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ABSTRACT

A study attempted to (1) define acoustically the learner's progress in acquisition of a set of phonological features, specifically interlingual differences in the voice onset time of voiceless stop consonants and the number of taps produced when attempting to produce the Spanish phoneme /r/ (trill); (2) determine if and at what stage of acquisition the given L2 targets are realized; and (3) use data from adult English-speaking learners of Spanish to test Flege's framework of second language speech acquisition known as the Speech Learning Model. Subjects were 40 native English-speaking college students of Spanish. The learners, representing four different proficiency levels, provided data that were analyzed acoustically using computer-based speech analysis software. In addition to tracing the acquisition of a set of sounds through the four levels, the study provides evidence that the Spanish trill is acquired differently than the voiceless stops. Furthermore, Flege's model is shown to be a relevant model of second language speech acquisition with respect to the sounds and language combination examined here. Contains 17 references. (MSE)

English Speakers' Acquisition of Voiceless Stops and Trills in L2 Spanish

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The purpose of this paper is threefold: (1) to define acoustically the learner progress in the acquisition of a set of phonological features, specifically interlingual differences in the voice onset time of voiceless stop consonants and the number of taps produced when attempting to produce the Spanish phoneme /r/; (2) to determine if and at what stage of acquisition the given L2 targets are realized; and (3) to use data from adult English-speaking learners of Spanish to test Flege's framework of second language speech acquisition known as the Speech Learning Model. The basis for addressing the above questions in this paper is a cross-sectional study of 40 native English-speaking learners of Spanish in a U.S. university. These learners, representing four different levels, provided data that were analyzed acoustically using computer-based speech analysis software. In addition to tracing the acquisition of a set of sounds through the four levels, this study provides evidence that the Spanish trill is acquired differently than the voiceless stops. Furthermore, Flege's SLM is shown to be a relevant model of second language speech acquisition with respect to the sounds and language combination examined in this study.

INTRODUCTION

This paper is divided into four sections. The first section provides the background for this study by summarizing current views of some of the factors constraining second language (L2) speech acquisition and by describing Flege's (1995) Speech Learning Model (SLM). Also in the first section is a description of the Spanish sounds that are studied in this work, accompanied by an overview of previous research done on the L2 acquisition of those Spanish sounds by English speakers. The second section of this paper describes the method used in this cross-sectional study, including a description of the participants and their experience with the study of Spanish, an explanation of the data collection procedure, and an outline of the scoring procedure. The next section presents the results of the perception test and the data from the participants' production attempts of the trill and the voiceless stops, and the final section summarizes the results and their implications for what is known about the acquisition of L2 Spanish speech.

BACKGROUND

In this section, current views of some of the factors governing second language (L2) speech acquisition are summarized. After this background information is given, a description of relevant portions of Flege's (1995) SLM is provided, given that it is a model of L2 speech acquisition that claims to be applicable to learners of all ages. Next is a description of the Spanish sounds /r/, /p/, /t/, and /k/ that are studied here, as well as an encapsulation of the research that has already been done on the L2 acquisition of those sounds by native English speakers.

L2 Speech Perception Constraints

Early in their linguistic experience, humans learn to organize the enormous set of perceived sounds by classifying them as speech or non-speech and, for the former, as sounds with phonemic significance in the L1 phonological inventory, in much the same way as they organize the infinite variety of color into categories such as red, pink, or orange. With respect to L2 acquisition, the research suggests that learners in early stages routinely categorize L2 speech sounds that they perceive in terms of their L1 phonological inventory. To test the hypothesis that L1 phonemic categorization rules influence perception of other speech sounds, Scholes (1967) designed an experiment in which listeners from a variety of language backgrounds were presented aurally with a set of synthetic vowel stimuli. The resulting data showed that subjects tended to organize the stimuli in accordance with the vowel systems of their native languages, suggesting an L1 influence in vowel perception. In experiments in which subjects were asked to categorize initial occlusives, for which voice onset time (VOT) is an acoustic cue, Lisker & Abramson (1964) reported that listeners regularly separated a continuum of stop consonant stimuli varying in VOT value according to the categorizations in their L1.

Also seeking evidence of how categories are established, Williams (1979) engaged bilingual adults in perceptory discrimination tasks and found that the subjects established compromise VOT values falling between the categories present in the L1 and L2, suggesting that learners may alter their perceptive categories in response to stimuli. This finding was later confirmed by Flege (1987) and forms the basis for his "equivalence classification" hypothesis, which proposes that learners may group similar L1 and L2 phones into one category based on such compromise values. According to this hypothesis, a learner projects L1 phonetic categories onto the L2 whenever the sounds are judged by the learner to be equivalent; new phonetic categories are formed only when the learner perceives the sounds as different. One effect that Flege (1995) proposed for such equivalence classification is that cases of continued perceptual linkage of L1 and L2 sounds limit the accuracy with which L2 sounds may be produced (Flege, 1995).

