DOCUMENT RESUME

ED 036 789 | 24 | AL 002 304

AUTHOR Skeel, Mary H.; And Others
TITLE Perceptual Confusions Among Fricatives in Preschool Children.
INSTITUTION Wisconsin Univ., Madison. Research and Development Center for Cognitive Learning.
SPONS AGENCY Office of Education (DHEW), Washington, D.C. Bureau of Research.
REPORT NO TR-73
BUREAU NO BR-5-0216
PUB DATE Feb 69
CONTRACT OEC-5-10-154
NOTE 18p.; Report from the Project on Language Concepts and Cognitive Skills Related to the Acquisition of Literacy, University of Wisconsin, Madison, Wisc.

EDRS PRICE EDRS Price MF-$0.25 HC-$1.00
DESCRIPTORS Articulation (Speech), *Child Language, Cognitive Development, *Consonants, *Language Research, Perceptual Development, *Preschool Children
IDENTIFIERS *Fricatives

ABSTRACT

This study examined perceptual and articulatory confusions among the fricatives /f, v, s, z/ and voiced and unvoiced "th" in preschool children. (These phonemes are among the most difficult for children to articulate.) Seventeen children from 3.3-5.1 years of age were tested on syllables formed by taking all combinations of the six fricatives in initial (CV) and final (VC) position with one of the vowels /a, i, aI/. Discrimination and articulation tests of this syllable set were then given. An audiovisual system was used to test discrimination. The fricatives were substantially more difficult to discriminate than the control items. Two contrasts, /v/ and voiced "th" and /f/ and unvoiced "th", were particularly difficult. There were fewer errors on VC than CV pairs. No differences were associated with the vowel, but there was some evidence that vowel duration was employed as a cue for discrimination of fricatives in final position. While there was a significant correlation between the number of discrimination and articulation errors per child, there was little evidence that articulation errors on specific phonemes were accompanied by discrimination errors on the same phonemes, and no evidence that the frequency of occurrence of specific phonemes in children's speech was substantially related to discrimination or articulation. (Author/AMM)

BR-5-0216
PA-24

PERCEPTUAL CONFUSIONS AMONG FRICATIVES IN PRESCHOOL CHILDREN

RESEARCH COGNITIVE LEARNING DEVELOPMENT

WISCONSIN RESEARCH AND DEVELOPMENT

CENTER FOR COGNITIVE LEARNING

Technical Report No. 73

PERCEPTUAL CONFUSIONS AMONG FRICATIVES IN PRESCHOOL CHILDREN

By Mary H. Skeel, Robert C. Calfee, and Richard L. Venezky

Report from the Project on Language Concepts and Cognitive Skills
Related to the Acquisition of Literacy
Robert C. Calfee and Richard L. Venezky, Principal Investigators

Wisconsin Research and Development
Center for Cognitive Learning
The University of Wisconsin
Madison, Wisconsin

February 1969

Appreciation is expressed to the personnel of WHA, The University of Wisconsin radio station, to the Electronics Section Department of Psychology for apparatus construction, to Suzanne Perkins for art work, to Robert Rudegeair for recording and transcription, and to Professor Leonard Ross for the use of the mobile laboratory under auspices of an NIMH developmental training grant.

The research reported herein was performed pursuant to a contract with the United States Office of Education, Department of Health, Education, and Welfare, under the provisions of the Cooperative Research Program (Center No. C-03, Contract OE 5-10-154).

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The Wisconsin Research and Development Center for Cognitive Learning focuses on contributing to a better understanding of cognitive learning by children and youth and to the improvement of related educational practices. The strategy for research and development is comprehensive. It includes basic research to generate new knowledge about the conditions and processes of learning and about the processes of instruction, and the subsequent development of research-based instructional materials, many of which are designed for use by teachers and others for use by students. These materials are tested and refined in school settings. Throughout these operations behavioral scientists, curriculum experts, academic scholars, and school people interact, insuring that the results of Center activities are based soundly on knowledge of subject matter and cognitive learning and that they are applied to the improvement of educational practice.

