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ABSTRACT

A study examined patterns in production of Spanish voiced and voiceless stop consonants by native English speakers, focusing on the interaction between two acoustic cues of stops: voice closure interval and voice onset time (VOT). The study investigated whether learners acquire the appropriate phonetic categories with regard to these stops and if so, how they manipulate the different acoustic cues of the speech signal to achieve the necessary distinction. Subjects were 14 students in an advanced college-level Spanish phonetics course, recorded throughout the semester in a series of pronunciation tasks. Resulting sentences were digitized and both voiceless closure interval and VOT of each word-initial target stop were measured. Results indicate: (1) the short lag category of Spanish voiceless stops is acquired more readily than the prevoiced category of the voiced stops; (2) Spanish stops are not acquired equally at all points of articulation; (3) voiceless closure interval is an important cue used and manipulated by learners in Spanish L2 speech production; (4) learners may differentiate up to three kinds of short lag stops in production; and (5) phonetic training may positively affect acquisition of L2 speech sounds. Contains three references. (MSE)

Strategies for the Production of Spanish Stop Consonants by Native Speakers of English

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Introduction

This paper will focus on the second language production of the Spanish stop consonants by native speakers of English. In particular, it will examine the interaction between two acoustic cues of stops: voiceless closure interval and voice onset time (or VOT). To produce a stop consonant, the articulators come together to momentarily stop the airflow. They then separate, causing an abrupt release of the air. The time that elapses between the articulators' coming together and the release burst is the closure interval; voiceless closure, therefore, is characterized by a lack of vocal fold vibration. VOT refers to the amount of time that elapses after the release burst and the (re)initiation of vocal fold vibration. Figure 1 shows a portion of a waveform that illustrates these acoustic properties of a stop consonant.

Insert Figure 1

Both Spanish and English contain a series of stop phonemes distinguished by voicing. However, the phonetic realization of these phonemes differs in the two languages. In English, voiceless /p t k/ are known as **long lag** voiceless stops, because they are produced with relatively long VOTs; this lag in the onset of voicing causes the aspiration that often accompanies the articulation of these phones. Voiced /b d g/, on the other hand, have short VOT values in English and, as such,

are considered **short lag** voiceless stops. This contrast is illustrated by the waveforms in Figures (2) and (3), which show the first syllable of the English words *poker* and *both*, along with their respective VOT values.

Insert Figure 2 and Figure 3

In Spanish, unlike English, voiceless /p t k/ are short lag stops, produced with short VOT values, while voiced /b d g/ are articulated with voicing lead (or prevoicing), in which the vocal folds begin to vibrate before the release burst. Waveforms illustrating this distinction for the Spanish words *poca* and *boca* appear in Figures (4) and (5):

Insert Figure 4 and Figure 5

From a phonological perspective, therefore, the stop consonants differ with regard to the feature [voiced] in both languages: [-voiced] /p t k/ contrast with [+voiced] /b d g/. From a phonetic perspective, however, Spanish /p t k/ are more like English /b d g/ in that both groups belong to the short lag voiceless stop category. Compare, for example, Figures (3) and (4) above; as shown, there is no real difference with regard to the VOT of English /b/ and Spanish /p/. To illustrate further, Table 1 provides the average VOT values for Spanish and English, as well as the range of VOT values found in production, reported by Lisker & Abramson (1964).

Insert Table 1

Note in Table 1 that the prevoiced values for Spanish /b d g/ are recorded as

negative VOTs. This follows from the fact that in the temporal measurement of the stop consonant, the release burst is considered point zero on the waveform. VOT (the lag after the release burst) is reported as a positive value, and prevoicing (which occurs before the release burst) is reported as a negative value.

Methods

The differences in phonetic realization of the Spanish and English stop consonants create a challenge for the English-speaking learner of Spanish and provided the motivation for the current study. The challenge is to reorganize the phonetic categories of the stop phonemes so as to reflect those of the target language. That is, the English-speaking learner of Spanish must shorten the VOT of L2 Spanish /p t k/ during production, so that they fall within the target range of a short lag stop. In addition, s/he must eliminate voicing lag from the production of Spanish /b d g/ and create a new, prevoiced, phonetic category. The present study, therefore, addressed two primary research questions:

1. Do learners acquire the appropriate phonetic categories with regard to the Spanish voiceless and voiced stops?

2. If so, how do they manipulate the different acoustic cues of the speech signal in order to achieve the necessary distinction?

In order to address these questions, an experimental study was designed to examine learner production of the L2 Spanish stop consonants by native English speakers. The participants were enrolled in an advanced undergraduate Spanish phonetics course. Fourteen learners volunteered for the study, in which they completed a series of pronunciation tasks while being recorded in a speech laboratory at several points throughout the semester. The tasks included, among other things, four repetitions of a set of 32 sentences; each sentence contained a

particular target word for later analysis. The results discussed here come from the subset of sentences that appear in Figure 6 on the handout. In each case, the target word of the sentence begins with a stop consonant. As shown, minimal (or near minimal) pairs were selected for each voiceless-voiced pair (for example, *paces* and *bases* in English; and *peso* and *beso* in Spanish). In addition, the vowel sound following the stop was closely matched for the two languages.