L2 Speech Production Constraints

Just as perceptual categories are established for L1 processing, Borden, Harris, Fitch, and Yoshioka (1981) claim that speakers have mentally pre-established representations of muscular gestures that are necessary to produce the articulatory target. Accordingly, L2 production would presumably be limited, either by the degree of similarity between the L1 and L2 targets or by the degree to which the learner is able to successfully establish new gestural representations. Borden (1980) suggests that self-perception plays an important role in establishing a link between the perception and production of novel phonetic targets in that the learner progressively modifies gestural representations until auditory feedback indicates to the learner that the L2 target has been met satisfactorily. Direct realist accounts of speech learning, such as that proposed by Best (1995), point out that learners have proprioceptive access to the gestures used to create speech sounds and are able to learn efficiently the important elements of the gestures used to create L1 speech sounds. Best proposed that this gestural proprioceptivity leads to the formation of relational "lower-order invariants," which may gradually give way to language-specific, "higher-order invariants," causing a reduced amount of lower-order phonetic detail to be detected and thus potentially interfering with the mechanisms used in the learning of new sounds.

A question that has generated controversy in the literature is whether L2 perception precedes production or whether accurate production can come before (or without) perception. Some studies, such as Lane (1963), Neufeld (1979), and Flege (1987), have suggested that accurate perception must come before production, but other research, such as Gass's (1984) study on English learners' VOT production, suggests that accurate production may precede perception.

The Speech Learning Model

In its current form, the Speech Learning Model (Flege, 1995) presents four postulates and seven hypotheses concerned with the ultimate attainment of L2 pronunciation. The SLM claims that learners of an L2 must create accurate perceptual "targets" to guide them in the production of L2 sounds; failure to do so will result in inaccurately produced targets. The first postulate of the SLM proposes that the same devices that are used by learners to learn their native language (L1) can be accessed at any age and applied to L2 learning. Since the present study treats the adult [1] acquisition of L2 Spanish, this postulate is of considerable importance since it provides the assumption that speech learning processes remain accessible to all L2 learners, regardless of age. Of the seven hypotheses of the model given by Flege (1995, p. 239), the second, third, and seventh are particularly relevant to the present study and are listed here:

Hypothesis 2: A new phonetic category can be established for an L2 sound that differs phonetically from the closest L1 sound if bilinguals discern at least some of the phonetic differences between the L1 and L2 sounds.

Hypothesis 3: The greater the perceived phonetic dissimilarity between an L2 sound and the closest L1 sound, the more likely it is that phonetic differences between the sounds will be discerned.

Hypothesis 7: The production of a sound eventually corresponds to the properties represented in its phonetic category representation.

Hypotheses 2 and 3 predict that learners will be able to create a new phonetic category once they perceive that a sound differs from a corresponding sound in the L1; the likelihood of this occurring increases as the differences between the L1 and L2 sounds magnify. According to Hypothesis 7, once learners have established such a phonetic category representation for a novel sound, their production of that sound will eventually correspond to that of native speakers of the L2, provided their phonetic categories were accurately represented.

Description of Sounds

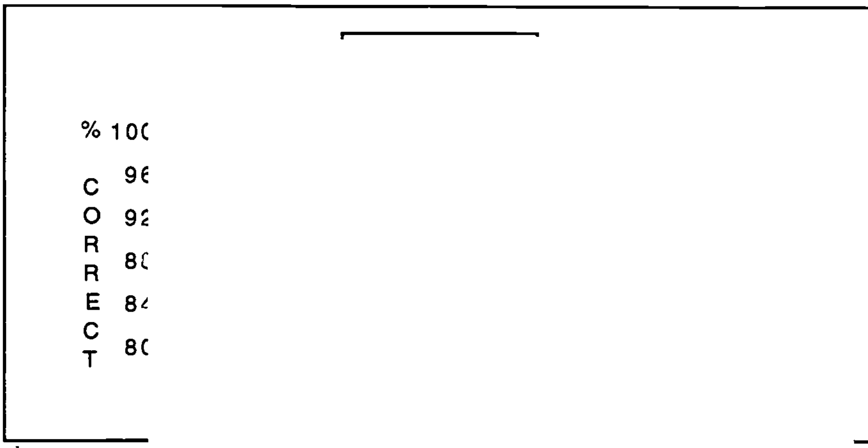
The Phonemes /p/, /t/, /k/

The phonemes /p/, /t/, and /k/ are present in both English and Spanish. Despite their apparent similarity, however, in English the allophones [p^h] (aspirated voiceless bilabial stop), [t^h] (aspirated voiceless alveolar stop), and [k^h] (aspirated voiceless velar stop) may occur in word-initial position or at the beginning of a stressed syllable, whereas in Spanish the three phonemes in question each have only one possible syllable-initial allophonic realization (the voiceless bilabial stop [p] for /p/, the voiceless dental stop [t] for /t/, and the voiceless velar stop [k] for /k/).

