VOWEL AMPLITUDE AND DURATIONAL MANIPULATIONS IN PREADOLESCENT AND ADULT SPEAKERS

By

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VOWEL AMPLITUDE AND DURATIONAL MANIPULATIONS

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PREFACE

Vowel amplitude and durational differences of seven-year-olds, eleven-year-olds, and college females were studied. The acoustic dimensions were derived from a controlled speech sample in which stressed and unstressed sysllables contained the vowels /i/, /ae/, and /u/. The measures were examined across the age groups, among the vowels, and between stressed and unstressed positions. Differences in vowel duration and amplitude manipulations are reported for each group.

I wish to express my sincere gratitude to all the people who assisted me in this study and encouraged me thoughout my education at Oklahoma State University. I would especially like to express my appreciation to my thesis adviser, Dr. Arthur Penz, Jr., for his continuous guidance and invaluable assistance. I am also thankful to the other committee members, Dr. John Panagos, Dr. Nancy Monroe, and Mr. Gary Beeby for their additional advice.

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CHAPTER I

INTRODUCTION

The English language system enables speakers to alter or manipulate utterances in numerous ways to convey very specific meanings. One of the most elementary forms of altering word meaning can be accomplished at the phonemes level by adding, deleting, or reversing the order of phonemes. Modifying the phoneme structure results in the formation of words related to or completely different from the original. Changing some singular nouns to plural forms can be achieved by the simple addition of the /s/ phoneme. An entirely different word results if the phoneme sequence "ts" is reversed in the plural noun "cats."

Manipulations at the word sequence level are another means of shaping and varying communicative impact. Syntactic variations resulting from the reordering of word sequences may change declarative statements into questions or vice versa. The declarative sentence, "She is working." is formed into a question by reversing the position of the first two words.

A much more abstract means of shaping utterances for altered interpretations can be accomplished by varying the frequency, intensity, and duration of the various syllables in an utterance. Stressed syllables are produced by increasing the frequencies (House and Fairbanks, 1953) and amplitudes (Fairbanks, House, and Stevens, 1950) of vowels and by lengthening their durations (Borden and Harris, 1984).

Lehiste and Peterson (1958) suggest that, in English, stress is actually physiological stress that is reflected in four acoustic parameters: speech power or amplitude, fundamental voice frequency, phonetic quality, and duration. The length of the vowel appears to be the primary perceptual marker of contextual stress and has received the most investigative attention of all the acoustic dimensions (Fry, 1955; Hixon, 1973; Klatt, 1976; and Matlock, 1989).

Linguistic stress results from an obligation of the various conventions of English language and can effectively change meaning without altering the word or phoneme order. The sentence, "The cat is black," contains subtle changes in meaning which can be detected when stress is placed on the word "cat" as opposed to stress placed on the word "black". Selective or individual word stress can further enhance the semantic impact of the sentence. The speaker may place stress on "cat" in the sentence, "The cat is black." if there is a need to clarify what is black, or stress may be placed on "black" if there is confusion on the color of the cat being described. Several factors have been found to influence linguistic stress in the form of durational patterns of vowels in an utterance (Klatt, 1976). The English language also exhibits certain linguistic conventions or rules which indicate a natural tendency to stress the final syllable of an utterance (Fromkin and Rodman, 1983).

Matlock (1989) has provided a description of the factors at a variety of levels in the speech production system beginning with anatomical and physiological constraints of the speech mechanism (Klatt, 1976), phonetic and phonological constraints (Peterson and Lehiste, 1960 and Klatt, 1976), syntactic (Klatt, 1976 and Martin, 1970) and semantic constraints (Bolinger, 1972; Holliday, 1967; Kloker, 1975; and Klatt, 1975), as well as discourse level (Lehiste, 1975 and Umeda, 1975) and extralinguistic factors (Klatt, 1976).