The time frame for completing the production tasks was as follows. First, the English productions were obtained only once during the second week of the semester. The Spanish productions were obtained three time. The first recording took place during the third week of the semester, one week following the English session. At this point, the learners had not yet begun to study the articulation of individual Spanish phonemes in class. The second Spanish recording session took place three weeks later, immediately after the Spanish voiceless stops had been discussed and practiced in class. The text used for presentation and practice of these phones was Barrutia & Schwegler (1994). In this text, the difference between the Spanish and English voiceless stops is not described in terms of short lag vs. long lag categories and VOT; however, the text does tell the learner to try to avoid aspiration of /p t k/ in Spanish by maintaining greater muscular tension of the articulators and vocal tract during production. The final Spanish production experiment took place near the end of the semester--during the fifteenth week of class (and nine weeks after the second session).

After all the data had been gathered, the sentences were digitized, and both the voiceless closure interval and VOT of each word-initial target stop was measured from the digitized waveform. Voiceless closure was not measured, however, if the learner produced a noticeable pause before the target word. In order to maintain consistency, any voiceless closure interval in excess of 200 msecs. was

reported as a pause. Prevoicing of the voiced stops was also measured where applicable; in this case, the duration of prevoicing was measured as a negative VOT value.

Results and Discussion

I will discuss first the results for the L2 Spanish voiceless stops; the relevant information appears in Figures 7, 8, and 9. These Figures show the mean voiceless closure interval and VOT values for the L1 English voiceless and voiced tokens and the L2 Spanish voiceless tokens produced in each session. The English voiced stops are included, since they, like the L2 target phones, are short lag stops. Consider, for example, the information in Figure 7.

Insert Figure 7

Figure 7 shows first that the learners produced English /p/ and /b/ with comparable voiceless closure intervals. These results replicate those found in earlier studies on the duration of closure, which found that closure interval is not an acoustic cue utilized by English speakers to distinguish the voiced and voiceless stops in word-initial position. The learners produced Spanish /p/, on the other hand, with voiceless closure intervals that were significantly longer than those for the English phones. Moreover, measurements of syllable duration of the English and Spanish tokens showed that the longer closure intervals in Spanish were not due to slower speaking rates.

As for VOT, Figure 7 shows that the learners produced average VOT values for Spanish /p/ that were significantly shorter than those for English /p/ and fall within the range of a short lag stop. The average VOT values for Spanish /p/ in the

first session were also significantly longer than for English /b/, but there was no significant difference in VOT between English /b/ and Spanish /p/ in the second and third sessions. In other words, although the learners produced Spanish /p/ as a short lag stop from the beginning of the semester, they also distinguished it from the corresponding English short lag stop through longer VOTs. However, by the second and third sessions, this was no longer the case.

With regard to L2 Spanish /t/, Figure 8 on the handout shows similar results in some respects to those for /p/.

Insert Figure 8

For example, the learners produced Spanish /t/ with significantly longer closure intervals than those for either English /t/ or /d/ in all three sessions. Furthermore, the VOT values for Spanish /t/ fall within the short lag range. When compared to English /d/, however, learner behavior over the course of the semester shows a somewhat different pattern than it did for the bilabial stop. In particular, the average VOT values of L2 Spanish /t/ were significantly longer than for English /d/ during the first and third sessions, but not the second. This suggests that the learners made an attempt to shorten the VOT of /t/ during session 2 after instruction in the voiceless stops had taken place in class. However, the changes were not sustained in the final session, as they were for Spanish /p/.

Finally, the results for L2 Spanish /k/ appear in Figure 9.

Insert Figure 9

First, it is interesting to note that the learners produced Spanish /k/ with

comparable voiceless closure intervals to English; this does not correspond to the results found for the other L2 Spanish stops. As for VOT, learner behavior is very similar to that found for L2 Spanish /p/--overall, the learners produced Spanish /k/ as short lag stops and with significantly shorter VOT values than for English /k/. Moreover, a comparison of the VOT of Spanish /k/ and English /g/ showed that the learners produced the Spanish phone with significantly longer VOT values during the first session only, whereas in the second and third sessions, there were no significant VOT difference between English and Spanish.

To summarize thus far, the learners proved successful in producing the L2 Spanish voiceless stops as short lag phones, as evidenced by the overall low VOT values. It appears, however, that acquisition may not take place equally across all points of articulation, since greater changes occurred over the course of the semester with regard to the VOT of Spanish /p/ and /k/, but not /t/. In addition, the results show that the learners produced Spanish /p/ and /t/ with longer voiceless closure intervals than those for the corresponding English phones. These results correspond to those found by Green, Zampini, & Magloire (1997) in a study on Spanish stop pronunciation by monolingual Spanish speakers and Spanish-English bilinguals. Specifically, the authors found that both groups of speakers produce Spanish /p/ with significantly longer voiceless closure intervals than Spanish /b/. In addition, they found that Spanish-English bilinguals produce Spanish /p/ with significantly longer closure intervals than either English /p/ or /b/.

Turning now to the results for Spanish /b d g/, Figures 10, 11, and 12 on the handout present the mean voiceless closure and VOT values for each phone, along with the same data for the corresponding English stop. Before discussing these results, however, it must be noted that Spanish exhibits an obligatory allophonic process whereby the voiced stops are produced as spirants (or fricatives) in certain

contexts. In fact, the sentence context in which the target voiced stops appeared is one in which the expected pronunciation is a spirant (see the final three sentences in Figure 6). For the most part, the learners of the present experiment did not produce spirants--only one learner did so consistently throughout all three sessions, and a few others produced spirants sporadically. However, since the spirants do not have either a closure interval or VOT, this data has been eliminated from the analysis and do not figure into the results presented in Figures 10 through 12.