This Technical Report is from the Language Concepts and Cognitive Skills Related to the Acquisition of Literacy Project in Program 1. General objectives of the Program are to generate new knowledge about concept learning and cognitive skills, to synthesize existing knowledge, and to develop educational materials suggested by the prior activities. Contributing to these Program objectives, this project's basic goal is to determine the processes by which children aged four to seven learn to read and to identify the specific reasons why many children fail to acquire this ability. Later studies will be conducted to find experimental techniques and tests for optimizing the acquisition of skills needed for learning to read.

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ABSTRACT

This study examined perceptual and articulatory confusions among the fricatives /f, v, s, z, θ, ð/ in preschool children. These phonemes were selected because they are among the most difficult for children to articulate. Seventeen children between 3.3 and 5.1 years old were tested on syllables formed by taking all combinations of the 6 fricatives in initial (CV) and final (VC) position with one of the vowels /a, i, aI/. Discrimination and articulation tests of this syllable set were then administered. An audiovisual system was used to test discrimination by the following procedure. The child heard a syllable (e.g., "/fa/") over earphones, and simultaneously saw a brightly colored animal drawing on the left side of the visual display. Next, a second syllable (e.g., "/va/") was heard, and a second animal appeared to the right of the display. Then both animals were shown and the child was asked to identify one of the syllables (e.g., "Who said /va/") by pressing a glass panel over the appropriate animal. Each fricative pair differed only in the fricative phoneme (e.g., /fa—va/), vowel and position being identical. Control pairs differing on several phonetic features were interspersed throughout the test series (e.g., /að—ki/). In the articulation test, the child repeated each syllable after the experimenter.

The fricatives were substantially more difficult to discriminate than the control items (error rates of 28% and 13%, respectively). Two contrasts, /v—ð/ and /f—θ/, were particularly difficult. There were fewer errors on VC than CV pairs. No differences were associated with the vowel, but there was some evidence that vowel duration was employed as a cue for discrimination of fricatives in final position. While there was a significant correlation between the number of discrimination and articulation errors per child, there was little evidence that articulation errors on specific phonemes were accompanied by discrimination errors on the same phonemes. Discrimination and articulation errors both resembled the pattern of errors found in tests of phoneme perception in adults. There was no evidence that the frequency of occurrence of specific phonemes in children's speech was substantially related to discrimination or articulation.

I

INTRODUCTION

While considerable information has been collected over the past 20 years on the acoustic cues which adults use to distinguish one phoneme from another, there has been relatively little research on phoneme discrimination by children. One possible reason for the scarcity of such studies is the difficulty of testing young children. In the present study, a speech discrimination test designed for preschool children was used to determine those features of the speech signal by which they made phonemic discriminations. The study concentrated on fricatives, since available evidence suggested that these constitute the major source of articulation and discrimination problems in kindergarten and first-grade children (Templin, 1957; Bricker, 1967).

Research at Haskins Laboratories has identified two features of the acoustic signal which allow discrimination among fricatives preceding vowels (Harris, 1958; Delattre, Liberman & Cooper, 1963). The frequency range of the friction, i.e., the initial burst of noise, is of primary importance. For /s/ and /z/ the friction is in the range above 3500 cps, while for /š/ and /ž/, the lower limit is 2000 cps. For the contrasting pairs/ f–v/ and /θ–ð/, friction extends in both cases from 1000 cps up. Hence, these pairs are differentiated solely on the basis of the transitional portion of the signal, which proved to be relatively weak. Other studies using natural stimuli have shown /f/ and /θ/ are most frequently confused in normal speech, followed by /v/ and /ð/ (Strevens, 1960; Hughes & Halle, 1956).

Duration of both the consonant and vowel may constitute significant cues in identification of fricatives which, unlike stops and plosives, can be sustained. Miller and Nicely (1955) suggest that length may be important in the isolation of /s/, /z/, /š/, and /ž/. Parmenter and Trevins (1935) showed sizeable differences in articulatory duration of selected fricatives (e.g., /z/, 110 ms; /s/, 100 ms; /f/, 91 ms; /v/, 63 ms; /ð/, 61 ms). Peterson and Lehiste (1960) found that average vowel duration was longer by 30 to 100 ms before final voiced fricatives than before voiceless fricatives. Vowel duration was not affected by the initial consonant. The cue of duration should therefore tend to facilitate VC discrimination, but not CV discrimination.[1]

The significance of durational cues is further indicated by Denes' (1955) study on the effect of duration on the perception of voicing for /s/ and /z/ in final position. He asked his subjects to report either the verb or noun form of the word *use*. When the word ended in /s/ but had the durational characteristics of /z/, the sound was heard as /z/. When the word ended in /z/ but had the durational characteristics of /s/, the final sound was perceived as /s/. Subsequent investigation indicated that perception of the consonant as voiced increased as the ratio of the consonant to vowel duration decreased.

