, there is a wide variety of theoretical models that approach L1-L2 transfer. In this study, our analysis is based on Best and Tyler's (2007) Perception Assimilation Model-L2 (PAM-L2), which accounts for the perception of non-native speech sounds by not only naive hearers, but also by experienced L2 learners. Basically, PAM-L2 states that L2 perceptual learning is driven by non-native principles of speech perception, as common and complementary elements between naive and more experienced L2 learners are taken into account. According to this model, learners may perceive gradient aspects, i.e., non-categorical aspects in the L2 system, which explain variable patterns within the vowel and consonant categories in the language systems involved.

METHOD

Research Questions

We proposed three research questions in this study:

- **Question 1**: Are the accuracy levels in perception higher in a specific place of articulation (labial [p˺], alveolar [t˺], velar [k˺]) in word-final position?
- **Question 2**: Does the nuclear vowel play a role in the perception of the final consonants?
- **Question 3**: Do intermediate students reach higher levels of accuracy in the perception tasks, when compared to basic learners?

Participants

Thirty-two undergraduate students of English, taking their first semester in the English course at the Federal University of Rio Grande do Sul (Brazil), took part in this study. All participants filled in a Student Information Questionnaire and also a Consent Form. Each participant was given an identification number, which provided access to the online perception tests.

In order to assess their proficiency in English, all participants sat for the *Oxford Placement Test* (Allan, 2004), which organized them in two different proficiency levels: basic and intermediate. Table 1 provides further information on the participants.

Table 1. Information on the participants

	Proficiency level		Sex		Age
N	Basic	Intermediate	Male	Female	*M* (*SD*)
32	11	21	15	17	20.2 (4.3)

Target Words Used as Stimuli

The target words were selected based on the information provided by the *Macmillan English Dictionary for Advanced Learners in CD Rom* (MacMillan Education, 2007), which allowed us to select the lexical items which would be used as stimuli in the experiments. As for the criteria used in the selection of the target words, all of them should present the CVC syllable pattern and also exhibit the front vowels [i], [ɪ] and [æ][1]. The final consonants consisted of unreleased voiceless stops exhibiting the three places of articulation under investigation: labial [p̚], alveolar [t̚], and velar [k̚].

The selected words that served as stimuli in both identification and discrimination experiments are presented in Table 2.

Table 2. Target words used in the study

	[p̚]	[t̚]	[k̚]
	beep	beat	beak
[i]	weep	wheat	weak
	seep	seat	seek
	pip	pit	pick
[ɪ]	lip	lit	lick
	sip	sit	sick
	bap	bat	back
[æ]	map	mat	mac
	sap	sat	sack

The audio stimuli were recorded by three male speakers of American English (Western US), aged between 20 and 21. For the recordings, a unidirectional microphone was used, with a frequency range from 20 to 20000Hz, and a sample rate at 44100 Hz. Each speaker read a list

[1] As we could not find a sufficient number of triads exhibiting back vowels in English, based on the search in the electronic dictionary, only front vowels were included in this study.

containing the target words twice, so that the best token in the two productions of the same word could be chosen for the design of the experiments.

Perception Tests

Two perceptual tests were used in this experimental study: (a) an identification test and (b) a discrimination test, which followed the ABX format (Liberman, Harris, Hoffmann, & Griffith, 1957).

The two tests were built with *Adobe Flash Professional CS5®* (2012) and were available online for learners, who had to enter a password in order to start taking the tests. As learners took the tests, their answers were stored in a *Google Docs®* (2012) file, and were later converted to a file in *Microsoft Excel®* (2010).

All participants took the online tests in the Language Lab at the university, and it took learners around 25 minutes to complete both tests. Silence was preserved in the Language Lab while the tests were being taken. All participants wore Sony - *MDR-XD100/B* earphones while performing the tasks.

In the sections that follow, each test will be described in detail.

Test A: Perceptual Identification Test (PIT). PIT presented 81 stimuli (27 types produced 3 times, by each one of the three native speakers who had recorded the stimuli) randomly. In this task, participants had to listen to the target word and answer a multiple-choice question that asked them which consonant the word ended in ([p˺], [t˺] or [k˺]). After choosing the alternative they thought correct, learners had to press a button in order to start the next question. Following the fortieth question, learners were given a five-minute interval so that they could rest.