Consider first, then, the results for Spanish /b/ in Figure 10.

Insert Figure 10

With regard to voiceless closure, the learners produced English /b/ and Spanish /b/ in the first session with comparable closure intervals, as shown. However, during the second and third sessions, the voiceless closure of the Spanish phone was significantly shorter than for English. With regard to VOT, the learners produced this phone with VOT values that were somewhat shorter than in English; however, these differences were not significant. What's striking in this data is the overall lack of prevoicing of Spanish /b/. It was mentioned above that prevoicing was measured as a negative VOT value--hence, if the learners prevoiced consistently, one would expect an overall negative VOT average. However, this was not the case. In fact, an examination of the individual data revealed only two prevoiced /b/'s in the first session, three during the second session, and four during the third (out of a total of 56 tokens with word-initial /b/ for each session).

The same overall lack of prevoicing was found for L2 production of Spanish /d/, shown in Figure 11.

Insert Figure 11

In this case, there were three instances of prevoicing in the first session, two in the second, and none in the third. In addition, paired t-tests of the VOT data revealed significant differences between English /d/ and Spanish /d/ in the first and third sessions. As for voiceless closure, Figure 11 shows that the learners did not show any significant changes in this cue over the course of the semester. Both English and Spanish /d/ had comparable voiceless closure intervals, and these remained stable for the Spanish phone across all sessions.

Finally, the information for Spanish /g/ appears in Figure 12.

Insert Figure 12

As shown, the learners produced this phone as a short lag, rather than prevoiced stop, as well. In fact, while three instances of prevoiced /g/ were found in the first session, none were found in either the second or third. In addition, there was no significant VOT difference between English and Spanish /g/ in the first session; however, the differences between the English and Spanish phones in the second and third sessions did prove significant. As for voiceless closure, there was no significant difference between English and Spanish /g/ in the first session, but in both the second and third sessions, Spanish /g/ was found to have significantly shorter voiceless closures than English /g/. Moreover, the difference in closure interval for Spanish /g/ in the first and third sessions proved significant.

To summarize these results, the learners produced Spanish /b d g/ as short lag stops, and much like their English counterparts with regard to VOT. Furthermore, the learners showed no voiceless closure difference between English

and Spanish at the beginning of the semester. However, these intervals became progressively shorter over the course of the semester for Spanish /b/ and /g/. Learner production of Spanish /d/, however, showed little voiceless closure change, which again suggests that learners may not acquire all phonetic properties across all points of articulation at an equal rate.

A comparison of the results for the L2 voiced stops to those of the voiceless stops illustrates an important difference in acquisition. Although the learners proved successful in producing the Spanish voiceless phones as short lag stops, they did not show the same degree of success with regard to the prevoiced category. From the beginning of the semester, the learners produced Spanish /p t k/ within the short lag range, and their behavior over the course of the semester reflected additional modifications in VOT to make their productions more Spanish-like. With regard to Spanish /b d g/, on the other hand, the learners produced very few prevoiced stops, and no appreciable gains were observed over the course of the semester. Nevertheless, the decline in the average voiceless closure intervals for L2 Spanish /b/ and /g/ may be indicative of a move toward eventual prevoicing. That is, it may be that learners acquire prevoicing in stages that entail a gradual decline in voiceless closure interval, rather than an abrupt switch from an articulation with voiceless closure to one with prevoicing.

In short, the results show that the learners produce both the Spanish voiced and voiceless stops as short lag stops. Given this, an interesting question arises concerning the learners' interlanguage representations. That is, since both L2 /p t k/ and /b d g/ are realized as short lag stops, how are they distinguished? In addition, how are they distinguished from the L1 short lag stops, if at all? Figure 13 provides a summary of the acoustic cues under examination that were exploited by the learners in order to differentiate the L1 English and L2 Spanish short lag stops. In

each case, the cues that were used to distinguish a given pair of phones were those in which the means proved significantly different. Consider, for example, the bilabial phones from the first L2 Spanish session in Figure 13.

Insert Figure 13

A comparison of English /b/ and Spanish /p/ shows that the learners used both voiceless closure and VOT to differentiate these phones. The learners produced English /b/ and Spanish /b/, on the other hand, with equal closure intervals and VOTs; this likely represents a case of transfer from L1 to L2. Spanish /p/ and /b/ were also distinguished in the first session by both voiceless closure and VOT. In the second session, however, VOT no longer played a role in distinguishing English /b/ from Spanish /p/. The learners began to utilize voiceless closure as a means to distinguish both English and Spanish /b/ as well. By the third session, voiceless closure was the only acoustic cue used to distinguish all three short lag bilabial stops. In other words, the learners appear to maintain three separate short lag categories that correspond to L2 Spanish /p/, L2 Spanish /b/ and L1 English /b/. All three phones have similar VOT values in production and are therefore distinguished by manipulations of voiceless closure interval: L2 Spanish /p/ has the longest voiceless closure interval, L1 English /b/ has an "intermediate" range voiceless closure interval, and L2 Spanish /b/ exhibits short voiceless closure intervals. The remaining phones in Figure 13 may be examined in a similar way.

