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AUTHOR Macken, Marlys A.; Barton, David
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ABSTRACT

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THE ACQUISITION OF THE VOICING CONTRAST IN SPANISH: A PHONETIC AND PHONOLOGICAL STUDY OF WORD-INITIAL STOP CONSONANTS.[1]

Marlys A. Macken and David Barton
Department of Linguistics
Stanford University

ABSTRACT. This paper reports on the acquisition of the voicing contrast in Mexican-Spanish word-initial stops. In Study 1, three monolingual children were recorded every two weeks for seven months, beginning when the children were about 1;7. In Study 2, four monolingual children about 3;10 were recorded once or twice. Two analyses were done. Instrumental analysis of the stop productions revealed that not even by age 3;10 were the children consistently distinguishing between voiced-voiceless stop cognate pairs on the basis of adult-like voice-onset time characteristics. The spirantization analysis, however, more clearly revealed the children's phonological knowledge. Discussion focuses on the implications of the data for phonological development in general and for the phonological description of voicing in Spanish.

Introduction

Spanish has a two way voicing contrast at the labial, dental and velar places of articulation. Lisker and Abramson 1964 and Williams 1977 found that adult Spanish speakers produce consistent voice onset time differences between members of voiced, voiceless cognate pairs. Voice onset time (or VOT) refers to the time interval between the release of stop closure and the onset of vocal fold vibration. The Spanish voiced phonemes are characterized by the presence of glottal pulsing during articulatory closure; they are called 'lead' voicing types in the Lisker and Abramson framework. The Spanish voiceless phonemes are 'short lag' stops: voicing does not begin until up to 25 milliseconds (ms) after release of closure. VOT has also been shown to be a sufficient cue for the discrimination of cognate pairs by adult Spanish speakers (Abramson and Lisker 1973; Williams 1977). Since VOT has been thus shown to reliably distinguish voiced-voiceless pairs in Spanish, we hypothesized that as the child acquires productive control over voicing, VOT values would change concomitantly.

The Spanish voicing contrast has another important phonetic property: the voiced phonemes have two allophones--a stop and a voiced spirant of the same place of articulation. According to conventional descriptions, the stops [bdg] occur in utterance initial position and after nasals, and [d] occurs after /l/ (e.g. Harris 1969 on the 'Spanish spirantization rule'). In addition, the voiced stop allophones may occur in any word-initial position in careful or andante speech (Harris 1969). The spirants occur in all other positions. Although the spirants occur much more frequently than the stops (cf. Navarro's analysis of

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written corpora, 1968), most phonological descriptions of Spanish set up the stops /bdg/ as the systematic phonemes and derive the spirants from the stops by rule. Since these analyses identify the stop phones as basic, we could expect that children acquire the stop phones [bdg] before the spirant phones [βðγ] and still later learn the correct pattern of distribution.

Thus, two analyses are presented: the first is based on an instrumental investigation of the VOT characteristics of word-initial stops consonants; and the second is based on a tabulation of the [-continuant] and [+continuant] phones produced for word initial voiced as opposed to voiceless stop phonemes. 'Continuant' is used here as a cover term to include both the spirants [βðγ] and the glides [wj], both of which the children produce in place of the voiced stop phonemes. These analyses are carried out for both of the studies: Study 1, which is the longitudinal study of the productions of three children who were about 1;7 at the beginning of the study; and Study 2, a cross-sectional study in which four children aged about 3;10 served as subjects.[2] These two groups of children will be referred to as the 'two-year-olds' and the 'four-year-olds', respectively. Since the data from the two sets of children are overall highly similar, we will discuss both studies in parallel.

Method

Subjects. Home interviews with prospective subjects and their families were conducted to determine the degree of cooperation, the verbal level, etc. of the children and the families' interest in participation in the study. The interviews were conducted by a native Mexican-Spanish speaker who was a member of the community and had been hired as our community liaison person. In nearly all cases, this person had known the families for some length of time. A typed statement (in Spanish) of the Project's goals and a detailed description of the experimental methodology were given to the parents after both aspects had been verbally covered by the community liaison person.

Four children were selected to be subjects in Study 1 because they were monolingual speakers of Spanish with no siblings of school age, they were producing at least some initial stop words, they showed evidence of normal language development, and they appeared to be cooperative. One of these children began learning some English mid-way through the study; this child's data are not included here. Four monolingual Spanish-speaking children were selected to be subjects for Study 2; although we would have preferred that these children also have no siblings of school age, this was not possible. Both sets of children also met the following criteria: native Mexican-Spanish speaking parents; no language other than Spanish spoken in the home; residence in Redwood City, California, a community with a substantial Spanish-speaking population (one exception). The one child whose family does not live in Redwood City is Maria; her family had moved to Stanford from Mexico City six months prior to her participation in the study. Finally, all the families return to Mexico every year for visits of up to several months in duration. Given that the families live in a country where English is the dominant language, some contact with English is unavoidable. We feel,

2. These studies were conducted as part of a cross-linguistic investigation of voicing acquisition in English, Spanish and Cantonese.

TABLE I. Subjects.

Subjects	Sex	First Session	Last Session	Approx. Vocab.@ Beginn.	Siblings	Years Family in USA	Parents: Mexican Dialect Area[1]	Parents: Knowledge of English[2]
A. 2-Year Olds								
Manuel	M	1;7.9	2;2.2	30 wds.	sister, 1 year younger	10	M: Guanajuato	4
							F: Mexico City	3
Fernando	M	1;7.3	2;1.20	15 wds.	sister, 2 years older	8	M: Colima	2
							F: Mexico City	2
Beto	M	1;9.24	2;4.8	20 wds.	—	12	M: Michoacán	4
							F: Michoacán	3
B. 4-Year Olds								
Jose	M	3;6.22			bro. 1;6 bro. 2;6 sis. 9;0 bro. 11;0 bro. 12;0 bro. 14;0	6[3]	M: Michoacán	1
							F: Michoacán	2
María	F	3;10.21			sis. 8;0 sis. 10;0	1/2	M: Mexico City	2
							F: Mexico City	4
Cecilia	F	3;10.5	3;10.16		bro. 1;0 sis. 2;0 bro. 6;0 bro. 9;0	2	M: Michoacán	1
							F: Michoacán	2
Beatriz	F	4;0.10	4;0.13		bro. 2;0	9[4]	M: Michoacán	2
							F: Michoacán	2

Notes: 1 - M = Mother; F = Father
2 - 4 = substantial; 3 = moderate; 2 = little; 1 = none.
3 - Jose's family had just returned from 5 months in Mexico.
4 - Beatriz's family had just returned from 3 months in Mexico.

however, that in our subject population the influence of English on the children's Spanish is minimal and that the children's data are representative of the data that could be collected from children of comparable ages in Mexico.

Table 1 gives pertinent data on the seven subjects who will here be identified as Manuel, Fernando, Beto (the two-year-olds, Study 1) and Jose, Maria, Cecilia and Beatriz (the four-year-olds, Study 2). Audiometric screening of the children in Study 1 was done by the staff of the Audiology Clinic, Stanford Medical School; all children were assessed as having normal hearing. For the four-year-olds, normal language development was taken to be sufficient evidence of normal hearing, and these children were not given audiometric screening exams.

Data collection. The children in Study 1 were seen approximately every two weeks, for a seven-month period (plus weekly for a short period at the beginning of the study). The Study 2 children were seen once or twice. Table 2 gives the age and the number of 'correct' stop-initial words produced by each child by session. 'Correct' means that the child's production began with a stop of the same place of articulation as the initial stop in the adult word.