It took the learners approximately 5.51 min (*SD*=1.08 min) to finish this task (not considering the five-minute rest and possible pauses between questions).

Test B: Categorical Discrimination Test (CDT). CDT was built in an ABX format (Liberman et al., 1957) and consisted of 135 questions, which were presented randomly. In this test, each question presented a sequence of three words, which henceforth will be denominated *clusters* and *catch trials*. In a *cluster*, two of the tokens in the triad refer to the same word and one of them corresponds to a different lexical item (*beep-beak-beep*), whereas in a *catch trial* the three tokens are productions of the same word (*beep-beep-beep*).

In this test, participants were asked to discriminate the final segments that appear in the triads. There was a 500 millisecond pause between the words in the triad. Learners should choose if the final consonant in the last word of the sequence was (a) the same as the final consonant in the second word of the triad; (b) the same as the final consonant in the first word of the triad; or if (c) the three final consonants in the triads were the same.

Following questions 45 and 90, learners were invited to take a five-minute interval, so that they could rest. It took the participants around 12.58 min (*SD*=1.18 min) to complete this task (not considering the intervals between questions and the five-minute intervals).

RESULTS AND DISCUSSION

Perception of a Specific Place of Articulation

The participants' perception of a specific place of articulation was assessed in terms of identification (Perceptual Identification Test, hereafter Test A) and discrimination (Categorical Discrimination Test, hereafter Test B), corresponding to two different tasks.

In Test A, the participants' levels of identification accuracy were 83% for [p˺], 55% for [t˺], and 77% for [k˺], as shown in Figure 1:

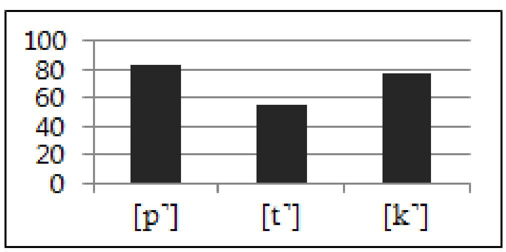

Figure 1. Percentage of accuracy in the identification of the unreleased final consonants.

A Friedman's test indicated that there were statistically significant differences among those final consonants ($\chi^2(2)=43.216$; $p<0.001$). Wilcoxon tests, followed by a Bonferroni adjustment, suggested significant differences between [p˺] and [t˺] ($Z=-4.868$; $p<0.001$) and between [t˺] and [k˺] ($Z=-4.899$; $p<0.001$).

According to these results, it seems that the learners find it easier to identify [p˺] and [k˺], while the identification of [t˺] remains more difficult.

As larger formant transitions provide more robust acoustic information (Hume, 1998), it is expected that dorsal and labial consonants carry more robust acoustic cues, as the tongue gestures in their formation take longer to be formed. Moreover, Stevens (1989) and Jun (1995) state that the larger perceptual salience in [k] also results from the fact that dorsal stops present an additional cue, which is the convergence of the F2 and F3 frequencies in the preceding vowel.

Jun (1995) states that the formant transitions in [t] are characterized as "weak", when compared to the ones in [p] or [k]. Furthermore, the tongue gesture that accounts for the production of [t] is very fast, implying short cues of formant transitions (Hume, Johnson, Seo, & Tserdanelis, 1999). By researching on places of articulation through electropalatographic technology, Reis and Espesser (2006) make it clear that the coronal and the dorsal regions are fairly apart; this statement gives rise to the hypothesis that the larger the distance between the places of articulation, the higher the accuracy rates in perception. In other words, the distance between [p] and [k] is larger than the one found between [p] and [t] or [t] and [k] – such a larger distance may facilitate the identification of the place of obstruction. In this regard, Hume et al. (1999), referring to the studies by Jun (1995), Côte (1997), Boersma (1998), and Hume (1998), reinforce that larger perceptual saliences are the result of more robust acoustic cues, based on more robust phonetic information.