Taken together, the information in Figure 13 shows that the learners manipulate voiceless closure interval to a greater extent overall than VOT. This is an important result, because VOT is often the only acoustic cue examined in studies on the L2 acquisition of stop consonants. The results of the present experiment

indicate, however, that VOT may not always be the best cue for examining L2 speech production, and certainly not the only relevant cue.

In summary, the present study has highlighted several important aspects regarding the acquisition of Spanish stops by native English speakers. First, the results indicate that the short lag category of the Spanish voiceless stops is acquired more readily than the prevoiced category of the voiced stops. This may be partly due to the fact that the learners already have a short lag category for L1, and the substitution in L2 may thus prove easier to make.

Second, the results suggest that Spanish stops are not acquired equally at all points of articulation. In particular, Spanish /t/ and /d/ showed fewer changes in articulation over the course of the semester. It may be that in discovering the proper phonetic realization of a given set of L2 phones, therefore, learners make the necessary substitution on a phone by phone basis, rather than for the set as a whole. However, given that the learners of the present experiment produced all L2 stops as short lag stops--despite variations in voiceless closure--this issue is difficult to explore with the current database. Studies that examine the L2 acquisition of Spanish stops by learners in earlier stages of acquisition may shed additional light on acquisition across points of articulation, as well as on possible stages in the acquisition of Spanish /p t k/ as short lag stops.

Third, this study has illustrated that voiceless closure interval is an important cue utilized and manipulated by learners in L2 Spanish speech production. This in turn raises interesting questions regarding, first, the role of closure interval in the production and perception of stop consonants by L1 speakers of Spanish, and second, the accessibility of acoustic cues in general for second language learners. This latter issue is an especially important one, since L1 English speakers do not manipulate closure interval to distinguish stops in word initial position, yet the present study

has shown that they are able to do so for L2 Spanish.

Fourth, the results have shown that learners may differentiate up to three "kinds" of short lag stops in production, corresponding to English voiced, Spanish voiceless, and Spanish voiced phonemes. This also has important implications for studies of speech perception and raises the question of whether or not such L2 learners are more sensitive to variations within the short lag range than monolingual English or Spanish listeners.

Finally, given that the learners of the experiment were enrolled in a Spanish phonetics course, the observed changes in L2 speech production over the course of the semester suggest that phonetics training may have a positive effect on the acquisition of L2 sounds by adult learners. However, without a control group against which to compare the trained learners, it is difficult to fully ascertain the effects of phonetics instruction on acquisition at this time.

To conclude, therefore, this study has served to point out apparent difficulties and inequalities in the acquisition of the L2 Spanish stop consonants and to highlight production strategies--in the form of the manipulation of different acoustic cues--employed by learners in their attempt to achieve the necessary distinctions during speech.

Works Cited

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Figure 1

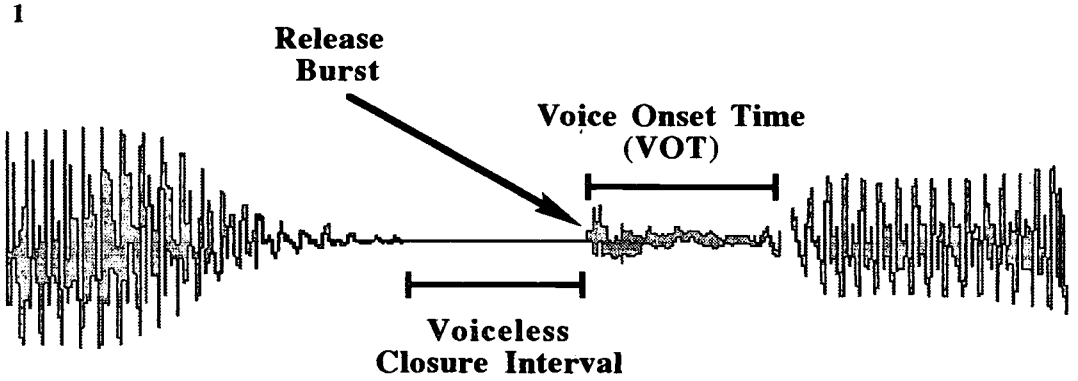
Release
Burst
Voice Onset Time
(VOT)
Voiceless
Closure Interval