Intensity, or sound pressure level, is also manipulated in creating a stress contrast. Fry's (1955) investigation of both duration and intensity as physical correlates of lnguistic stress, suggested that duration ratio may be a more effective cue for judgment of stress than the intensity ratio. Nonetheless, the two parameters, duration and amplitude, interact along with changes in the fundamental frequency of a vowel to produce the impression of linguistic stress (Klatt, 1976). But, there is little information about the exact nature of that interaction. For instance, it is not known whether certain vowels rely more on durational or intensity changes for their perception as stressed sounds.

There is even less information about whether adults and children might modify intensity and duration in different ways to produce the impression of a stressed or unstressed word. It is not known whether children will apply stress rules in the same way that adults do, or whether they will be less precise in the application of those rules.

Speech timing is considered to be a critical parameter affecting motor performance and linguistic output (Kent, 1976). Physiological and acoustic data suggest that the timing of sequential speech gestures changes as a function of neuromuscular maturation (Kent, 1976; Kent and Forner, 1980; Tingley and Allen, 1975; and Watkin and From, 1984). The acoustic data on various aspects of speech production for fundamental frequency and voice onset time, reported by Kent (1976), indicated that the accuracy of motor control improves with age until "adult-like" performance is achieved at about 11 or 12 years of age, somewhat after the age at which speech sound acquisition is thought to be complete. The maturation of motor skills is not completed until the child enters puberty (Kent, 1976).

Very little is known about whether younger, communicatively less mature, preadolescents produce unusual acoustic changes in the earlier communicative years. Little is known about the age levels at which preadolescent speakers become more "adult-like" in their stress patterns. The younger preadolescents may show slight variations in durational patterns and amplitude levels between stressed and unstressed syllables. Adults may illustrate distinct differences indicative of a more precise system of applying stress rules. The group differences observed should provide basic information on the developmental changes that occur in duration and amplitude stress patterns in the speech of normally developing children.

The purpose of the present study is to derive and contrast the simultaneous vowel duration and amplitude level changes of adult and preadolescent speakers and to contrast the nature and application of syntactically induced vowel stress. The present investigation will attempt to fulfill this purpose by addressing the research hypothesis that vowel duration and vowel amplitude patterns in sentence-level stressed and unstressed syllables will be significantly different among the young preadolescent, older preadolescent, and adult speakers.

CHAPTER II

METHODS

Subjects

Three groups of volunteer subjects, young preadolescents, older preadolescents, and adults, participated in this study and in the informed consent process. The preadolescent data set was extracted from a larger sample gathered previously (Pentz, 1987). Two groups from that public elementary school sample, 15 seven-year-olds and 15 eleven-year-olds were examined. The information for male and female children was combined since previous studies had indicated that the gender factor was not a significant variable for those subjects (Kent, 1976; Pentz, 1987). None of the preadolescents selected presented any evidence of communicative or vocal pathologies and were required to have passed a school hearing screening.

The adult population contained 24 female college students between the ages of 18 and 25 years. Each adult subject participated in a hearing screening which was conducted in an acoustically treated auditory test suite. The experimenter screened at a 25 dB level for 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz, 6000 Hz, and 8000 Hz. A subject did not participate further if they failed to pass the screening at the designated intensity level for two or more frequencies, in either ear. A subject was also excluded if they presented any evidence of a communication disorder or voice pathology as determined by an independent evaluator. Finally, subjects who were receiving short-term, remediative prescriptive medications were also excluded.

Procedure

Each child was seated in a quiet room and the examiner presented a set of instructions to the participant. Each was allowed an opportunity to ask questions, and the subjects were to orally repeat, a series of sentences, one at a time after a model presented by the examiner.

Each adult subject was seated in the acoustically treated sound suite where tape-recorded directions were provided through two free-field speakers. The subject listened to a set of prerecorded instructions and was given an opportunity to ask questions. The adults then repeated the recorded sentences which were presented at 55 dB HL through the free field speakers in the sound suite. The directions and sentences were prerecorded in a sound suite using a high quality cassette tape player with an appropriately matched microphone. The target sentences to be repeated were randomly recorded, about one minute apart on each of four cassette tapes.