In Test B, the participants' levels of discrimination regarding pairs with different consonants were 52% for [p˺-t˺], 80% for [p˺-k˺], and 62% for [t˺-k˺], as presented in figure 2:

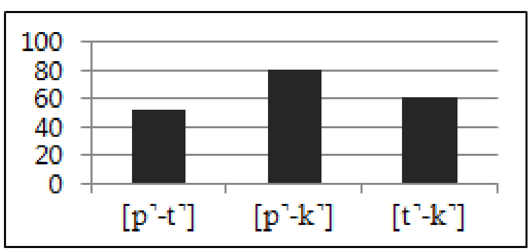

Figure 2. Percentage of accuracy in the discrimination of different unreleased final consonants.

A Friedman's test indicated that there were statistically significant differences among those pairs of consonants ($\chi^2(2)=48.778$; $p<0.001$). Wilcoxon tests, followed by a Bonferroni adjustment, suggested significant differences among the three pairs, respectively [p˺-t˺] and [p˺-k˺]

(Z=-4.915; p<0.001), [p˺-t˺] and [t˺-k˺] (Z=-4.801; p<0.001), and also [p˺-k˺] and [t˺-k˺] (Z=-4.663; p<0.001).

Again, the rates of accuracy in test B were not sufficiently high in those stimuli which presented the unreleased coronal stop with another stop. It sounds reasonable that all that acoustic and gestural characterization of the segment [t], which has been previously explained, is maintained for the purposes of discrimination. Interestingly, still regarding the role of acoustic cues, Jun (1995) proposes a universal ranking of perceptual salience for unreleased plosives, according to which dorsal stops outrank labials, which, in turn, outrank coronals.

Best and Tyler's (2007) model provides an explanation which seems to account for the lowest accuracy rates concerning [t]. The authors state that the target sounds which are more likely to be acquired are those that are phonetically more distant from the L1 sounds, or from well-established L2 categories in the learners' systems. In this sense, the coronal stop [t], when compared to [p] and [k] in a discrimination task, plays the role of an intermediate consonant in the oral tract, making its perception more difficult. This considered, it seems that participants are not yet able to establish an individual phonological category for [t˺], given its intermediate role; as a result, this consonant seems to be identified as either [p˺] or [k˺].

With respect to the catch trials (pairs with identical consonants) in Test B, the participants' levels of discrimination were 88% for [p˺-p˺], 55% for [t˺-t˺], and 77% for [k˺-k˺], as demonstrated in figure 3:

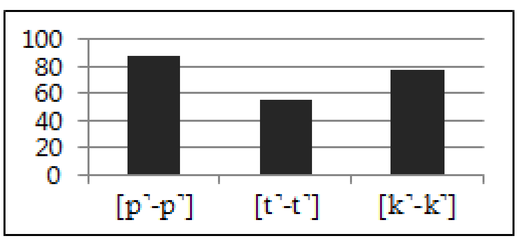

Figure 3. Percentage of accuracy in the discrimination of identical unreleased final consonants.

A Friedman's test indicated that there were statistically significant differences among the three pairs of consonants ($\chi^2(2)=39.982$; $p<0.001$). Wilcoxon tests, followed by a Bonferroni adjustment, suggested significant differences between the pair [p˺-p˺] and [t˺-t˺] (Z=-4,564; p<0,001), and the pair [t˺-t˺] and [k˺-k˺] (Z=-4,567; p<0,001).

As it had already been found in the results concerning both tests, those stimuli containing pairs with unreleased coronal stop are the ones with the lowest accuracy rates. Once again, it seems that the gestural and acoustic properties of [t̚] impose some kind of perceptual difficulty to the learners' judgments. Thus, factors such as (a) the "weakness" of its formant transitions, (b) the rapidity with which it is produced, and (c) its intermediate place of articulation are still taken into account to explain these lower accuracy rates in [t̚]. On the other hand, stimuli containing pairs with unreleased labial and dorsal stops seem to be quite well perceptible, considering their robust acoustic information, their longer timing and also their larger formant transitions.

