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ABSTRACT

The development of differential vowel duration was observed in six children who were tape recorded at 1-month intervals from 26 to 36 months of age and in three children from 21 to 24 months of age. By differential vowel duration is meant the relatively different durations of vowels according to whether the following consonant is voiced or voiceless, stop or fricative. The children's task was to produce a series of consonant-vowel-consonant English words using each of the vowels /I i u/ before one voiceless and one voiced fricative. Four stimulus conditions were used: a visual stimulus using familiar storybook pictures and three sets of tape-recorded stimuli with the vowel /i/. One set had normal differential vowel duration, another had abnormal equal vowel duration, and the third had four occurrences of each word with graded vowel durations. Results showed that acquisition of differential vowel duration preceded control of the voicing feature which conditions it in adult English. Correct intrinsic vowel duration was produced in all responses. This document, Part 2, includes the report of the fourth stimulus condition, conclusions, appendixes, and a bibliography. Part 1 of this study can be found in document RE 003 491. (Author/DH)

Technical Report No. 144 (Part 2 of Two Parts)

THE AMERICAN CHILD'S ACQUISITION OF DIFFERENTIAL VOWEL DURATION

Report from the Project on
Basic Pre-Reading Skills
Identification and Improvement

By Margaret A. Naeser

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STATEMENT OF FOCUS

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 disigned 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 Basic Pre-Reading Skills: Identification and Improvement 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 prior activities. Contributing to these Program objectives, this project's basic goal is to determine the processes by which children aged 4 to 7 learn to read, examining the development of related cognitive and language skills, and to identify the specific reasons why many children fail to learn to read. Later studies will be conducted to find experimental techniques and tests for optimizing the acquisition of skills needed for learning to read. By-products of this research program include methodological innovations in testing paradigms and measurement procedures; the present study is an example.

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Abstract

The development of differential vowel duration was observed in six children who were tape recorded at one-month intervals from 26 to 36 months of age, and in three children from 21 to 24 months of age. By differential vowel duration is meant the relatively different durations of vowels according to whether the following consonant is voiced or voiceless, stop or fricative (apart from intrinsic duration of the different vowels). The children's task was to produce a series of CVC English words using each of the vowels /I i u/ before one voiceless and one voiced fricative. Four stimulus conditions were used: 1) A visual stimulus, using familiar story-book pictures, and 2-4) three sets of tape recorded stimuli with the vowel /i/: one set had normal differential vowel duration, another had abnormal equal vowel duration, and the third had four occurrences of each word with graded vowel durations.

The children's responses were tape recorded in a sound-treated booth, and acoustic displays were made of their attempts to reproduce the stimulus words. Vowel duration measurements were made on duplex oscillograms; productions of the final consonants were transcribed by three linguists.

Results showed that acquisition of differential vowel duration preceded control of the voicing feature which conditions it in adult English. Since there were very few mistakes in manner of articulation of the final consonants it was not possible to determine whether its control preceded that of differential vowel duration. Correct intrinsic vowel duration was produced in all responses.

Some inferences were made from the results regarding development of differential vowel duration and control of voicing of final consonants. Variations in responses under the four types of stimuli used, and individual variations between one child whose parent evidenced distinct dialect differences (black dialect), and the other eight children (white dialect), permitted the positing of three stages in the acquisition of differential vowel duration in American English in relation to the voicing of final consonants. In the first stage, the child imitates the adult's differential vowel duration very well and produces it correctly regardless of the final consonant. He does not have control of voicing of final consonants in the majority of his CVC utterances. As the child gains control of final consonant voicing in the majority of his CVC utterances (second stage), voiced final consonants become associated with increased vowel duration. In this stage, a voiced final consonant would be his cue to produce a longer vowel, rather than direct imitation of the vowel. In the third stage, which may perhaps be simultaneous with the second, or occur later, the child makes the reverse association, increased vowel duration with voiced final consonants, which eventually permits increased vowel duration to act as a sufficient cue to the perception of voiced final consonants.

Chapter 5

FOURTH STUDY: RESPONSES TO TAPED STIMULI WHERE EACH WORD HAD FOUR GRADED DURATIONS

INTRODUCTION

This study investigated the production of vowel duration in utterances elicited with a stimulus tape where each word had 4 graded vowel durations. Children approximately 35 months of age were compared to 2 groups of adults. The following questions were asked:

1. Do children 35 months of age imitate graded vowel durations for the same word on a stimulus tape, or do they produce the same word with the same duration all the time?

2. Do adults imitate graded vowel durations for the same word on a stimulus tape when instructed to imitate the word exactly as it is on the tape, or do they produce the same word with the same duration all the time?

3. Do adults avoid imitating graded vowel durations for the same word on a stimulus tape when instructed only to say the word (not imitate), or do they produce the word with the graded durations as on the tape?

METHOD

STIMULUS MATERIALS

The same 8 words that were used on the stimulus tapes in the second and third studies were used in this study. The same speaker who recorded the tapes for those studies recorded the tape for this one using the same tape recording equipment. He recorded each word with several different vowel durations, using a monotone, list intonation pattern. Vowel duration measurements for the 32 stimulus utterances were taken from duplex oscillograms with the same procedure as described in Appendix B.

The final stimulus tape was produced by copying the words and re-ordering vowel durations so that each group of 4 words (story words, then constant /#p--/ words) had 4 different grades of duration present. The words and vowel duration values are shown in Word list for stimulus tape with four graded vowel durations for each word, in Appendix A.

SUBJECTS

Children

Five children who participated in the first study from Group 1 also participated in this study for 2 months. The mean age over the 2 month period was 35 months.

Adults

Ten adults (female) who were on the staff at the Wisconsin Research and Development Center for Cognitive Learning were chosen for this study. They were all native speakers of American English and none of them spoke any other language.

PROCEDURE

Children

Children were tape recorded with the same procedure as that used in the second study. No special instructions were given. Each child completed the tape one the first months, and once the second month.

Adults

Each adult subject was recorded in a quiet room at the Wisconsin Research and Development Center for Cognitive Learning. The stimulus tape was played back at the recorded speed of 7½ i.p.s. on an Ampex tape recorder (Model 1100). The subject sat at a desk and the utterances were recorded with an Ampex microphone (Model 2001) on 1½ mil 175 Tenzar Scotch magnetic recording tape at 7½ i.p.s. on an Ampex tape recorder (Model 1100). For a schematic diagram of the recording procedure see Fig. 33. It was not necessary to stop the playback of the stimulus tape to allow the subject to utter the response as there was an adequate amount of silence (approximately 2 seconds) left for this purpose on the stimulus tape.

The 10 adult subjects were divided into 2 groups. Adult Group 1 (5 subjects) was instructed to imitate the vowel durations of the words on the stimulus tape as closely as possible. Adult Group 2 (5 subjects) was instructed not to imitate the durations of the words on the stimulus tape, but to just say the words.

Acoustic Analysis of Responses

Acoustic analysis of the responses was done with duplex oscillograms in the same way as in the other studies.

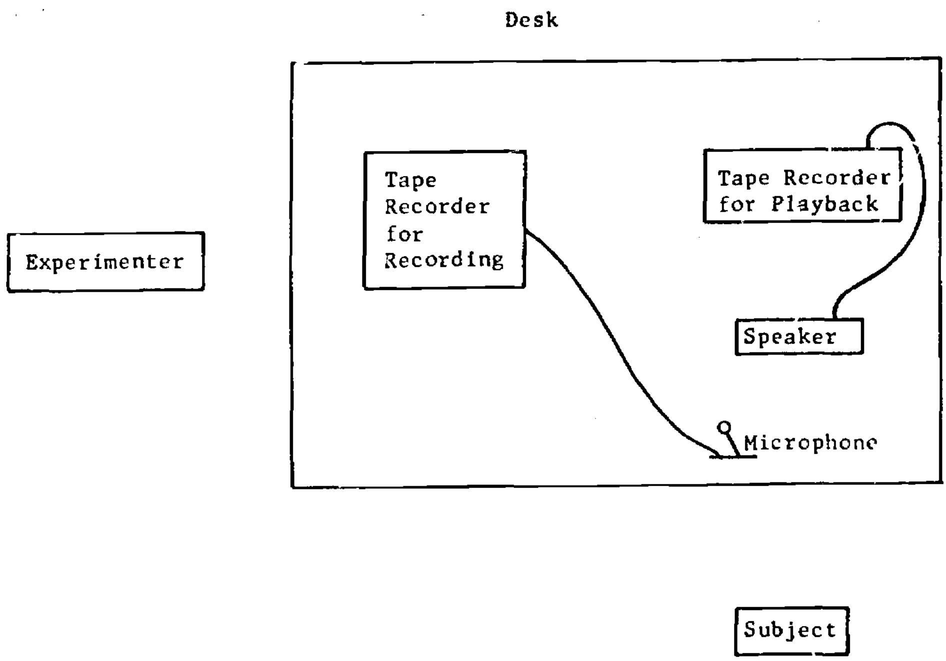

Fig. 33 Schematic diagram for recording utterances elicited with a stimulus tape at the Wisconsin Research and Development Center

RESULTS AND DISCUSSION

The children at the mean age of 35 months made no final consonant production errors in their responses for the words used in this study. Thus, there was no need to apply data scoring procedure types 1 - 5 to their responses, as in the other studies.

STATISTICAL ANALYSIS OF RESPONSES

The subjects' responses were separated into 3 groups.

1. Mean vowel durations for responses from the children over the 2 sessions.
2. Mean vowel durations for responses from Adult Group 1 (imitating).
3. Mean vowel durations for responses from Adult Group 2 (not imitating).

To test if any group was imitating the vowel durations on the stimulus tape, an analysis of variance test was performed on the deviations from the tape stimuli with the design, group (3), by word (8), by duration (4). The last 2 factors were treated as repeated measures.

The overall responses of the 3 groups showed statistically reliable deviations from the tape ($F(1,12) = p < .0001$). The average deviation from the tape was 82 msec.

There was a significant difference between the response deviations for the groups ($F(2,12) = 17.00$, $p < .0004$). The average absolute deviation from the tape stimuli for the children was 32 msec; for Adult Group 1, 41 msec; and Adult Group 2, 173 msec.

Using Scheffé's simultaneous inference technique, 3 contrasts were used to identify the average group differences. Adult Group 2 (not imitating) differed significantly from the average of Adult Group 1 (imitating) and the children ($p < .01$), and from the children alone ($p < .01$). There was no significant difference between the children and Adult Group 1 (imitating). The observed group means and mean deviations are listed in the table below:

	Group mean (msec)	Mean deviation
Children	371	-53.875
Adult Group 1	350	-32.500
Adult Group 2	230	-173.680

To find out if the responses for any of the groups deviated significantly from the stimulus tape the studentized maximum modulus method was used. Adult Group 2 and the children both showed significant deviation from the stimulus tape ($p < .05$). Adult Group 1 did not. Thus, the only subjects in this study who did imitate the tape values at a significant level were in Adult Group 1, i.e. those who were specifically instructed to do so.

The analysis of variance test also showed that there was a significant difference overall between words ($F(7,84) = 15.38$, $p < .001$). See Table 30 for overall response means and mean deviations from the stimulus tape for each word.

There was also a significant interaction between words and groups ($F(14,84) = 2.70$, $p < .005$). Adult Group 1 (imitating) and the children ranged in overall deviations from words on the tape, from 3 msec for /pib/, where the average tape duration was 371

Table 30

Fourth study, responses to taped stimuli of 4 graded vowel durations. Mean vowel duration for 3 groups of subjects: children (3[illegible] mo.), adults instructed to imitate duration (Adult 1), and adults instructed not to imitate duration (Adult 2); and mean vowel duration difference from tape for each group.

	/fit/	Rs-St	/sid/	Rs-St	/tiθ/	Rs-St	/piz/	Rs-St	/pip/	Rs-St	/pib/	Rs-St	/pis/	Rs-St	/piz/	Rs-St
Vow 1 St Tp	290		315		305		415		295		295		305		395	
Chdn.	332	+42	357	+42	302	3	435	+20	243	52	344	+49	302	3	378	17
Ad. 1	261	29	322	+7	254	51	379	36	248	47	324	+29	282	23	317	78
Ad. 2	168	122	244	71	198	107	320	95	166	129	234	61	178	127	321	74
Vow dur 2 St Tp	375		365		405		435		310		345		420		420	
Chdn.	333	42	384	+19	337	68	422	13	290	20	348	+3	344	76	425	+5
Ad. 1	332	43	348	17	319	86	428	7	319	+9	291	54	352	68	411	9
Ad. 2	164	211	259	106	222	183	317	118	159	151	245	100	193	227	333	87
Vow dur 3 St Tp	410		375		440		495		395		380		445		435	
Chdn.	337	73	411	+36	343	97	494	1	289	106	402	+22	358	87	436	+1
Ad. 1	369	41	338	37	356	97	422	73	351	44	362	18	349	96	411	24
Ad. 2	167	243	266	109	202	238	306	189	154	241	236	144	204	241	307	128
Vow dur 4 St Tp	425		475		520		530		445		465		520		495	
Chdn.	439	+14	456	19	409	111	457	73	283	162	380	85	381	139	444	51
Ad. 1	345	80	418	57	373	147	440	90	373	72	326	139	394	126	405	90
Ad. 2	162	263	231	244	209	311	312	218	157	288	238	227	183	337	332	163
Mean for vow dur 1-4 St Tp	375		382		417		468		361		371		422		436	
Chdn.	360	15	402	+20	347	70	452	16	276	85	368	3	346	76	421	15
Ad. 1	326	49	356	26	325	92	417	51	322	39	325	46	344	78	386	50
Ad. 2	165	210	250	132	207	210	313	155	159	202	238	133	189	233	323	113
Mean Vl/Vd ratio				Rat				Rat				Rat				Rat.
St Tp	375		382	.98	417		468	.89	361		371	.97	422		436	.96
Chdn.	360		402	.89	347		452	.76	276		368	.75	346		421	.82
Ad. 1	326		356	.91	325		417	.77	322		325	.99	344		386	.89
Ad. 2	165		250	.66	207		313	.66	159		238	.66	189		323	.58

and that for the children was 368; to 92 msec for /tiθ/, where the average tape duration was 417 and that for the adults imitating was 325 msec. Adult Group 2 (not imitating) ranged in overall deviations from 113 msec for /piz/, where the average tape duration was 436, and that for Adult Group 2 was 323; to 250 msec for /fit/, where the average tape duration was 375 and that for Adult Group 2 was 165. It is not unexpected that the largest deviations for adults not imitating duration would be for vowel duration before a voiceless stop, /fit/, and the smallest deviation for vowel duration before a voiced fricative, /piz/, as these represent the shortest and the longest normal vowel duration environments for American English.

For the adults imitating, and for the children, rank order of deviations, overall, per word is not the same. The adults imitating came closest to imitating vowel duration before final stop consonants, /sid/, /pip/, /pib/, /fit/, with deviations from 26 to 49 msec for these words. Deviations before the fricatives ranged from 50 to 90 msec for /piz/, /piz/, /pis/, /tiθ/.

The children showed no particular pattern for manner or voicing or familiarity of words in their rank order of deviations. For them, the word /pib/, perhaps the most unfamiliar word in the list, was the word they deviated from the least, only by 3 msec. But another non-story word, /pip/, was the word they deviated from the most, by 85 msec. The other words were in between in no patterned order, /fit/, /piz/, /piz/, /sid/, /tiθ/, /pis/.

Difference between graded durations was significant ($F(3,36) = 110.56$, $p < .005$). The overall graded durations and duration deviations from the stimulus tape are given in the table below:

Four graded durations for 8 stimulus words (msec)

	Dur. 1	Dur. 2	Dur. 3	Dur. 4
Stimulus tape	326	384	421	145
Three groups	250	315	326	339
Deviations from tape	76	69	95	145

As can be seen from the above table, the 3 groups overall, came closest to imitating durations for the 2 relatively shorter durations, 1 and 2 vs. the longer durations, 3 and 4.

There was a significant interaction between durations and groups ($F(6,36) = 7.82$, $p < .0005$). This interaction between durations and groups is shown in the table below:

Four graded durations for 8 stimulus words (msec)

	Dur. 1	Dur. 2	Dur. 3	Dur. 4
Stimulus tape	326	384	421	484
Children's resp.	336	360	383	406
Absolute deviations from tape	10	24	38	78
Adult 1 resp.	298	350	369	384
Absolute deviations from tape	28	34	52	100
Adult 2 resp.	228	236	230	228
Absolute deviations from tape	98	148	191	256

This table clearly shows that the deviations for each graded duration were much greater for Adult Group 2 (not imitating) than for Adult Group 1 (imitating) and the children.