There is some evidence that interaction between the consonant and the adjacent vowel may influence perception of consonants. However, the effect is most noticeable for the back (velar) consonants (Fletcher, 1953; Licklider & Miller, 1951), and hence it is of relatively little consequence for fricatives. Position of the consonant, preceding or following the vowel, also appears to affect both the intensity and discriminability of the consonant, but the data are scanty and puzzling. Thus, Black (1950) found consistently greater pressure in production of initial consonants, while Tolhurst (1949) found that voiceless consonants were slightly easier to recognize in final position than voiced ones.

The purpose of the study reported here was to test the ability of preschool children to discriminate among the fricatives /f/, /v/, /θ/, /ð/, /s/, and /z/ in both CV and VC pairs. The experiment also permitted evaluation of the relationship between discrimination and articulation performance on this set of fricatives.

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[1]Consonant is abbreviated C, vowel by V. Hence CV means consonant-vowel as in /fa/.

II
METHOD

MATERIALS

Pairs of syllables were prepared so that each of 6 consonants, /f/, /v/, /θ/, /ð/, /s/, and /z/, was paired with each of the remaining consonants, yielding 15 pairs. Each pair was tested 6 times, once with each of the 3 vowels /a/, /i/, and /aI/ in VC or CV order. In other words, the vowel and order were fixed for each of the two syllables in any test pairing so that /fa–va/ was tested, but not /fa–vi/ or /fa-av/.

In addition to the 90 syllable pairs described above, 7 maximally distinguishable control pairs were selected. In each control pair, a different vowel was used in each syllable; VC order was used in one syllable and CV in the other; and the consonants were from different manner classes (e.g., a fricative and a plosive). An example of a control pair is /að–ki/. By mistake, the vowel was not changed in one of the control pairs, /az-ta/.

Recording of the stimulus materials was done in a radio studio, using a Telefunkin ELA-M-251E condenser microphone. Recording was with an Ampex 351 recorder using Scotch 311 Tenzar tape at 15 ips. The speaker was a male graduate student majoring in linguistics. His dialect most closely approximated Upper Midwest (Wise, 1957).

To determine the quality of the recording and the difficulty of the task for mature speakers, 6 parents of the preschoolers were administered the same tests as the children received. There were two errors out of 444 opportunities, an error rate of .5%.

The visual stimuli consisted of 48 distinctive "pseudo-Seuss" figures of animals and common objects printed in bright, two-color combinations.

PROCEDURE

Each trial consisted of sequences of auditory and visual events. Auditory stimuli were presented by a Uher 5000 recorder through Telex HFR-91 earphones. The original recording was re-recorded at 3.75 ips, which was the fastest speed on the Uher. An MTA 400 Scholar served for display of the visual stimuli. This device is essentially an elaborate memory drum. The display area was covered by two one-way vision panels, 3.5 x 5 in., to the right and left sides, light-shielded to form two separate display areas. Either of the two displays could be viewed when the corresponding panel was back illuminated. The child responded by pressing one of the display panels, which were mounted on sensitive micro-switches.

A typical trial might follow this sequence, as an example. The left picture was illuminated on the MTA for 2 sec., and the child simultaneously heard /fa/. Then the left picture was turned off; the right picture was turned on for 2 sec.; and /va/ was presented. Next both pictures were illuminated, and the child heard "Who said /fa/?" The child was allowed to take as long as he wished to respond. A lockout system prevented responses except during the response period. If the response was correct (in this case, if the left panel was pressed), a green light at the top of the MTA was turned on; the right stimulus was turned off; and the child heard "I said /fa/." If the response was incorrect, a red light was turned on, and after a 2-sec. delay the child was allowed to correct his error, after which the events proceeded as after a correct response. During the 4-sec. intertrial interval, a new pair of pictures moved into the display area.