The Role of the Nuclear Vowel in the Perception of the Final Consonants

The role played by the nuclear vowel in the participants' perception of the place of articulation of the final consonants was measured both in an identification task (Test A) and in a discrimination task (Test B).

In Test A, when the words ending in [p̚] had the vowel [i] as the nuclear segment, participants reached 77% of accuracy in the identification of the final consonant. When [ɪ] was the nuclear segment preceding the same consonant, they reached 88% of correct answers. In addition, when [æ] preceded [p̚], the participants' level of accuracy in the identification of the final consonant was 77%.

When the words ending in [t̚] had the vowel [i] as the nuclear segment, participants reached 33% of accuracy in the identification of the final consonant. When [ɪ] was the nuclear segment preceding the same consonant, they reached 55% of correct answers. In contrast, when [æ] preceded [t̚], the participants' level of accuracy in the identification of the final consonant was 77%.

When the words ending in [k̚] had the vowel [i] as the nuclear segment, participants reached 66% of accuracy in the identification of the final consonant. When [ɪ] was the nuclear segment preceding the same consonant, they reached 88% of correct answers. Likewise, when [æ] preceded [k̚], the participants' level of accuracy in the identification of the final consonant was 88%. Figure 4 shows these results:

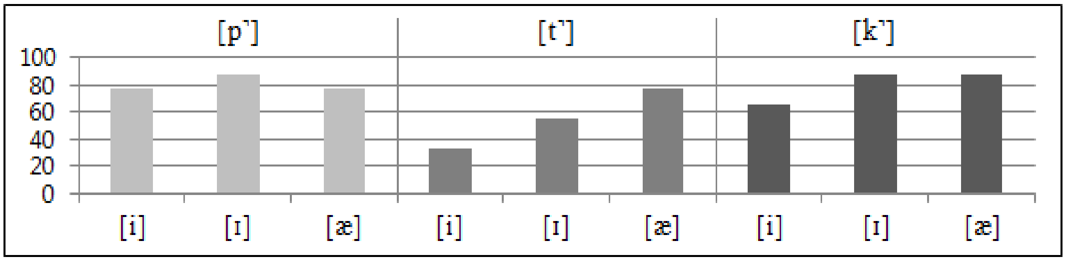

Figure 4. Percentage of accuracy in the identification of the unreleased final consonants according to nuclear vowel.

A Friedman's test indicated that there were statistically significant differences among the vowels preceding [p˺] ($\chi^2(2)=26.636$; $p<0.001$). Wilcoxon tests, followed by a Bonferroni adjustment, suggested significant differences between [i] and [ɪ] ($Z=-3.426$; $p=0.001$) and between [ɪ] and [æ] ($Z=-4.224$; $p<0.001$). Significant differences were also found among the three vowels preceding [t˺] ($\chi^2(2)=41.450$; $p<0.001$), which were then verified in Wilcoxon tests, corresponding to [i] and [ɪ] ($Z=-4.104$; $p<0.001$), [i] and [æ] ($Z=-4.819$; $p<0.001$), and also [ɪ] and [æ]: $Z=-3.535$; $p<0.001$). In addition, significant differences were found among the vowels preceding [k˺] ($\chi^2(2)=23.145$; $p<0.001$), which were attested in Wilcoxon tests, corresponding to [i] and [ɪ] ($Z=-3.895$; $p<0.001$) and also [i] and [æ] ($Z=-3.939$; $p<0.001$).

Several hypotheses have been proposed by many authors aiming to explain the relationship between a vowel and its adjacent consonant in terms of perception. Householder (1956) states that a vowel's tenseness and/or laxness are the main properties for it to be accurately perceived. According to his claim, lax vowels would imply higher rates of consonant perception. Lisker (1999) understands that the accuracy rates in the perception of a word-final stop are directly related to the monophthongal or diphthongal status of the nuclear vowel. According to him, diphthongs tend to imply greater perception of the word-final stop. A phonological hypothesis, proposed by Oostendorp (1995) and Kang (2003), presumes that lax vowels enable greater perception of word-final consonants because lax vowels in English need a consonant following them in coda position. Before we reach a more conclusive answer regarding these hypotheses, let us analyze the relationship between vowels and word-final consonants in test B.