There was a significant interaction between words and durations (but not by group) ($F(21,252) = 3.79$, $p < .0005$). Table 30 and Fig. 34 show which of the graded durations was most closely imitated for each word. For /fit/, (stimulus tape values given in parentheses), graded duration 1 (290) was the most closely imitated; for /sid/, duration 2 (365); for /tiθ/, duration 1 (305); for /piz/, duration 2 (435); for /pip/, duration 2 (310); for /pib/, duration 3 (380); for /pis/, duration 1 (305); for /piz/, duration 2 (420). All these durations which were most closely imitated were relatively long compared to responses from the parents, but not necessarily the children, for these same words in the first and second studies. However, regardless of previous vowel durations produced for these words by other adults duration was best imitated before voiceless consonants when it was between 290 and 310 msec; and before voiced consonants when it was between 365 and 435 msec. Thus, graded duration 1 was usually best imitated before voiceless consonants; and graded duration 2 was usually best imitated before voiced consonants by all subjects tested, children and adults.

DESCRIPTIVE ANALYSIS OF RESPONSES

The voiceless-to-voiced ratios are also shown on Table 30. The overall voiceless-to-voiced ratio for the tape was .95; for the children, .80; for Adult Group 1, .89; and for Adult Group 2,

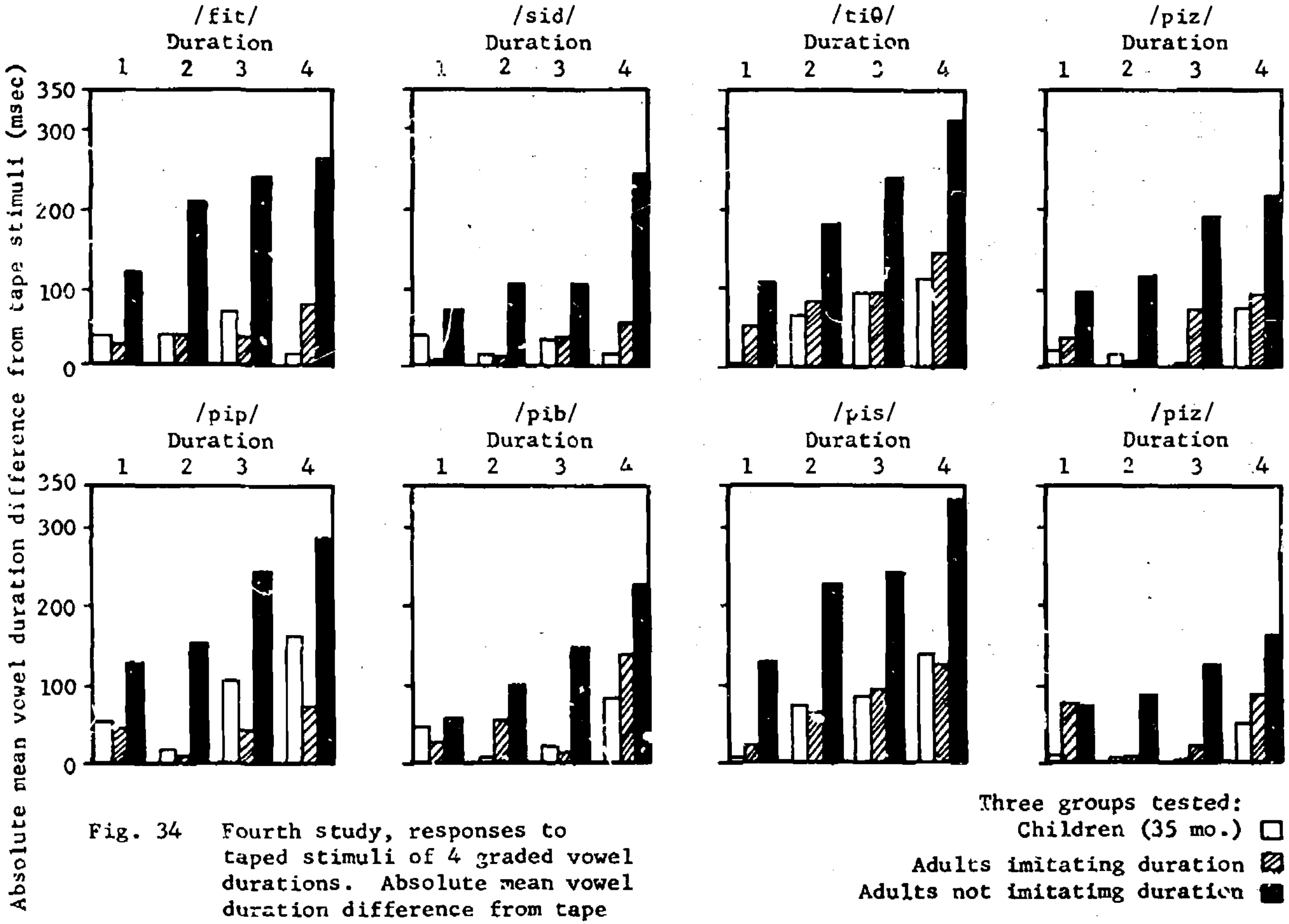

Fig. 34 Fourth study, responses to taped stimuli of 4 graded vowel durations. Absolute mean vowel duration difference from tape stimuli, as a function of 3 groups tested.

.64. These ratio differences could be expected from the results of the statistical analysis which showed that the adults instructed to imitate the tape were the only subjects who did not deviate significantly from the tape, and thus had the closest voiceless-to-voiced ratio to that for the tape. The children's voiceless-to-voiced ratio was further from that for the tape, than that for the adults who were imitating, but the ratio for the adults instructed not to imitate the durations was the farthest from the tape. The latter succeeded in producing a normal voiceless-to-voiced vowel duration ratio for American English of .64.

SUMMARY

This study showed that adults instructed to imitate the vowel durations on the stimulus tape used in this study did imitate the 4 durations for each word without significantly deviating from those on the stimulus tape. Children at 35 months of age, given the same tape as the 2 adult groups, but given no special instructions about imitating duration closely, behaved similarly to the adults who were instructed to imitate closely. The children's productions did deviate significantly from those on the stimulus tape, but they did not deviate significantly from those for the adults instructed to imitate vowel duration.

It is thus clear from this study that children at 35 months naturally are attentive to vowel duration and will imitate it well within certain limits. Those limits which were found in the third study also showed up in this study, e.g. differential vowel duration before voiceless and voiced consonants. The stimulus tape here had the overall voiceless-to-voiced ratio of .98, but the children kept their overall voiceless-to-voiced ratio down to .80. This is between the ratio for the adults instructed to imitate (.91) and those not instructed to imitate (.64), but it is closer to those instructed to imitate. Thus, the role of imitation is still very great in the children of 35 months of age and quite accurate within certain constraints - i.e. some differential vowel duration before voiceless vs. voiced consonants must be maintained.

Chapter 6

CONCLUSIONS

This study investigated the acquisition of differential vowel duration in CVC utterances of American children from 21 months to 36 months of age. Results showed that differential vowel duration had already been acquired by the youngest children studied, those at 21 months of age. Control of differential vowel duration preceded control of the voicing feature which conditions it in adult speech. There were very few mistakes in manner of articulation of the final consonants in responses from even the youngest children, thus it is not known if control of differential vowel duration preceded control of manner of articulation or not. Correct intrinsic vowel duration was produced in responses of all children studied. Results from the research indicate there may be 3 stages in the acquisition of differential vowel duration before voiced and voiceless consonants.

Stage 1

During stage 1 the child imitates the differential vowel duration in a CVC word from a model, that of a parent, for example. During this imitation stage, the child usually produces correct differential vowel duration regardless of the voicing of the final response consonant.

During this imitative stage, the production of differential vowel duration precedes full control of production of the feature of voicing of final consonants.

Evidence for this stage is provided primarily from responses from child 8, who from 21 to 23 months of age, substituted voiceless consonants for stimulus voiced consonants in 67% of her responses, but still maintained correct differential vowel duration. She maintained this correct differential vowel duration under stimulus conditions where she uttered CVC words for familiar pictures practiced with her parents at home, and where she uttered familiar words, and unfamiliar words from a stimulus tape where differential vowel duration was normal. However, when presented with these same unfamiliar words on a tape with no differential vowel duration, i.e. where vowel durations were equal before voiceless and voiced final consonants, the child imitated the equal vowel durations, and did not produce correct differential vowel duration, as did the other 8 children.

It is hypothesized that because a child in stage 1 of the acquisition of differential vowel duration does not have control over production of the feature of voicing in final consonants, he imitates the non-phonemic feature of differential vowel duration very closely. It is possible that differential vowel duration at this stage has a phonemic status, as it did briefly in the Leopold study, 1939-49, and the Velten study, 1943.

It must be remembered, however, that evidence for this stage came primarily from child 8, one of the youngest children recorded, 21 to 23 months, the only child who spoke a black dialect, and the only child who produced more stimulus voiced final consonants as voiceless than as voiced, in all her responses (67%).

The other 8 children from 21 to 36 months of age spoke a white dialect and although they did sometimes substitute voiceless consonants for voiced consonants, it was never in the majority of their responses. They also continuously maintained correct differential vowel duration. Thus, the other 8 children were probably in a different, second, stage of differential vowel duration development, from almost their first recording sessions in the study.

Stage 2

During stage 2, the child who already has control of differential vowel duration from stage 1, now also has control of the feature of voicing of final consonants in the majority of his CVC utterances. This child has come to associate the production of a final voiced consonant, with greater vowel duration.

Evidence for the association of a final voiced consonant with greater vowel duration is provided from the responses of children 1-7 and 9 (at 23 and 34 months of age) elicited with taped stimuli where the familiar and unfamiliar words had no differential vowel duration present, i.e. where vowel duration before voiceless and voiced consonants was equal. The children did not imitate vowel duration on this tape (as had child 8) and they always produced normal differential vowel duration just as they had done in utterances elicited with pictures and with taped stimuli of normal vowel duration. For these children, less than 25% of their final "voiced" responses were voiceless.

Thus, it is speculated that the perception of the final voiced consonant is what cued these children to produce correct differential vowel duration for these stimulus words where vowel duration before voiceless and voiced consonants was equal. They already had proper control of the phonemic feature of voicing in the majority of their utterances, and thus voicing had become tied to the phenomenon of increased vowel duration for them.[2]

Stage 3

During stage 3, the reverse association take place from that in stage 2, i.e., greater vowel duration becomes associated with a final voiced consonant. It is acquired sometime before adulthood and perhaps even simultaneously with stage 2.

Evidence for the existence of this stage is provided by the research of Denes, 1955. In this study, adults were shown to use greater vowel duration as a cue to the perception of final voiced consonants.

In summary then, in stage 1, the child imitates differential vowel duration very well and produces it correctly irrespective of the final consonant. He does not have control of voicing of final consonants in the majority of his CVC utterances. The child continues to imitate differential vowel duration until he does have control of voicing of final consonants in the majority of his CVC utterances (stage 2). At this time he forms an association of the final voiced consonant with greater vowel duration. Later, or perhaps simultaneously, greater vowel duration is associated with voicing of the final consonant (stage 3). No particular age is associated with any of these stages; it is entirely dependent upon phonological development. It is arbitrary that stage 1 was observed in child 8 from 21-23 months of age (the youngest ages studied).[3]

In the Introduction, it was mentioned that differential vowel duration could be either physiologically conditioned by the voicing and manner of articulation of the following consonant (hence, possibly a phonetic universal), or learned (hence, language specific). And it seemed likely that some insight into these two possibilities could have come from investigation of the acquisition of differential vowel duration by children. If children acquire differential vowel duration and control of the conditioning features simultaneously, then one could infer that differential vowel duration is physiologically conditioned. If they acquire control of the conditioning features first, then differential vowel duration at a later time, then one could infer that differential vowel duration was learned. However, in this study neither of the above clear-cut possibilities occurred, as differential vowel duration was acquired prior to the conditioning feature of voicing, and the results could argue in favor of either possibility. It is possible that differential vowel duration is learned, because it is produced so well by young children, whether the final response consonant is correct or incorrect. But it is equally possible that differential vowel duration is physiologically conditioned, because even though the children actually produced correct increased vowel duration preceding a voiceless consonant substituted for a stimulus voiced consonant, they may have initiated the motor commands necessary to produce a voiced consonant, and even made the necessary accomodations for increased vowel duration, but for some unknown reason, were unable to voice the final consonant. More would have to be known about the neuromuscular development of the entire vocal apparatus of a 2-year-old child before one could speculate on the presence or absence of physiological conditioning of differential vowel duration. Hence, the results of the study do not necessarily support either of the 2 possibilities suggested in the Introduction: 1) that differential vowel duration is physiologically conditioned (hence, possibly a phonetic universal), or 2) that differential vowel duration is learned (hence, language specific). It does, however, establish a clear pattern of the order of acquisition of differential vowel duration and the voicing of final consonants.

Variations in the types of stimuli used (in the four studies), and individual variations (between child 8 and the other 8 children) permitted the positing of three stages in the acquisition of differential vowel duration in American English. It is understood, of course, that these stages may not exist for every child in the way they are presented here. To further test the development of (or even existence of) these stages, more children, and younger children should be studied from both black and white dialects. Fry has stressed (1966) that we know very little about the ways in which the use of acoustic cues develop as speech is acquired. This study was limited totally to the responses the children produced, in making inferences about the acquisition process of differential vowel duration. New research techniques, such as those suggested by Preston, Phillips, and Yeni-Komshian, 1968, should enable future researchers to examine young children's perception of differential vowel duration, as well.

FOOTNOTES (Chapter 6)

1. However, when presented the familiar words on the stimulus tape where there was no differential vowel duration, i.e. where vowel durations were equal before voiceless and voiced consonants, child 8 did produce correct differential vowel duration for the familiar words. Thus, she did not imitate equal vowel duration for the familiar words. This indicated that perhaps these words were "over-learned" to some extent, because she produced them just the same as she had under the previous stimulus conditions.
2. The same pattern was seen for children presented a tape where each word had 4 graded vowel durations and overall vowel duration before voiceless consonants was almost equal to that before voiced consonants. The children came close to imitating the tape, but they maintained correct differential vowel duration. They produced no final consonant errors in this study, and thus were probably well into stage 2 (they were 35 months of age).
3. Results from this study form an interesting parallel to suggestions made by Malécot, 1970, where he speculates that increased vowel duration before voiced consonants has come about diachronically as a straightforward case of second-order conditioning.

Appendix A

STIMULUS MATERIALS

The Scary Goose Story (Version 1)

Here's George Brown. On his foot he's wearing only one black . . . (boot).

And here's his sister Marian. She's just finished eating and she's still wearing her green . . . (bib).

They live in a little house in the woods. Marian is talking to her pet canary. The canary is hers. George is playing with his pet cat. The canary belongs to Marian, it's hers. The cat belongs to George, it's . . . (his).

"Twee-eet," chirped the canary.

"Mee-eeow," said George's cat very loudly.

"The animals are hungry," said Mother. "George, will you go to the grocery for me and buy some . . . (food)."

"Why sure," said George.

"May I go too?" asked Marian.

"Yes," said Mother, "but you can't go barefoot. You must put some . . . (shoes) on your . . . (feet)."

"Okay," said Marian. Mother asked George to buy a can of . . . (peas), and a can of cat food, and for the canary, some bird . . . (seed).

They started home. When they came around a bend, they saw a large white mother . . . (goose).

"H-s-s-s," said the goose.

"Move away," said George.

"H-s-s-s," said the goose.

"I'll have to scare her," said George. So George made a face and showed his front . . . (teeth).

The large goose did not move. George reached down to the ground and picked up a . . . (stick).

He waved the stick in her face, still she didn't move.

"Maybe she likes to eat birdseed," said Marian.

So George quickly threw some seeds in the bushes. The goose moved off into the bushes and started eating. George and Marian ran past the goose. They ran all the way home.

"Mother, Mother," Marian cried. "A goose scared us!" Mother picked Marian up to hug her. She gave her a big hug and a big . . . (kiss).

<u>The Scary Goose Story</u> (Version 2)

Version 2 is the same as version 1 except the sentence with the word "his" in it is removed and the sentence: "Mother also asked them to buy a box of . . . (biz)." is inserted in the story following the sentence with the word "seed" in it.