The subjects' responses were recorded at a tape speed of 7.5 i.p.s. using a professional quality reel-to-reel tape recorder and an appropriately matched microphone. The task order and the elements of each task were randomized for each subject.

Target Sentences

The stimulus material used for all subject groups consisted of following three sentences: "The seat is green."; "The cat is black."; and "The boot is new." The subject and complement element in each subject-verb-complement (SVC) sentence were monosyllabic words containing the same vowel. The sentences represented three different vowels /i/, /ae/, /u/, respectively. The simple SVC sentences allowed for a comparative analysis of the sentence-position, vowel amplitude, and durational stress patterns, and provided a natural context response that could be understood and reproduced by all the participants.

Analysis

Each subjects' tape-recorded sentences were directed through a Kay Elemetrics 6061B Sonagraph sound spectrograph operating in the 16 KHZ mode. A wideband spectrogram of each sentence was produced and the duration of each vowel was measured by the point at the onset and offset of the vowel, marked by the presence of the first and second formant transitions (House, 1961). Examples of determined onset and offset of vowels are contained in Appendix A. The vowel segments of the target words were measured in millimeters and then were converted to milliseconds of vowel duration.

The sentences were also analyzed using a B & K Graphic sound level recorder. A voltmeter and real-time analyzer were used to enter the speech frequencies of 500 Hz, 1000 Hz, and 2000 Hz into the graphic level recorder. For each frequency, the intensity was increased in 5 dB increments across a range of 75 to 120 dB SPL. A 5 mm displacement of the stylus corresponded to 5 dB increments for each frequency across the intensity range, establishing a one-to-one ratio between SPL and the stylus deflection. The amplitudes of the vowels were measured in dB SPL above the premeasured baseline calibration. Relative amplitude level differences (Vi-Vf) were used to control for the intensity variability factors created by ranging speaker-to-microphone distance and individual intensity variability. Examples of determined relative vowel amplitude differences can be found in Appendix C.

The vowel durations and relative vowel amplitudes provided the interval data necessary for parameter statistical analysis. The obtained measures for the two parameters were analyzed to make comparisons and to determine: (a) how adults alter duration and intensity in relation to each other; (b) how younger and older preadolescents manipulate these same parameters; and (c) whether all three groups differ when manipulating different vowels under different stress patterns.

CHAPTER III

RESULTS

Vowel durations were subjected to a three-factor (age x vowel x sentence position) mixed design analysis-of-variance. Three age groups, seven-year-olds, eleven-year-olds, and adults, formed three levels of a between-groups measure. The three vowels, /i, ae, u/, formed three levels of one within group, repeated measure. The initial and final vowel positions within sentences constituted two levels of the second within group, repeated measure.

A summary of the analysis-of-variance findings for vowel duration is included in Table 1. The results of that analysis revealed the following: First, there was a between-groups difference in vowel duration patterns. Second, the durations differed among the three vowels. Third, there was a difference between durations of vowels which occurred in the initial versus final positions within sentences. All differences were significant at the $< .01$ level. Finally, only the vowel x position interaction was significant at the $< .01$ level. Table 2 contains the mean vowel durations for each groups' /i/, /ae/, and /u/ vowels. Appendix B lists the individual vowel durations for all groups.

All significant vowel duration differences were further analyzed using the Tukey multiple comparison follow-up tests (Brunig and Kintz, 1987). This analysis revealed the following: First, vowel durations, regardless of vowel or position, were significantly longer for the adult

Table 1

Analysis of Variance Summary Table for Vowel Duration

Source	Mean-Square	df.	F-ratio	P
Between Groups				
Age (7, 11, adult)	47681.111	2	26.12	<.01
Within Groups				
Vowel /i, ae, u/	23143.793	2	40.33	<.01
Position (in sentence)	67057.736	1	56.35	<.01
Interaction				
Vowel x Age	1461.801	4	2.55	0.0438
Position x Age	1872.614	2	1.57	0.2172
Vowel x Position	5242.022	2	13.13	<.01
Vowel x Position x Age	923.201	4	2.31	0.0626