Each session was conducted in a high quality sound-isolated room (with associated control room) at the Stanford Speech Research Laboratory. Recording was done on a Revox A77 tape recorder with a Sony Electret microphone attached to a soft cloth vest which the child wore. All sessions were conducted by a native speaker of Mexican-Spanish. There were three experimenters. The first served for two months at the beginning of Study 1 and was a fluent English-Spanish bilingual whose first language was Mexican-Spanish. The other two were monolingual Mexican-Spanish speakers. During the session, the observer, who sat in the control room, ran the tape recorder, took notes and kept a tally of the number of stop-initial words produced by the child for all six stop consonants.

Sessions were between twenty and thirty minutes long. The goal for each session was to obtain at least fifteen tokens for each stop consonant. The observer would indicate towards the end of the session that a certain number of words beginning with particular stops were needed. The experimenter would then focus on words beginning with those stops. This number was estimated to be the maximum number of tokens which we could reasonably expect to obtain from the youngest children (aged 1;7) and the minimum number of tokens required for statistical analysis. However, it was difficult to obtain ninety target items (fifteen tokens per stop) from all of the children in Study 1. Since the children in Study 1 used few d- and g-initial words (at least at the beginning of the study), we introduced a few such words which were then learned at some point by the children. In general, the majority of words produced by the children in Study 1 were two syllable, CVCV words with initial stress.

Stimulus materials included a specially constructed stimulus book (with approximately equal numbers of word-initial stops represented), several children's picture books, a small wooden puzzle and many small toys. Word lists were obtained from the parents of children in Study 1 at the beginning of the study; objects for or pictures of stop-initial words that each child knew were then added to the stimulus materials. During the sessions the children played with the toys, looked at pictures, and were encouraged to speak.

VOT analysis. All tapes were transcribed by a researcher using a Revox A77 tape recorder and Super St-pro B-V head phones. The tape script included all

TABLE 2: Age and number of tokens* for each subject by session.

A. Two-Year Olds						
	Manuel		Fernando		Beto	
Session	Age	Tokens	Age	Tokens	Age	Tokens
1	1;07.16	8	1;07.12	2	1;09.24	6
2	1;07.25	17	1;07.17	4	1;10.00	12
3	1;07.30	29	1;08.03	21	1;10.22	18
4	1;08.16	37	1;09.07	12	2;00.07	20
5	1;09.25	30	1;09.12	7	2;00.21	25
6	1;10.08	41	1;09.19	29	2;01.07	23
7	1;10.26	51	1;10.02	7	2;01.21	55
8	1;11.08	108	1;10.19	14	2;02.07	27
9	1;11.22	85	1;10.26	16	2;02.17	37
10	2;00.11	139	1;11.05	28	2;03.00	21
11	2;00.25	83	1;11.23	52	2;03.11	28
12	2;01.05	95	2;00.06	50	2;03.18	40
13	2;01.12	104	2;00.23	55	2;04.02	43
14	2;01.26	145	2;01.04	77	2;04.08	49
15	2;02.02	176	2;01.20	108		

B. Four-Year Olds								
	José		María		Cecilia		Beatriz	
Session	Age	Tokens	Age	Tokens	Age	Tokens	Age	Tokens
1	3;06.22	156	3;10.21	181	3;10.05	105	4;00.10	103
2					3;10.16	94	4;00.13	178

*Tokens = Words which began with an initial singleton stop in the adult model and which were produced by the child with a stop at the same place of articulation.

words that the child said. 'Target words' were those that began with an initial singleton stop in the adult model and for which the child produced a stop of the correct place of articulation, as judged by the transcriber (see Table 2). For the target words, the initial phone was transcribed narrowly and the rest of the utterance somewhat more broadly. The transcription system used is that of the International Phonetic Association with a supplemental symbology and diacritic system devised by the Stanford Child Phonetics Workshop (Bush et al. 1973). Preceding context and the gloss were noted for all productions.

Of the biweekly recorded sessions in Study 1, approximately four anchor point sessions from each subject were selected for instrumental analysis. The purpose behind selecting anchor points was to sample throughout the data. Thus, these anchor points were at approximately two month intervals, beginning with the first sessions and ending with the last ones. Since in the earliest sessions, none of the children produced the requisite fifteen tokens of each stop consonant, the first three or four sessions were combined into one anchor point if the sessions had been conducted at close time intervals. When sessions were combined, equal proportions of stops were taken from each session. The data from Study 2 children were pooled if a child had been seen twice.

Wide-band (and in some cases, narrow-band) spectrograms were made of the first fifteen tokens of each stop type on a Kay Sonograph (model 7029 ADC, with an added custom shaping circuit (HS2, 12 db high frequency pre-emphasis)). To achieve better temporal resolution, utterances were recorded on the Kay in the 160-16K mode (which resulted in a time base of 41 ms per centimeter and a scanning filter width of 600 Hz) and were reproduced with scale magnifier set at 0 to 50%. Measurements of VOT were made at the same time on a Tektronix Oscilloscope with storage capability (Type 564), which was used in conjunction with a locally designed and constructed triggering system. In all cases where possible the time scale used was 2 ms or 5 ms per centimeter. Directly following the oscilloscope measurement, VOT was measured on the spectrogram(s). When the oscilloscope and spectrogram measurements differed by more than 3 ms, the problem was identified and then resolved by further instrumental analysis. In general, if the difference between the two measurements was equal to or less than 3 ms, they were averaged to give a final VOT value. However, for VOT values greater than -50 or +50 ms (i.e. cases in which the time scale had to be set at 10, 20 or 50 ms per division), fine time resolution was more difficult on the oscilloscope (due to greater compression of the signal in each time division), and greater reliance was placed on the spectrogram measurement. The procedures for instrumental analysis and VOT measurement are described in detail in Huntington et al. 1978.

If an utterance presented a problem that the researcher could not solve, all spectrograms for the item were presented at weekly group meetings where Project staff (four to six persons) discussed and resolved the problem. In the few cases where the staff could not reach unanimous agreement, the utterance was not included in the statistical analysis. The criteria for rejection of an utterance from VOT measurement were: 'noisy' (e.g., clanging toys during the child's production); 'voice overlay' (where an adult's voice was superimposed over the child's and each could not reliably be separated by narrow-band analysis); 'no burst'; 'following voiceless vowel'; and 'continuous voicing' (where voicing continued uninterrupted from the child's previously voiced segment). Approximately 10% of the total set of utterances from all children were rejected.

Three research assistants carried out the transcription and instrumental analysis. At approximately two month intervals, reliability checks were made. For these checks, six items were selected (usually the first token of each stop consonant on a tape). Each research assistant transcribed, instrumentally analyzed and measured each item. Because the six items had been analyzed by an individual research assistant several months previously, the comparison checks indicated both inter- and intra-observer reliability. In the reliability check procedure (as in the regular analysis procedure), provision was made to allow an observer to label any utterance as a problem which should then be referred to the weekly group meetings. Five of the 35 reliability check items were identified as problems by all research assistants. Excluding these five items, the three research assistants agreed to within 10 ms on 83% of the items checked. During the weekly group meetings, Project staff resolved the problems for all the five problem utterances.

For each child, each anchor point (Study 1) or each session/combined session (Study 2) was analyzed separately. When definitive VOT values were obtained for fifteen tokens of each of the six stop consonants, separate frequency distributions were drawn and the mean, standard deviation and range calculated. Tests of significance were made of the differences between the mean VOT of the voiced and voiceless phonemes at each place of articulation. Throughout, the probabilities given are for one-tailed t-tests. Where F values are significant, separate variance estimates are used; where they are not significant, pooled variance estimates are used. Since none of the differences between the means for a pair were significant on any of the anchor points for children in Study 1, the data from these anchor points were combined; all tables in the text present the pooled data only. The difference between the means for each pair from the combined sessions were compared (one tailed t-tests), and a two-way analysis of variance was carried out. The decision to collapse data in Study 1 was motivated by the assumption that if no significant change occurred over the time period, the data from that time period represented a single stage and thus were comparable.