Word list for stimulus tape A

Stimulus Word	Vowel Duration (msec)
/fit/	208
/piz/	400
/sid/	325
/tiθ/	205
/pis/	210
/pib/	310
/piz/	490
/pip/	180
/fit/	208
/piz/	400
/sid/	325
/tiθ/	205
/pib/	340
/pis/	240
/pip/	205
/piz/	420

Word list for stimulus tape B

Stimulus Word	Vowel Duration (msec)
/fit/	208
/piz/	400
/sid/	325
/tiθ/	205
/pib/	340
/pis/	240
/pip/	205
/piz/	420
/fit/	208
/piz/	400
/sid/	325
/tiθ/	205
/pis/	210
/pib/	310
/piz/	490
/pip/	180

Word list for stimulus tape A'

Stimulus Word	Vowel Duration (msec)
/fit/	315
/piz/	410
/sid/	315
/tiθ/	410
/pis/	410
/pib/	335
/piz/	410
/pip/	335
/fit/	315
/piz/	410
/sid/	315
/tiθ/	410
/pib/	335
/pis/	410
/pip/	335
/piz/	410

Word list for stimulus tape B'

Stimulus Word	Vowel Duration (msec)
/fit/	315
/piz/	410
/sid/	315
/tiθ/	410
/pib/	335
/pis/	410
/pip/	335
/piz/	410
/fit/	315
/piz/	410
/sid/	315
/tiθ/	410
/pis/	410
/pib/	335
/piz/	410
/pip/	335

Word list for

stimulus tape with four graded vowel durations for each word

Stimulus Word	Vowel Duration (msec)	Stimulus Word	Vowel Duration (msec)
/fit/	375	/fit/	290
/piz/	495	/piz/	530
/sid/	475	/sid/	365
/tiθ/	305	/tiθ/	405
/pis/	305	/pis/	520
/pib/	345	/pib/	380
/piz/	495	/piz/	435
/pip/	445	/pip/	295
/fit/	410	/fit/	425
/piz/	435	/piz/	415
/sid/	315	/sid/	375
/tiθ/	520	/tiθ/	440
/pib/	465	/pib/	295
/pis/	420	/pis/	445
/pip/	395	/pip/	310
/piz/	395	/piz/	420

Appendix B

PRODUCTION OF DUPLEX OSCILLOGRAMS AND CRITERIA FOR SEGMENTATION

Introduction

The durations of the vowels produced by the children in the CVC response utterances were measured from visual displays of the acoustic properties of these words on duplex oscillograms. Visual displays of the acoustic properties of speech, such as seen in sound spectrograms, have been used for this purpose for some time (Koenig, Dunn & Lacy, 1946).

The acoustic properties of a speech sound are correlated with the articulatory movements used in producing that speech sound. For example, the adult speaker of English articulates vowels through periodic vibration of the vocal cords in a vocal tract which, throughout its length, has no complete constrictions. Thus, a vowel sound articulated by such an adult has the acoustic properties of 1) a periodic wave form with 2) a relatively high amplitude. On a sound spectrogram these acoustic properties are displayed as the darkened vowel formants, and generally, vowel duration is measured from the onset of these formants to their termination. However, due to the very high fundamental frequency and the weak amplitude present in the utterances articulated by the 2 year old children in this study, the sound spectrograph did not produce satisfactory sound spectrograms for segmentation of vowel duration. The acoustic properties of the children's CVC utterances were better seen on duplex oscillograms. Because all basic segmentation criteria for vowels used in this study are based on those criteria set forth by Peterson and Lehiste (1960) for sound spectrograms, a short explanation concerning the difference between sound spectrograms, plain oscillograms and duplex oscillograms is given below.

A sound spectrogram displays the speech signal on a frequency (ordinate) /time (abscissa) plot, where the frequency range is generally 85-8000 Hz. A plain oscillogram displayed on a conventional oscilloscope shows the speech signal on an amplitude (ordinate)/time (abscissa) plot. The positive and negative parts of the amplitude wave are separated by the zero line. A duplex oscillogram as filtered by a Trans Pitchmeter and written out by an Oscillomink also shows the speech signal on an amplitude (ordinate)/time (abscissa) plot. The duplex oscillogram, however, differs from the plain oscillogram in that it makes separate use of the positive and negative parts of the amplitude wave. A direct-writing Oscillomink has a frequency response of approximately 1000 Hz. Thus, a filtering device must first filter the speech signal so that the negative part of the amplitude wave is replaced by the rectified function of the speech signal above 1000 Hz. The high frequency sounds (above 1000 Hz) appear clearly on the duplex oscillogram as marked negative dips below the zero line. This additional difference in amplitude display makes segmentation of a duplex oscillogram easier than that for a plain oscillogram (Fant, 1958, p. 326). For comparisons of duplex oscillograms and sound spectrograms, see Fig.B.1-5.

<u>Production of duplex oscillograms</u>

The response tapes were played back on a Sony tape recorder (Model TC-777-4) at the recorded speed of 7½ i.p.s. and input to a Trans Pitchmater (B. Frøkjaer-Jensen, Denmark). The duplex oscillograms were then produced on a 4-channel Siemens Oscillomink (1966 Model), with direct writing ink jets on white adding machine paper tape moving

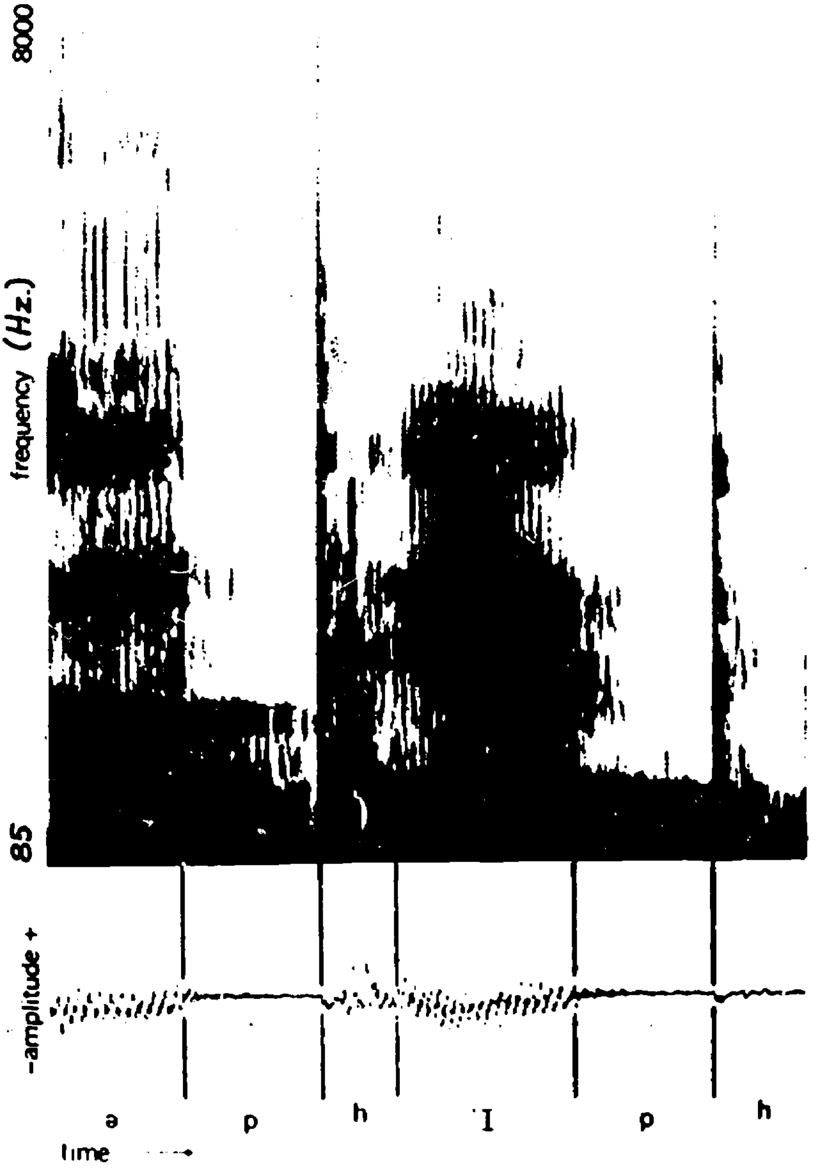

Fig. B. 1 Adult male speaker. Sound spectrogram (enlarged) above, duplex oscillogram (real time 20 cm/sec) below.

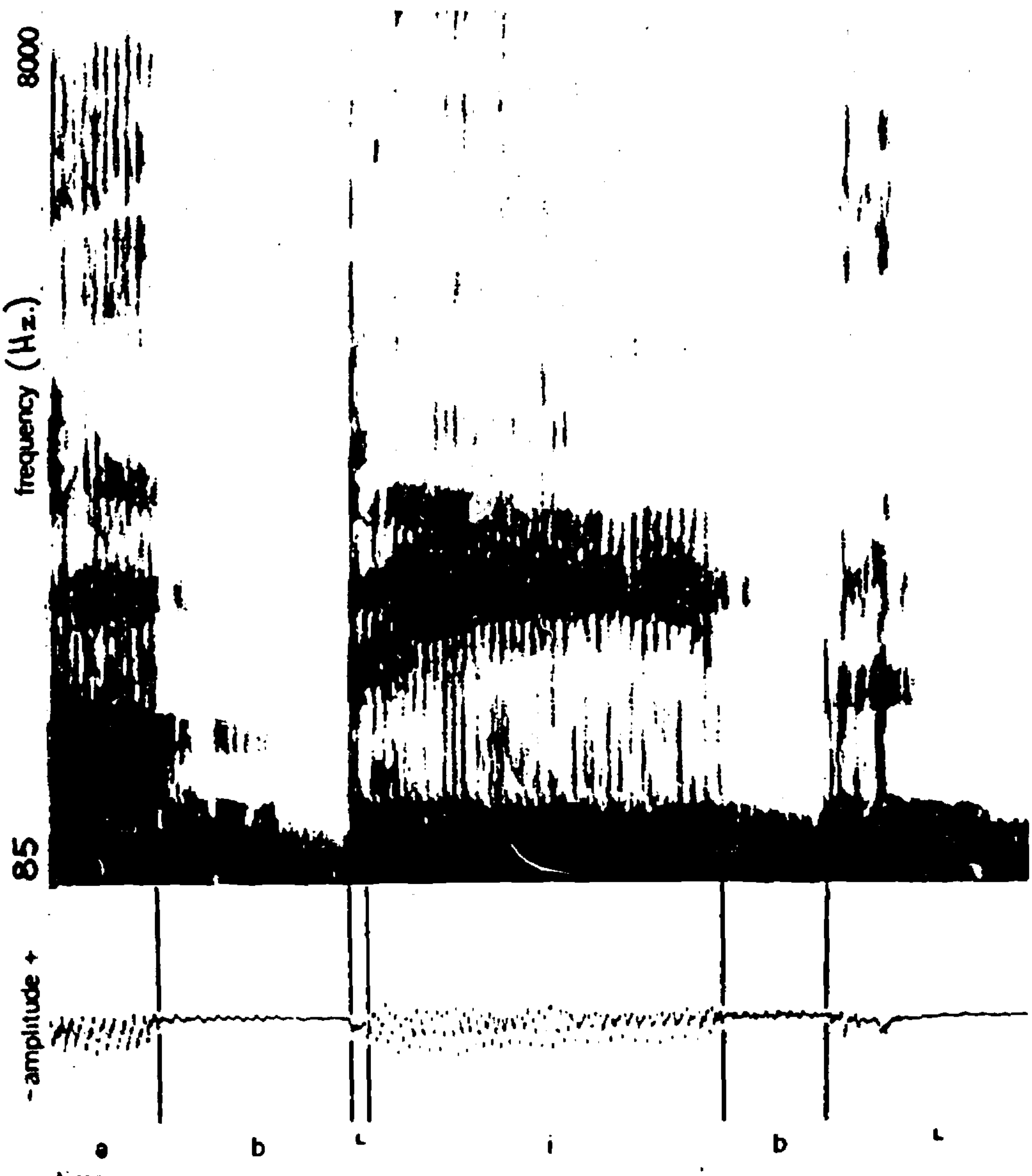

Fig. B. 2 Adult male speaker. Sound spectrogram (enlarged) above, duplex oscillogram (real time 20 cm/sec) below. (ᒪ= release of voiced stop).

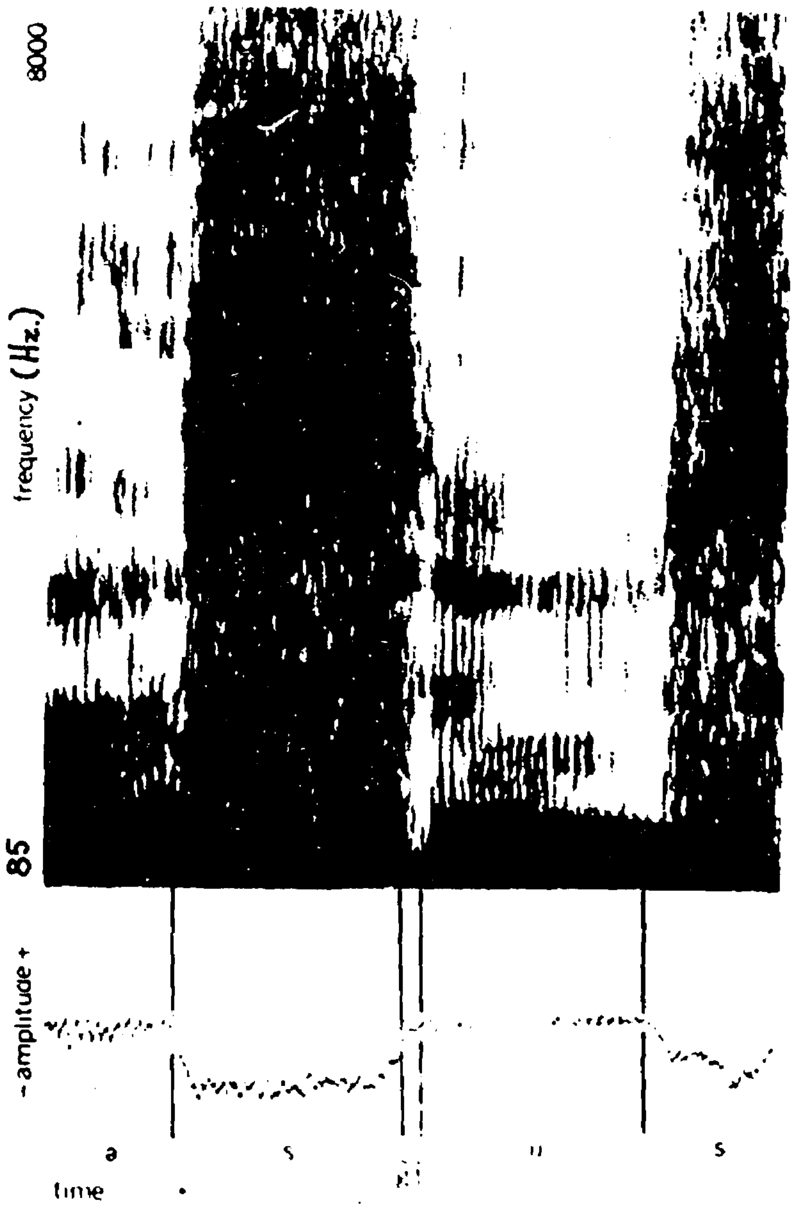

Fig. B.3 Adult male speaker. Sound spectrogram (enlarged) above, duplex oscillogram (real time 20 cm/sec) below. (g.t. = glottal transition).