Table 2

Mean Vowel Duration of Preadolescent and Adult Speakers

Subjects	/i/ Mean	/i/ SD	/ae/ Mean	/ae/ SD	/u/ Mean	/u/ SD
7 year olds						
first vowel position	97	25	116	23	123	33
second vowel position	146	32	141	34	152	28
11 year olds						
first vowel position	83	19	116	20	131	21
second vowel position	133	43	135	28	165	36
Adults (18-25 years)						
first vowel position	136	20	157	26	164	22
second vowel position	163	27	155	32	200	37

Note. N = 15 for the two preadolescent groups and N = 24 for the adult group. Duration recorded in milliseconds.

speakers than for the preadolescent groups (See Table 3).

Second, each of the three vowels exhibited significantly different duration patterns in both positions (See Table 4). For example, in the initial sentence position, the vowel /u/ exhibited the longest duration followed by /ae/ and /i/. Whereas in the final sentence position, /u/ was the longest, followed by /i/ and /ae/.

Third, the vowel durations for the final sentence position were notably longer than the initial position patterns. The vowels in the final position were significantly different for vowels /i/ and /u/. The vowel /u/ had a duration of 143.57 msec in the initial position and 176.76 msec in the final position. The vowel /i/ had a duration of 110.41 msec in initial position and 149.81 msec in the final position. The vowel /ae/ had a duration of 134.24 msec in the initial position and 145.54 msec in the final position.

Vowel amplitude differences were subjected to a two-factor (age-group x vowel) mixed design analysis-of-variance. The age-group factor was an independent measure with three levels. The relative amplitude differences for the vowels /i/, /ae/, and /u/ constituted the three levels of a dependent repeated measure. There was no word position factor involved in this contrast since the relative amplitude values used in the analysis were determined from the amplitude level differences between the words in the initial and final sentence positions.

Table 3

Follow-Up Analysis: Vowel Durations Between Age Groups

Vowel	7 yrs	11 yrs		Adult
	<------------*------------>			
/i/ initial	97	83	<----*---->	136
/i/ final	146	133	<----*---->	163
	<------------*------------>			
/ae/ initial	116	116	<----*---->	157
/ae/ final	141	135		155
	<------------*------------>			
/u/ initial	123	131	<----*---->	164
/u/ final	152	165	<----*---->	200
	<------------*------------>			

Note. The asterisk (*) indicates duration differences exceeding the critical difference value. Duration in milliseconds.

Table 4

Follow-Up Analysis: Vowel Durations Between Vowels and Positions

Sentence Position	Vowel /i/		Vowel /ae/		Vowel /u/
			<------------*----------->		
Initial	110.41	<--*-->	134.24		143.57
	| * |				| * |
Final	149.81		145.54	<--*-->	176.76
			<------------*----------->		

Note. The asterisk (*) denotes durational differences exceeding the critical value. Duration recorded in milliseconds.

The results of that analysis revealed no significant differences between age groups or in relative amplitude differences among the vowels (See Table 5). Table 6 contains the mean vowel amplitude differences for each groups' /i/, /ae/. and /u/ vowels. Appendix D lists the individual vowel amplitudes for all groups.

Table 5

Analysis of Variance Summary Table for Vowel Amplitude

Source	Mean-Square	df	F-ratio	P
Between Groups				
Age (7, 11, Adult)	81.8Ø9	2	3.13	Ø.Ø523
Within Groups				
Vowel /i, ae, u/	8.813	2	.61	Ø.5435
Interaction				
Age x Vowel	34.495	4	2.4Ø	Ø.Ø548

Table 6

Mean Relative Vowel Amplitude Differences of Preadolescent and Adult Speakers

Subjects	/i/ Mean	/i/ SD	/ae/ Mean	/ae/ SD	/u/ Mean	/u/ SD
7 year olds						
Relative Amp Difference (Vi-Vf)	19	4	22	7	21	6
11 year olds						
Relative Amp Difference (Vi-Vf)	20	3	19	6	20	6
Adults (18-25 years)						
Relative Amp Difference (Vi-Vf)	19	2	17	2	18	3

Note. N = 15 for the two preadolescent groups and N = 24 for the adult group. Relative vowel amplitude differences recorded in dB SPL. A constant of 20 was added to each difference to obtain positive values.