As originally proposed by Lisker and Abramson (1964), and as since expanded further by many other researchers, the standard acoustic correlate used to measure stop consonant production is VOT [2]. Within the VOT continuum, Lisker and Abramson found that most languages tend to cluster VOT around three or fewer categories of values: long voicing lead, zero onset or short lag, and long voicing lag. Keating (1984) proposed describing these as phonetic categories, such that Lisker and Abramson's categories would be phonetically realized as the following: *voiced* (also referred to as *prevoiced*), *voiceless unaspirated*, and *voiceless aspirated*, respectively. Figure 1 illustrates the phonological differences for stop consonants between English and Spanish along the VOT continuum. The figure shows that English uses all three phonetic categories, with the voiced and voiceless unaspirated categories used for voiced phonemes and the voiceless aspirated category used for voiceless phonemes. Spanish, however, uses only two of the phonetic categories. In Spanish, the voiced category represents voiced phonemes and the voiceless unaspirated category is used for voiceless phonemes. The voiceless aspirated phonetic category is not used in Spanish.

The Phoneme /r/

The Spanish trill /r/ has no counterpart in any dialect of American English, nor in most other dialects of English. Although this phoneme's allophonic distribution may include allophones that are voiced or voiceless fricatives, uvular trills, and voiced or voiceless alveolar trills, the most common allophone in most dialects and the one that is most frequently taught to learners of



L2 Spanish is the voiced alveolar trill represented by the International Phonetic Alphabet symbol /r/. The most readily identifiable acoustic correlate of the /r/ is a regular interruption in the waveform and spectrograph caused by the brief, periodic cessations of phonation that correspond to each contact between the tongue and the alveolar area.

Existing Research On L2 Spanish Phonemes /p/, /t/, /k/, and /r/

Although interest in the acquisition of L2 Spanish stop consonants by English-speaking populations has developed relatively recently, there have been a number of important advances. González-Bueno (1997) tested two groups of intermediate learners of Spanish in a foreign language setting. The first, an experimental group, received explicit instruction and practice in the production of Spanish stop consonants, while a control group received no special instruction. Over the course of one semester, she found that learners in the experimental group were able to significantly shorten VOT in their production of /p/ and /g/, thus rendering their production more Spanish-like. Although the /t/, /k/, /b/, and /d/ also improved, the degree of improvement was not statistically significant, which González-Bueno attributes to the interactive operation of developmental and transfer processes.

Flege and Eefting (1988) conducted an experiment in which English monolinguals, Spanish monolinguals, and native Spanish bilinguals imitated a consonant-vowel continuum in which the VOT of the initial consonant varied. As expected, the Spanish monolinguals showed a tendency to produce stops with Spanish-like VOT values (short lag, long lead) and the English monolinguals tended to produce English-like stops (short lag, long lag). With the bilingual group, however, the researchers reported stop production in all three VOT ranges, suggesting that those subjects had processed the stops in terms of the three phonetic categories present in both languages.

Contrasting with the amount of attention that has been given to the acquisition of L2 Spanish stop consonants as evidenced by the aforementioned studies, the trill has not been the subject of recent published studies. Consequently, this study hopes to fill a gap in the research by directing inquiry to the L2 acquisition of the /r/ among adult English speakers.

METHOD

This section of this paper describes the research method employed in this cross-sectional study. A description of basic characteristics of the participants as well as information about their background with L2 Spanish is given. Following the description of the subjects, an explanation of the data collection procedure and an outline of the scoring procedure are provided.

Subjects

The present study examines data gathered in 1997 from 45 volunteers affiliated with the Spanish program at a medium-sized, private university in the United States. Of these participants, 40 were native speakers of English and the remaining 5 were native speakers of Spanish. The native English-speaking subjects were recruited from among those who had no significant childhood background with Spanish, neither through significant formal study prior to age 12, through residence or extensive travel in Spanish-speaking communities, nor through family contact. The native English-speaking subjects are categorized as below and are described in Table 1.

Level 1 (Beginning Learners): The 10 participants in this group were students enrolled for credit in a first-semester university Spanish language course.

Level 2 (Intermediate Learners): The 10 participants in this group were students enrolled for credit in a third-semester university Spanish language course.

Level 3 (Advanced Learners): The 10 participants in this group were enrolled for credit in an upper-division or graduate-level university course in Spanish language, literature, or culture.