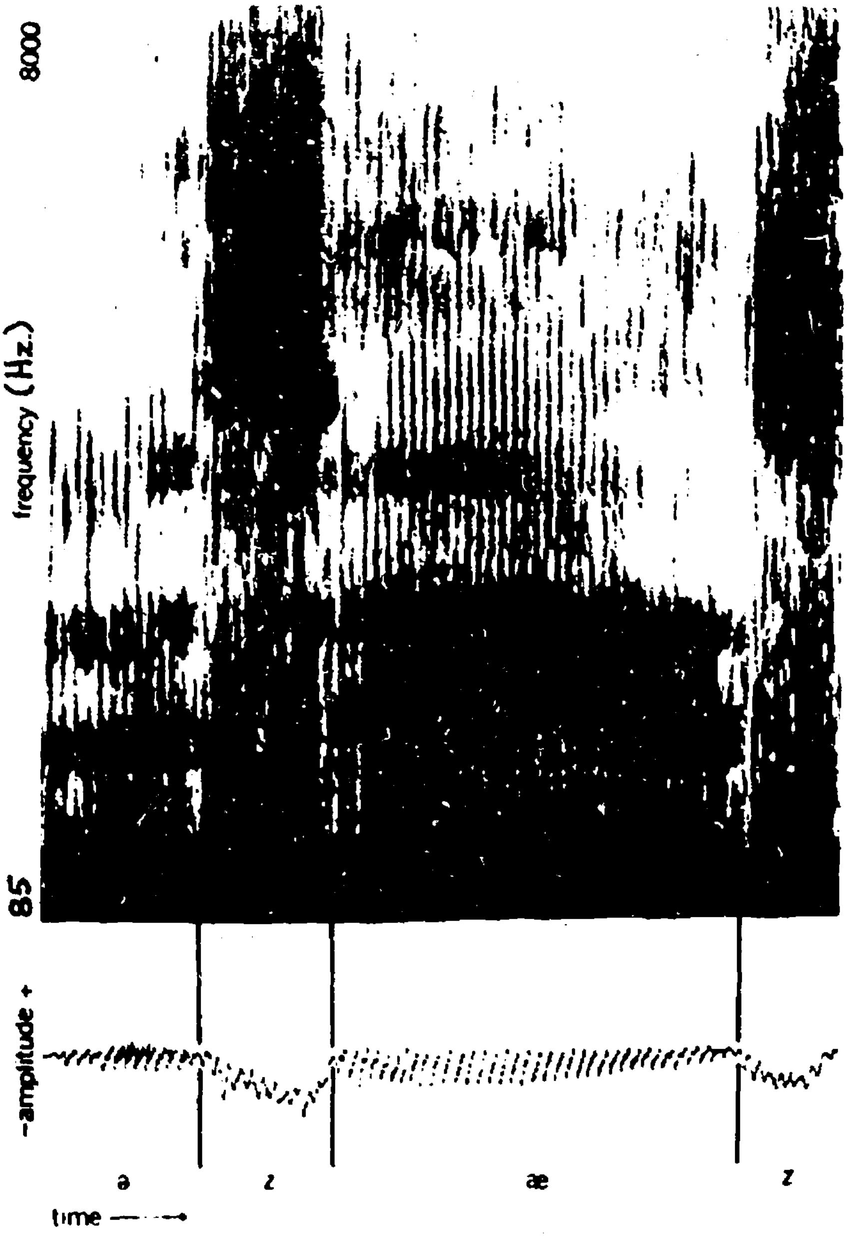

Fig. B. 4 Adult male speaker. Sound spectrogram (enlarged) above, duplex oscillogram (real time 20 cm/sec) below.

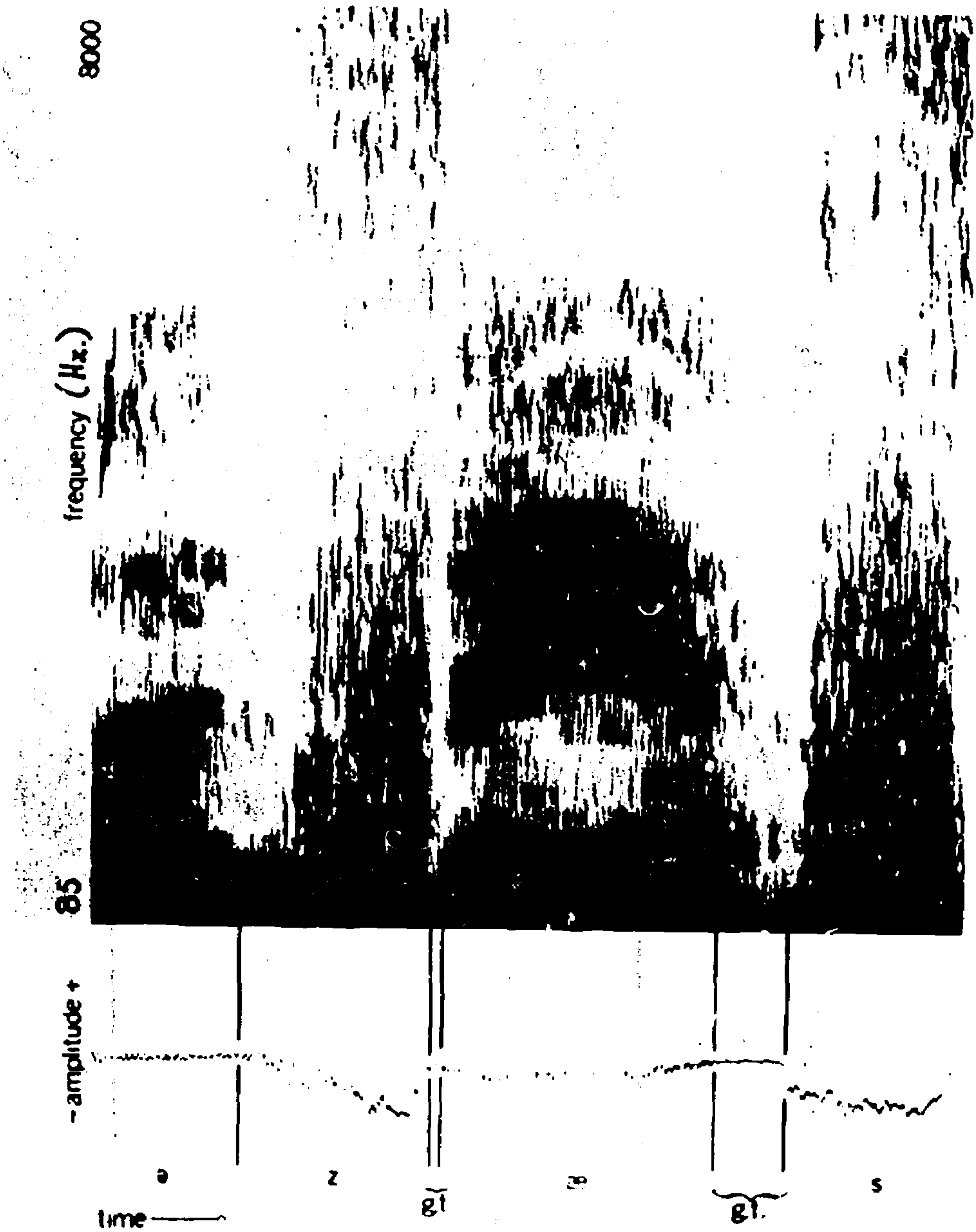

Fig. B. 5 Adult female speaker. Sound spectrogram (enlarged) above, duplex oscillogram (real time 20 cm/sec) below. (g.t. = glottal transition).

at the speed of 20 cm/sec. Channel 1 was used for a straight line which on the finished duplex oscillogram served as a guide for lining up a right triangle for segmentation purposes, Channel 2 was used for the fundamental frequency as filtered out by a fundamental frequency extractor in the Trans Pitchmater, and channel 3 was used for the duplex oscillogram also filtered out by the Trans Pitchmeter. A 50 Hz sine wave time signal from a Hewlett Packard signal generator (200 CD Wide Range Oscillator) was displayed on channel 4. The utterances were monitored through earphones as they were processed by the data writer and gross phonetic transcriptions were entered on the output tape (Fig.B.6). Finer transcriptions were later done as described in Chapter 2.

The vowel durations on duplex oscillograms were measured to the nearest .5 mm. A clear plastic ruler with .5 mm markings and a .5 mm 4H lead pencil were used in marking the actual segmentation lines.

Segmentation criteria for English vowels on duplex oscillograms

Vowels-general

The periodic vibrations of the vocal cords used in vowel production are represented on duplex oscillograms by a periodic wave form which has very sharp-pointed amplitude peaks. To make comparable measurements, it is necessary to develop a set of reasonable segmentation criteria and apply them consistently. The criteria used in this study are described in detail in the following sections.

Generally, the termini of vowels in CVC words are well set off by the manner and voicing of the adjacent consonants. Vowel amplitude peaks contrast with those of the periodic wave forms of voiced

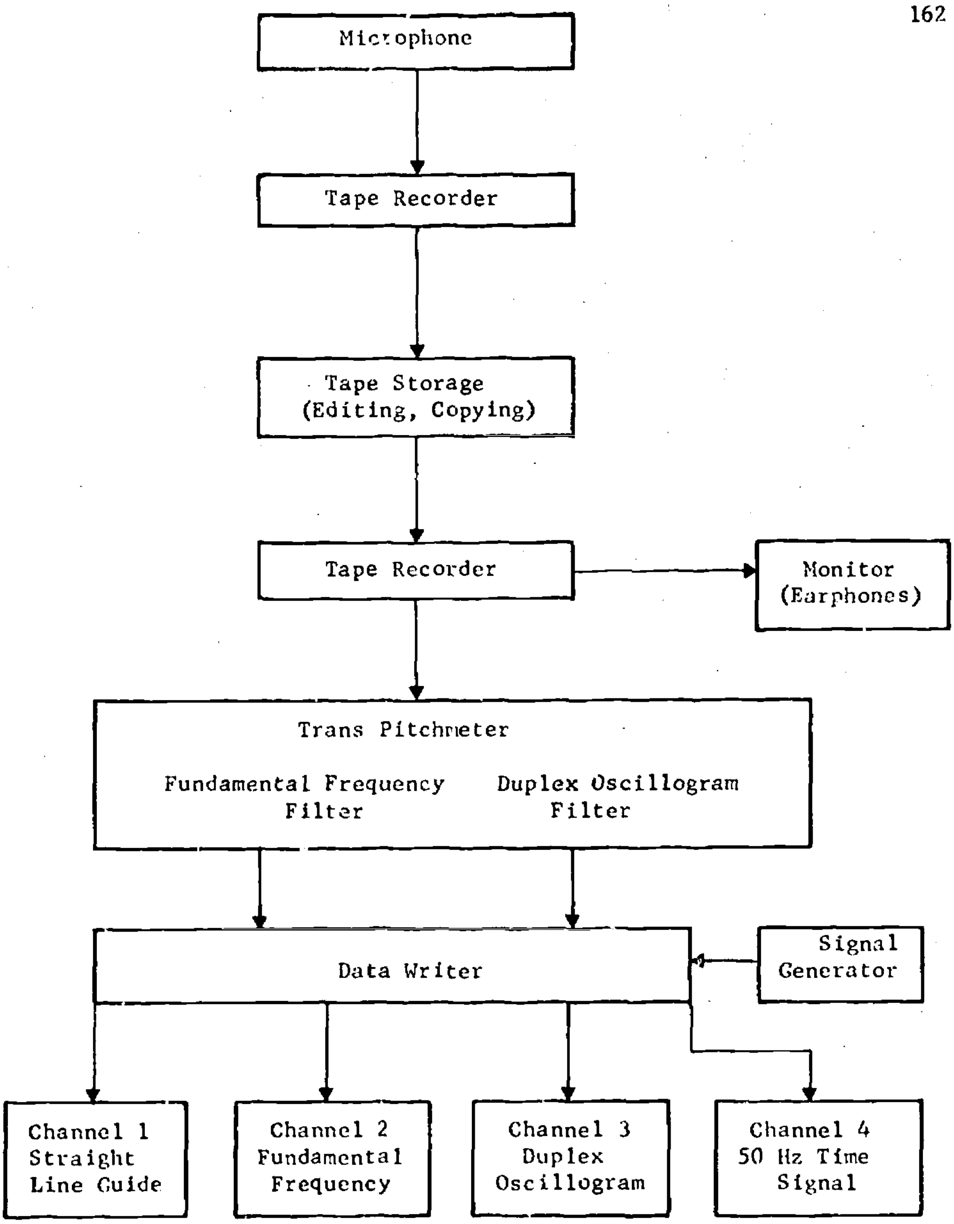

Fig. 8. 6 Production of Duplex Oscillograms

consonants and nasals, because for the latter, the ends of the peaks are somewhat rounded. The amplitude waves of the vowels are also of a greater deflection distance from the zero line than those of the consonants. Figures B. 2 - 5 show that each vowel has a different wave form pattern.

Vowel onset after initial consonants

After initial voiceless stop: An initial voiceless stop on the sound spectrogram was marked by a blank space (Fig.B.1). On the duplex oscillogram it was marked by no deflection from the zero line. The release was marked by a spike on the sound spectrogram and by a short negative dip on the duplex oscillogram. The concentration of high frequency fricative energy throughout the aspiration period, marked by a negative dip in the duplex oscillogram was not counted in the vowel duration. Vowel duration after a voiceless stop was measured from the first patterned amplitude deflection. When looking at vowel amplitude, it was important to look at the whole general pattern of the vowel amplitude wave first, and to begin the vowel duration measurement from where the general steady pattern was established. Thus, pattern here referred to established pattern for that particular vowel segment and not to a transition pattern which may have occurred briefly in the beginning of the vowel.

After initial voiced stop: An initial voiced stop in a sound spectrogram was marked by the presence of the voice bar in an otherwise blank space (Fig.B.2). In the duplex oscillogram it was marked by little or no deflection from the zero line; there may have been ripples in the amplitude pattern, however, which distinguished the voiced stop from the voiceless stop. In sound spectrograms the release of the stop was marked by a short frication period (energy present across all frequencies) and in duplex oscillograms by a short negative dip. The release period was not measured as a part of the vowel duration, which began with the first patterned amplitude deflection.

After initial voiceless fricative: The onset of the vowel in the sound spectrogram began with a complete striation across two or more formants (Fig. B.3). The fricative noise in the higher frequencies of the sound spectrogram, as mentioned with the aspirated release of stops above, showed up as a large negative dip in the duplex oscillogram. The first patterned deflection of the vowel amplitude after this negative dip marked the beginning of vowel duration.

In this study, however, sometimes the end of the fricative noise did not coincide with the onset of the vowel and there was an interval which I have termed glottal transition (g.t.) as noted in Fig.B.3.[1] If a glottal transition period was present, the deflection line hovered around zero before starting the vowel pattern; this transition was not counted as part of the vowel duration. An exact count was not kept of the frequency of occurrence of glottal transitions following initial fricatives in this study with the children but they were of short duration, less than 20 msec, and the frequency of occurrence was small compared to those preceding final fricatives (25%). A detailed discussion of glottal transitions appears in the next section under vowel ending before voiceless fricative.

After initial voiced fricative: The segmentation criteria for the initial voiceless fricative applied also to the initial voiced fricative. In sound spectrograms, the cessation of noise and beginning of vowel striations across two or more formants was considered to be the beginning of the vowel duration (Fig.B.4). In duplex oscillograms the onset of vowel duration was taken from the first patterned deflection of vowel amplitude registration. If a glottal transition was present before the vowel, it was not measured as part of the vowel duration.

Vowel ending before final consonants

Before final voiceless stop: In sound spectrograms the termination of the vowel before the final voiceless stop was marked by the abrupt cessation of all formants (Fig.B.1). The final striation which could be found in two or more vowel formants was considered to be the end of the vowel; sometimes, however, the first formant did follow through the voiceless stop. In duplex oscillograms, this abrupt cessation of formant energy was manifested by a sudden leveling out of the deflection line. The vowel duration measurement terminated with the end of the patterned deflection, which was often before complete silence (shown by no deflection of the zero line on the duplex oscillogram). In duplex oscillograms the aspirated release of the final stop was marked by a negative dip from the zero line similar to, but of less distance, than the dip after the initial voiceless stop.

Before final voiced stop: The same criteria for a final voiceless stop were applied to a final voiced stop. In sound spectrograms, when there was a cessation of formant activity across most of the formants above the first, the vowel was considered to be terminated (Fig.B.2). In duplex oscillograms the termination of a vowel was marked by a sudden decrease in amplitude and absence of a patterned amplitude deflection as shown by a general leveling off of the deflection line. Some ripples of amplitude deflection around the zero line continued through the voiced stop. The release, if any, was marked by a short negative dip.

Before final voiceless fricative: In sound spectrograms the termination of a vowel before a voiceless fricative was marked by the sudden onset of random noise in the high frequencies (Fig.B.3). In duplex oscillograms the beginning of high frequency energy was marked by the sudden onset of a large negative dip in the deflection line. However, there were times when actual fricative onset was not sudden. Peterson and Lehiste considered the vowel to be terminated at the point where the noise pattern began, even though voicing in a few low harmonics often continued for a few centiseconds. It is this short continuation of periodic vibrations which sometimes made vowel duration measurements before a final fricative difficult in duplex oscillograms. The most satisfactory cues for terminating the vowel in this position were 1) the onset of negative dip or 2) the end of the periodic pattern in the amplitude wave; i.e., when the amplitude wave became irregular and began to dip into the negative half of the duplex oscillogram. It may still have retained a positive segment, however.

If a glottal transition was present here, it was counted as part of the vowel rather than the following fricative consonant; i.e. only the onset of fricative noise was used to select the transition point from vowel to fricative consonant. See (Fig.B.5).[2]

Before final voiced fricative: The same criteria in segmenting vowels before a final voiceless fricative were applied to segmenting them before a final voiced fricative. In sound spectrograms the onset of high frequency energy was considered to be the beginning of a voiced fricative (Fig.B.4). In duplex oscillograms the negative dip marked the onset of the fricative and the end of the vowel. If the aperiodic vibrations preceded the negative dip, they signaled the end of the vowel and beginning of the voiced fricative. If a glottal transition was present where the deflection line hovered over the zero line, before onset of the negative dip, it was considered to be a part of the vowel just as with final voiceless fricatives.