Figure 2: English /p/

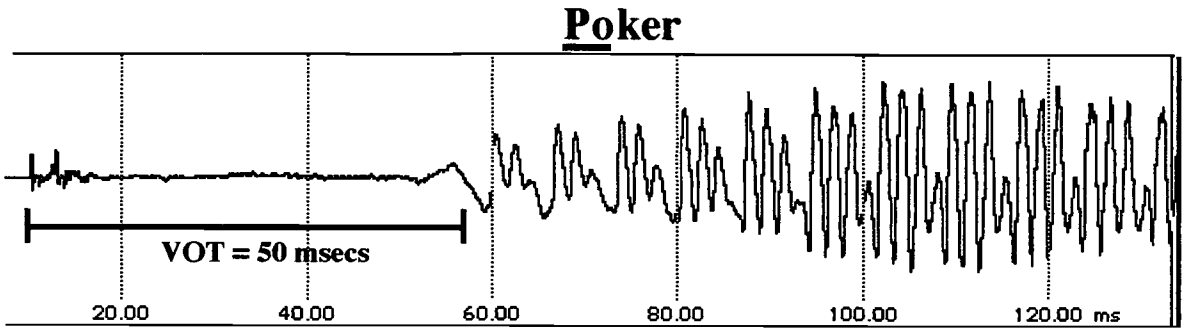

Figure 3: English /b/

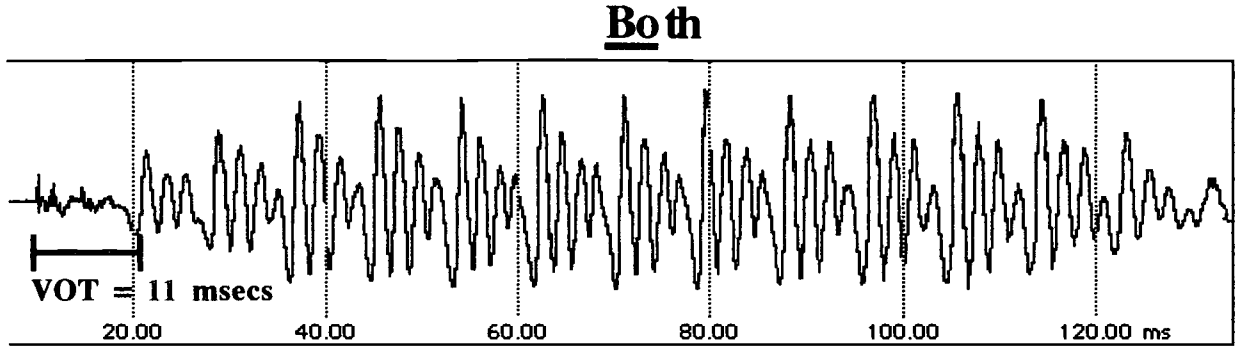

Figure 4: Spanish /p/

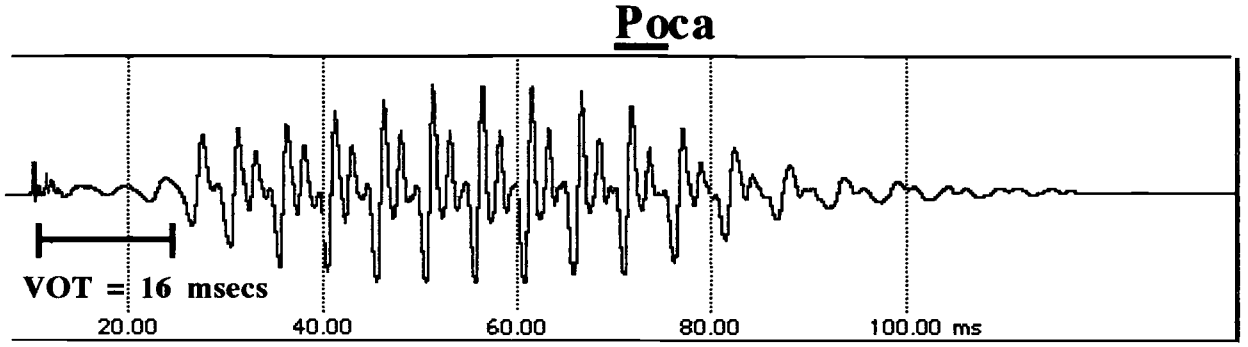

Figure 5: Spanish /b/

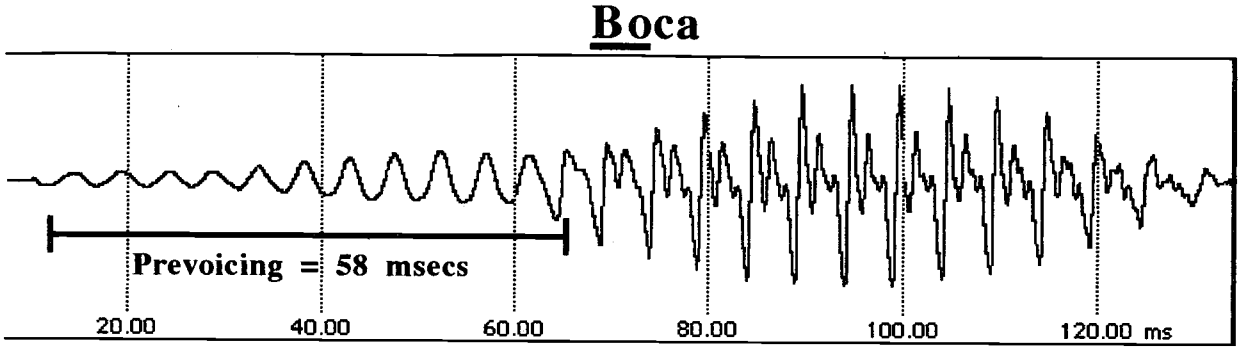

Table 1:

Mean VOT Measurements (in msecs) of English and Spanish Stops
(Lisker & Abramson, 1964)

Positive values indicate voicing lag; negative values indicate voicing lead (prevoicing)

	English	Mean VOT	VOT Range	*Spanish*	Mean VOT	VOT Range	
Long Lag	/p/	58	20 / 120	/p/	4	0 / 15	
	/t/	70	30 / 105	/t/	9	0 / 15	**Short Lag**
	/k/	80	50 / 135	/k/	29	15 / 55	
Short Lag	/b/	1	0 / 5	/b/	-138	-235 / -60	
	/d/	5	0 / 25	/d/	-110	-170 / -75	**Prevoiced**
	/g/	21	0 / 35	/g/	-108	-165 / -45	

Figure 6: Production sentences used in the analysis (with the target word in *italics*)

English Productions:

/p/: Please say the word '*paces*' to me.
/t/: Please say the word '*take*' to me.
/k/: Please say the word '*cot*' to me.