CHAPTER IV

DISCUSSION

The results of this investigation seemed to indicate the following: First, there were significant differences between the preadolescent and adult durational stress patterns. Vowel durations for all three vowels in both positions were significantly longer for the adult speakers. The duration patterns of both preadolescent groups, seven year-olds and 11 year-olds, were slightly more variable than those of the female adult subjects. The wider range of variability among developing preadolescents concurs with Kent's (1976) survey of acoustic studies of speech development in which the accuracy of motor controls improves with age until "adult-like" performance is achieved at around 12 years.

DiSimoni (1974) also reported that variability of vowel and consonant durations in CVC and VCV utterances of children aged three, six, and nine years, tended to decrease with age. Eguchi and Hirsh (1969) found that standard deviations of the first and second formants, for five vowel segments within sentences, revealed a fairly uniform decrease in the variability as subject age increased from three to 11 years. The investigations of timing in phrase- and sentence-length utterances by Tingley and Allen (1975) give further evidence of a definite developmental pattern in which all of the 11 year-old children performed within adult limits of relative variance. The present investigation also indicates that the seven- and 11 year-old subjects demonstrated greater variability and, perhaps, less precision than the adults in using durational stress patterns.

Temporal properties of speech production may be a valuable means of evaluating developmental abnormalities because timing is viewed as one of the most critical factors in skilled motor performance (Lashley, 1951; Martin, 1972; and Michon, 1974). Since significant timing differences continued to be manifest in the performance between the preadolescents and adults, further studies should address the pattern of maturational growth across 11-, 12-, and 13-year-old children. Such a study on the temporal aspects of speech production would provide additional baseline data on the neuromuscular maturation of the speech mechanism.

Second, the results indicated that there were significant durational differences among the vowels regardless of which group produced the utterances. Statistical comparisons indicated that /u/ exhibited the longest duration in both positions, followed by /ae/ then /i/ in the initial position and followed by /i/ then /ae/ in the final position. The durational differences among vowels were probably due, not only, to the inherent differences in duration among vowels (Borden and Harris, 1984) but also, to the effect of the consonant environment (House and Fairbanks, 1952).

For example, the vowel /u/ appears in the initial position with an arresting stop consonant and in final position with no arresting consonant allowing for a longer sustained production. The vowel /i/ appears in the initial position with an arresting stop consonant and in the final position with an arresting nasal consonant which supports the voicing quality of the vowel. The vowel /ae/ appears in the initial position with an arresting stop consonant and in the final position with an arresting voiceless velar consonant which quickly ends the vowel's duration.

Third, the results also indicated a significant difference in the vowel durations across the two sentence positions for all subjects. For each vowel, the final sentence position was longer than it was in the initial position. Gaitenby (cited in Klatt, 1976) and Lyberg (1977) reported that final syllables in sentences were longer in duration than their initial counterparts. This finding further supports Halliday's (1967) report that speakers tend to stress the information at the end of sentences. Klatt (1975) reported an approximate 30 percent difference in stressed and unstressed vowel durations. Matlock (1989) found a cummulative 35 percent difference in final versus initial sentence position in four vowels /ae, i, a, u/. The present investigation suggests that the stress was marked primarily with vowel lengthening and to a lesser degree with vowel intensity even in the younger preadolescent group of speakers.