Reliability of duplex oscillogram segmentation criteria

The reliability of the duplex oscillogram segmentation criteria was tested against sound spectrograms. Sixty-four sound spectrograms (Set A) were segmented by the author using the Peterson and Lehiste sound spectrogram segmentation criteria.[3] A set of the same 64 sound spectrograms were segmented by two other persons (Sets B and C).[4] These segmentations correlated with Set A at .97 and .99. Sixty-four duplex oscillograms (Set D) of the same items were then segmented by the author using the duplex oscillogram segmentation criteria developed from sound spectrogram segmentation criteria as reported above.

The vowel duration measurements taken from the duplex oscillograms (Set D) correlated with those vowel duration measurements taken from the sound spectrograms (Set A) at .97. Thus, these criteria developed for segmenting English vowels on duplex oscillograms were judged to be as reliable as these criteria used in previous studies on sound spectrograms.

FOOTNOTES

Appendix B

1. Peterson and Lehiste do not mention a glottal transition period. Apparently in their study the cessation of fricative noise coincided with onset of vowel formant activity.
2. Glottal transitions were observed before 25% of the final fricatives in the CVC responses of the children in the first study, and before 3% of the fricatives in the CVC responses of the parents. Some had also been found in the speech of adults in another study (Naeser, 1970b) where they were observed before 29% of the final fricatives with the same vowels tested here, /I/, /i/, /u/. For the children's responses, 38% of the glottal transitions occured in utterances with /I/ before final fricatives (77% of these were before voiceless fricatives, and 23% before voiced); 36% of the glottal transitions occurred in utterances with /u/ before final fricatives (75% of these were before voiceless fricatives, and 25%, before voiced); and 25% occurred in utterances with /i/ before final fricatives (65% of these were before voiceless fricatives and 35% were before voiced fricatives). The parents' occurrences of glottal transitions were all before voiceless fricatives - 2% with /I/, .6% with /i/, and .3% with /u/. The average duration of a glottal transition was 20 msec.

The relative high frequency of occurrence of glottal transitions with the vowel /I/ before final fricatives is in accordance with the suggestions set forth by Stevens, et al. (1967) concerning the necessity of different vocal cord positioning for consonant and vowel production. Stevens states that for higher first formant frequencies (above 250 Hz), such as those found in vowels, the supraglottal sound pressure is low compared to that found in consonants, where the first formant is below 250. The first formant frequency for /I/ is 430 Hz, for /u/ 370 Hz, and /i/ 310 Hz (average female voices, Denes and Pinson, 1963, p. 118). In the air flow trace for vowels preceding voiceless or voiced consonants, the air flow in the latter part of the vowel (last 100 msec) tends to increase in anticipation of the consonant (Klatt, 1967). At this time, the vocal folds are re-positioned to form a larger glottal opening to prevent a large pressure drop across the glottis and extreme fluctuations. Thus, because the vowel /I/ had the highest first formant frequency and therefore the lowest supraglottal sound pressure level in this study, this vowel may have required more accomodation time for sound pressure adjustment before consonants, and hence showed more overt glottal transitions.

Stevens then continued to suggest that the actual rate at which vocal cord positioning could be achieved was relatively slow, and that a talker must compensate for this slow response in timing his commands to the larynx musculature. In the case of a voiceless consonant following a vowel, it was suggested that the necessary wide separation of the vocal cords could be achieved more rapidly than the more finely adjusted smaller separation for a voiced consonant. This would then, of course, speak to a physiological explanation of increased vowel duration in English before voiced rather than voiceless consonants. This latter statement, however, does not explain the relative by high frequency of occurrence of overt glottal transitions before voiceless fricatives vs. that before voiced fricatives in this study, which was also the case in the other adult study.

Thus, there is no ready explanation for the relatively higher frequency of occurrence of glottal transitions before voiceless fricatives than before voiced fricatives in the children's responses as well as the adults'. But the higher frequency of occurrence of glottal transitions with the vowel /I/, rather than /i/, or /u/ may be explained by the physiological model because /I/ has a higher first formant frequency than do /i/ or /u/.

3. For details on procedure and the word lists used, see Naeser, 1970a.

4. Prof. Fred. D. Minifie and Richard M. Merson of the Communicative Disorders Department.

Appendix C

RESPONSE LISTING FOR EACH CHILD

Table C. 1

Vowel durations (msec) for child 7:
male, white, 5 older sisters, 2 older brothers
Group 2

Stimulus word	Age (mo.) 24				26				Parent
	Response No.*				Response No.*				
	1	2	3	4	1	2	3	4	
/stIk/	110	110	175	180	155	160	180	235	142
	k	k	k	k	k	k	k	k	k
/bIb/	285	300	275	240	255	235	245	205	258
	b	b	b	b	b	b	b	b	b
/kIs/	170	210	155	240	150	200	95	145	202
	s	s	s	s	s	s	s	s	s
/bIz/	385	370	445	285	330	310	345	225	524
	z	z	z	z	z	z	z	z	z
/fit/	105	180	220	275	275	185	190	180	190
	t	t	t	t	t	t	t	t	t
/sid/	410	515	325	300	325	290	250	370	392
	d	d	d	d	d	d	d	d	d
/tiθ/	165	160	120	250	185	175	180	215	268
	θts	θs	θ	s	s	θ	θ	θ	θ
/piz/	---	425	320	335	390	280	285	345	620
		z	s	z	θs	z	z	z	z
/but/	180	165	250	215	185	210	220	130	209
	t	t	t	t	t	t	t	t	t
/fud/	220	270	390	380	290	290	285	255	401
	d	d	d	t	d	d	d	d	d
/gus/	170	230	220	200	265	185	225	280	312
	s	s	s	s	s	s	s	s	s
/ʃuz/	230	290	345	380	415	235	570	325	589
	z	z	z	z	z	z	z	z	z

*Final consonant produced by child for each utterance given below duration value

Table C. 2

Vowel durations (msec) for child 8:
female, black, 1 older brother
Group 2

Stimulus word	Age (mo.) 21				23				Parent
	Response No.*				Response No.*				
	1	2	3	4	1	2	3	4	
/stIk/	175	130	180	155	215	220	200	185	178
	k	k	k	k	k	k	k	k	k
/bIb/	200	310	330	285	400	355	225	380	334
	p	p	p	p	p	p	p	p	bp
/kIs/	145	275	320	245	285	220	315	350	225
	s	s	s	s	s	s	s	s	s
/biz/	785	565	330	490	480	440	440	480	488
	s	s	s	s	s	s	s	s	z
/fit/	240	255	195	170	365	405	640	625	230
	t	t	t	t	t	t	t	t	t
/sid/	400	380	300	270	525	550	630	645	448
	t	t	t	t	t	t	t	t	dt
/tiθ/	210	240	240	255	390	385	395	395	267
	t	t	t	t	t	t	t	t	θ
/piz/	390	615	485	---	450	520	885	725	490
	ts	s	s		s	s	s	s	z
/but/	265	320	285	220	395	300	225	325	239
	t	t	t	t	t	t	t	t	t
/fud/	310	275	355	---	450	425	490	455	409
	t	t	t		t	t	t	t	dt
/gus/	385	335	430	500	440	335	365	345	302
	s	s	s	s	s	s	s	s	s
/ʃuz/	340	430	370	370	505	505	510	705	474
	z	z	bus	ts	z	s	z	z	z

* Final consonant produced by child for each utterance given below duration value

Table C. 3

Vowel durations (msec) for child 9:
male, white, only child
Group 2

Stimulus word	Age (mo.) 21				23				Parent
	Response No.*				Response No.*				
	1	2	3	4	1	2	3	4	
/stIk/	60	75	125	110	80	95	110	---	187
	k	k	k	k	k	k	k		k
/bIb/	260	265	210	220	200	240	225	210	238
	b	b	p	p	b	b	b	b	b
/kIs/	255	200	195	200	220	215	230	190	216
	s	s	s	s	s	s	s	s	s
/bIz/	360	360	410	390	535	280	310	400	419
	z	z	z	z	z	z	z	z	z
/fit/	110	95	145	165	230	225	220	130	203
	ts	t	t	t	t	t	t	t	t
/sid/	320	295	305	340	635	435	560	355	312
	t	t	d	d	d	d	d	d	d
/tiθ/	265	250	290	260	250	270	120	185	270
	s	s	θ	θ	θ	θ	θ	s	θ
/piz/	400	320	475	545	500	305	380	410	443
	s	s	z	z	z	z	z	z	z
/but/	160	110	235	175	160	190	170	110	200
	t	t	t	t	t	t	t	t	t
/fud/	310	315	265	280	665	615	190	400	282
	t	t	d	d	d	d	d	d	d
/gus/	280	280	325	365	360	320	250	265	283
	s	s	s	s	s	s	s	s	s
/ʃuz/	380	450	480	440	310	335	335	400	384
	s	s	z	z	z	z	z	z	z

* Final consonant produced by child for each utterance given below duration value

Table G. [illegible]

Vowel durations (msec) for child 1:
female, white, only child
Group 1

Story stimulus word and	response No.*	26	28	29	30	31	32	33	34	35	36	Parent
		Age (mo.)										
/stIk/	1	225	180	145	---	105	125	150	160	90	135	124
		k	k	k		k	k	k	k	k	k	k
	2	105	125	195	---	170	140	185	150	125	85	
		t	k	k		k	k	k	k	k	k	
/bIb/	1	380	305	605	---	205	185	215	550	305	150	198
		p	m	b		m	b	p	b	b	b	b
	2	265	210	290	---	190	175	210	305	450	195	
		p	m	b		b	m	p	b	b	b	
/kIs/	1	195	350	405	---	135	425	320	155	190	255	168
		s	s	s		s	s	s	s	s	s	s
	2	245	455	205	---	200	165	190	295	295	260	
		s	s	s		s	s	s	s	s	s	
/hIz/	1	---	580	415	---	310	495	675	310	560	420	306
			z	z		z	z	z	z	z	z	z
	2	---	---	---	---	430	395	625	425	595	455	
						z	z	z	z	z	z	
/fit/	1	280	---	190	---	140	135	220	105	140	180	159
		t		t		t	ts	t	t	t	t	t
	2	355	---	165	---	185	160	330	265	470	240	
		t		t		ts	ts	t	t	ts	t	
/sid/	1	535	170	330	---	315	200	480	---	375	330	219
		d	d	d		d	t	d		d	d	d
	2	435	260	300	---	295	290	380	395	345	420	
		Ø	d	d		t	ts	d	d	d	d	
/tiθ/	1	625	300	245	---	335	280	405	235	300	405	212
		Ø	θ	θ		θ	s	θ	θ	s	θ	θ
	2	700	335	310	---	355	230	285	340	330	450	
		Ø	θ	θ		θ	θ	s	s	s	θ	
/piz/	1	450	305	325	---	300	310	480	435	380	750	345
		z	z	z		z	z	z	z	z	z	z
	2	225	390	480	---	380	670	435	425	645	410	
		ts	Ø	z		z	z	z	z	z	z	
/but/	1	350	190	225	---	110	280	370	245	255	185	183
		t	t	t		t	t	t	t	t	t	t
	2	295	275	185	---	135	200	355	445	210	170	
		t	t	t		t	t	t	t	t	t	
/fud/	1	---	595	435	---	470	355	805	320	350	290	252
			d	n		d	d	t	d	d	d	d
	2	410	850	330	---	455	360	680	370	385	285	
		t	d	n		d	d	t	d	d	d	
/gus/	1	---	380	285	---	290	335	260	230	255	700	230
			ts	s		s	s	s	s	s	s	s
	2	335	230	300	---	255	280	315	355	400	300	
		s	s	s		s	s	s	s	s	s	
/ʃuz/	1	455	200	275	---	375	255	595	305	570	345	355
		Ø	Ø	Ø		z	Ø	z	z	dz	z	z
	2	425	165	430	---	475	390	470	300	690	405	
		Ø	Ø	s		z	z	z	z	z	z	

inal consonant produced by child for each utterance given below duration

Vowel durations (msec) for child 2:
male, white, 1 older brother
Group 1

Story stimulus word and	response No.*	Age (mo.) 27	28	29	30	31	32	33	34	35	36	Parent
/stIk/	1	---	155	115	170	160	150	145	160	160	115	108
			k	k	k	k	k	k	k	k	k	k
	2	---	185	150	130	130	180	120	120	150	115	
			k	k	k	k	k	k	k	k	k	
/bIb/	1	---	355	280	305	230	195	155	190	125	180	195
			b	b	b	b	b	b	b	b	b	b
	2	---	325	280	225	215	175	190	160	185	210	
			b	b	b	b	b	b	b	b	b	
/kIs/	1	---	---	240	150	265	145	230	155	220	205	162
				s	s	s	s	s	s	s	s	s
	2	---	---	360	185	165	175	160	200	195	210	
				s	s	s	s	s	s	s	s	
/hIz/	1	---	300	335	300	380	205	260	135	265	275	352
			s	z	z	z	z	z	z	z	z	z
	2	---	405	360	200	210	275	285	125	255	325	
			z	z	z	z	z	z	z	z	z	
/fit/	1	---	360	170	195	140	155	190	130	145	150	174
			d	ts	t	t	t	t	t	t	t	t
	2	---	---	140	160	120	175	235	120	135	160	
				ts	t	t	t	t	t	t	t	
/sid/	1	---	475	365	380	200	350	325	---	395	200	295
			dz	d	d	d	d	d		d	d	d
	2	---	640	485	265	170	340	325	230	240	225	
			d	d	d	d	d	d	d	d	d	
/tiθ/	1	---	205	190	200	165	160	200	120	185	260	236
			s	ʃ	ʃ	s	s	θ	θ	θ	θ	θ
	2	---	190	185	200	185	175	170	170	225	165	
			s	s	s	s	s	θ	θ	θ	θ	
/pIz/	1	---	620	275	480	485	275	380	225	320	265	420
			z	dz	z	z	z	z	z	z	z	z
	2	---	590	490	450	305	360	350	270	230	325	
			z	dz	z	s	z	z	z	z	z	
/but/	1	---	230	205	165	190	215	145	125	160	105	184
			t	t	t	t	t	t	t	t	t	t
	2	---	240	260	165	100	155	145	175	150	120	
			t	t	t	t	t	t	t	t	t	
/fud/	1	---	---	250	365	375	340	275	330	245	260	296
				d	d	d	d	d	d	d	d	d
	2	---	545	320	395	315	315	290	240	215	315	
			d	dz	d	d	d	d	d	d	d	
/gus/	1	---	360	240	185	260	255	290	250	285	295	236
			s	s	s	s	s	s	s	s	s	s
	2	---	---	300	215	210	220	215	235	245	295	
				s	s	s	s	s	s	s	s	
/ʃuz/	1	---	610	---	425	329	310	335	270	265	320	390
			z		z	z	z	z	z	z	z	z
	2	---	610	485	300	370	265	425	320	320	360	
			z	z	z	z	z	z	z	z	z	

*Final consonant produced by child for each utterance given below duration value

Table C. 6

Vowel durations (msec) for child 3:
male, white, 1 older sister, 1 older brother
Group 1