<u>Spirantization analysis</u>. From the transcription sheets for each session, a count was made of the continuant and non-continuant phones produced for all word-initial voiced and voiceless stop phonemes. Included among the continuant totals are sporadic cases of weakenings to half segment continuants and deletions (see Ferguson 1978 on spirantization and deletion in Spanish). For the voiced stops, the distribution of phones was further separated into the obligatory environments for the stop and spirant allophones. For Study 1, 'word-initial' was in nearly all cases 'utterance initial' also, since the children remained in the one-word stage throughout most of the study. The analysis of the few cases where the children produced initial voiced stop words in sentence medial position showed no significant differences in the distribution of continuant-noncontinuant phones; thus in the results, the word-initial voiced stop data from the two-year-olds are pooled across all sentence positions. For Study 2, 'word-initial' includes both utterance initial position and sentence medial position. Since our goal for each session was to elicit a large number of words, the experimenters tended to ask the children a lot of the Spanish equivalents of wh-questions. Thus, our methodology biased the Study 2 corpus in the direction of single word utterances. For this reason, much of the data from even the older children was stop phonemes in utterance initial position also. Because the children in Study 2 tended to use

TABLE 3. Mean VOT values, number of tokens, standard deviation, and range for each Stop, by subject.

		Manuel	Fernando	Beto	José	María	Cecilia	Beatriz
		1;7.9 - 2;2.2	1;7.3 - 2;1.20	1.9.24 - 2;4.8	3;6.22	3;10.21	3;10.5 - 3;10.16	4;0:10 - 4;0.13
/b/	Mean	+12.83	-3.54	+5.12	-63.13	-5.07	-6.25	+5.07
	N	42	48	26	8	14	4	15
	S.D.	17.71	35.53	19.14	55.69	46.72	42.88	56.02
	Range	-40/+51	-130/+51	-65/+37	-137/0	-163/+22	-70/+22	-125/+68
/p/	Mean	+18.72	+5.49	+16.37	+23.73	+13.33	+16.20	+28.47
	N	71	67	30	15	15	15	15
	S.D.	19.96	30.61	14.42	21.39	13.86	19.66	18.11
	Range	-13/+112	-110/+170	0/+50	0/+72	+2/+45	-9/+74	+9/+71
Sig. Level				p = .008	p = .002			
/d/	Mean	+20.61	+16.15	--	-6.50	+12.30	+9.67	+35.43
	N	23	26	0	12	10	3	7
	S.D.	20.65	19.98	--	56.42	19.55	47.61	30.39
	Range	-5/+86	-54/+50	--	-120/+75	-37/+35	-45/+42	+3/+77
/t/	Mean	+20.20	+14.98	+34.67	+16.40	+10.07	+25.27	+31.67
	N	74	50	9	15	15	15	15
	S.D.	11.88	16.54	60.40	18.44	4.08	20.08	24.40
	Range	+2/+60	-44/+67	+14/+191	-33/+48	+4/+16	+4/+83	+12/+112
Sig. Level								
/g/	Mean	+26.14	+30.25	+16.00	+20.73	+10.73	+30.80	+60.62
	N	14	12	1	15	15	5	13
	S.D.	19.71	20.51	--	56.39	17.37	6.46	23.73
	Range	0/+67	+10/+74	+16.00	-75/+109	-28/+36	+23/+40	+25/+112
/k/	Mean	+26.40	+23.45	+35.51	+23.67	+17.47	+39.93	+52.87
	N	43	33	60	15	15	15	15
	S.D.	15.22	14.26	26.75	17.44	12.89	11.77	22.85
	Range	+8/+71	+2/+66	+6/+134	0/+71	+3/+39	+11/+52	+15/+97
Sig. Level								

andante speech style, we might expect a larger number of stop phones produced for the voiced phonemes in word-initial position than would be found in other types of corpora. The analysis of word-initial voiced stop productions by sentence position showed significant differences. Thus, we present the four-year-olds' data separately by environment.

After the tabulation was completed, percentages were calculated of the occurrence of [+continuant] (both spirants and glides) phones for each phoneme and for each child. Where the occurrence of stops and continuants were compared, Chi-square tests were used, or--where there were small amounts of data--Fisher's exact tests.