Testing was conducted over a period of seven weeks, each child being tested once per week. During the first week, a pretraining test of 10 pairs was given. The first 7 pairs were pictures of real animals accompanied by the sounds of those animals as mimicked by a human voice. The last 3 pairs consisted of pictures and nonsense syllables similar to those used in the experimental sessions.

During each of the six experimental sessions which followed, 15 fricative pairs and 7 control pairs were tested. During each session, each of the 15 basic fricative contrasts was tested once. The vowel remained constant throughout a session, and roughly the same number of CV and VC orderings appeared (7 of one, 8 of the other).

A single random order of each of the six lists was prepared (cf. Appendix). The first two pairs were always control items. Order of presentation of the six lists was counterbalanced over subjects.

During both of the last two sessions, an 18-item articulation test was given following the discrimination test. The 36 experimental syllables were assigned randomly to one of two test lists of 18 syllables each. The child was asked to repeat each item after the experimenter said it. The child's responses were transcribed by a second experimenter and were also recorded (Uher 5000 recorder, Unidyne-Shure 545L lavalier microphone).

At the first session, each child was given the following instructions:

> We are going to play a game which has pictures and also sounds. You will see some pictures of animals on this machine [indicating the MTA] and you will hear a man say the sounds that these animals make through these earphones. After you have seen two pictures the man will ask you a question and you can answer him by pressing the glass over the correct picture. Let's try it. [Experimenter demonstrates.] After a while you will see some funny pictures and you will hear a man say a sound for each picture. You will have to listen very carefully and answer the man's question in the same way as before.

The experimenter reinforced correct responses by comments such as "good" or "fine." Comments such as "listen carefully" were used for incorrect responses. Subjects were also rewarded at the end of all but the first session with candy or a small toy.

Each session lasted approximately 10 minutes. Testing was conducted in a mobile trailer which was relatively quiet but not totally soundproof.

SUBJECTS

Seventeen children between 3 years 4 months and 5 years 1 month of age were recruited during the summer of 1965 from a graduate-student housing area at the University of Wisconsin, Madison. There were 10 boys and 7 girls. Some of the subjects had attended nursery school, but none had gone to kindergarten.

III

RESULTS

DISCRIMINATION TEST

Seven control pairs were tested on each of the six sessions. Mean errors ranged from 10% to 18% for these items over sessions, with a mean of 13%. There was no systematic change in error rate over sessions. The number of errors per subject ranged from 1 to 16 (maximum possible 42). Since the control items were maximally discriminable synthetic syllables, it can be argued that the discrimination task was difficult, but not beyond the children's capacity, and that the pretraining was adequate. Performance improved with age; the eight children in the sample who were 4 years old or younger had an error rate of 18%, the nine older children, an error rate of 9%.

The overall mean error rate on the fricative pairs was 28%. As expected, these contrasts proved substantially more difficult for the children. There was no consistent trend in the error rates for these items over sessions. The number of errors per child ranged from 14 to 38 (maximum possible 90). There was a relatively high correlation between the number of errors on the control pairs and the fricative pairs ($r = .55$, $p < .01$).

Two analyses of variance were carried out to determine the effects of variation in vowel, position of the consonant in the syllable, and specific pair. (Recall there were three vowels and 15 pairings of the six fricatives.) For analysis of the vowel effect, error scores were summed over the position variable, yielding for each subject an error score of 0, 1, or 2 for every vowel-pair combination. There were no differences in performance associated with the three vowels ($F < 1$), nor was the vowel-by-pair interaction statistically reliable, $F(28,448) = 1.49$, $p < .10$. There were differences between pairs, to be discussed below.

In the second analysis, the error scores were summed over the vowel variable, yielding a score of 0–3 for each position-pair combination. There were significantly fewer discrimination errors when the consonant followed the vowel (24% errors) than when it preceded the vowel (31% errors), $F(1, 16) = 9.35$, $p < .01$. The interaction between position and pairs was also statistically significant, $F(14,224) = 1.79$, $p < .05$. Investigation of specific combinations (Table 1) showed that the pairs /ð–s/ and /f–v/ were relatively much easier as VC than CV, whereas /v–z/ and /f–s/ were much easier as CV than VC, contrary to the overall trend.