/b/: Please say the word '*bases*' to me.
/d/: Please say the word '*day*' to me.
/g/: Please say the word '*got*' to me.

Spanish Productions:

/p/: Diga la palabra '*peso*' por favor.
/t/: Diga la palabra '*teja*' por favor.
/k/: Diga la palabra '*cato*' por favor.

/b/: Diga la palabra '*beso*' por favor.
/d/: Diga la palabra '*deja*' por favor.
/g/: Diga la palabra '*gato*' por favor.

Figure 7: Mean Voiceless Closure & VOT Values (in msecs) - Learner Production of English /p, b/ & Spanish /p/

peso-1: 1st session (week 3 of the semester)
peso-2: 2nd session (week 6)
peso-3: 3rd session (week 15)

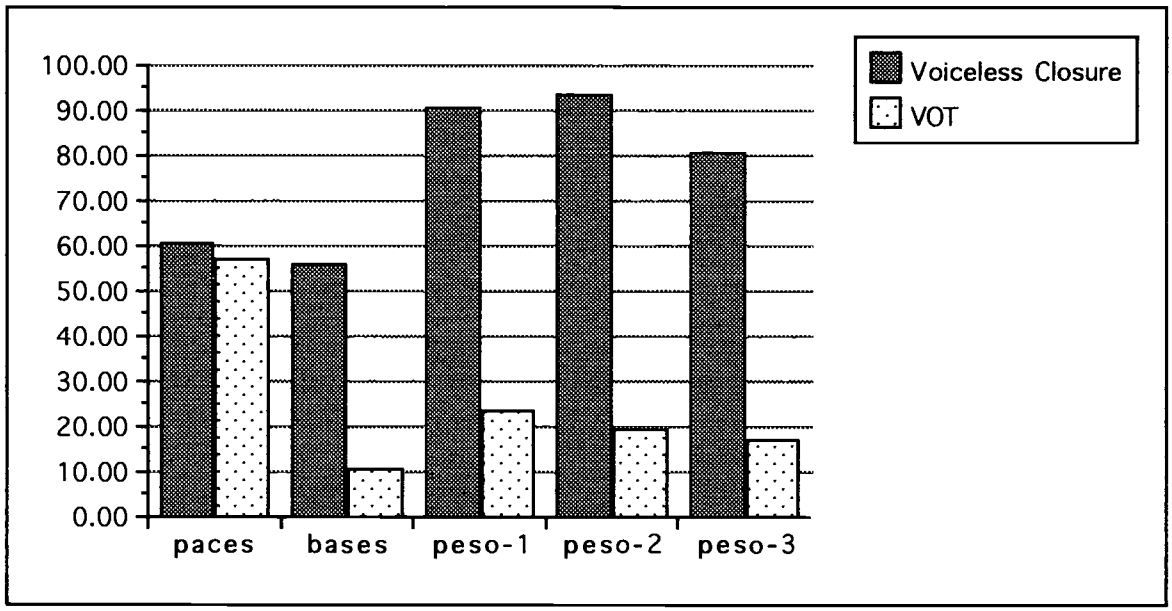

Figure 8: Mean Voiceless Closure & VOT Values (in msecs) - Learner Production of English /t, d/ & Spanish /t/