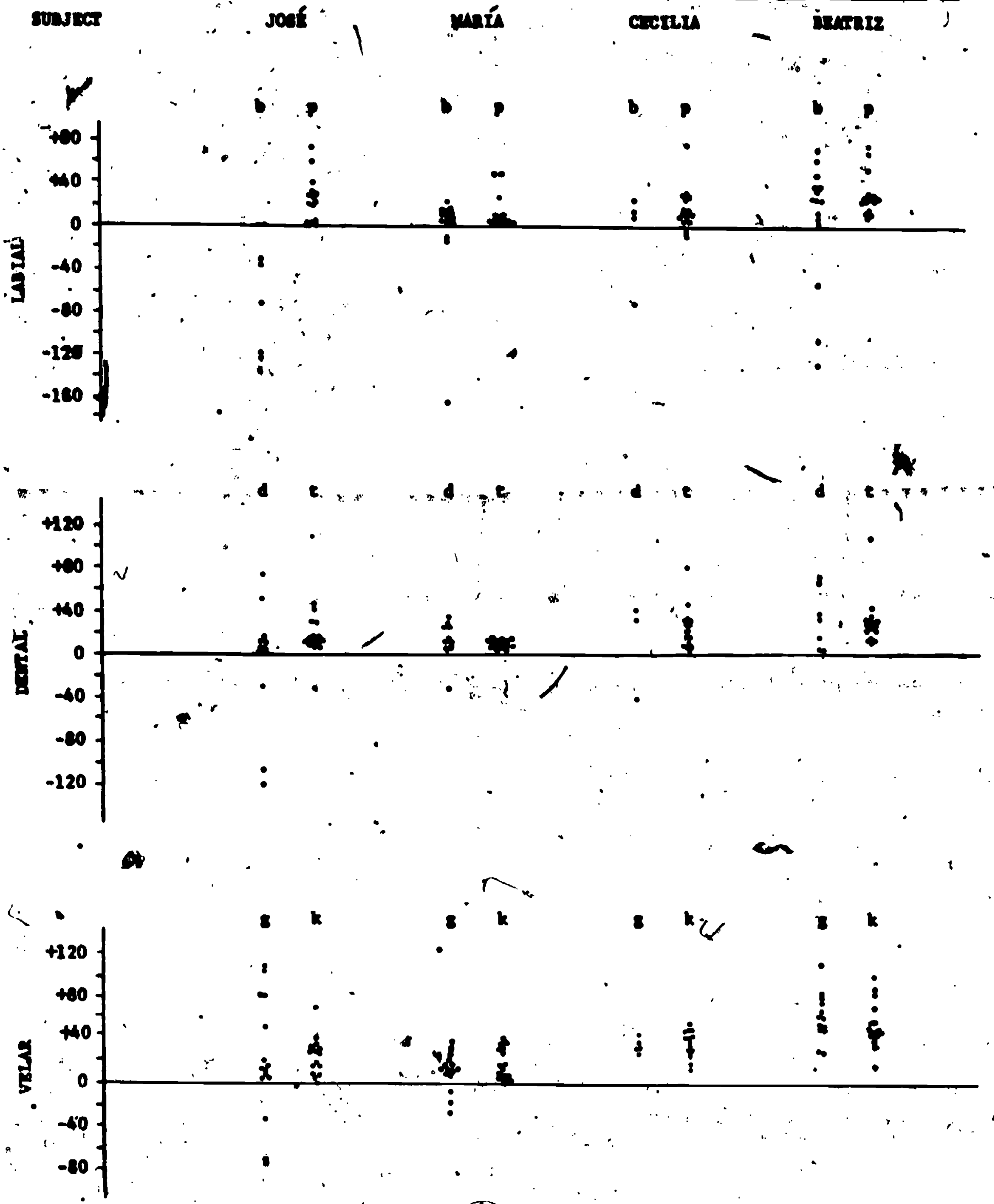
Results: the VOT analysis

We initially hypothesized that two VOT criteria would be sufficient to determine whether or not the children had acquired the phonological voicing contrast. First, even if child VOT values varied a great deal or clustered in a particular, restricted area of the VOT continuum, the difference between mean VOT values of a voiced-voiceless pair could still show significance, if the children were in fact attempting to distinguish between the members of a pair. Second, if the children's means and ranges resembled the Lisker and Abramson adult data, then quite clearly the children could be said to have acquired the voicing contrast. Table 3 contains the mean VOT values, number of tokens, standard deviations and range of production for all stops and all children.

In Table 3 we find that five of the seven children produce no significant differences between the means for any voiced and voiceless stop pair at any place of articulation and the remaining two children--Beto and Jose--produce a significant difference only between /b/ and /p/. If we compare the children's means and ranges to those reported for adult (Puerto Rican) Spanish speakers by Lisker and Abramson, we further find that only Jose's /b/ and /p/ productions are somewhat adult-like. In both sentence and isolation contexts, Lisker and Abramson's voiceless stop data are similar, while the voiced stops consistently show shorter lead values in the sentence as opposed to the isolation context. Simply to minimize the difference between the adult and our child data (and thereby to emphasize the nature of the discrepancy between the two corpora), we will compare the children's data to the Lisker and Abramson adult sentence data (rather than to their isolation data): /p/ mean +4 ms, range 0 to +15 ms; /t/ mean +7 ms, range 0 to +15 ms; /k/ mean +25 ms, range +15 to +55 ms; /b/ mean -110 ms, range -175 to -35 ms; /d/ mean -109 ms, range -170 to -55 ms; /g/ mean -92 ms, range -145 to -50 ms.

Returning to Table 3, we can see that the children's means for /p/ and /t/ are consistently longer than adult /p/ and /t/ means, while the children's /k/ means generally cluster around the adult /k/ mean VOT value. In the data from Fernando, Maria and Cecilia, the mean for /b/ falls in the short lag region (less than -10 ms). Only Jose's mean for /b/ (-63.13 ms) approaches the adult mean of -110 ms. None of the children's mean VOT values for /d/ and /g/ resemble adult mean VOT values: all child means with the exception of Jose's mean for /d/ fall in the short to moderately long lag region. Similarly, the ranges of tokens for the voiced and voiceless phonemes are not distinct; the only exception is the

Figure 2. 4 year olds; VOT values for each stop token, by place of articulation and by session*



*Each dot represents the VOT value for one token; VOT values are in milliseconds.

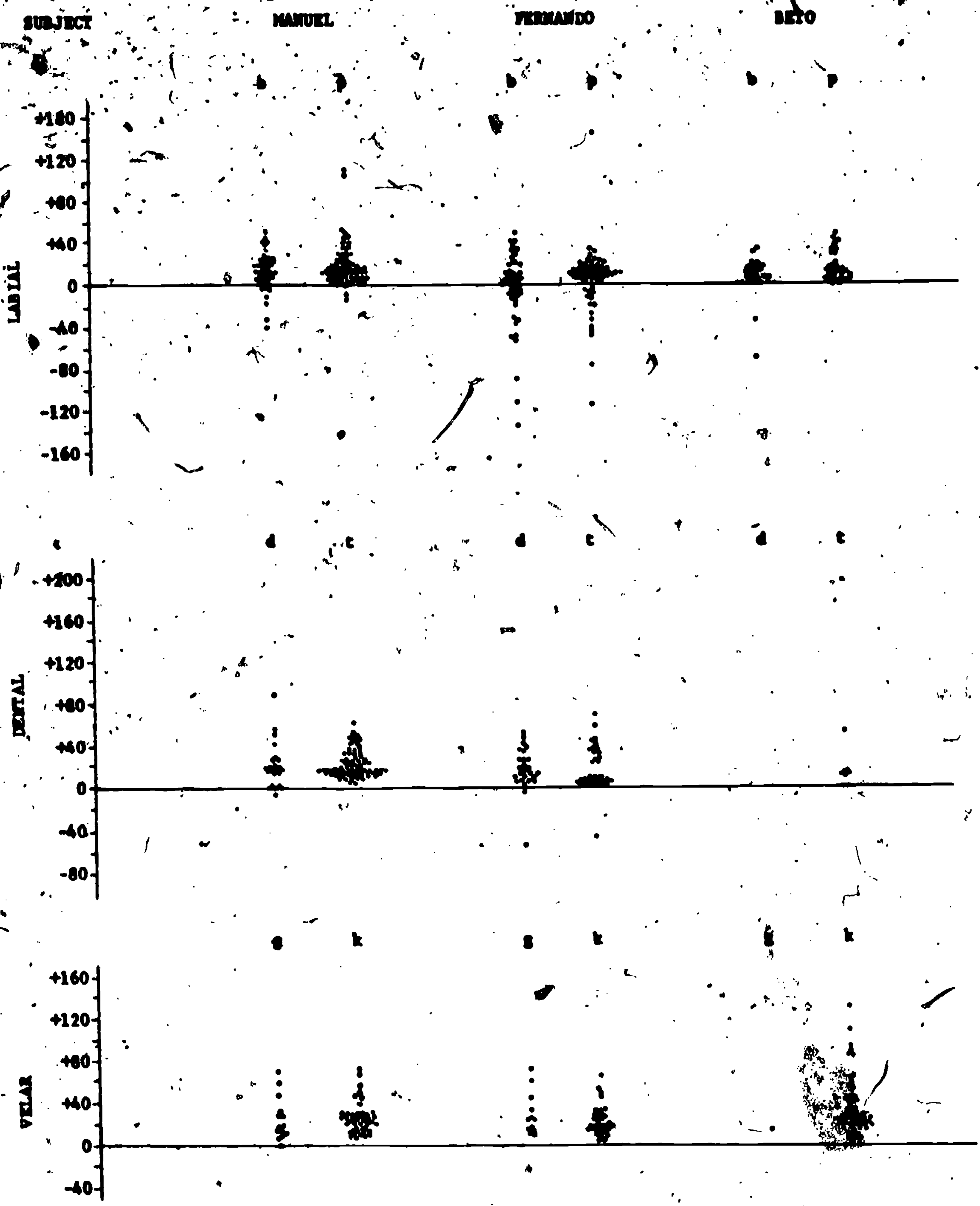
almost non-overlapping ranges of Jose's /b/ and /p/ tokens, but even here the ranges are not adult-like. To see more clearly the similarity between the children's productions for the voiced and voiceless phonemes, we need the VOT values of individual tokens. Figures 1 and 2 below plot the range of individual tokens of each stop consonant for Study 1 and Study 2 children, respectively.