Differences between the mean errors per pair in the lowest row of Table 1 were also statistically significant, $F(14,224) = 6.13$, $p < .01$. The results of a Duncan range test of these means are also indicated in Table 1. Discrimination of pairs /v–ð/ and /f–θ/ was at the chance level, while /θ–z/ and /s–z/ tended to be easier than the other pairs.

ARTICULATION TEST

Each child pronounced 36 fricative syllables, all combinations of 6 fricative phonemes, 3 vowels, and CV or VC. Aside from fricative substitutions, there were only 4 other errors: one child added a final /-b/ to /sa/ and /za/, there was one vowel substitution, and in one instance /h-/ was placed before /av/. These 4 errors were disregarded in the analysis of the articulation data, the summary results of which are shown in Table 2. The number of articulation errors ranged from 2 to 16 per subject, with a mean error rate of 21%. There were 75 CV errors and 56 VC errors; just as in the discrimination test, CV items were more difficult than VC. The correlation between the number of errors by a child on the articulation test and the fricative discrimination test was substantial ($r = .62$, $p < .01$). The number of errors on the articulation test was not as closely related to discrimination of the control pairs ($r = .40$, $p < .05$). It is very possible that these correlations are the result of age differences, as reported by Templin (1957).

No statistical evaluation of the data in Table 2 was attempted, but certain trends are apparent. First, there were no errors in manner of articulation; all of the responses given were from the subset of fricatives used in the study. Second, the pattern of substitutions is quite similar for initial and final consonant positions. The number of errors involving only a change in place of articulation is about the same for both positions (45 in initial, 49 in final). There were more errors in voicing for initial than final positions (17 and 2, respectively), and more errors in both voicing and position for initial than final positions (13 and 5, respectively). Of the 131 errors, 92 preserve the voicing feature. Third, when a substitution involves a shift in place of articulation, the shift is generally small. The majority (59%) of the substitutions come about when an interdental fricative (/θ/ or /ð/) is replaced by a labiodental fricative (/f/ or /v/). Next most common (19%) is replacement of an alveolar fricative (/s/ or /z/) by an interdental fricative. There are only two occurrences of an interchange between labiodental and alveolar positions, the largest possible change in place of articulation for these materials.

Table 1. Mean Probability of an Error in the Phoneme Discrimination Task, Averaged Over Vowels

Pair	θ z	s z	f z	ð s	v z	f ð	f s	θ s	θ v	s v	θ ð	ð z	f v	ð v	f θ
CV	18	18	20	33	16	26	22	30	30	33	39	37	51	45	55
VC	8	10	20	8	30	20	28	22	24	26	24	34	21	52	51
Mean	13	14	20	21	23	23	25	26	27	30	32	35	36	49	53
Range Test	———	———	———	———	———	———	———	———	———	———					
			———	———	———	———	———	———	———	———	———	———	———		
										———	———	———	———	———	
														———	———

Note.—Any two entries in the *Mean* row not underlined by the same line are significantly different, $p < .05$, by a Duncan range test. Decimals have been omitted.

Table 2. Frequency of Fricative Substitutions in Articulation Test

Stimulus	Substitution f	v	θ	ð	s	z
f	---	1, 0	1, 3	0, 0	0, 0	0, 0
v	4, 1	---	0, 1	0, 0	0, 0	0, 0
θ	19, 11	0, 0	---	1, 0	1, 2	0, 0
ð	7, 2	13, 25	3, 1	---	0, 0	0, 0
s	1, 0	0, 0	6, 4	0, 0	---	1, 0
z	0, 0	0, 1	6, 2	3, 2	7, 0	---

Note.—First entry in each cell is for CV position, second entry is for VC.