In Test B, when the triads ending in [p˺-t˺] had the vowel [i] as the nuclear segment, participants reached 41% of accuracy in the discrimination of the final consonants. When [ɪ] was the nuclear segment preceding the same consonants, they reached 58% of accuracy. Moreover, when [æ] preceded [p˺-t˺], the participants' level of accuracy in the discrimination of the final consonants was 54%.

When the triads ending in [p˺-k˺] had the vowel [i] as the nuclear segment, participants reached 66% of accuracy in the discrimination of the final consonants. When [ɪ] was the nuclear segment preceding the same consonants, they reached 83% of correct answers. In the same way, when [æ] preceded [p˺-k˺], the participants' level of accuracy in the discrimination of the final consonants was 83%.

When the triads ending in [t˺-k˺] had the vowel [i] as the nuclear segment, participants reached 45% of accuracy in the discrimination of the final consonants. When [ɪ] was the nuclear segment preceding the same consonants, they reached 66% of correct answers. Besides, when [æ] preceded [t˺-k˺], the participants' level of accuracy in the discrimination of the final consonants was 75%. Figure 5 shows the results:

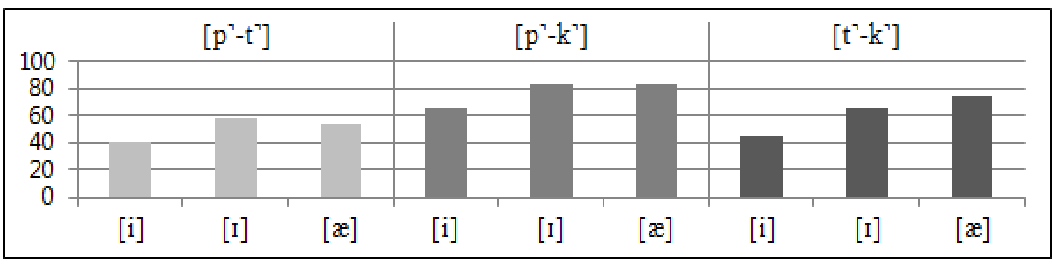

Figure 5. Percentage of accuracy in the discrimination of the different unreleased final consonants according to nuclear vowel.

A Friedman's test indicated that there were statistically significant differences among the vowels preceding [p˺-t˺] ($\chi^2(2)=12.932$; $p=0.002$). Wilcoxon tests, followed by a Bonferroni adjustment, suggested significant differences between [i] and [ɪ] ($Z=-3.100$; $p=0.002$) and between [i] and [æ] ($Z=-3.006$; $p=0.003$). Significant differences were also found among the vowels preceding [p˺-k˺] ($\chi^2(2)=24.268$; $p<0.001$), which were then verified in Wilcoxon tests, corresponding to [i] and [ɪ] ($Z=-3.980$; $p<0.001$) and in [i] and [æ] ($Z=-3.824$; $p<0.001$). Additionally, significant differences were found among the vowels preceding [t˺-k˺] ($\chi^2(2)=26.914$; $p<0.001$), which were attested in Wilcoxon tests, corresponding to [i] and [ɪ] ($Z=-3.199$; $p=0.001$) and also [i] and [æ] ($Z=-4.468$; $p<0.001$).

When it comes to the relationship between a nuclear vowel and its following stop in regard to perception, it is relevant that we take into account the explanation for formant transitions provided by Delattre, Liberman and Cooper (1955). They posit that the more anterior the vowel which precedes [t] is, the more this segment, in terms of F2, will resemble a [p]. The opposite is also true: the more posterior the vowel which precedes [t] is, the more this segment, in terms of F2, will resemble a [k].

By considering the formant transitions departing from the vowel towards the final consonant (in a VC structure), Ladefoged (2005) describes their behavior according to the course along the acoustic space: acoustically speaking, an "ideal" [p] would have falling F2 and F3 transitions, a [t] would have flat and small F2 and F3 transitions, and a [k] would represent F2 and F3 close together. In other words, the greater the formant transitions for [p] and [k] (from the vowel up to the consonant), the higher the accuracy in perception. However, the flatter the formant transitions for [t] (from the vowel up to the consonant), the higher the accuracy in perception.