While some amount of stress was marked through intensity changes, the results of the vowel amplitude analysis did not reveal significant differences between the age groups or between the vowels at the .01 level; however, the tail probabilities for the between group factor and the age x vowel interaction were considerably close to the probability factor of .05 (0.0523 and 0.0548 respectively) indicating a trend toward age-group differences and an age x vowel interaction. While not a significant difference, this trend needs to be investigated further to determine the nature of amplitude manipulations across various age groups in stressed and unstressed syllables. The standard deviations for the mean relative vowel amplitude differences also revealed a fairly uniform decrease in variability as subject age increased. This finding parallels the age-related variances in the studies of Eguchi and Hirsh (1969) and DiSimoni (1974).

CHAPTER V

SUMMARY

Tape recorded samples of the speech of 15 seven-year-olds, 15 eleven-olds, and 24 college females were used to study the duration and amplitude levels of vowels. Three vowels, /i, ae, u/, were represented in sentence-initial unstressed and sentence-final stressed positions to compare the acoustic parameters in different stressing environments.

The durations and amplitudes of the vowels were determined and the analyses of variance contrasting these values revealed that final sentence position stress was primarily indicated through vowel lengthening in all subject groups. Significant between-groups differences were evident in vowel duration patterns. The durations also differed significantly among the three vowels. Finally, there was a significant difference between durations of vowels which occurred in the two sentence positions with the final position receiving the most emphasis.

The amplitude patterns did not reveal significant differences between the age groups or among the vowels; however, the increased variability among the preadolescents follows the developmental trend found with the durational changes. Neuromuscular maturation of the speech mechanism and consequent motor control may be more appropriately measured through durational changes which require a neural-timing control mechanism (Tingley and Allen, 1975).

The lack of any definitive durational trends in the vowel x position interaction led the investigator to conclude that at least part of this interaction might be attributable to contextual variations. It may follow that vowel amplitude is also context sensitive. Future research involving the interaction of these acoustic parameters in developmental studies should control for the contextual environment.

Finally, the present results indicate that developing speakers, even as young as age seven, tend to manipulate vowel duration and to a lesser extent vowel amplitude levels in producing stress contrast patterns. They do so in a manner very much like that used by their mature adult counterparts. However, they seem to lack the manipulative precision of the adult speakers. Future investigations will need to address additional acoustic and segmental manipulations including pausal patterns and frequency variations so that an even better understanding of the developing speech skill of the preadolescent can be provided.

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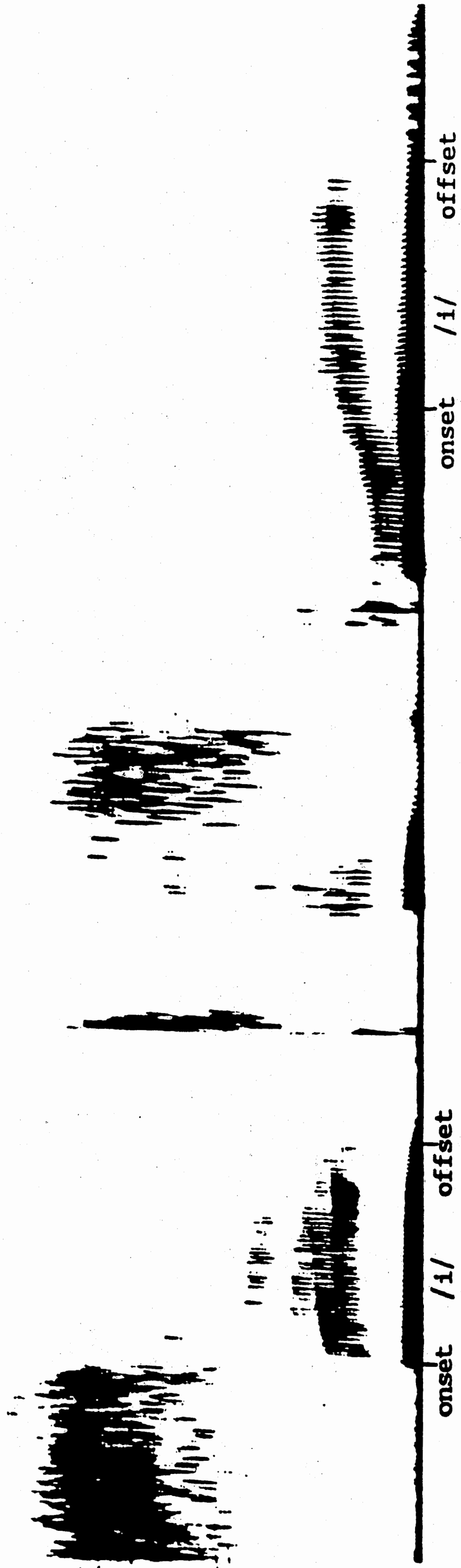
APPENDIXES