IV
DISCUSSION

The major point to be made about these data is that they follow the pattern of confusions found in speech perception by adults. In other words, if one asks, What pairs of fricatives are difficult for young children to articulate or discriminate? the answer is, Those pairs which adults most often confuse. The classic study of Miller and Nicely (1955) serves well as a reference. Adults were presented with CV items in a noise background and asked to identify each consonant. The vowel was held constant throughout as /a/. They described their results by a model based on three articulatory features—manner and place of articulation, and voicing.[2] A similar analysis gives considerable order to the present data. In Table 3, proportion of discrimination errors for various pairs are arranged according to place and voicing characteristics. This analysis indicates that the highest error rates occurred when *neither* articulatory dimension provided a strong cue (i.e., when there was identical voice character and the place difference was small). When either place or voicing provided a suitable cue for differentiation, error rates were substantially lower. There were, however, no large differences associated with the size of the place difference when voicing was different, nor was the voicing cue more salient than the place cue. Moreover, the combination of a voicing difference with a large place difference did not make it easier to distinguish a pair. The relations between articulation and discrimination data from the present study, the Miller-Nicely confusion matrix based on adults, and the frequency of occurrence of the phonemes in the speech of young children are examined by the analysis presented in Table 4. The first entry in each cell of the half-matrix is the rank-order difficulty of discriminating the pair in the present study. The second entry is the rank-order difficulty of articulation in the present study. The confusion matrices in Table 2 were collapsed over CV and VC, and then the half-matrix was formed by "folding" on the main diagonal. Visual examination of Table 2 suggests that collapsing over VC and CV does no injustice to the data. In the half-matrix, certain asymmetries in the tables are disregarded, but

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[2]Confusions among the stimuli tended to preserve certain features more than others. In particular, voicing was least likely to be lost. Thus, for the stimulus /ga/, the most common substitutions were /da/, and /za/, while /ka/ was relatively uncommon. For /da/, place of articulation is wrong but manner and voicing correct, whereas for /za/, manner is incorrect, place and voicing correct. Menyuk (1968) has demonstrated the application of a feature-analysis model to articulation errors in young children. Also cf. Jakobson, Fant, and Halle, 1963.

Table 3. Proportion of Errors in Discrimination Task as a Function of Voicing and Place-of-Articulation Features

	Place of Articulation		
Voicing	Same	Small Difference	Large Difference
Same	---	.41	.24
Different	.27	.21	.25

these are relatively unimportant for purposes of comparing articulation and discrimination data.[3]

The third entry is from Miller and Nicely (1955; Table III, frequency response 200–6500 cps, S/N = -6 db), where again a half-matrix was formed by folding a full matrix. The lowest entry is based on data from Poole's (1934) study of the frequency of occurrence of consonants in the free speech of preschool and primary children.[4] She found a wide range in the frequency per hundred words of the fricatives used in the present study (/s/, 12.5; /ð/, 9.5; /z/, 7.0; /v/, 4.0; /f/, 3.5; /θ/, 1.5). To obtain a measure based on her count that could be compared with our data, for each pair in Table 4 the total frequency of occurrence of the two elements of the pair was computed, and then the set of pairs was rank ordered on this total. Thus, the pair /θ-f/ had a total frequency of 5.0 and was assigned a rank order of 1, being least frequent.

Rank-order correlations were then calculated for the various combinations of the four measures in Table 4. Correlation between the rank-order difficulty of articulation and discrimination in the present study was marginally significant ($\rho = .34$, $p < .10$). Correlation of discrimination and articulation by the preschoolers with the Miller-Nicely data was reasonably high: .59 for discrimination, .62 for articulation, $p < .01$ in both cases.

Table 4. Half-Matrix of Rank Order of (1) Discrimination and (2) Articulation Data from Present Study, (3) Miller-Nicely Confusion Data from Adult Subjects, and (4) Poole Count of Frequency of Occurrence in Preschool and Primary Grade Children

First Member of Pair	Data Set	Second Member of Pair				
		v	θ	ð	s	z
f	1	3	1	10.5	9	13
	2	7	2	4	11	14
	3	8.5	1	7	4	14
	4	3	1	8	11	5
v	1		7	2	6	10.5
	2		11	1	14	11
	3		10	2	13	6
	4		2	9	12.5	6.5
θ	1			5	8	15
	2			8.5	3	5.5
	3			11	3	12
	4			6.5	10	4
ð	1				12	4
	2				14	8.5
	3				15	5
	4				15	12.5
s	1					14
	2					5.5
	3					8.5
	4					14

Note.—See text for more detailed description of how rank orders were computed. For each data set, Rank 1 indicates highest error rate (or lowest frequency), Rank 15 lowest error rate.