Level 4 (Very Advanced Learners): The 10 participants in this group were native speakers of English who were full-time instructional faculty teaching university courses in Spanish language, literature, or culture and who otherwise met the criteria for inclusion in the study.

The native Spanish-speaking participants were recruited from among teachers of Spanish at the same university. These native speakers, from Chile, Colombia,

Table 1
Participant Characteristics (Group Means)

	Level 1	Level 2	Level 3	Level 4
Age (years)	18.5	19.7	21.6	41.8
H.S. Span. (years)	2.2	2.5	2.3	2.2
Univ Span. (semesters)	1.1	2.6	7.9	21.6
Hrs Span used/day	1.2	0.9	1.8	4.1
Days in Span country	4.2	5.0	18.3	1615.5

Mexico, and Spain, were selected to provide speech data for purposes of comparison, and they represent many of the most common varieties of Spanish.

Data Elicitation

The data collection process consisted of three separate types of data-gathering methods. A questionnaire collected relevant biographical data and learner characteristics, a forced-choice minimal pair test prompted by a Spanish audio recording provided a measure of auditory discrimination, and three different types of audio recordings of each subject's Spanish captured L2 production. To ensure consistency and cross-level comparability of data, the data collection procedure was identical for each participant, regardless of level. All instructions were given in English.

After signing a form indicating their informed willingness to participate in the study, each participant completed the first part of the study, a questionnaire that identified the relevant individual learner characteristics and established a profile of each level of subjects, as seen in Table 1. The second part of data collection was a two-alternative, forced-choice discrimination test designed to measure perception of discrete target language items among 12 minimal pairs. The stimulus for this portion of the experiment was a previously recorded audio recording of a native Spanish speaker reading one of the minimal pair items; subjects circled the item they believed they heard on a score sheet. The recording was presented via a Sony TCM-919 cassette player.

The third part of this study recorded the subjects' production of Spanish. This part consisted of three different segments, each involving a different elicitation protocol. In the first of these segments, the researcher instructed subjects to read from a list of ten Spanish words or phrases embedded in a carrier phrase common to all items (e.g. *"digo ~ esta vez"*). These items were selected to provide a wide variety of phonemic targets and to measure sensitivity to (and influence from) orthographic cues in an elicitation protocol where all or most of the participant's attention could be directed to pronunciation. In the second segment, also designed to measure discrete lexical items, participants were sequentially shown 11 picture cards, each with a drawing of a relatively common item. The task was for the subjects to say the names of the objects in Spanish. Finally, in the third speech elicitation protocol, participants provided a 30-second guided narration in Spanish in response to a written cue. This segment provided data from a context in which the participant's mental resources were presumably engaged in many elements of language production besides pronunciation.

Speech data for all participants were recorded as follows: Each subject was recorded individually in the researcher's office (which, while not an anechoic chamber, includes a number of sound muffling features). Having been prompted, subjects spoke into a Sony SV-9 microphone mounted on a Nissin tripod stand. The resulting input fed directly into the audio input of a Macintosh desktop computer, which then processed and recorded the signals digitally using *Signalyze* speech analysis software.

RESULTS

The results section presents the findings of the perception and speaking elicitation tests. These findings, presented in tabular and graphic formats, are also analyzed statistically to evaluate the significance of the findings.

Perception Test

The results of the two-alternative forced-choice perception test for each level are presented in Figure 1. The perception test in this study provides a general assessment of the participants' perception of Spanish minimal pairs, including 5 vocalic and 6 consonantal features. These results show that in this study learners at more advanced levels were better able to discriminate among Spanish minimal pairs than those at beginning levels, although learners at all levels showed a high percentage of correct responses, suggesting that most learners correctly perceive phonemic features in Spanish.

Spanish Production Data: Stop Consonants

The data collected from the speech elicitation tests appear in Tables 2 and 3. Table 2 indicates the shortest, longest, and mean VOT values recorded for each stop consonant (the data are also arranged graphically in Figures 2 through 7). The results of the ANOVA shown in Table 3 suggest that stop consonants are produced with a significantly more Spanish-like VOT when

Table 2
VOT Values for Each Phoneme, by Group

	/p/	/t/	/k/
Level 1			
Shortest VOT (ms)	36	26	41
Longest VOT (ms)	89	102	117
Mean VOT (ms)	54	53	73
Level 2			
Shortest VOT (ms)	27	30	53
Longest VOT (ms)	86	98	116
Mean VOT (ms)	51	55	74
Level 3			
Shortest VOT (ms)	13	15	34
Longest VOT (ms)	54	79	112
Mean VOT (ms)	36	36	60
Level 4			
Shortest VOT (ms)	17	16	31
Longest VOT (ms)	46	58	73
Mean VOT (ms)	29	29	49
Native Speaker [3]			
Shortest VOT (ms)	9	10	17
Longest VOT (ms)	27	33	41
Mean VOT (ms)	17	17	28