APPENDIX A

ONSET AND OFFSET OF VOWELS IN THE

PHRASE "THE SEAT IS GREEN"


onset
/i/
offset
onset
/i/
offset

APPENDIX B

INDIVIDUAL VOWEL DURATIONS

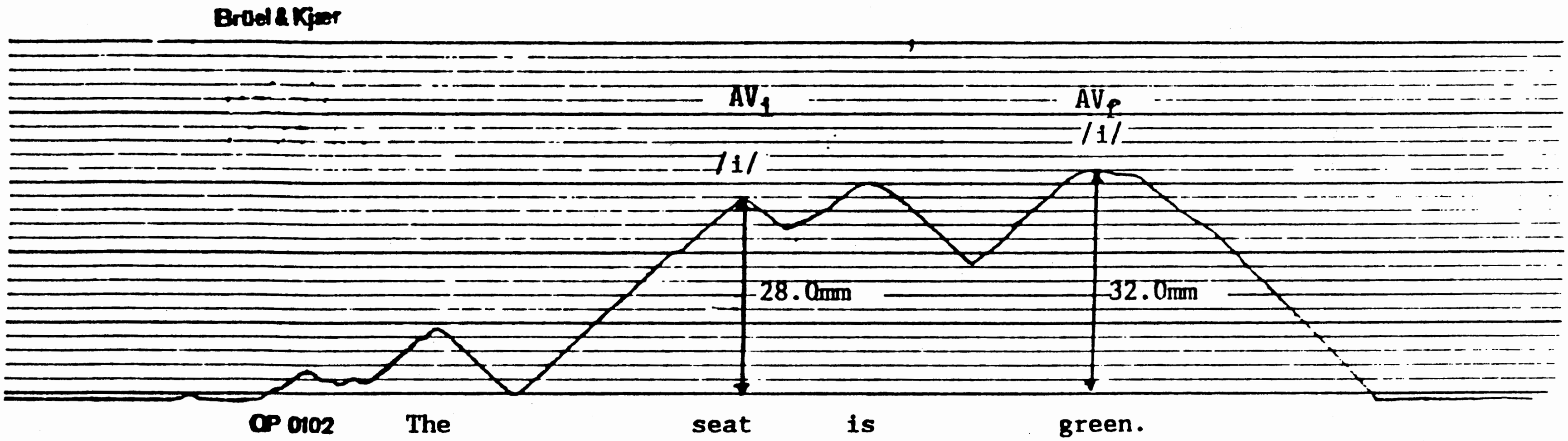
Adult SUBJECT	Vowel /i/ Position Initial	Final	Vowel /ae/ Position Initial	Final	Vowel /u/ Position Initial	Final
SA1	177	181	147	124	173	173
SA2	158	177	200	196	170	215
SA3	158	207	158	200	170	283
SA4	128	139	139	158	158	189
SA5	136	158	177	162	162	189
SA6	147	158	234	204	162	268
SA7	128	204	151	151	211	264
SA8	151	189	166	177	170	207
SA9	109	170	143	147	132	173
SA10	147	200	143	098	181	200
SA11	155	189	162	173	189	192
SA12	124	170	158	121	166	166
SA13	143	124	147	147	139	177
SA14	151	121	192	170	181	185
SA15	124	166	136	143	151	155
SA16	140	132	166	170	177	226
SA17	098	109	109	102	128	151
SA18	147	140	166	155	204	200
SA19	140	170	155	162	140	192
SA20	121	155	124	158	140	151
SA21	098	143	162	109	143	162
SA22	106	185	124	222	177	215
SA23	155	185	166	124	177	230
SA24	128	140	140	151	136	238