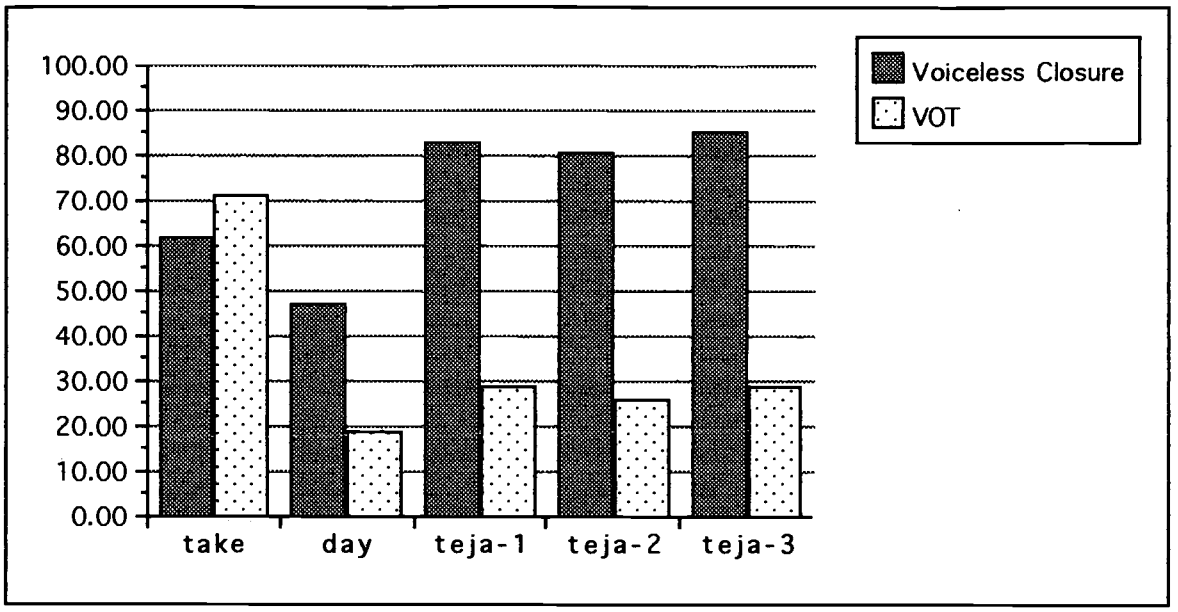

Figure 9: Mean Voiceless Closure & VOT Values (in msecs) - Learner Production of English /k, g/ & Spanish /k/

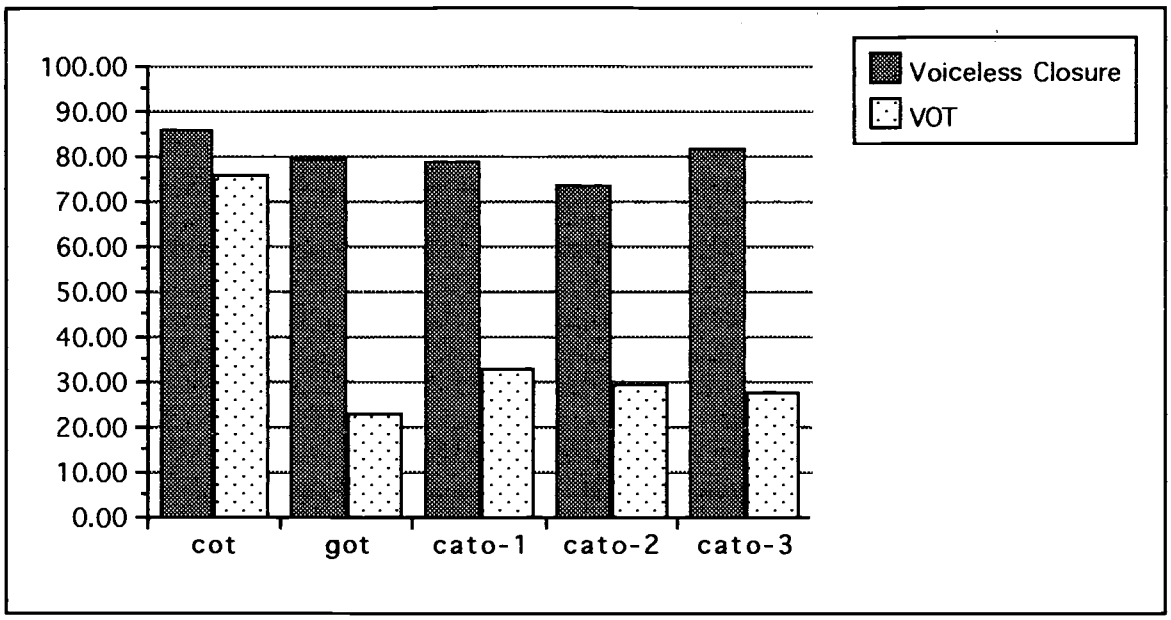

Figure 10: Mean Voiceless Closure & VOT Values (in msecs) - Learner Production of English & Spanish /b/

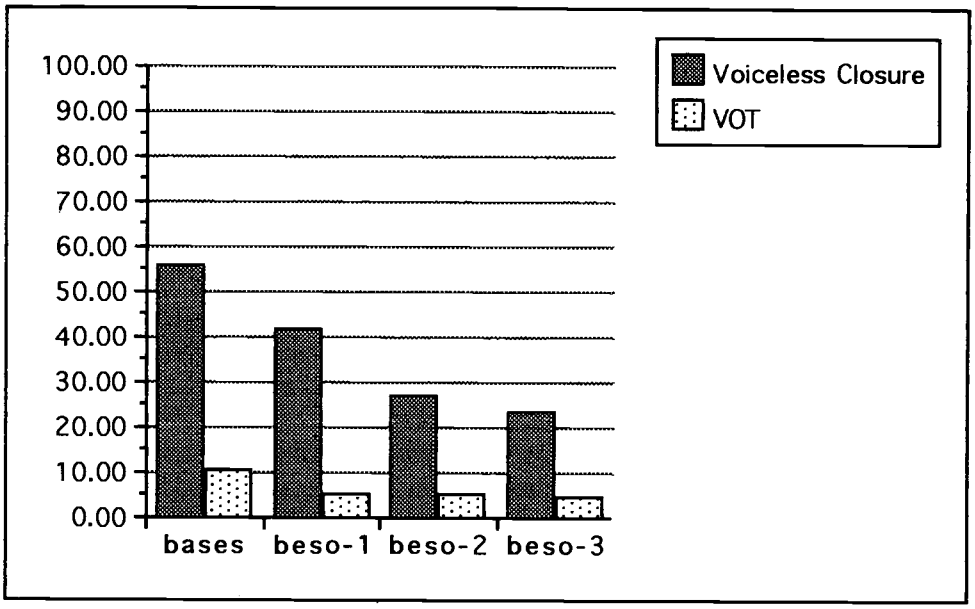

Figure 11: Mean Voiceless Closure & VOT Values (in msecs) - Learner Production of English & Spanish /d/