Table 3
ANOVA on the Difference of Mean VOT Values Between Levels

Comparison	Difference in Mean VOT (ms)
Level 1 > Level 2	0
Level 1 > Level 3	-48*
Level 1 > Level 4	-73**
Level 2 > Level 3	-48*
Level 2 > Level 4	-73**
Level 3 > Level 4	-25

*p <0.01
**p <.001

comparing Level 1 with Levels 3 and 4, as well as when comparing Level 2 with Levels 3 and 4. With some exception, reduction of VOT times was a general tendency throughout all of the levels, but only the increases evident between the first two andlast two levels reached confidence levels of 99% or greater.

Table 3 shows the results of an ANOVA on the difference of mean VOT values between levels for all three voiceless stops. The difference between the Level 1 values and the Level 2 values were, coincidentally, zero (the reduction in /p/ values from Level 1 to Level 2 was offset by the slightly higher values with /t/ and /k/). Statistically significant VOT reductions occur from Level 1 to Levels 3 and 4, and from Level 2 to Levels 3 and 4. Although a VOT reduction occurs from Level 3 to Level 4, it does not reach significance.

Figures 2 through 7 on the following pages illustrate the range of mean VOT values recorded from participants' speech samples. Figures 2 through 4 show the entire range of VOT mean values for /p/, /t/, and /k/, respectively, whereas the overall mean VOT for each level appears in Figures 5 through 7.

As shown in Figures 2 through 7 above, the three voiceless stop sounds follow the same pattern of acquisition. Learners in the earlier stages of acquisition, such as those in Levels 1 and 2, tend to produce the target sound inconsistently, as

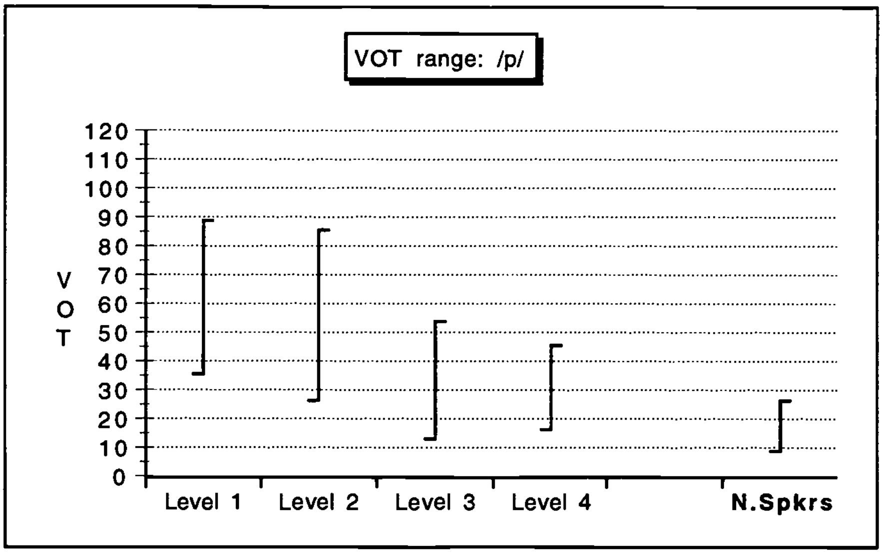


Figure 2. Range of Mean VOT Values for /p/, in Milliseconds.