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[3]In the articulation data in Table 2, /f/ and /v/ are frequently substituted for /θ/ and /ð/, respectively. In fact, these two substitutions account for 53% of all the errors in Table 2. Considering only the fricative subset in Bricker's (1967) study of articulation of CV syllables (V = /a/) by children from 3 to 6 years of age, these two substitutions constituted 13 to 25% of the errors depending on the age group. Substitutions in the opposite direction (/θ/ for /f/, /ð/ for /v/) were much less common, 5% in our study, 2 to 5% in Bricker's. This asymmetry may be the result of response bias: /f/ is more common in children's speech than /θ/ according to both Poole (1934) and Carterette and Jones (1965). On the other hand, /v/ is relatively infrequent, although /ð/ occurs with high frequency in part because of its appearance in initial position in the closed set of function words. In the data of Miller and Nicely (1955), the probability of replacing an interdental by a labiodental is about double the probability of the reverse substitution. These asymmetries suggest that further work is needed with discrimination tasks where response bias is more adequately controlled. The presence of such asymmetries in the perceptual processing of the speech signal would seem to raise problems for simple feature analysis models.

[4]Poole's phoneme count agrees well with the more recent data of Carterette and Jones (1965) on first-grade children. If the counts are normalized on totals over the six fricatives used in study, the proportions for each fricative from Poole and Carterette-Jones, respectively, are: /s/, .328, .341; /ð/, .250, .212; /z/, .184, .209; /v/, .105, .078; /f/, .092, .105; /θ/, .039, .051.

None of the other correlations approached significance. In particular, correlations between the frequency index and other performance measures were uniformly low ($\rho < .25$). Inspection of Table 4 shows that the frequency predictor is off in several comparisons. Neither /θ–v/ nor /θ–z/ were as difficult for the children to discriminate as the frequency measure would predict. Also, /ð–v/ is a very difficult pair, although both phonemes are common in children's speech. Where the frequency predictions are in closest agreement with the data (e.g., /s–ð/ is easy and /θ–f/ difficult), the predictions are similar to those of a feature analysis.

In short, frequency of occurrence (at least, the gross measure obtained by Poole) is not a reliable indicator of the ease with which young children discriminate or articulate fricative consonants. On the other hand, there is a reasonably close relationship between both articulation and discrimination performance in young children and the performance of college students in a perceptual recognition test.

It is pertinent at this point to consider the relation between articulation and discrimination. A child is unlikely to produce in a consistent fashion contrasts that he cannot hear; on the other hand, not all contrasts that can be heard need be produced in speaking. The semivowels /r/ and /l/ are frequently misarticulated, but there is no good evidence that discrimination of these phonemes is particularly difficult.[5]

Our discrimination data agree closely with predictions based on the acoustic properties of the various fricatives. The frequency range of the friction is sufficient for identification of /s/ and /z/. This cue does not permit discrimination between the interdentals /θ–ð/ and labiodentals /f–v/ for which the weaker, transitional cues must be used. Averaging over all contrasts, the mean error rate in discrimination of /s/ is 23%, and of /z/, 21%. For the other four phonemes, the mean error rate ranges from 30% to 32%.

The pattern of articulation results differs in some significant details from the discrimination results. In articulation, the interdental position is much more difficult (41% errors) than either the labiodental (6%) or alveolar (16%) fricatives. Similar error rates were found by Bricker (1967): interdental, 72%; labiodental, 37%; alveolar, 25%. His error rates were considerably higher, but the interdental position is clearly the most difficult. Templin (1957) used real words as stimuli and found error rates for /θ/ and /ð/ of around 75% over a comparable age range; /f/ and /s/ were easier (around 50%), but /v/ and /z/ were as difficult as /θ/ and /ð/ (around 75%).

In view of the imperfect correspondence between discrimination and articulation, it may be useful to consider the different cues available to a child in the development of speech perception. In addition to the information in the speech of others, a child must rely on feedback from his own efforts at speech.[6] Both acoustic and articulatory feedback must be taken into account. In producing a spoken word, the child hears what he produces and matches it against some target representation in memory, but he must also identify and retain the articulatory sequence used to generate the word, if learning is to occur. When developmental aspects of speech behavior are being considered, it is especially important to remember that children may hear and produce phonological sequences very differently from the manner in which adults (particularly linguists) operate. It seems quite possible that much of the misarticulation observed in children's speech stems primarily from motoric difficulties—the motoric commands for certain phonemes may be missing, and for other phonemes the child may use some approximation that is sufficient for communication but differs substantially from the motor pattern used by adults.