On Figures 1 and 2, we can see that although adult tokens for /p/ and /t/ fall within the range of 0 to +15 ms, the children's tokens for both the voiced and voiceless labial and dental phonemes fall within the 0 to +40 ms range. The adult tokens for /k/ fall in the 0 to +55 ms range; the children's tokens for both /g/ and /k/ fall almost completely in the adult /k/ range. While there are few tokens in the long lag region +60 to +100 ms, there are equally few tokens in the lead range -125 to -75 ms. With the exception of Jose, the children simply do not produce adult voiced stops consistently with voicing lead. Moreover, they produce both the voiced and voiceless phonemes in a manner more nearly resembling the adult voiceless stop phonemes. However, there is a trend which may indicate that the children are making some form of a contrast at the labial place of articulation: for all seven children, the mean for /p/ is longer than the mean for /b/ (Table 3) and the ranges are somewhat different (Figures 1 and 2). There is no evidence for any similar trend in the dental and velar data.

Because of this apparent trend, we looked for other evidence in the VOT data. Two characteristics of the children's productions proved to show significance in some cases: the proportion of lead tokens and the incidence of continuous voicing. If we include 'proportion of lead' among our criteria for acquistion, then both Manuel and Fernando can also be credited with acquisition of the voicing contrast at the labial place of articulation; note, however, the frequency with which Fernando produced /p/ with voicing lead (Figure 1). Although the incidence of lead is not significant, Maria and Beatriz also produce only /b/ (and not /p/) with voicing lead, and similarly for /g/ (and not /k/) in Jose's and Maria's data (Figure 2). 'Continuous voicing' refers to those cases where voicing continued uninterrupted from a previous voiced segment through the initial stop phone of the following word. As noted before, such sentence embedded words were not common in the Study 1 data and less common than might be expected in the Study 2 data. On the basis of this criterion--significantly more voiced (than voiceless) initial stops exhibiting continuous voicing--, Cecilia can be said to have a contrast at all three places of articulation and Jose a contrast at the labial and dental places. None of Maria's tokens were characterized by continuous voicing, and Beatriz produced no d- or g-initial words with continuous voicing.

In summary, we find evidence in the VOT data that suggest that all the children except Maria and Beatriz had a contrast between /b/ and /p/ and that Cecilia and Jose had a rudimentary contrast at three and two places respectively. Nevertheless, the children's data do not resemble the adult VOT/voicing system: none of the children--not even the four-year-olds--were producing adult voiced stops with lead voicing in contradistinction to short lag productions for adult voiceless phonemes. We then turned to the spirantization component of the Spanish voicing contrast and to the phonetic feature [continuant].

Figure 1. 2 year olds: VOT values for each stop token, by place of articulation and by session.



*Each dot represents the VOT value for one token; VOT values are in milliseconds.

Results: the spirantization analysis

Table 4 presents the first results of the spirantization analysis. In this table, the number and percent of voiced and voiceless stop phonemes produced as continuants are given for each child. Included among the totals for continuants are sporadic cases of weakenings to half segment continuants and deletions. Frequencies for all word-initial voiced stops (irrespective of position) are given for the two-year-olds in this table, while frequencies for only utterance-initial, word-initial stop phonemes are given for the four-year-olds.

For our purposes, the first question to be asked of the spirantization analysis is: using the continuant-noncontinuant criterion, how many children can be credited with having acquired the voicing contrast and at what places of articulation? Critical evidence would be statistically significant differences in the number of continuant phones produced for the voiced as opposed to the voiceless phonemes at each place of articulation. Among the two-year-olds, both Manuel and Fernando produce continuant phones more often for /bdg/ than for /ptk/ (*p≤.05). Beto's data also show somewhat different patterns for voiced as opposed to voiceless phonemes; however, the number of /d/ and /g/ tokens is too small to be conclusive. Evidence for a voicing contrast at all three places of articulation can also be found in the data from Jose and Beatriz among the four-year-olds. The differences between /b:p/ and /d:t/ are significant in Cecilia's data. Maria's labial and velar data show that both /b/ and /g/ are produced as continuants more often than are /p/ and /k/, although a larger number of tokens would be necessary to verify this trend for /b:p/, and the difference for /b:p/ is not significant. Two other trends are that labial stops are most likely to be spirantized and dental stops are least susceptible to spirantization (Table 4). This is in general true for both voiced and voiceless stop phonemes.

In general, the voiceless stops are produced as continuants only 1.6% of the time by the two-year-olds and only 0.8% of the time by the four-year-olds. We might consider then that a figure of 1 to 2% reflects the margin of error that could be expected with children, or speakers who do not have perfect articulatory control. In contrast, the children produce 45.7% (two-year-olds) and 31.4% (four-year-olds) of /bdg/ tokens as continuants. The 45.7% figure is surprisingly high in that the two-year-olds produced /fsx/ as noncontinuants throughout nearly all of the study[3] and it is generally accepted that stops are acquired early by children (see Jakobson 1941/1968). The figure 31.4% is particularly unexpected, since the four-year-olds used primarily andante speech (n.b. except Beatriz) and presumably were old enough to have already learned the allophonic rule. During the course of the spirantization analysis, it became clear that the four-year-olds but not the younger children had in fact acquired the allophonic rule, although their productions did not completely correspond to the expected adult pattern. To discuss this, other age-related phenomena and some individual differences, we present the rest of the spirantization results separately by age groups.

<u>The two-year-olds</u>. Table 5 below gives the results of the spirantization analysis by child and by time period. Two types of changes occurred in the children's data: first, changes in the frequency with which a

3. Only Manuel produced continuants for the voiceless fricative phonemes and this only toward the end of the study.

TABLE 4. Spirantization of Initial /b d g/: Number and percent of voiced and voiceless stops produced as continuants by child.[1]

	Voiceless Stops						Voiced Stops[2]					
	/p/		/t/		/k/		[b]		[d]		[g]	
A. Two-year Olds												
Manuel	2/312	0.6%	1/222	0.5%	4/350	1.1%	202/328	*61.6%	12/73	*16.4%	7/91	*7.7%
Fernando	11/168	6.5%	3/107	2.8%	2/70	2.9%	61/147	*41.5%	9/56	*16.1%	11/31	*35.5%
Beto	2/99	2.0%	0/56	0.0%	1/196	0.5%	28/81	*34.6%	1/3	33.3%	1/2	50.0%
B. Four-Year Olds												
José	1/38	2.6%	0/34	0.0%	0/17	0.0%	8/20	*40.0%	3/18	*16.7%	9/31	*29.0%
María	0/44	0.0%	0/30	0.0%	0/54	0.0%	2/15	13.3%	0/9	0.0%	2/16	*12.5%
Cecilia	2/64	3.1%	0/28	0.0%	0/73	0.0%	7/12	*58.3%	2/5	*40.0%	0/2	0.0%
Beatriz	0/98	0.0%	0/30	0.0%	2/86	2.3%	15/32	*46.9%	8/15	*53.3%	4/16	*25.0%

1 - The figures for voiceless stops are given for all word-initial position tokens. The tabulation for voiced stops is based on word-initial position (both sentence medial and utterance initial) for the two-year olds, but only on utterance initial position for the four-year old data.

2 - * by percentage indicates a significant difference between the number of continuant phones produced for the voiced as opposed to the voiceless phonemes (p≤.05).

particular word-initial voiced stop phoneme was produced; and second, changes in the frequency with which a particular voiced phoneme was produced as a continuant. Such changes in each child's data are used here to mark the beginning of new 'stages' in each child's particular development. In order to present and compare the data from all three children in one table, time periods (rather than individual session numbers) are used in Table 5. In all but one case, the eight time periods in Table 5 accurately describe the child's ages on the sessions listed under the particular time period. The exception is Beto's data from sessions 4 through 6 that are listed under time period V: Beto was actually 2;0.7 to 2;1.7, not 2;0.6 to 2;1.0. The important points are that stages in each child's particular development were identified individually and by sessions and that the time periods given in the table were selected to correlate with the points of change for each of the three children: age is assumed not to be a critical variable.