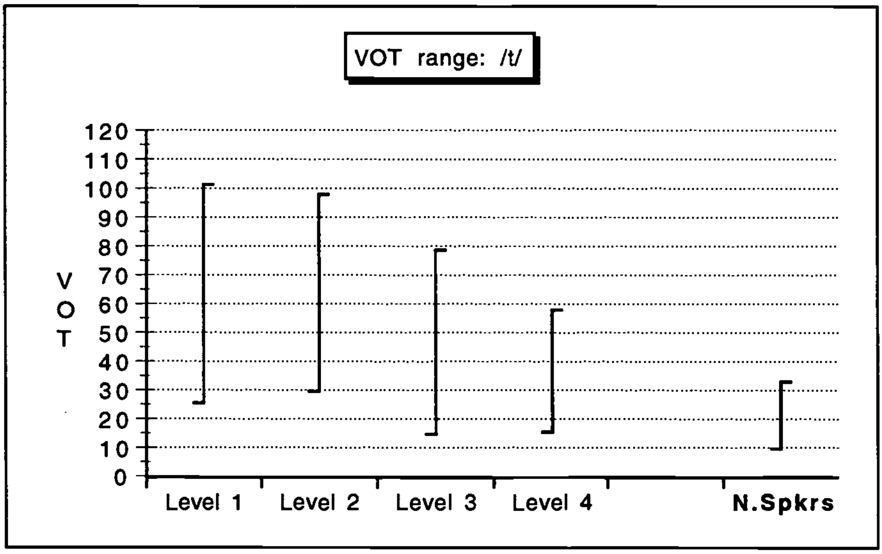


Figure 3. Range of Mean VOT Values for /t/, in Milliseconds

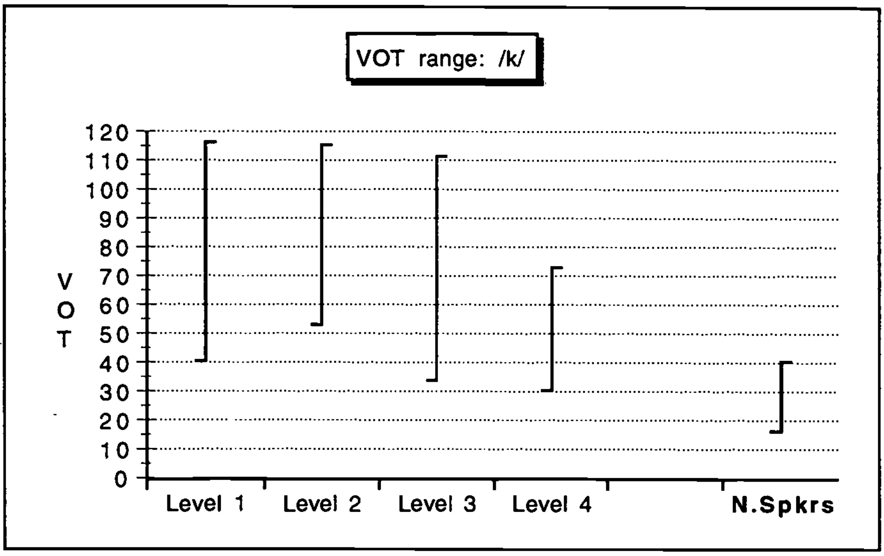


Figure 4. Range of Mean VOT Values for /k/, in Milliseconds.

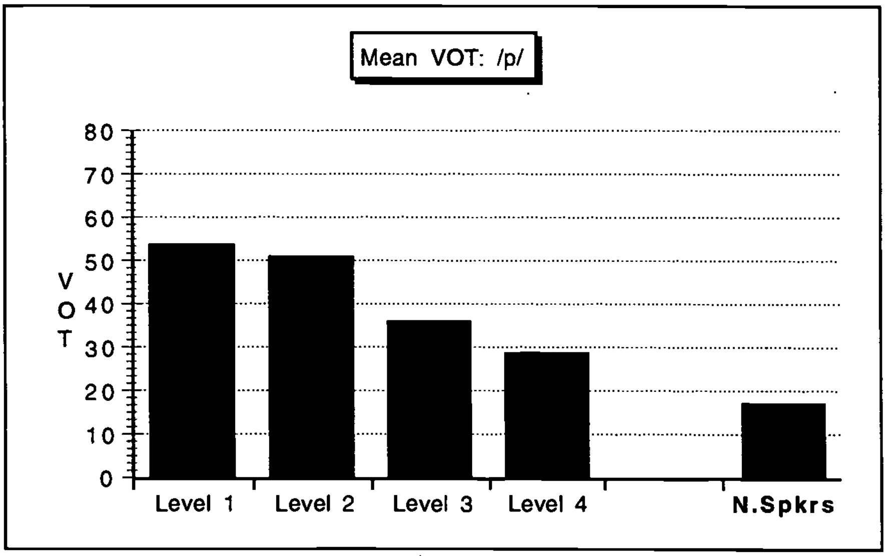


Figure 5. Group Mean VOT Values for /p/, in Milliseconds.