Story stimulus word and response	No.*	Age (mo.) 23	26	27	28	29	30	31	32	33	34	Parent
/stIk/	1	160	---	125	80	115	95	75	130	180	90	122
		k		k	k	k	k	k	k	k	k	k
	2	140	---	120	110	180	85	115	120	125	80	
		k		k	k	k	k	k	k	k	k	
/bIb/	1	685	---	180	195	270	100	205	295	285	325	162
		b		b	b	b	b	b	b	b	b	b
	2	665	---	140	150	290	140	155	190	265	215	
		b		b	b	b	b	b	b	b	m	
/kIs/	1	785	---	135	140	210	120	115	140	210	290	143
		Ø		s	s	s	s	s	s	s	s	s
	2	1215	---	75	195	285	130	225	125	130	135	
				s	s	s	s	s	s	s	s	
/hIz/	1	725	---	150	850	210	220	240	350	390	475	270
		z		z	z	z	ð	z	z	z	ð	z
	2	550	---	205	640	475	210	365	340	180	430	
		z		z	z	z	ð	z	z	z	z	
/fit/	1	180	---	145	240	190	120	120	220	150	115	162
		t		t	t	t	t	t	t	t	t	t
	2	250	---	195	195	190	125	280	150	275	70	
		t		t	t	t	t	t	t	t	t	
/sid/	1	290	---	430	920	1210	430	450	445	745	430	232
		d		d	d	Ø	d	d	d	d	d	d
	2	305	---	370	480	595	285	470	270	405	460	
		d		d	d	d	d	d	t	d	d	
/tiθ/	1	420	---	280	295	380	230	210	360	270	175	194
		θ		θ	θ	θ	θ	θ	θ	θ	θ	θ
	2	420	---	160	375	---	270	175	225	290	440	
		θ		θ	θ		θ	θ	θ	θ	θ	
/piz/	1	820	---	640	990	1500	520	560	810	745	490	388
		Ø		z	Ø	Ø	z	z	s	z	Ø	z
	2	1455	---	750	1020	375	470	615	545	545	410	
		z		z	Ø	z	z	z	z	z	z	
/but/	1	445	---	155	105	155	130	165	105	220	185	160
		t		t	t	t	t	t	t	t	t	t
	2	545	---	105	185	165	150	165	120	215	140	
		t		t	t	t	t	t	t	t	t	
/fud/	1	980	---	490	540	290	420	575	315	485	520	265
		d		d	d	d	d	d	d	d	d	d
	2	755	---	495	590	815	375	290	310	340	580	
		d		d	d	s	d	d	d	d	d	
/gus/	1	685	---	265	440	155	245	285	245	235	200	213
		Ø		s	θ	s	s	s	s	s	s	s
	2	860	---	135	440	185	240	230	165	215	225	
		Ø		?	s	s	ʃ	s	s	s	s	
/ʃuz/	1	620	---	775	780	---	545	245	525	485	950	360
		Ø		z	Ø		z	z	z	Ø	z	z
	2	1465	---	405	620	---	480	310	590	565	520	
		Ø		z	z		z	z	z	Ø	z	

*[illegible] produced by child for each utterance given below duration

Table 6.7

Vowel durations (msec) for child 4:
female, white, 1 older brother, 1 older sister
Group 1

Story stimulus word and response	No.*	Age (mo.) 24	26	27	28	29	30	31	32	33	34	Parent
/stIk/	1	100	145	165	80	180	150	435	185	---	---	112
		kt	k	k	k	k	k	k	k			k
	2	105	70	75	80	175	180	220	85	---	---	
		kt	k	k	k	k	k	k	k			
/bIb/	1	175	290	200	280	300	250	440	245	---	---	212
		p	p	p	p	b	p	b	b			b
	2	215	260	195	155	320	310	355	155	---	---	
		p	p	p	p	b	b	b	b			
/kIs/	1	165	255	225	215	215	350	320	380	---	---	172
		s	s	s	s	s	s	s	s			s
	2	185	210	245	195	215	420	325	290	---	---	
		s	s	s	s	s	s	s	s			
/hIz/	1	205	345	415	235	185	205	515	255	---	---	372
		s	ts	s	s	s	z	z	z			z
	2	180	355	460	150	190	285	380	405	---	---	
		s	ts	s	s	s	s	z	z			
/fit/	1	100	280	315	210	200	280	300	250	---	---	202
		t	t	t	t	t	t	t	t			t
	2	195	225	390	345	210	365	480	155	---	---	
		t	t	t	t	t	t	t	t			
/sid/	1	530	270	225	515	250	250	370	265	---	---	325
		t	t	t	t	d	d	d	d			d
	2	405	185	245	370	345	470	430	390	---	---	
		d	t	d	t	d	d	d	d			
/tiθ/	1	365	160	270	235	155	250	520	210	---	---	225
		ts	t	t	t	s	s	s	θ			θ
	2	260	190	180	255	185	260	310	280	---	---	
		s	t	t	t	s	s	s	s			
/piz/	1	325	255	190	510	490	520	475	560	---	---	535
		s	s	z	z	z	z	z	z			z
	2	355	265	170	415	465	400	520	510	---	---	
		s	ts	ts	z	z	z	z	z			
/but/	1	170	170	280	165	170	250	330	455	---	---	205
		t	t	t	t	t	t	t	t			t
	2	180	140	165	170	160	220	280	470	---	---	
		t	t	t	t	t	t	t	t			
/fud/	1	285	845	840	795	360	840	740	320	---	---	312
		t	d	t	d	d	d	d	d			d
	2	415	605	575	520	350	700	665	285	---	---	
		d	t	t	d	d	d	d	d			
/gus/	1	275	210	430	195	455	205	260	420	---	---	265
		ts	tʃ	s	s	ts	s	s	s			s
	2	185	170	415	305	515	245	270	340	---	---	
		ts	ts	s	s	s	s	s	s			
/ʃuz/	1	270	370	330	505	770	265	580	500	---	---	455
		h	s	z	z	z	z	z	z			z
	2	185	325	630	460	475	560	620	650	---	---	
		ø	s	s	ʒ	z	z	z	z			

*Final consonant produced by child for each utterance given below duration

Table C. 8

Vowel durations (msec) for child 5:
female, white, only child
Group 1

Story stimulus word and response No.*		Age (mo.) 26	28	29	30	31	32	33	34	35	36	Parent
/stIk/	1	---	80	140	270	90	225	255	260	225	210	108
			k	k	k	k	k	k	k	k	k	k
	2	315	85	235	---	70	295	140	---	325	275	
		k	k	k		k	k	k		k	k	
/bIb/	1	325	180	145	180	285	230	430	320	310	320	176
		t	b	b	b	b	b	b	b	b	p	b
	2	225	180	140	230	305	225	310	330	380	440	
		p	b	b	b	b	b	d	b	b	p	
/kIs/	1	240	160	220	295	165	165	285	370	355	330	139
		s	s	s	s	s	s	s	s	s	s	s
	2	275	205	280	395	230	255	260	560	325	455	
		s	s	s	s	s	s	s	s	s	s	
/hIz/	1	240	205	---	285	360	490	465	605	295	555	282
		s	z		dz	z	z	z	z	z	z	z
	2	305	465	---	375	305	440	390	590	450	490	
		s	z		ts	z	z	z	z	z	z	
/fit/	1	350	150	195	270	200	115	295	350	310	275	160
		t	t	t	t	t	t	t	t	t	t	t
	2	565	175	210	180	150	200	305	440	365	355	
		t	t	t	t	t	t	t	t	t	t	
/sid/	1	655	320	300	325	210	320	415	415	375	355	226
		t	t	d	d	d	d	d	d	d	d	d
	2	---	220	335	225	195	315	510	585	360	455	
			t	d	d	d	d	d	d	d	d	
/tiθ/	1	---	345	275	355	310	190	515	440	390	355	198
			θ	s	θ	θ	θ	θ	θ	θ	θ	θ
	2	240	240	360	455	220	290	395	430	465	510	
		s	s	θ	θ	θ	θ	θ	θ	θ	θ	
/piz/	1	445	270	250	410	355	460	700	690	480	465	349
		t	z	z	z	z	z	z	z	z	z	z
	2	500	275	340	445	285	465	735	585	585	605	
		z	z	z	z	z	z	z	z	z	z	
/but/	1	495	180	215	305	170	220	380	---	340	250	178
		t	t	t	t	t	t	t		t	t	t
	2	420	270	---	380	---	200	235	260	405	355	
		t	t		t		t	t	t	t	t	
/fud/	1	465	530	355	550	295	260	495	520	360	355	228
		t	d	d	d	d	d	d	d	d	d	d
	2	375	320	405	570	255	410	570	415	415	335	
		t	d	t	d	d	d	d	d	d	t	
/gus/	1	285	190	355	470	170	290	385	420	475	585	216
		s	s	s	s	s	s	s	s	s	s	s
	2	280	370	400	---	220	315	330	490	515	710	
		s	s	s		s	s	s	s	s	s	
/ʃuz/	1	430	265	---	510	370	570	605	480	630	495	326
		z	z		z	z	z	z	z	z	z	z
	2	555	380	515	---	375	420	565	700	545	835	
		z	z	z		z	z	dz	z	z	z	

al consonant produced by child for each utterance given below duration value

Table [illegible]

Vowel durations (msec) for child 6:
male, white, 1 older sister
Group 1

Story stimulus word and	response No.*	Age (mo.) 27	28	29	30	31	32	33	34	35	36	Parent
/stIk/	1	135	135	150	150	70	80	110	---	---	105	114
		k	k	k	k	k	k	k			k	k
	2	160	170	270	215	95	225	---	---	---	75	
		k	k	k	k	k	k				k	
/bIb/	1	230	245	260	335	235	135	225	---	---	155	215
		b	b	b	b	b	b	b			b	b
	2	225	250	300	200	220	430	150	---	---	145	
		b	b	b	b	b	b	b			b	
/kIs/	1	215	185	280	365	175	145	150	---	---	185	136
		s	s	s	s	s	s	s			s	s
	2	145	220	415	265	280	---	---	---	---	320	
		s	s	s	s	s					s	
/hIz/	1	245	440	400	580	285	275	350	---	---	410	346
		z	z	z	z	z	z	z			z	z
	2	155	325	320	560	290	210	400	---	---	375	
		z	z	z	z	z	z	z			z	
/fit/	1	160	335	180	210	85	125	305	---	---	290	166
		t	t	t	t	t	t	t			t	t
	2	180	270	210	195	160	135	---	---	---	330	
		t	t	ts	t	t	t				t	
/sid/	1	285	450	265	915	210	510	455	---	---	370	312
		d	d	d	d	d	d	d			d	d
	2	230	450	275	315	265	515	---	---	---	350	
		d	d	d	d	d	d				d	
/tiθ/	1	550	270	340	340	155	240	365	---	---	275	182
		θ	θ	θ	θ	θ	θ	θ			θ	θ
	2	430	520	265	430	175	245	---	---	---	170	
		θ	θ	θ	θ	θ	θ				θ	
/piz/	1	320	735	340	820	400	570	230	---	---	325	390
		z	z	z	z	z	z	z			z	z
	2	230	840	380	710	405	590	---	---	---	340	
		z	z	z	z	z	z				z	
/but/	1	225	315	185	260	160	150	135	---	---	145	193
		t	t	t	t	t	t	t			t	t
	2	215	410	290	225	270	160	125	---	---	---	
		t	t	t	t	t	t	t				
/fud/	1	435	545	365	595	425	545	225	---	---	215	323
		d	d	d	d	d	d	d			d	d
	2	290	725	340	395	550	235	---	---	---	240	
		d	d	d	d	d	t				d	
/gus/	1	425	460	355	365	350	180	290	---	---	170	198
		s	s	s	s	s	s	s			s	s
	2	400	465	465	250	275	390	---	---	---	200	
		s	s	s	s	s	s				s	
/ʃuz/	1	---	670	575	770	370	340	560	---	---	305	408
			z	z	z	z	z	z			z	z
	2	325	830	410	755	675	380	---	---	---	---	
		z	z	z	z	z	ð					

Table C. 10

Second study, children's responses to taped stimuli of normal duration.
Vowel durations (msec) for child 7
Group 2

Tape A Vowel duration (msec) and Stimulus word	Age (mo.) 24				26				Parent
	Response No.*				Response No.*				
	1	2	3	4	1	2	3	4	
208	175	185	240	25	225	120	160	170	186
/fit/	t	t	t	t	t	t	t	t	t
325	150	290	370	375	405	315	315	390	397
/sid/	t	d	d	d	d	d	d	d	d
205	175	395	185	170	175	190	180	175	255
/tiθ/	θ	θ	s	s	θ	θ	θ	θ	θ
400	445	355	265	260	510	500	455	415	549
/piz/	z	z	z	z	z	z	z	z	z
192	130	190	135	165	155	145	220	185	172
/pip/	p	p	p	p	p	p	p	p	p
325	280	250	260	215	295	230	450	505	390
/pib/	b	b	b	b	b	b	b	b	b
225	320	290	155	115	190	225	170	220	220
/pis/	s	sts	s	s	s	s	s	s	s
455	275	325	530	440	585	290	625	420	558
/piz/	z	dz	z	z	z	z	z	z	z

*Final consonant produced by child for each utterance given below duration value

Table C. 11

Second study, children's responses to taped stimuli of normal duration. Vowel durations (msec) for child 8
Group 2

Tape A Vowel duration (msec) and Stimulus word	Age (mo.) 21				23				Parent
	Response No.*				Response No.*				
	1	2	3	4	1	2	3	4	
208	170	205	125	150	245	260	255	255	225
/fit/	t	t	t	t	t	t	t	t	t
325	610	540	280	265	255	420	485	370	380
/sid/	t	dt	d	t	ø	t	d	d	dt
205	230	275	170	165	270	370	275	330	252
/tiθ/	t	t	t	t	t	t	t	t	θ
400	605	550	320	425	6?5	820	620	610	416
/piz/	z	z	s	s	z	z	z	s	z
192	185	210	205	215	190	135	235	170	212
/pip/	p	p	p	p	p	p	p	p	p
325	470	335	455	355	415	490	320	290	372
/pib/	m	m	m	b	p	p	b	p	bp
225	315	380	265	330	260	315	345	360	246
/pis/	s	s	s	s	s	s	s	s	s
455	485	655	380	420	680	395	545	380	434
/piz/	z	z	s	z	z	s	sts	s	z

*Final consonant produced by child for each utterance given below duration value

Table C. 12

Second study, children's responses to taped stimuli of normal duration.
Vowel durations (msec) for child 9
Group 2

Tape A Vowel duration (msec) and Stimulus word	Age (mo.) 21				23				Parent
	Response No.*				Response No.*				
	1	2	3	4	1	2	3	4	
208	110	115	150	145	110	85	110	110	192
/fit/	t	t	t	t	t	t	t	t	t
325	245	310	240	320	325	365	385	175	308
/sid/	t	dt	d	t	n	d	d	d	d
295	365	350	335	235	485	325	130	305	224
/tiθ/	θ	θ	θ	θ	θ	θ	θ	θ	θ
400	380	370	465	555	550	445	395	390	420
/piz/	s	s	s	z	z	z	z	ð	z
192	110	140	115	120	100	95	55	70	194
/pip/	p	p	p	p	p	p	p	p	p
325	255	220	170	210	400	275	230	235	296
/pib/	m	b	b	b	b	b	b	b	b
225	285	240	250	405	320	200	170	265	232
/pis/	s	s	s	s	s	s	s	s	s
455	380	415	445	535	640	510	505	550	420
/piz/	s	z	z	z	z	z	z	z	z

*Final consonant produced by child for each utterance given below duration value

Table C. 13

Second study, children's responses to taped stimuli of normal duration.
Vowel durations (msec) for child 1
Group 1

Tape A or B Vowel duration (msec) and Stimulus word	Response No.*	Age (mo.) 28	29	30	31	32	33	34	Parent
208	1	185	220	---	310	290	200	135	159
/tit/		t	t		ts	ts	ts	t	t
	2	175	195	---	225	355	300	160	
		t	t		t	ts	t	t	
325	1	615	505	---	175	640	430	315	230
/sid/		d	v		d	d	d	d	d
	2	560	280	---	300	430	510	395	
		d	d		d	d	d	d	
205	1	445	265	---	315	450	305	240	209
/tiθ/		θ	θ		s	θ	θ	θ	θ
	2	350	200	---	365	325	270	325	
		θ	θ		θ	θ	θ	s	
400	1	550	440	---	415	640	475	520	320
/piz/		z	Ø		z	Ø	Ø	z	z
	2	600	280	---	---	605	680	540	
		Ø	z			z	z	z	
192	1	285	200	---	145	225	210	220	123
/pip/		p	p		p	p	p	p	p
	2	265	230	---	220	200	230	370	
		p	p		p	p	p	p	
325	1	345	325	---	200	405	430	420	222
/pib/		b	b		b	b	b	b	b
	2	160	365	---	450	560	415	400	
		b	b		b	b	b	b	
225	1	200	295	---	250	380	315	405	200
/pis/		s	s		s	s	s	s	s
	2	280	185	---	310	365	335	350	
		s	Ø		s	s	s	s	
455	1	595	370	---	400	750	690	640	312
/piz/		z	z		z	z	z	z	z
	2	385	375	---	525	475	870	800	
		z	z		Ø	z	z	z	

*Final consonant produced by child for each utterance given below duration value

Table C. 14
Second study, children's responses to taped stimuli of normal duration.
Vowel durations (msec) for child 2
Group 1