To summarize, all three children acquired a phonemic voicing contrast first at the labial place of articulation: Manuel by 1;7.16, Fernando by 1;10.26, and Beto by 2;0.7. For Fernando and possibly also for Manuel, the next stage is one in which the velar voiced-voiceless contrast is acquired: Fernando by 2;0.6, and Manuel by 2;1.5 (but maybe as early as 1;11.22). Finally the dental voiced-voiceless contrast is acquired: by 2;1.5 for Manuel (but perhaps as early as 2;0.11), and by 2;1.4 for Fernando (but perhaps as early as 2;0.6). Manuel may have acquired the dental and velar contrasts at the same time. Beto was possibly in the process of acquiring a dental and velar voicing contrast at the end of the study when he was 2;4.8.[4] The evidence for these phonemic contrasts is based on significantly different patterns of substitutions for adult voiced as opposed to voiceless stop phonemes. The children's voicing contrast is not adult-like: the children produce the adult voiced stop phonemes with primarily short lag voicing; thus, the stop phones the children produced for word-initial /bdg/ are very similar to adult /ptk/ in terms of voice onset time characteristics. (Recall that only the means for Beto's /b/ and /p/ show a significant difference.) Finally, there is a parallel between the order in which the children acquired the voicing contrast and the asymmetry in the distribution of stop phonemes in the children's corpora: the children acquire the voicing contrast first at the labial place of articulation, and the frequency of /b/ is substantially greater than that for /d/ and /g/ during both the stages preceding the first voicing contrast (/b:p/) and also during subsequent stages up to the stage in which the dental and velar voicing contrasts are acquired. In fact, the children generally do not produce any /d/ and /g/ initial words for several months after /b/ initial words are used and also after the voicing contrast between /b:p/ is acquired. (Table 5.)

<u>The four-year-olds</u>. Table 6 presents the frequency with which continuants (and the sporadic cases of weakening to half segment continuants and deletions) were produced for word initial /bdg/ in obligatory environments for continuant and noncontinuant allophones by the four-year-olds. The first three columns give the number and percent of continuant phones produced in the obligatory noncontinuant environments. If we assume the children's production to accord with that which is expected from adults, then we would expect zero percent

4. On the basis of a spirantization analysis, a Spanish-speaking child--J-- in a previous Project study acquired the voicing contrast in an idential set of stages at the following ages: /b:p/ 1;11; /g:k/ 2;0; and /d:t/ at 2;1 (Macken 1978).

TABLE 5: Two-year olds. Spirantization of Word-Initial /b d g/: Number and percent of voiced stops produced as continuants, by child and by time period.

	I 1;7	II 7;9	III 1;10¾	IV 1;11¾	V 2;0	VI 2;1	VII 2;2½	VIII 2;3½
	1;7.12 - 1;8.16	1;9.7 - 1;10.22	1;10.26 - 1;11.8	1;11.22- 1;11.23	2;0.6 - 2;1.0	2;1.4 - 2;2.7	2;2.17 - 2;3.11	2;3.18 - 2;4.8
Manuel								
b	24/36 66.7%*	33/44 75.0%	59/70 84.3%	10/15 66.7%	27/55 49.1%	49/108 45.4%		
d	0/3 0.0%	0/5 0.0%	0/3 0.0%	0/5 0.0%	1/12 8.3%ʼ	11/45 24.4%*		
g	- -	- -	- -	1/16 6.3%*	1/24 4.2%ʼ	5/51 9.8%*		
Fernando								
b	0/5 0.0%	0/8 0.0%	5/16 31.3%*	9/18 50.0%	26/44 59.1%	21/56 37.5%		
d	- -	1/10 10.0%	0/3 0.0%	0/5 0.0%	1/9 11.1%ʼ	7/29 24.1%*		
g	- -	0/3 0.0%	- -	0/1 0.0%	9/12 75.0%*	2/15 13.3%		
Beto								
b		- -			5/21 23.8%*	6/12 50.0%	5/11 45.5%	12/37 32.4%
d		- -			- -	- -	0/1 0.0%	1/2 50.0%ʼ
g		- -			- -	0/1 0.0%	- -	1/1 100.0%ʼ

* Indicates first time period during which child contrasts the voiced and voiceless adult phonemes at a particular place of articulation (ps.03).

ʼ Indicates a possible contrast.

\- Means that no tokens of a particular voicing type were produced by the child during the time period indicated.

in each of the first three columns for each child. In the right-most three columns are given the number and percent of continuant phones produced in the obligatory environments for continuants; here we would expect 100% entered for each child, provided the children are producing the voiced stop phonemes in the presumed adult-like manner.

From Table 6, we can see first that, as Table 4 has already demonstrated, the children do not regularly produce noncontinuant phones for /bdg/ in all the obligatory environments for the [bdg] allophones. Since Table 4 presented data for utterance initial position only and if we compare the percentages for each stop phoneme on Table 4 and Table 6, we can also determine that the children produce continuants for /bdg/ approximately equally in all stop allophone environments; this means that the children produce continuants for /bdg/ both in utterance initial position and in word-initial position following a nasal consonant and for /d/ after /l/. In addition, however, Maria and Beatriz also produce noncontinuant phones for /bdg/ in obligatory [βðγ] environments more than would be expected, given the presumed adult input; Jose and Cecilia also produce some noncontinuant phones for /g/ (and /d/ by Cecilia) in the adult [γ] (and [ð]) environment(s). Thus, none of the children follow the adult allophonic rule completely.

In spite of the fact that the children's data are not completely adult-like, the data show that most of the children do produce /bg/ differently in the adult [bg] versus [βγ] environments. The data for /b/ and /g/ in Maria's data approach significance ($p = .09$ and $.055$ respectively), as do Beatriz' /g/ data ($p < .1$). For none of the children are there enough tokens of /d/ in obligatory [+cont] environments to indicate a pattern. We assume then that the differential treatment of at least /bg/ by environment is evidence that the children have acquired the allophonic rule, although it is not mastered at the performance level. It is, however, possible that their productions are similar to adult productions, in which case conventional descriptions of the allophonic rule in adult Spanish are stated incorrectly to the extent that the descriptions disallow spirants in utterance initial position (and other 'obligatory' stop environments) (and, perhaps, stops in 'obligatory' spirant environments, as well). We return to this issue in the discussion section.

Table 6 also shows that the labial place of articulation is most conducive to spirantization: the frequency with which /b/ is produced as a continuant is consistently higher than that found for /d/ and nearly always higher than that found for /g/, regardless of the environment. Conversely, /d/ is most resistant to spirantization in all environments. It should also be noted that one of the four children--Maria--overwhelmingly produces stop phones: she does so more consistently than do the other children in the (correct) obligatory environments for [bdg]; and she does so more often than the other children in the (incorrect) obligatory environments for [βðγ]. Jose and Cecila produce more continuants in the obligatory [bdg] environments than noncontinuants in the obligatory [βðγ] environments. Beatriz regularly produces the 'incorrect' phone approximately 29-48% of the time (assuming that the one stop token of /d/ in a continuant environment is insufficient evidence of any trend).