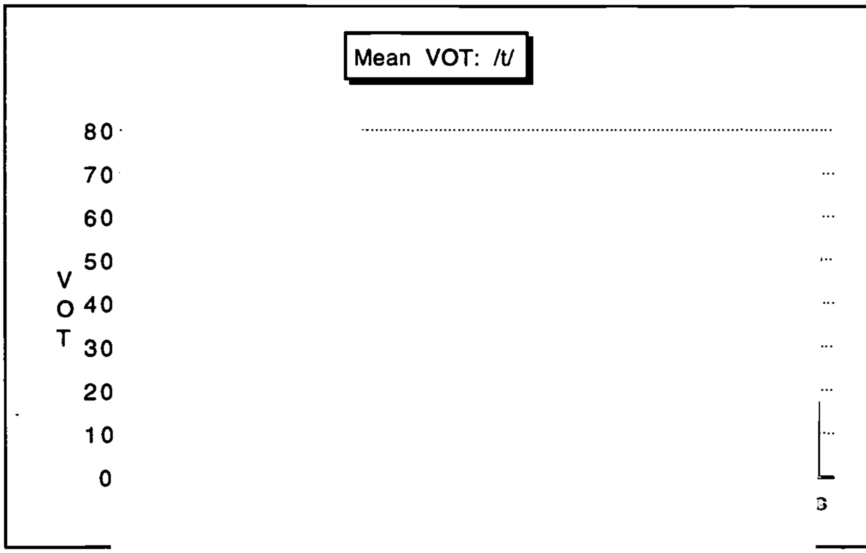


Figure 6. Group [illegible] onds.

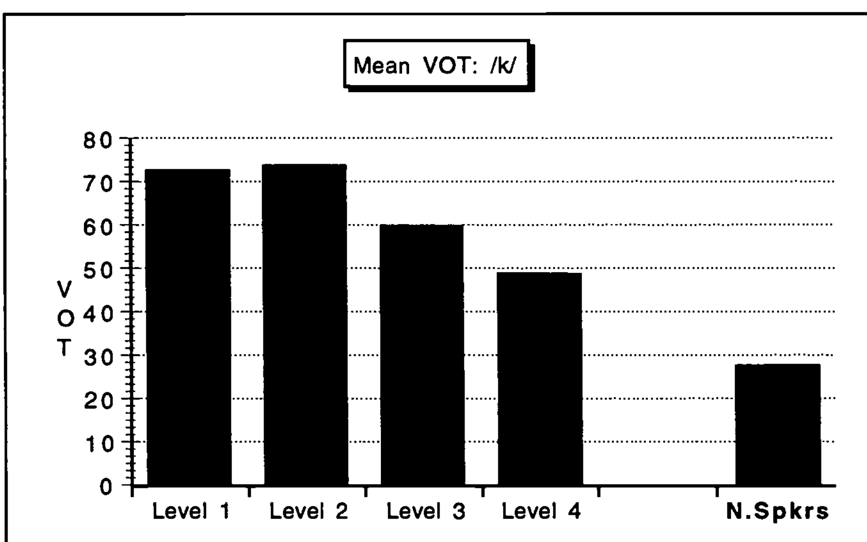


Figure 7. Group Mean VOT Values for /k/, in Milliseconds.

evidenced by a wide range of VOT values in their attempts at the L2 target.

For example, Figure 3 shows that there is more than 70 ms difference between the shortest and longest Level 1 mean VOT. Additionally,the less advanced learners show a tendency to equate the L2 sound with its L1 counterpart, resulting in the high, English-like mean VOT values that are shown in Figures 5 through 7. Although the learners in Levels 3 and 4 show considerably shorter, more Spanish-like mean VOT values than those in Levels 1 and 2, their VOT ranges are still not significantly Spanish-like and instead are intermediate between English and Spanish norms, suggesting the possibility of continued, although diminished, association between the L1 and L2 sounds.

Spanish Production Tests: Trill

With respect to the acquisition of the Spanish trill, the data show clearly definable progress. Evidence of this progress shown in Table 4 is that the mean number of trills produced by learners in each level steadily increases from 0.6 taps per /r/ attempt among the beginners to 2.6 taps per /r/ attempt among the very advanced learners. Similarly, the percentage of /r/ attempts with at least two taps increases from 7% to 83% from beginners to very advanced learners.

Given that this sound does not exist in the L1 of the participants in this study, it is not surprising that the beginning learners in Level 1 demonstrated an almost complete inability to produce the Spanish trill when necessary, evidenced by the low 7% of all Level 1 /r/ attempts

Table 4
Number of Closures (Trills) for /r/ Attempts

	Min	Max	Mean	% with 2+ trills
Level 1	0	4	0.6	7
Level 2	0	4	0.9	13
Level 3	0	5	1.8	37
Level 4	1	4	2.6	83
N. Spkrs.	2	5	3.2	100 [4]

that were produced within the native speaker range of 2-5 trills. Contrarily, the near complete mastery of this novel sound by the Level 4 participants suggests that learners are ultimately able to construct and employ an entirely new sound category.

DISCUSSION

The subjects in this study represent Spanish L2 learners of all levels, ranging from beginners whose exposure to Spanish came largely from input available in a formal foreign language study context to advanced learners with years of target language experience in both formal and naturalistic settings. Despite the existence of many differences between the populations represented in each of the four groups, all subjects shared several important characteristics. Before reaching age 12, none of the 40 participants in the four groups of native English-speakers had studied Spanish, been a part of a Spanish-speaking family, or lived in a Spanish-speaking community. Thus, this study can serve as a measure of the progress in L2 Spanish pronunciation of voiceless stops and trills by a group of English-speaking adult learners.