This way, what seems to be crucial is that the maximum respect to the "ideal or primitive" formant transition would lead to accurate perception. Therefore, for [p˺] to be correctly perceived, a more abrupt transition from the vowel up to the consonant is necessary. For [k˺] to be correctly perceived, the same is needed (greater transitions are preferable). For [t˺], in turn, it is fundamental that the formant transitions from the vowel up to the consonant follow a flat a smooth pattern, so that the perception can be accurate. Perozzo (2013) confirms it is true that the maximum respect to the ideal formant transitions is responsible for greater perception of word-final consonants and, if they are not enough, then the accurate perception lies on the lax or short status of the nuclear vowel.

One possibility to account for the low accuracy rates in the discrimination involving the coda pairs [p˺-t˺] and [t˺-k˺] may be based on the second assimilation case stated by a PAM-L2 perspective (Best &Tyler, 2007), which claims that "both L2 phonological categories are perceived as equivalent to the same L1 phonological category, but one is perceived as being more deviant than the other". By considering the data presented in this study as well as the aforementioned statement, it is clear that, when the learners are not able to discriminate between [p˺-t˺] and [t˺-k˺], they may perceive [t˺] as [p˺] or [k˺], respectively. As the phonological category which corresponds to [t˺] might still be under development, in an attempt to discriminate the pair [p˺-t˺], learners associate the labial consonant to an excellent exemplar category of [p˺]; in turn, coronal [t˺] is also associated to this phonological category of [p˺], even though it might be classified as a more deviant exemplar of the labial plosive. The same occurs in the discrimination of [t˺-k˺], in which the dorsal consonant might be associated as an excellent exemplar in the phonological representation corresponding to [k˺], whereas the coronal plosive might be considered to be a more deviant exemplar belonging to the [k˺] category.

Regarding the catch trials (identical pairs of consonants) in Test B, when the triads ending in [p˺-p˺] had the vowel [i] as the nuclear segment, participants reached 78% of accuracy in the discrimination of the final consonants. When [ɪ] was the nuclear segment preceding the same consonants, they reached 90% of correct answers. Additionally, when [æ] preceded [p˺-p˺], the participants' level of accuracy in the discrimination of the final consonants was 78%.

When the triads ending in [t˺-t˺] had the vowel [i] as the nuclear segment, participants reached 33% of accuracy in the discrimination of the final consonants. When [ɪ] was the nuclear segment preceding the same consonants, they reached 66% of accuracy. Also, when [æ] preceded [t˺-t˺], the participants' level of accuracy in the discrimination of the final consonants was 66%.

When the triads ending in [k˺-k˺] had the vowel [i] as the nuclear segment, participants reached 62% of accuracy in the discrimination of the final consonants. When [ɪ] was the nuclear segment preceding the same consonants, they reached 87% of correct answers. Similarly, when [æ] preceded [k˺-k˺], the participants' level of accuracy in the discrimination of the final consonants was 80%. Figure 6 shows the results:

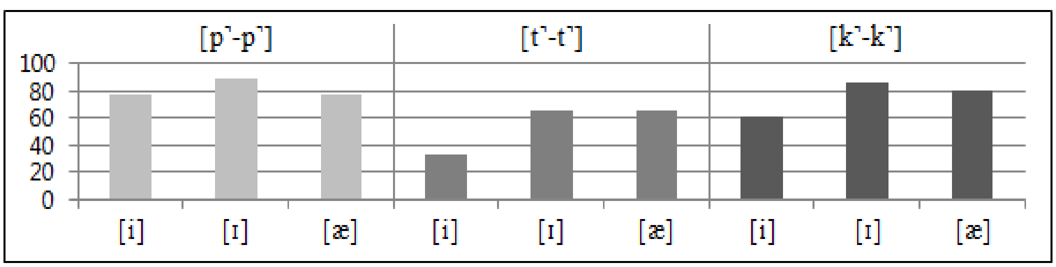

Figure 6. Percentage of accuracy in the discrimination of the identical unreleased final consonants according to nuclear vowel.