TABLE 6, 4-Year Olds: Spirantization of word-initial /b d g/ in obligatory environments for [- continuant] and [+ continuant] allophones.(1)

	Word-Initial /b d g/ Productions											
	Child productions of [+ cont] in obligatory environments for [- cont]						Child productions of [+ cont] in obligatory environments for [+ cont](2)					
	[β]		[δ]		[γ]		[β]		[δ]		[γ]	
José	11/30	36.7%	3/24	12.5%	10/37	27.0%	5/5	*100.0%	0/0	—	6/7	*85.7%
María	2/15	13.3%	0/9	0.0%	2/18	11.1%	5/12	41.6%	0/1	0.0%	6/15	40.0%
Cecilia	7/22	31.8	2/8	25.0%	4/16	25.0%	25/25	*100.0%	3/4	75.0%	8/10	*80.0%
Beatriz	16/46	34.8%	10/21	47.6%	7/24	29.2%	15/21	*71.4%	0/1	0.0%	8/12	66.7%

(1)- /b d g/ → [- cont] / { ##___ , N#___ , l#d___ } . /b d g/ → [+ cont] elsewhere.

(2)- * next to a percentage indicates a significant difference between the number of continuant phones produced in the obligatory [+cont] environment as opposed to the obligatory [-cont] environment (p .05).

Results: summary from both analyses

Table 7 presents the evidence for the children's acquisition of phonemic contrasts between voiced and voiceless cognate pairs, as determined by the VOT and spirantization analyses. On this table, major and minor types of evidence are contrasted by means of upper versus lower case letters. For the VOT analysis, two criteria were used initially: (1) child productions in close approximation to VOT characteristics reported by Lisker and Abramson 1964 for adult Spanish speakers (V', Table 7); and/or (2) significant differences between the means for a voiced-voiceless pair (V'', Table 7). Both of these characteristics were taken to provide strong evidence for a phonemic contrast in the child's system. Secondarily, two other criteria were used for the VOT data: (1) a significant number of voiced phonemes produced with lead voicing as compared to the number of voiceless phonemes produced with lead (vl, Table 7); and (2) a significant number of voiced as opposed to voiceless phonemes characterized by continuous voicing (v2, Table 7). In the absence of V' or V'' evidence, both lead and continuous voicing (vl and v2) were taken to provide weaker evidence for a phonemic contrast in the child's system. For the spirantization analysis, evidence for a child contrast was assumed to be provided by a significant number of voiced as opposed to voiceless phonemes produced as continuants (where 'continuant' corresponds to a category of weakening from [-stop] through to zero) in the adult obligatory environments for noncontinuants (S, Table 7).

Table 7 shows that the spirantization analysis proved most useful in determining the children's acquisition of the voicing contrast. On the basis of the strong VOT criteria, only two children could be said to have acquired a voicing contrast and at only one place of articulation. In contrast, on the basis of the spirantization criterion, we can conclude that four children had a voicing contrast at all three places of articulation, the fifth child at two places and the sixth and seventh children at one place. The only point at which the spirantization analysis did not prove as or more revealing than the VOT analysis was Cecilia's /g:k/. Finally, neither the VOT or the spirantization criteria show evidence for a /b:p/ or /d:t/ contrast in Maria's data, and the evidence for a velar contrast is weak in Cecilia's data. In general, considerably more evidence for a contrast is found for all the children's productions of /b/ and /p/. The longitudinal data show that the voicing contrast is first acquired at the labial place of articulation and that this contrast precedes by several months any contrast at the other two places of articulation. In addition, we found that /d/ and /g/ occur significantly less often in the corpora from both the two- and four-year-olds. Table 8 below gives a total for the number of tokens produced by each group of children for each adult phoneme.

A striking feature of the data provided in Table 8 is the high degree of similarity in the distributions of word initial phonemes in both groups of subjects. Differences in the distribution of stops appear in the data in spite of our elicitation goals to obtain equal proportions of all stops types. That there are these differences for both age groups suggests that this asymmetry in stop distribution is a property of Spanish, rather than merely a function of some aspect of young children's speech; the latter interpretation would be most reasonable if the asymmetry only occurred in the two-year-old data. These frequency figures also demonstrate the special status of the labial contrast.

TABLE 7. Evidence for the children's acquisition of phonemic contrasts between voiced and voiceless cognate pairs, as determined by the VOT and Spirantization analyses.

	/b : p/		/d : t/		/g : k/	
	VOT	Spirantization	VOT	Spirantization	VOT	Spirantization
A. 2-Year Olds						
Manuel	v1	S	--	S	--	S
Fernando	v1	S	--	S	--	S
Beto	V"	S	--	--	--	--
B. 4-Year Olds						
José	V'V" v1 v2	S	v2	S	--	S
María	--	--	--	--	--	S
Cecilia	v2	S	v2	S	v2	--
Beatriz	--	S	--	S	--	S

VOT Criteria:

V' both voiced & voiceless stops produced with adult-like VOT characteristics.

V" statistically significant difference between the means (and the voiced stop mean is less than the voiceless stop mean) ($p \leq .05$)

v1 more voiced as opposed to voiceless stops produced with lead voicing ($p \leq .05$)

v2 more voiced as opposed to voiceless stops produced with continuous voicing ($p \leq .05$)

Spirantization Criterion:

S more voiced as opposed to voiceless stops produced as spirants ($p \leq .05$)

TABLE 8. Frequency of Voiced and Voiceless, Word-Initial Phonemes

	Two-Year Olds		Four-Year Olds	
	# of Tokens	percent	# of Tokens	percent
I. By phoneme				
/p/	579	24.2%	242	24.8%
/t/	385	16.1%	122	12.5%
/k/	616	25.8%	230	23.5%
/b/	556	23.2%	176	18.0%
/d/	132	5.5%	68	7.0%
/g/	124	5.2%	139	14.2%
Total	2,392	100.0%	977	100.0%
II. By voicing category				
Voiceless	1,580	66.1%	594	60.8%
Voiced	812	33.9%	383	39.2%
Total	2,392	100.0%	977	100.0%

Discussion

We initially had hypothesized that, because VOT had been shown to reliably distinguish voiced-voiceless pairs in production and perception for adult speakers of Spanish, as children acquired productive control over voicing, VOT values would change concomitantly. However, for both Spanish studies, neither was the hypothesis confirmed nor did an analysis of VOT prove to be completely useful in determining the phonological acquisition process. These findings stand in sharp contrast to the results of our investigation of the acquisition of the voicing contrast in American English (Macken and Barton 1977).

Because VOT had likewise been shown to reliably distinguish English voiced ('short lag') stop phonemes from voiceless ('long lag' or aspirated) phonemes, we had made a similar hypothesis regarding developmental changes in VOT in the speech of children acquiring English--an hypothesis that was proven valid. In the English longitudinal study, the children did progress in stages from initially undifferentiated productions of phonemically voiced and voiceless stops toward productions with VOT values similar to those reported by Lisker and Abramson 1964 for adult speakers of English. Moreover, the choice of VOT as the unit of analysis proved to be particularly valuable in that the analysis of VOT provided evidence that the children were making systematic contrasts between voiced and voiceless phonemes even at an early stage when both sets of phonemes were produced as short lag stops--in other words, precisely in the stage in which all their stop productions would have been labelled 'Voiced' by adult speakers of English. Our English-learning subjects were making VOT contrasts between adult voiced and voiceless phonemes well before the age of two years and were producing relatively adult-like short lag versus long lag contrasts by age 1;9 to 2;6. (Macken and Barton 1977.) Zlatin and Koenigsknecht 1976, Gilbert 1977 and Barton and Macken 1978 also found that English-learning children produce relatively adult-like voicing in stops before age 4;0.