Tape A or B Vowel duration (msec) and Stimulus word	Response No.*	Age (mo.) 28	29	30	31	32	33	34	Parent
208	1	300	85	210	195	310	250	160	168
/fit/		t	t	t	t	t	t	t	t
	2	295	455	200	185	330	240	160	
		t	d	t	t	t	t	t	
325	1	485	490	335	330	[illegible]	520	255	250
/sid/		d	d	d	d	d	d	d	d
	2	600	510	260	295	375	405	310	
		n	d	d	d	d	d	d	
205	1	300	230	320	250	195	260	165	209
/tiθ/		h	t	s	s	s	θ	θ	θ
	2	265	250	375	235	230	235	240	
		s	t	z	s	s	θ	θ	
400	1	535	515	345	420	285	420	240	355
/piz/		z	z	z	z	z	z	z	z
	2	535	775	250	320	365	305	410	
		z	z	z	z	z	z	z	
192	1	215	205	185	170	180	340	180	172
/pip/		p	p	p	p	p	p	p	p
	2	260	165	230	190	210	295	200	
		t	k	p	p	p	p	p	
325	1	640	480	400	305	415	405	230	286
/pib/		h	b	b	b	b	b	b	b
	2	535	385	365	330	230	400	275	
		b	p	b	b	p	b	b	
225	1	545	365	330	360	180	405	190	219
/pis/		s	dz	s	s	s	s	s	s
	2	500	380	255	310	280	400	265	
		z	s	s	s	z	s	s	
455	1	520	630	455	365	325	370	375	368
/piz/		z	z	z	z	z	z	z	z
	2	555	540	405	415	290	345	260	
		z	z	z	z	z	z	z	

*Final consonant produced by child for each utterance given below duration value

Table C. 15
Second study, children's responses to taped stimuli of normal duration.
Vowel durations (msec) for child 3
Group 1

Tape A or B Vowel duration (msec) and Stimulus word	Response No.*	26	27	28	29	30	31	32	Parent
		Age (mo.)							
208	1	---	---	240	275	200	175	295	180
/fit/				t	t	t	t	t	t
	2	---	160	240	180	155	180	460	
			t	t	t	t	t	t	
325	1	---	290	565	325	330	380	370	302
/sid/			d	d	d	d	d	d	d
	2	---	345	325	355	415	490	485	
			d	d	d	d	d	d	
205	1	---	220	185	490	160	140	360	212
/tiθ/			s	θ	θ	θ	θ	h	θ
	2	---	155	190	415	215	160	370	
			θ	θ	θ	θ	θ	θ	
400	1	---	500	720	395	485	530	540	430
/piz/			z	∅	∅	z	z	z	z
	2	---	450	520	610	440	470	470	
			z	z	z	ð	z	z	
192	1	---	160	190	160	170	160	105	173
/pip/			p	p	p	p	p	p	p
	2	---	245	205	110	160	115	120	
				p	p	p	p	p	
325	1	---	260	430	380	295	360	315	300
/pib/			b	b	b	b	b	b	b
	2	---	320	365	605	365	355	310	
			b	b	∅	b	b	b	
225	1	---	165	910	255	200	230	245	212
/pis/			s	∅	∅	s	s	θs	s
	2	---	90	245	515	450	150	165	
			s	ts	s	s	s	s	
455	1	---	420	690	590	510	465	525	459
/piz/			z	z	z	z	z	z	z
	2	---	455	550	335	510	430	590	
			z	z	z	z	z	z	

*Final consonant produced by child for each utterance given below duration value

Table C. 16
Second study, children's responses to taped stimuli of normal duration.
Vowel durations (msec) for child 4
Group 1

Tape A or B Vowel duration (msec) and Stimulus word	Response No.*	Age (mo.) 26	27	28	29	30	31	32	Parent
208	1	155	260	175	105	140	265	190	185
/fit/		t	t	t	t	t	t	t	t
	2	160	190	130	140	170	300	170	
		t	t	t	t	t	t	t	
325	1	180	300	440	185	260	470	365	265
/sid/		t	t	d	d	d	d	d	d
	2	190	315	420	160	250	420	355	
		t	t	d	d	d	d	d	
205	1	205	210	355	125	205	230	365	202
/tiθ/		tʃ	s	s	s	s	θ	θ	θ
	2	90	120	400	140	165	160	215	
		ts	s	s	s	s	θ	s	
400	1	235	250	405	250	410	560	400	362
/piz/		s	s	s	z	z	z	z	z
	2	330	185	485	260	260	350	325	
		s	ts	z	z	z	z	z	
192	1	150	95	130	145	180	130	145	142
/pip/		p	p	p	p	p	p	p	p
	2	130	110	155	150	115	155	160	
		p	p	p	p	p	p	p	
325	1	205	175	350	195	215	215	245	238
/pib/		p	p	p	b	b	b	b	b
	2	200	160	290	220	160	225	255	
		p	p	p	b	b	b	b	
225	1	200	130	270	160	135	185	210	205
/pis/		s	ts	s	s	s	s	s	s
	2	205	145	235	145	220	220	220	
		s	s	s	s	s	s	s	
455	1	150	165	430	390	255	450	585	372
/piz/		tʃ	s	z	z	z	z	z	z
	2	185	320	505	335	295	300	340	
		tʃ	z	z	z	z	z	z	

*Final consonant produced by child for each utterance given below duration value

Table C. 17
Second study, children's responses to taped stimuli of normal duration.
Vowel durations (msec) for child 5
Group 1

Tape A or B Vowel duration (msec) and Stimulus word	Response No.*	Age (mo.) 28	29	30	31	32	33	34	Parent
208	1	200	185	140	140	195	335	315	176
/fit/		t	t	t	t	t	t	t	t
	2	---	185	190	150	200	225	170	
			t	t	t	t	t	t	
325	1	160	215	220	160	500	450	520	270
/sid/		t	d	d	d	d	d	d	d
	2	405	260	170	290	355	385	435	
		t	d	d	d	d	d	d	
205	1	295	270	270	125	285	250	250	196
/tiθ/		s	s	θ	θ	s	θ	θ	θ
	2	345	320	220	170	255	245	345	
		θ	θ	θ	θ	θ	s	θ	
400	1	280	310	290	230	485	910	515	388
/piz/		z	z	z	z	z	z	z	z
	2	280	390	380	335	525	545	425	
		z	z	z	z	z	z	d	

Tape A or B Vowel duration (msec) and Stimulus word	Response No.*	28	29	30	31	32	33	34	Parent
192	1	---	95	170	70	130	140	300	153
/pip/			p	p	p	p	p	p	p
	2	230	190	---	120	190	190	210	
		p	p		p	p	p	p	
325	1	275	250	240	165	480	300	310	219
/pib/		b	b	b	b	b	b	b	b
	2	3/5	230	320	260	355	380	420	
		p	b	b	b	b	b	b	
225	1	280	135	160	180	225	335	500	189
/pis/		s	s	s	s	s	s	s	s
	2	250	235	190	160	225	245	405	
		s	s	s	s	s	s	s	
455	1	485	170	390	385	480	610	570	376
/piz/		z	dz	z	z	z	z	z	z
	2	315	360	340	340	365	580	450	
		z	z	z	z	z	z	z	

*Final consonant produced by child for each utterance given below duration value

Table C. 18
Second study, children's responses to taped stimuli of normal duration.
Vowel durations (msec) for child 6
Group 1

Tape A or B Vowel duration (msec) and Stimulus word	Response No.*	Age (mo.) 28	29	30	31	32	33	34	Parent
208	1	245	135	260	230	125	140	125	168
/fit/		t	t	t	t	t	t	t	t
	2	165	265	305	130	135	255	210	
		t	t	t	t	t	t	t	
325	1	510	285	470	320	510	295	300	294
/sid/		d	d	d	d	d	d	d	d
	2	530	620	370	340	515	360	445	
		d	d	d	d	d	d	d	
205	1	405	---	295	185	240	140	200	213
/tiθ/		θ		θ	θ	θ	θ	θ	θ
	2	485	255	315	170	245	320	300	
		θ	θ	θ	θ	θ	θ	θ	
400	1	740	415	485	360	570	345	480	364
/piz/		z	z	z	z	z	z	z	z
	2	760	495	695	275	590	425	330	
		z	z	z	s	z	z	z	
192	1	130	190	220	155	95	140	275	165
/pip/		p	p	p	p	p	p	p	p
	2	195	385	215	110	90	130	210	
		p	p	p	p	p	p	p	
325	1	415	205	465	260	305	350	380	258
/pib/		b	b	b	b	b	b	b	b
	2	330	285	450	210	290	330	395	
		b	b	b	b	b	b	b	
225	1	325	385	320	140	145	140	170	182
/pis/		s	s	s	s	s	s	s	s
	2	160	500	225	155	190	140	365	
		s	s	s	s	s	s	s	
455	1	825	410	390	425	690	370	285	425
/piz/		bz	z	z	z	z	z	z	z
	2	---	595	260	325	630	395	335	
			z	z	z	z	z	z	

*Final consonant produced by child for each utterance given below duration value

Table C. 19

Third study, children's responses to taped stimuli of abnormal equal vowel durations. Vowel durations (msec) for child 7
Group 2

Tape A' Vowel duration (msec) and Stimulus word	Age (mo.) 25			
	Response No.*			
	1	2	3	4
315	230	170	140	255
/fit/	t	t	t	t
315	315	340	250	355
/sid/	d	d	d	d
410	110	135	260	270
/tiθ/	s	s	θ	θ
410	320	460	555	380
/piz/	z	z	z	z
335	180	110	105	165
/pip/	p	p	p	p
335	125	120	300	375
/pib/	b	b	b	b
410	140	200	155	240
/pis/	s	s	s	s
410	335	363	365	365
/piz/	z	z	z	z

*Final consonant produced by child for each utterance given below duration value

Table C. 20

Third study, children's responses to taped stimuli of abnormal equal vowel durations. Vowel durations (msec) for child 8
Group 2

Tape A' Vowel duration (msec) and Stimulus word	Age (mo.) 22 Response No.* 1	2	3	4
315	280	255	270	220
/fit/	t	t	t	t
315	275	330	255	290
/sid/	t	dt	t	t
410	220	250	240	375
/tiθ/	t	t	t	s
410	420	435	365	360
/piz/	z	z	s	s
335	305	255	235	265
/pip/	p	p	p	p
335	325	260	265	275
/pib/	p	p	b	p
410	365	420	440	355
/pis/	s	s	s	s
410	475	365	475	465
/piz/	z	zs	s	s

*Final consonant produced by child for each utterance given below duration value

Table C. 21

Third study, children's responses to taped stimuli of abnormal equal vowel durations. Vowel durations (msec) for child 9
Group 2

Tape A' Vowel duration (msec) and Stimulus word	Age (mo.) 22 Response No.* 1	2	3	4
315	195	140	175	155
/fit/	ts	t	t	t
315	330	205	365	165
/sid/	d	t	d	t
410	340	260	380	260
/tiθ/	θ	θ	θ	θ
410	490	380	490	265
/piz/	z	z	z	s
335	200	170	130	135
/pip/	p	p	p	p
335	275	280	265	205
/pib/	b	b	b	b
410	235	260	210	185
/pis/	s	s	s	s
410	500	385	---	335
/piz/	z	z		z

*Final consonant produced by child for each utterance given below duration value

Table C. 22

Third study, children's responses to taped stimuli of abnormal equal vowel durations. Vowel durations (msec) for child 1
Group I

Tape A' or B' Vowel duration (msec) and Stimulus word	Response No.*	Age (mo.) 34	35	36
315 /fit/	1	210 t	300 t	350 t
	2	465 t	285 t	460 t
315 /sid/	1	515 d	345 d	820 d
	2	260 d	310 d	490 d
410 /tiθ/	1	505 s	355 θ	465 s
	2	435 s	380 s	400 θ
410 /piz/	1	690 z	335 z	460 z
	2	470 z	340 z	520 z
335 /pip/	1	275 p	310 p	330 p
	2	550 p	320 p	625 p
335 /pib/	1	570 m	325 m	595 m
	2	460 m	335 m	470 m
410 /pis/	1	345 s	370 s	610 s
	2	340 s	370 s	620 s
410 /piz/	1	400 z	280 z	450 z
	2	570 z	350 z	580 z

* Final consonant produced by child for each utterance given below duration value

Table C. 23

Third study, children's responses to taped stimuli of abnormal equal vowel durations. Vowel durations (msec) for child 2
Group 1

Tape A' or B' Vowel duration (msec) and Stimulus word		Age (mo.)		
	Response No.*	34	35	36
315	1	195	160	205
/fit/		t	t	t
	2	195	230	175
		t	t	t
315	1	235	220	250
/sid/		d	d	d
	2	285	315	275
		d	d	d
410	1	205	270	235
/tiθ/		θ	θ	θ
	2	285	265	290
		θ	θ	θ
410	1	235	320	275
/piz/		z	z	z
	2	420	430	265
		z	z	z
335	1	155	230	225
/pip/		p	p	p
	2	275	220	185
		p	p	p
335	1	220	230	305
/pib/		b	b	b
	2	265	375	345
		b	b	b
410	1	225	370	190
/pis/		s	s	s
	2	290	300	270
		s	s	s
410	1	250	460	285
/piz/		z	z	z
	2	340	430	325
		z	z	z

* Final consonant produced by child for each utterance given below duration value

Table C. 24

Third study, children's responses to taped stimuli of abnormal equal vowel durations. Vowel durations (msec) for child 3
Group 1

Tape A' or B' Vowel duration (msec) and Stimulus word	Response No.*	Age (mo.) 32	33	34
315 /fit/	1	295 t	340 t	280 t
	2	460 t	285 t	435 t
315 /sid/	1	370 d	435 d	525 d
	2	485 d	465 d	525 d
410 /tiθ/	1	360 θ	500 θ	470 θ
	2	370 θ	325 θ	545 θ
410 /piz/	1	540 z	560 z	495 z
	2	470 z	640 z	510 z
335 /pip/	1	260 p	255 p	295 p
	2	280 p	180 p	285 p
335 /pib/	1	405 b	425 b	475 b
	2	345 b	455 b	490 b
410 /pis/	1	460 s	400 s	350 s
	2	680 s	405 s	485 s
410 /piz/	1	665 z	500 z	470 z
	2	545 z	475 z	585 z

* Final consonant produced by child for each utterance given below duration value

Table C. 25

Third study, children's responses to taped stimuli of abnormal equal vowel durations. Vowel durations (msec) for child 4
Group 1

Tape A' or B' Vowel duration (msec) and Stimulus word	Response No.*	Age (mo.) 32
315 /fit/	1	210 t
	2	205 t
315 /sid/	1	230 d
	2	225 d
410 /tiθ/	1	240 θ
	2	460 s
410 /piz/	1	670 z
	2	490 z
335 /pip/	1	200 p
	2	200 p
335 /pib/	1	240 b
	2	255 b
410 /pis/	1	200 s
	2	155 ts
410 /piz/	1	350 z
	2	355 z

* Final consonant produced by child for each utterance given below duration value

Table C. 26

Third study, children's responses to taped stimuli of abnormal equal vowel durations. Vowel durations (msec) for child 5
Group 1

Tape A' or B' Vowel duration (msec) and Stimulus word	Response No.*	Age (mo.) 34	35	36
315	1	300	340	315
/fit/		t	t	t
	2	445	395	320
		t	t	t
315	1	375	480	405
/sid/		d	d	d
	2	540	425	480
		d	d	d
410	1	680	495	320
/tiθ/		θ	θ	θ
	2	395	475	400
		θ	θ	θ
410	1	555	455	405
/piz/		∅	z	z
	2	580	510	440
		z	z	z
335	1	360	265	280
/pip/		p	p	p
	2	380	345	275
		p	p	p
335	1	555	410	220
/pib/		b	b	b
	2	480	255	340
		b	b	b
410	1	595	390	335
/pis/		s	s	s
	2	500	450	440
		s	s	s
410	1	695	440	405
/piz/		z	z	z
	2	535	535	510
		z	z	z

* Final consonant produced by child for each utterance given below duration value

Table C. 27

Third study, children's responses to taped stimuli of abnormal equal vowel durations. Vowel durations (msec) for child 6
Group 1

Tape A' or B' Vowel duration (msec) and Stimulus word	Response No.*	Age (mo.) 34	35	36
315 /fit/	1	170 t	165 t	215 t
	2	255 t	300 t	260 t
315 /sid/	1	380 d	485 d	290 d
	2	360 d	285 d	385 d
410 /tiθ/	1	230 θ	245 θ	295 θ
	2	300 θ	335 θ	205 θ
410 /piz/	1	275 z	375 z	380 z
	2	440 z	405 ð	580 z
335 /pip/	1	275 p	265 p	310 p
	2	210 p	130 p	150 p
335 /pib/	1	380 b	270 b	230 b
	2	395 b	420 b	215 b
410 /pis/	1	170 s	170 s	300 s
	2	365 s	220 s	235 s
410 /piz/	1	285 z	350 z	380 z
	2	335 z	275 z	515 z

* Final consonant produced by child for each utterance given below duration value

Appendix D

RESPONSES FROM SCORING PROCEDURE TYPES 4 AND 5 FOR FIRST STUDY,

CHILDREN'S RESPONSES TO PICTURE STIMULI

Scoring procedure types 4 (Incorrect response consonants/stimulus) and 5 (Incorrect response consonants/response) for the first study are discussed in detail in this appendix. It is only in this sort of detailed discussion of incorrect responses that one can see where certain individual children did deviate from others in their group. It is hoped that this detailed discussion will show greater insight into some of the different approaches used by some of the children in their development of differential vowel duration.