A Friedman's test indicated that there were statistically significant differences among the vowels preceding [p˺-p˺] ($\chi^2(2)=7.896$; $p=0.019$). Wilcoxon tests, followed by a Bonferroni adjustment, suggested significant differences between [i] and [ɪ] ($Z=-2.676$; $p=0.007$) and between [ɪ] and [æ] ($Z=-2.556$; $p=0.011$). Significant differences were also found among the vowels preceding [t˺-t˺] ($\chi^2(2)=6.660$; p=0.036), which were then verified in Wilcoxon tests, corresponding to [i] and [ɪ] (Z=-2.967; p=0.003) and [i] and [æ] (Z=-2.137; p=0.013). Additionally, significant differences were found among the vowels preceding [k˺-k˺] ($\chi^2(2)=11.318$; p=0.003), which were attested in Wilcoxon tests, corresponding to [i] and [ɪ] (Z=-3.245; p=0.001) and also [i] and [æ] (Z=-2.659; p=0.008).

It seems that there is a strong pattern to elect lax vowels as the ones responsible for great accuracy related to the perception of word-final consonants. Nevertheless, we would need to investigate a much wider set of vowels in order to start searching for a common pattern concerning the nuclear vowel.

The Influence of Proficiency in the Perception of the Final Consonants

In order to determine whether the participants' level of proficiency would influence the perception of the final consonants, we compared the basic (*n*=11) and the intermediate learners (*n*=21) in both tests A and B.

In test A, basic learners reached 79% of accuracy in the identification of the final consonants, and intermediate learners reached 77%. In test B, basic learners reached 62% of accuracy in the discrimination of the pairs of consonants, and intermediate learners reached 65%. Figure 7 shows the comparison of the two groups in both tests.

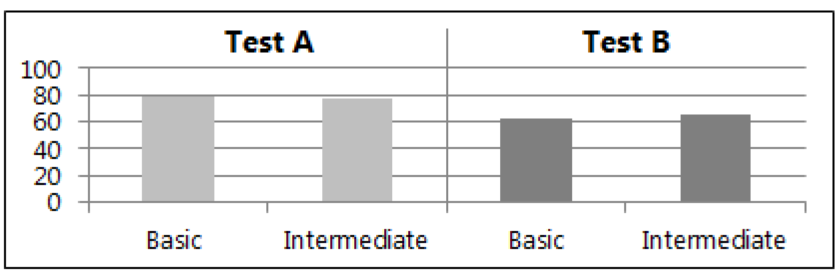

Figure 7. Percentage of accuracy in the perception tests according to both levels of proficiency.

Regarding test A, a Mann-Whitney test indicated no significant differences between basic and intermediate learners in terms of accuracy in perceptual identification (U=112.0; p=0.889). In test B, respectively, a Mann-Whitney test did not reveal significant differences between basic and intermediate learners in terms of accuracy in categorical discrimination (U=98.5; p=0.499).

As the participants' level of proficiency does not have an influence on the perception of word-final unreleased stops, a reasonable conclusion we may draw from the results is that, from the earlier stages of acquisition, learners have fair accuracy levels in both perception tasks, which means that reaching even higher scores can be very demanding.

FINAL REMARKS

This study intended to verify the perception of English unreleased voiceless stops by Brazilian EFL learners. Not only did discuss the effect of place of articulation in identification and discrimination tasks, but we also looked back on important discussions concerning the relationship between the nuclear vowel and its following unreleased stop in coda position. This allowed us to contribute to the theoretical background established so far in the field of Acoustic Phonetics and also enabled us to reconsider the impact that assimilation patterns of a non-native sound may have on a phonological system. Forthcoming studies with pseudowords (in which phonotactic restrictions would be respected and all English vocalic segments could be considered) and larger amount of participants would prove relevant for us to reach more definite results on the effects of the nuclear vowel upon unreleased final stops.

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