11 yr-old SUBJECT	Vowel /i/ Position		Vowel /ae/ Position		Vowel /u/ Position	
	Initial	Final	Initial	Final	Initial	Final
SOC1	075	064	132	102	128	132
SOC2	087	106	090	102	124	124
SOC3	109	136	132	109	132	113
SOC4	090	109	106	094	143	177
SOC5	113	151	121	147	155	158
SOC6	068	136	102	143	106	222
SOC7	072	155	162	177	166	204
SOC8	057	109	124	151	106	185
SOC9	068	215	098	158	128	170
SOC10	072	185	094	117	094	158
SOC11	083	128	102	162	106	143
SOC12	075	158	109	151	143	204
SOC13	057	128	113	147	139	215
SOC14	113	162	147	166	158	158
SOC15	106	049	106	102	143	109

7 yr-old SUBJECT	Vowel /i/ Position		Vowel /ae/ Position		Vowel /u/ Position	
	Initial	Final	Initial	Final	Initial	Final
SYC1	102	173	113	177	106	139
SYC2	132	173	147	189	170	177
SYC3	079	124	098	098	117	147
SYC4	143	106	143	128	185	155
SYC5	083	124	121	109	113	102
SYC6	083	139	098	166	098	215
SYC7	072	230	072	128	121	173
SYC8	102	132	113	113	128	158
SYC9	079	143	117	173	064	166
SYC10	068	143	136	117	128	128
SYC11	068	132	121	177	087	106
SYC12	121	113	109	079	094	166
SYC13	124	158	102	128	170	139
SYC14	113	173	158	170	136	158
SYC15	079	124	098	155	128	143

APPENDIX C

RELATIVE AMPLITUDE DIFFERENCES IN THE PHRASE "THE SEAT IS GREEN"



<u>Note</u>. $AV_i - AV_f + 20$ = Relative Vowel Amplitude Difference in dB SPL.

The constant 20 was added to obtain positive values.

APPENDIX D

INDIVIDUAL VOWEL AMPLITUDES

Adult SUBJECT	Vowel /i/	Vowel /ae/	Vowel /u/
SA1	23	18	19
SA2	21	18	16
SA3	23	18	23
SA4	20	20	18
SA5	18	17	17
SA6	14	14	12
SA7	19	20	19
SA8	20	15	18
SA9	18	17	20
SA10	17	19	17
SA11	21	18	19
SA12	20	14	19
SA13	19	16	17
SA14	22	18	22
SA15	20	16	20
SA16	20	14	18
SA17	19	16	16
SA18	16	18	15
SA19	22	20	24
SA20	19	15	18
SA21	18	15	20
SA22	17	16	17
SA23	21	10	21
SA24	18	19	18

11 yr-old SUBJECT	Vowel /i/	Vowel /ae/	Vowel /u/
SOC1	17	22	17
SOC2	23	15	19
SOC3	21	14	18
SOC4	17	03	17
SOC5	14	21	15
SOC6	21	21	17
SOC7	22	25	26
SOC8	25	19	26
SOC9	19	17	20
SOC10	16	16	28
SOC11	24	27	30
SOC12	22	23	26
SOC13	22	22	19
SOC14	23	21	17
SOC15	17	18	10

7 yr-old SUBJECT	Vowel /i/	Vowel /ae/	Vowel /u/
SYC1	15	28	19
SYC2	20	17	17
SYC3	22	23	35
SYC4	14	32	25
SYC5	19	25	23
SYC6	25	09	21
SYC7	24	29	23
SYC8	18	23	07
SYC9	16	16	29
SYC10	15	18	19
SYC11	20	17	22
SYC12	14	14	16
SYC13	17	18	20
SYC14	23	31	20
SYC15	21	24	18

VITA

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