The results suggest that the phonological interlanguage in the groups tested, as measured by the test instrument used in this study, may be characterized as having an acoustically definable and statistically significant acquisitional sequence that initially shows many L1 characteristics and progresses over time to a more L2-like production, supporting Flege's postulate that the mechanisms and processes used in learning the L1 sound system remain intact throughout one's life and are available to be applied to L2 learning. Although the beginners were generally unable to produce the speech targets with phonetic accuracy, the advanced learners in this study were able to produce Spanish trills and voiceless stops that frequently matched or closely resembled those produced by native Spanish speakers.

The SLM claims that inaccurate productions in L2 sounds may result from the learners' failure to create appropriate perceptual "targets" to guide their production (Hypothesis 7), which may in turn be caused by the learners not discerning at least some of the phonetic differences between the L1 and L2 sounds (Hypothesis 2). This learner awareness and identification of the phonetic differences between the L1 and L2 are made more likely as the perceived phonetic dissimilarity between an L2 sound and the closest L1 sound increases (Hypothesis 3). The SLM thus predicts that the native English speakers learning Spanish in this study will be more likely to create a new phonetic category for the /r/, which differs from any sound in the L1, than for either of the voiceless occlusives /p/, /t/, or /k/, which share many similarities between the two languages. Evidence of the formation of (or failure to form) new phonetic categories, according to Hypothesis 7, will come from learner production of that sound, which may eventually correspond to that of native speakers. The data presented in Table 4 on the acquisition of the /r/ indicate a near-complete mastery of the /r/ among the group of very advanced learners compared to a near-zero ability among the beginners. Since the /r/ represents a novel phonetic category for the participants in this study, these findings support the SLM. The results of the data collected on the voiceless stops /p/, /t/, and /k/ also support Flege's model. As seen in Figures 4 through 6, the VOT values of the target voiceless stop phonemes were rarely produced within the native speaker ranges by the beginners; however, even the VOT ranges of the most advanced learners do not convincingly overlap the native speaker ranges. One explanation for this finding is that the phonetic dissimilarity between the Spanish and English stops is not as great as with the /r/ and thus learners are not as likely to perceive the need to actively and accurately create new phonetic categories.

In sum, this paper suggests that English-speaking adult learners' acquisition of the trill and the voiceless stops in L2 Spanish evolves in an acoustically definable manner. It also suggests that significant improvement is evident between many of the levels, even though none of the L2 Spanish sounds examined in this study were acquired completely enough to show significantly similar acoustic parameters to native speakers' production of the same sounds. Finally the evidence suggests that over the long term, the /r/, a sound for which no English counterpart exists, is acquired much more completely and consistently than the /p/, /t/, or /k/, all sounds that have similar English counterparts. This finding supports the SLM's (Flege, 1995) contention that L2 sounds for which no L1 equivalent exists are ultimately more likely to be acquired than sounds for which there are L1 equivalents.

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NOTES

1 The term *adult* in this paper refers to any individual beyond puberty. Although I have chosen the term "adult language acquisition" for language acquisition after puberty and have set a criterion in participant selection which excludes those significantly exposed to Spanish prior to age 12, my doing so is arbitrary. Researchers such as Lenneberg (1967) and Scovel (1988) have proposed that language cannot be learned perfectly once a biologically predetermined critical period has been passed, due at least in part to neurological maturation. However, recent evidence (e.g., Flege, Munro, and MacKay, 1995) suggests that the acquisition of L2 speech, at least, follows a strong linear relationship with age and shows no evidence of a definable critical period.

2 Voice onset time (VOT) is the time between the release of the articulators in a stop consonant and the onset of vocal fold vibra-

tion in the following vowel. VOT is usually measured in milliseconds (ms), with the stop consonant release representing zero. When vocal fold vibrations begin before the articulators' release, as may occur with voiced stops, the convention is to assign a negative VOT value.

3 For comparison, Nathan (1987) presented the following mean VOT values (ranges in parenthesis) for seven Spanish speakers from Costa Rica, Colombia, and Venezuela: /p/ 18.8 (8.2/31), /t/ 22.6 (13.5/30.3), /k/ 40.7 (22.5/55.5). From the same source, mean values for English were given as /p/ 82.5, /t/ 105, and /k/ 117.

4 One of the native speakers produced the voiced alveolar trill allophone during the reading and picture identification portions of the data collection, but produced a voiceless alveolar slit fricative during the free-speaking portion. This allophone is fairly common in certain regions of Spanish America, and its appearance in the speaking task, but not the reading or identification tasks, is consistent with Dalbor (1980), who reports that many speakers use the trill in formal speech and the fricative in informal speech.

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