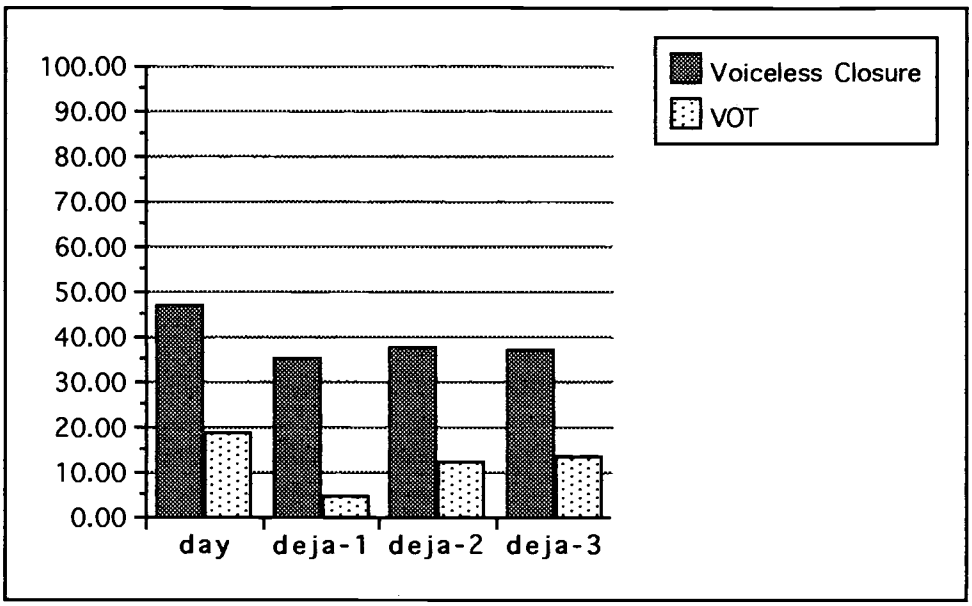

Figure 12: Mean Voiceless Closure & VOT Values (in msecs) - Learner Production of English & Spanish /g/

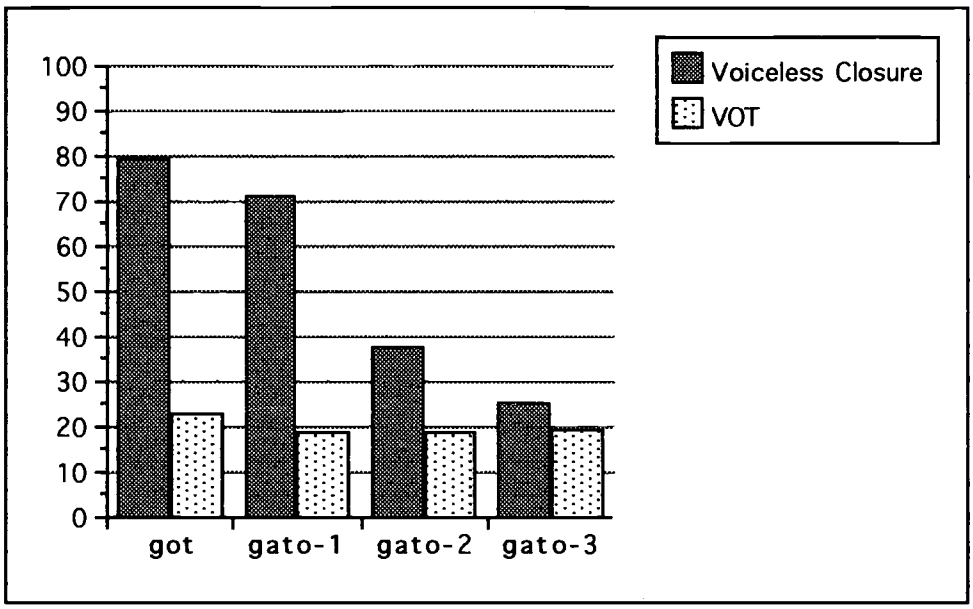

Figure 13: Acoustic Cues Utilized by Learners to Distinguish L1 English and L2 Spanish Short Lag Productions

	Bilabial			*Dental*			*Velar*	
1st Session	**Peso**	**Beso**		**Teja**	**Deja**		**Cato**	**Gato**
	Bases	Closure, VOT	None	**Day**	Closure, VOT	VOT	**Got**	VOT	None
	Peso		Closure, VOT	**Teja**		Closure, VOT	**Cato**		VOT
2nd Session	**Peso**	**Beso**		**Teja**	**Deja**		**Cato**	**Gato**
	Bases	Closure	Closure	**Day**	Closure	None	**Got**	None	Closure, VOT
	Peso		Closure, VOT	**Teja**		Closure, VOT	**Cato**		Closure, VOT
3rd Session	**Peso**	**Beso**		**Teja**	**Deja**		**Cato**	**Gato**
	Bases	Closure	Closure	**Day**	Closure, VOT	VOT	**Got**	None	Closure, VOT
	Peso		Closure	**Teja**		Closure, VOT	**Cato**		Closure, VOT

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