With regard to "what the child hears," the saliency of various cues may well change during acquisition of speech. As previously mentioned, duration of the friction and transition components varies widely from one fricative to another, and the vowel duration is longer before voiced than unvoiced consonants. Spectrographic analysis of selected items from our discrimination test tape indicated that before a voiced fricative, the vowel

[5]For some reason, discrimination of the laterals has not been investigated. Research from Haskins Laboratories (O'Connor, Gerstman, Liberman, Delattre, & Cooper, 1957) would indicate that adequate acoustic cues exist to differentiate among the phonemes in the set /w, j, r, l/. Both second and third format transitions differ considerably between the patterns for /r/ and /w/, although /w/ is frequently substituted for /r/.

[6]Note that visual cues may also be important, particularly for phonemes with labial components. We are not aware of any systematic work with children on this problem.

was longer by 50 to 100% than before an unvoiced fricative. The durational cue may account for the relative ease with which voiced-unvoiced combinations in final position were discriminated by the preschoolers (cf. Table 1; except for /f–z/, VC for these combinations had a much lower error rate than CV).

It would be interesting to have more detailed information about the phonetic environment in which children develop speech ability. If our interpretation of the data is correct, the children tested in this study were quite sensitive to temporal cues. It may be that, in speaking to their children, parents provide redundant phonetic cues on several dimensions in an exaggerated form, in this fashion facilitating the child's acquisition of speech. Further work with synthetic speech will be necessary for evaluation of the relative importance of these various cues in the development of speech recognition.

APPENDIX

STIMULUS PAIRS USED IN DISCRIMINATION TASK

Set I		Set II		Set III		Set IV		Set V		Set VI	
fa*	ig	gaI	af*	ip*	va	za	at*	da*	iθ	az	ta*
gaI*	af	ip	va*	zaI*	at	da	iθ*	az*	ta	að	ki*
va	ða*	af*	as	vi	ði*	if*	is	vaI	ðaI*	aIf*	aIs
aθ*	az	va	za*	iθ*	iz	vi	zi*	aIθ*	aIz	vaI	zaI*
da	iθ*	zaI*	at	fa	ig*	az*	ta	að	ki*	fa*	ig
af	av*	as*	aθ	if	iv*	is*	iθ	aIf	aIv*	aIs*	aIθ
ða*	sa	að	af*	ði*	si	ið	if*	ðaI*	saI	aIð	aIf*
af*	aθ	za	sa*	if*	iθ	zi	si*	aIf*	aIθ	zaI	saI*
zaI	at*	da*	iθ	az	ta*	að*	ki	fa	ig*	gaI*	af
ða*	za	va	θa*	ði*	zi	vi	θi*	ðaI*	zaI	vaI	θaI*
va*	sa	az	af*	vi*	si	iz	if*	vaI*	saI	aIz	aIf*
az	ta*	að*	ki	að	ki*	fa*	ig	gaI	af*	ip*	va
að	aθ*	ða*	θa	ið	iθ*	ði*	θi	aIð	aIθ*	ðaI*	θaI
za*	fa	av	as*	zi*	fi	iv	is*	zaI*	faI	aIv	aIs*
av	aθ*	að*	az	iv	iθ*	ið*	iz	aIv	aIθ*	aIð*	aIz
az	as*	fa*	θa	iz	is*	fi*	θi	aIz	aIs*	faI*	θaI
ip*	va	az	ta*	da*	iθ	gaI	af*	ip*	va	zaI	at*
ða*	fa	að	as*	ði*	fi	ði	si*	ðaI*	faI	ðaI	saI*
sa	θa*	fa*	va	si	θi*	fi*	vi	saI	θaI*	faI*	vaI
av*	az	θa	za*	iv*	iz	θi	zi*	aIv*	aIz	θaI	zaI*
að	ki*	fa*	ig	gaI	af*	ip*	va	zaI	at*	da*	iθ
fa	sa*	av*	að	fi	si*	iv*	ið	faI	saI*	aIv*	aIð

Note.—Syllable on left was presented first. Asterisk indicates test syllable. Control pairs are underlined.

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GPO 811-840-2