Given that the typical phonological descriptions of Spanish set up the stops /bdg/ as the systematic phonemes with the spirant allophones derived from the stops by rule, we further hypothesized that children would acquire the stop phones before the spirant phones and in yet a later stage learn the correct pattern of distribution. It was felt that this hypothesis received further a priori support from the assumption that stop phones would be considerably more frequent than the spirant phones in the input that the children would be receiving from adults, in that the stop allophones may occur in any word-initial position in careful or andante speech and that adult speech to children is typically careful and slow. The results of the spirantization analysis support the hypothesis that children acquiring Spanish produce the stop phones before learning to produce the spirants. This finding is not particularly surprising, because children in general typically produce stops well before using fricatives; however, continuant phones such as glides often appear among the earliest sounds produced by children acquiring a wide variety of languages. We also found that, in fact, the allophonic distribution rule is not learned until after age two and even at age four children have not mastered the presumed adult distribution pattern. Contrary to expectations based on adult descriptions of Spanish, the phonetic feature [continuant]--rather than voice onset time--proved to be most useful in determining the acquisition process for the Spanish phonological feature of voicing: in fact, the children learned the supposedly redundant feature before the feature claimed to be distinctive.

In both our English and Spanish studies, the children initially produce most stops with short lag voicing (cf. Jakobson 1941/1968 on the early, exclusive use of voiceless, unaspirated stops and the similar claim of Kewley-Port and Preston 1974 on the priority of short lag stops). Thus, our first question is: why do Spanish-learning children acquire 'lead' voicing--and, to this extent, the Spanish voicing contrast--apparently after age four (while English-learning children acquire 'long lag' stops--and thus the English voicing contrast--by about 2;6)? One possible explanation is that lead voicing is inherently difficult to produce or at least more difficult to learn than long lag (i.e. aspiration). Although we know of no VOT acquisition studies that would address this issue, Srivastava 1974 reports on one child's acquisition of Hindi--a language that also contains lead voicing as part of its voicing system. This child first used the voiceless unaspirated (short lag) stops (at 1;1) and next acquired the prevoiced (i.e. lead) Hindi stops (1;4). Not until 2;0 did the voiceless aspirates (i.e. long lag) and voiced aspirates appear. The data from this Hindi-learning child appear to counter an argument for the late acquisition of Spanish voiced stops based on an inherent difficulty of lead voicing.

It may be that the Spanish spirantization rule is the source of the problem. Why this should be the case is not clear. Because adults sometimes produce, for example, bola with an initial stop and sometimes with an initial spirant (depending on context and speech style), children may encounter difficulty learning the +/-continuant feature and the rules for distribution. But, if we assume that adults consistently produce the stop allophones with lead voicing, the learning of VOT should be relatively independent of the effects of an input that is variable with regard to the presence of absence of continuancy. An independent factor that may complicate the acquisition of voiced /d/ and /g/ phones is the relative infrequency of words beginning with these phonemes in the children's vocabulary (see Table 8). To resolve this issue, research must be done with children acquiring a language that has a VOT/voicing contrast similar to that in Spanish but does not have a spirantization rule or extreme asymmetries in the distribution of stop phonemes.

An alternative approach to this problem is to inquire why the Spanish-learning children acquire the supposedly redundant continuant feature early. Although spirant phones are more common than stop phones in adult corpora, we originally hypothesized that in adult-to-child speech, stop phones would at least occur more frequently than they occur in other adult contexts. However, we noted that during the recording sessions our experimenters produced spirant phones in absolute utterance-initial position. Subsequent examination of eighty minutes of tape recording per experimenter revealed that these adults produced from 30% to 40% of all utterance-initial /bdg/ phonemes as spirants. Preliminary analysis of the obligatory environment for spirants showed that spirant phones were produced in these environments at least 95% of the time. Working with adult-to-adult conversational data, Hammond 1976 found a similar use of spirants in obligatory stop environments for the Miami Cuban dialect of Spanish (cf. also Timm 1976 on Chicano Spanish and the discussion of Spanish $d \rightarrow ð$ in Ferguson 1978). Our adult-to-child data and the adult-to-adult data from Hammond provide for the interesting possibility that the spirantization patterns in the four-year-old data are in fact relatively adult-like and that, moreover, the conventional analyses of adult Spanish are incorrect. If we assume that spirants are more basic to the adult system, it no longer is surprising that it is the continuant feature that is learned early and before the VOT feature.

In conclusion, it appears, on the basis of the data from the two- and four-year-olds, that VOT is not the most critical phonetic feature underlying the Spanish voicing contrast (cf. Williams 1977) and that the spirants [βðɣ] play a more important role than would be expected given their allophonic status in most descriptions of Spanish phonology. These results raise several important issues concerning aspects of the the voicing system in Spanish that deserve further investigation, specifically the distinguishing versus redundant features of the Spanish voicing contrast and the distribution of allophones in actual speech. With regard to acquisition issues, our data show the complex interaction between phonology and phonetics during the acquisition of phonetic features like voice onset time. Further research needs to be done to resolve the issue of the learnability of lead and other VOT/voicing types and to determine the role that allophony plays during acquisition.

REFERENCES

Abramson, A. and Lisker, L. (1973). Voice-timing perception in Spanish word-initial stops. J.Phonetics. 1.1-8.

Barton, D. and Macken, M.A. (1978). An instrumental analysis of the English voicing contrast in four-year-olds. Papers and reports on child language development. 15.

Bush, C.N., Edwards, M. L., Luckau, J. M., Stoel, C. M., Macken, M. A. and Petersen, J. D. (1973). On specifying a system for transcribing consonants in child language: a working paper with examples from American English and Mexican Spanish. Stanford University: Department of Linguistics.

Ferguson, C.A. (1978). Phonological processes. In J.H. Greenberg, C.A. Ferguson and E.A. Moravcsik (eds.), Universals of human language. Stanford: Stanford University Press. Volume 2. 403-442.

Gilbert, J.H.V. (1977). A voice onset time analysis of apical stop production in three-year-olds. J.Ch.Lang. 4.103-110.

Hammond, R.M. (1976). Phonemic restructuring in Miami-Cuban Spanish. In F.M. Aid, M.C. Resnich and B. Saciuk (eds.), 1975 Colloquium on hispanic linguistics. Washington, D.C.: Georgetown University Press. 42-51.

Harris, J. W. (1969). Spanish phonology. Cambridge, Mass.: The MIT Press.

Huntington, D. A., Clumeck, H., Macken, M. and Ohsiek, D. (1978). Some methodological considerations on the study of VOT in children. Unpublished ms. Stanford University: Hearing and Speech Sciences.

Jakobson, R. (1941/1968). Child language, aphasia and phonological universals. The Hague: Mouton. (Translated by A. Keiler, 1968.)

Kewley-Port, D. and Preston, M. S. (1974). Early apical stop production: a voice onset time analysis. J. Phonetics. 2.195-210.

Lisker, L. and Abramson, A. S. (1964). A cross-language study of voicing in initial stops: acoustical measurements. Word. 20.384-422.

Macken, M. A. (1978). Permitted complexity in phonological development: one child's acquisition of Spanish consonants. Lingua. 44.219-253.

______ and Barton, D. (1977). A longitudinal study of the acquisition of the voicing contrast in American-English word-initial stops, as measured by voice onset time. Papers and reports on child language development. 14.74-120. (J.Ch.Lang.; revised version in press.)

Navarro Tomas, Tomas. (1968). Studies in spanish phonology. Coral Gables: University of Miami Press.

Srivastava, G. P. (1974). A child's acquisition of Hindi consonants. Indian Linguistics. 35.112-118.

Timm, L.A. (1976). Three consonants in Chicano Spanish: /x/, /b/ and /d/. Bilingual Review. 3(2).153-162.

Williams, L. (1977). The voicing contrast in Spanish. J.Phonetics 5.169-184.

Zlatin, M. and Koenigsknecht, R. A. (1976). Development of the voicing contrast: a comparison of voice onset time in stop perception and production. JSHR. 19.93-111.