The discussion begins with scoring procedure types 4 and 5 for the vowel /i/ before stops, because those for /I/ were discussed in the text of Chapter 2. All tables and figures referred to may be found in Chapter 2.

<u>Scoring procedure types 4 and 5 for /i/ before stops</u>

Scoring procedure type 4 on Table 4 and Fig. 4 shows the mean vowel duration before all response consonants which were substituted for the stimulus voiceless stop /t/. At 22 months the mean vowel duration before response consonants substituted for /t/ (Type 4) was 110 msec (all following durations in msec) and vowel duration before voiceless stops produced correctly (Type 3) was 182. This is only a 72 msec difference. Thus, it is clear that at 22 months, the mean vowel duration used with the response consonant substituted for the stimulus /t/ was used with the correct shortened vowel duration appropriate for the stimulus consonant rather than the substituted response consonant. This pattern was also the case for ages 27 months and 30 months where similar substitutions occurred. However, for the group with the mean age of 34 months, child 1 produced 1 incorrect final response consonant, the voiceless affricate /ts/ for the stimulus /t/. The vowel duration for this, 470, was an extremely long duration which was 266 msec greater than that produced before correctly used voiceless stops for that child, and 80 msec longer than vowel duration before correctly used voiced stops. This was thus probably a duration much closer to that associated with an affricate for that child and his production of the vowel duration in this instance was more closely associated with the quality of the final response consonant than the final stimulus consonant. This is a pattern contrary to the other 7 substitutions of /ts/ for /t/.

Scoring procedure type 4 on Table 4 and Fig. 4 shows the mean vowel duration which was used with all incorrect response consonants substituted for the stimulus voiced stop /d/. At 22 months the mean vowel duration before response consonants substituted for /d/ (Type 4) was 322 and vowel duration before voiced stops produced correctly (Type 3) was 355. This is only a 33 msec difference, thus showing that at 22 months, the mean vowel duration used with the response consonants substituted for the stimulus /d/ were used with the correct lengthened vowel duration expected with the stimulus consonant, not the substituted response consonant. This same pattern was true for observations at 24, 27, and 30 months but *not* for one substitution which occurred in the 34 months age group. In this group, child 3, at 32 months, substituted the voiceless stop /t/ for the stimulus voiced stop /d/. The vowel duration used was 270. This duration was much closer to that of the child's production of vowel duration preceding correctly produced voiceless stops (Type 3) 172, than it was to his production of voiced stops (Type 3) 481. Thus, in this instance, the vowel duration used with the response consonant substituted for the stimulus consonant was appropriate for the response consonant, not the original stimulus consonant. This pattern was contrary to the other 21 instances where /t/ was substituted for /d/. The pattern established in the majority of these instances is further substantiated by scoring procedure type 5.

Scoring procedure type 5 on Table 4 and Fig. 3 and 4 shows the mean vowel duration for the incorrectly used response consonants. At 22 months, for the voiced stop /d/, the mean vowel duration before the incorrectly used voiceless stops (Type 5) was 297 and the mean vowel duration before the correctly used voiceless stops (Type 3) was 182. This 115 msec difference showed that the children did not produce the correct vowel duration expected for the response consonant, but rather they produced the correct increased vowel duration for the stimulus consonant. This same pattern was true for all age groups except for that instance in the 34 month age group which was discussed in detail under Analysis 4.

Scoring procedure types 4 and 5 for /u/ before stops

Scoring procedure type 4 on Table 5 and Fig. 5 shows the mean vowel duration before all response consonants which were substituted for the stimulus voiced stop /d/. At 22 months the mean vowel duration before response consonants substituted incorrectly for /d/ (Type 4) was 335 and the mean vowel duration before voiced stops produced correctly (Type 3) was 282. This is a 53 msec difference. Thus, it is shown that at 22 months the mean vowel duration used with the response consonants substituted for the stimulus /d/ were used with the correct increased vowel duration appropriate for the stimulus consonant, rather than the incorrectly substituted response consonant. This same pattern was used with all other age groups, and is further supported by results from scoring procedure type 5.

Scoring procedure type 5 on Table 5 and Fig. 3 and 5 shows the mean vowel duration for the incorrectly used response consonants. At 22 months, for the voiced stop /d/, the mean vowel duration before the incorrectly used voiceless stops (Type 5) was 335, and the mean vowel duration before the correctly used voiceless stops (Type 3) was 215. This 120 msec difference shows that the children did not produce the correct increased vowel duration appropriate for the final response consonant, but rather they produced the correct increased vowel duration for the original stimulus consonant.

<u>Scoring procedure types 4 and 5 for /I/ before fricatives</u>

Scoring procedure type 4 on Table 7 and Fig. 6 shows the mean vowel duration before all response consonants which were substituted for the stimulus voiceless fricative /s/. As mentioned in chapter 2, there were only 2 vowel durations observed here. One of these was before a voiced fricative /ð/ of 1215, the other was an open syllable at 785. Both were produced by the same child and both with much greater duration than mean vowel duration before voiceless fricatives produced correctly by that child in other sessions. Thus, it is assumed that in this single instance at 25 months, that the produced vowel duration was irregularly long and if anything, varied in accordance with the substituted response consonant, not the stimulus consonant.

Scoring procedure type 5 on Table 7 and Fig. 6 and 7 further shows the exaggeration of the duration before the incorrectly used voiced fricative /ð/ (1215). Vowel duration before correctly produced voiced fricatives for that child was 408 - a 807 msec difference. This makes this particular vowel duration somewhat difficult to interpret, but if anything, places it closer to the final consonant actually produced, rather than the stimulus consonant, as explained under Type 4.

Scoring procedure type 4 on Table 7 and Fig. 6 shows the mean vowel duration before all response consonants which were substituted for the stimulus voiced fricative /z/. At 22 months, the mean vowel duration before response consonants substituted incorrectly for /z/ (Type 4) was 542. These incorrect substitutions, however, were all made by child 8, at 21 months. She used the voiceless fricative /s/ incorrectly with a vowel duration of 542 for the stimulus voiced fricative /z/. She never produced any voiced fricatives, and she used the same voiceless fricative /s/ correctly at 246 for vowel duration before the stimulus voiceless fricative /s/. Thus, using the same final response consonant she maintained correct differential vowel duration with a voiceless/voiced ratio of 45% and always produced the differential vowel duration appropriate for the stimulus consonant, not the response consonant. The same is true of this child for the same incorrect substitutions at 23 months.

At 27 months the mean vowel duration before response consonants substituted incorrectly for the voiced fricative /z/ (Type 4) was 299 and vowel duration before the voiced fricatives produced correctly (Type 3) was 386, a 87 msec difference, and that before the voiceless fricatives produced correctly (Type 3) was 234, a 65 msec difference. Because most of the substitutions for the voiced fricative /z/ were the voiceless fricative /s/, it is difficult here to say whether the produced increased vowel duration was really appropriate for the stimulus consonant or the response consonant. If the observations are considered separately, those for child 2 at 28 months and those for child 5 at 27 months follow the pattern expected for the substituted response consonant. However, the observations for child 4, at 25 months show the produced vowel duration to follow that of the original stimulus consonant.

At 30 months the mean vowel duration before response consonants substituted incorrectly for the voiced fricative /z/ (Type 4) was 276 and vowel duration before the voiced fricative produced correctly (Type 3) was 346, a 70 msec difference. Mean vowel duration produced before the voiceless fricative produced correctly (Type 3) was 223, a 53 msec difference. Again, because most of the substitutions for the voiced fricative /z/ were the voiceless fricative /s/, it is difficult here to say whether the produced vowel duration was appropriate for the stimulus consonant or the response consonant. However, when the observations are considered separately, for child 4 at 29 months, and child 5 at 31 months, it appears that both children probably produced vowel duration expected for the stimulus consonant, not the response consonant. Child 4 substituted the voiceless fricative /s/ 5 times for the stimulus voiced fricative /z/ with a mean vowel duration of 222 msec. The vowel duration before correctly produced voiced fricatives for this child was 205, only a 17 msec difference. Child 5 used the voiceless affricate /ts/ and the voiced affricate /dz/ as substitutions for the stimulus voiced fricative /z/ with a mean vowel duration of 330. Her vowel duration before correctly produced voiced fricatives was 398, a 68 msec difference. This thus showed her vowel duration was also produced for the final stimulus consonant, not the substituted response consonants.

There were no incorrect response consonants produced in the 34 month age group. The same patterns which were shown here in Analysis 4 are shown in Analysis 5.

Scoring procedure type 5 on Table 7 and Fig. 6 and 7 shows the mean vowel duration for the incorrectly used response consonants. For child 8, at 21 months, the mean vowel duration before the incorrectly used voiceless fricatives (Type 5) was 542 and the mean vowel duration before the correctly used voiceless fricatives (Type 3) was 376. This 166 msec difference shows that the child did not produce the correct vowel duration expected of the final response consonant, but rather she produced the correct increased vowel duration of the original stimulus consonant. The same pattern was true for the same child at age 23 months, as was discussed under Type 4.

Child 2 at 28 months and child 5 at 27 months both used voiceless fricatives incorrectly for the voiced fricative /z/ and produced vowel duration with the means of 300 and 272 respectively. The mean vowel duration before voiceless fricatives used correctly for child 2 was 300, that for child 5 was 230. Thus, in these 2 instances, the vowel duration with the voiceless fricatives used incorrectly were produced as expected for the substituted response consonants, not the stimulus consonant. Child 4, at 25 months, however, used a voiceless fricative incorrectly for the voiced fricative /z/ and produced the vowel duration of 315. His mean vowel duration, for voiceless fricatives produced correctly, was only 214, so his production of increased vowel duration before the voiceless fricative was appropriate for the original stimulus consonant.

In the 30 month age group, child 4, at 29 months incorrectly substituted the voiceless fricative /s/ 5 times for the voiced fricative /z/ with a mean vowel duration of 222. The mean vowel duration before correctly used voiceless fricatives for this child was 268, a difference of 46 msec, however, the mean vowel duration before voiced fricatives produced correctly for this child was only 205, a 17 msec difference. It is difficult to make a decision with such small differences involved, but it is assumed that the duration before the incorrectly used voiceless fricatives was appropriate for the stimulus consonant (the smallest difference here), not the response consonant.

The only occurrence of an incorrectly used voiced fricative was by child 3 at 25 months where the voiced fricative /ð/ was substituted for the voiceless fricative /s/. The vowel duration produced before the incorrectly used voiced fricative was 1215 - a duration which far exceeded even that before correctly produced voiced fricatives (408) and thus, the vowel duration produced here probably followed that for the response consonant, not the original stimulus consonant.

<u>Scoring procedure types 4 and 5 for /i/ before fricatives</u>

Scoring procedure type 4 on Table 8 and Fig. 8 shows the mean vowel duration before all response consonants which were substituted incorrectly for the stimulus voiceless fricative /θ/. At 22 months, the mean vowel duration before response consonants substituted incorrectly for /θ/ (Type 4) was 236 and vowel duration before voiceless fricatives produced correctly (Type 3) was 220, a 16 msec difference. This indicated that the incorrect substitutions for the voiceless fricative were used with the correct vowel duration appropriate for the stimulus consonant, and not the incorrectly substituted response consonant. This was also the pattern at 27, 30, and 34 months.

At 24 months, the pattern is actually the same but it is not so clear. The mean vowel duration before response consonants which were substituted incorrectly for the stimulus voiceless fricative /θ/ was 391. There were 4 incorrect substitutions here and they were all produced by child 8. She used the voiceless stop /t/ for the voiceless fricative /θ/ substitutions. Her vowel duration before voiceless stop /t/ when produced correctly (Type 3) at that age was 508, a 117 msec difference. However, vowel duration before her production of voiceless fricatives used incorrectly for voiced fricatives here was 654, a 254 msec difference. This showed that she used the lower value 391 produced with voiceless stops for the voiceless fricative and the higher value, 645 produced with voiceless fricatives for the voiced fricative. This differential contrast resulted in the proper voiceless/voiced ratio of 61%

Scoring procedure type 4 on Table 8 and Fig. 8 shows the mean vowel durations before all response consonants which were substituted incorrectly for the stimulus voiced fricative /z/. At 22 months the mean vowel duration before response consonants substituted incorrectly for the voiced fricative /z/ (Type 4) was 392 and duration before voiced fricatives produced correctly (Type 3) was 445, a 53 msec difference. This indicated that the incorrect substitutions for the voiced fricative were used with the correct vowel duration as a function of the stimulus consonant and not the incorrectly substituted final consonant. This was also the pattern for the overall mean at 24, 27, 30 and 34 months. This pattern was further supported by results from scoring procedure type 5.

Scoring procedure type 5 on Table 8 and Fig. 7 and 8 shows the mean vowel duration for the incorrectly used response consonants. At 22 months, the mean vowel duration before the incorrectly used voiceless fricatives (Type 5) was 410 and the mean vowel duration before the correctly used voiceless fricatives (Type 3) was 220, a 190 msec difference and that before the correctly used voiced fricatives was 445, a 35 msec difference. The large 190 msec difference shows that at 22 months the children did not produce the correct vowel duration appropriate for the final response consonant, but rather for the original stimulus consonant.

The same pattern was true at 24 months as explained under Analysis 4. The same pattern was not true, however, for child 4, at 25 months where the vowel duration for the voiceless fricative substituted for the voiced fricative was 298, a mean very close to the correct production of mean vowel duration before voiceless fricatives (Type 3) of 260 for that child. The other instances where incorrect substitutions occurred were for child 2, at 31 months, and child 3, at 32 months, both of these substitution types, however, followed the pattern established at 22 months where the vowel duration was used as expected for the stimulus consonant, not the substituted response consonant.

Scoring procedure types 4 and 5 for /u/ before fricatives

Scoring procedure type 4 on Table 9 and Fig. 9 shows the mean vowel duration before all response consonants which were substituted incorrectly for the stimulus voiceless fricative /s/. At 22 and 24 months there were no incorrect substitutions. The mean vowel duration before response consonants substituted incorrectly for /s/ (Type 4) was 348 and vowel duration before voiceless fricatives produced correctly (Type 3) was 338. This indicated that the incorrect substitutions for the voiceless fricatives were used with the correct vowel duration appropriate for the stimulus consonant, and not the incorrectly substituted response consonant. The only other observation of an incorrect substitution of /s/ occurred with child 4, at 29 months. She articulated the voiceless affricate /ts/ with a vowel duration of 455. This was longer than her vowel duration before correctly used /s/ of 330 (Type 3), but still shorter than her vowel duration before correctly used /z/ of 566. Thus, she still maintained the correct voiceless/voiced ratio and produced vowel duration appropriate for the stimulus word rather than the quality of the final response consonant.

Scoring procedure type 4 on Table 9 and Fig. 9 shows the mean vowel duration before all response consonants which were substituted incorrectly for the stimulus voiced fricative /z/. At 22 months the mean vowel duration before all response consonants substituted incorrectly for /z/ (Type 4) was 392 and duration before voiced fricatives produced correctly (Type 3) was 395, a 7 msec difference. This indicated that the incorrect substitutions for the voiced fricative were used with the correct vowel duration appropriate for the stimulus word and not the incorrectly substituted response consonants. This was also the pattern at 24, 27, 30 and 34 months. The pattern was further established in Type 5.

Scoring procedure type 5 on Table 9 and Fig. 7 and 9 shows the mean vowel duration for the incorrectly used response consonants. At 22 months for the voiced fricative /z/, the mean vowel duration before incorrectly substituted voiceless fricative /s/ (Type 5) was 415 and the mean vowel duration before the correctly used voiceless fricatives (Type 3) was 312, a 103 msec difference. Vowel duration before the correctly used voiced fricatives was 385, a 30 msec difference. The larger 103 msec difference shows that at 22 months the children did not produce the correct vowel duration expected for the final response consonant, but rather for the original stimulus consonant. The same pattern was true for the incorrect use of voiceless fricatives at 24 and 27 months. There were no incorrect uses of voiceless fricatives at 30 and 34 months.

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