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I am submitting herewith a thesis written by Karen Annita Colson entitled "Acoustical Analyses of Duration Differences in the Production of Nonsense Syllables by Normal and Apraxic Speakers." I recommend that it be accepted for the degree of Master of Arts, with a major in Speech Pathology.

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ACOUSTICAL ANALYSES OF DURATION DIFFERENCES IN THE PRODUCTION OF NONSENSE SYLLABLES BY NORMAL AND APRAXIC SPEAKERS

A Thesis

Presented for the

Master of Arts

Degree

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ABSTRACT

The purpose of this study was to determine if there were differences between normal and apraxic speakers in the durations of selected consonants and vowels. Five normal and five apraxic speakers were presented prerecorded stimuli consisting of the three nonsense disyllables, /pɑkə/, /tɑpə/, and /kɑtə/ embedded within the carrier phrase, "You will say ____." Tape recordings were made as each of the subjects imitatively produced each of the three nonsense disyllables twenty times. The responses were judged for articulatory accuracy, and five productions of each nonsense disyllable for each subject were selected for the duration analyses. The consonant and vowel durations in these utterances were analyzed and measured by use of a digital storage oscilloscope.

The consonant and vowel duration measurements were statistically treated by computing means, standard deviations, and ranges for each speaker as well as for the normal and apraxic groups. The group means, standard deviations, and ranges were compared to determine differences between the groups in consonant and vowel durations. The duration measurements for each apraxic subject also were compared with measures for the normal group to determine whether individual speakers followed the trend evidenced by the group as a whole.

The major findings of this investigation were that the apraxic group consistently demonstrated longer consonant durations than the normal group, particularly for the initial consonants. This trend also

was evidenced by each individual apraxic speaker. Further, the results were that the apraxic group consistently exhibited longer vowel durations than the normal group, particularly for the final vowels. This trend often was less apparent among the vowel durations for each individual apraxic subject.

From the results of this study, it may be concluded that there are differences in the durations of selected consonants produced by normal and apraxic speakers. Similarly, there are differences in the durations of selected vowels produced by normal and apraxic speakers. These differences in duration are one aspect of the disturbance of prosody in apraxia of speech, and further research is necessary to determine whether these alterations are compensatory in nature or whether they reflect a primary prosodic disturbance in the disorder.

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CHAPTER I

INTRODUCTION

Apraxia of speech is a neurogenic disorder characterized by disturbances in both articulation and prosody (Darley, Aronson, and Brown, 1975; Rosenbek, 1978). Previous investigators (Shankweiler and Harris, 1966; Johns and Darley, 1970; Trost and Canter, 1974; LaPointe and Johns, 1975; Marquardt, Reinhart, and Peterson, 1979) have provided detailed phonemic analyses of the articulatory behavior of apraxic speakers. Varied factors influencing the articulation of apraxic speakers have been examined and identified in a number of studies (Deal and Darley, 1972; Dunlop and Marquardt, 1977; Hardison, Marquardt, and Peterson, 1977). However, few investigations have been conducted to systematically examine the prosodic disturbances manifested in apraxia of speech (Tonkovich, Asp, Shadden, and Mason, 1977). As a major feature of the disorder, disturbed prosody should be a prominent area of evaluation. This study was designed to examine selected aspects of prosody in apraxic speaker's speech patterns.

Review of the Literature

Studies of Articulation

Traditional approaches employed by investigators to differentiate apraxia of speech from other expressive neurological disorders have focused on obtaining descriptive criteria of the articulatory disturbance manifested in the condition. Shankweiler and Harris (1966)

analyzed the performance of apraxic patients in reading specially constructed monosyllables. From the results, the researchers reported that initial sounds were more difficult than final, and more errors were produced on consonants than vowels. Consonant clusters, fricatives, and affricatives were most frequently in error with unrelated substitutions and omissions predominating error type. The investigators concluded that the errors were not attributable to specific muscles or muscle groups.

Johns and Darley (1970) analyzed and compared the articulatory performance of apraxic speakers with that of dysarthric and normal subjects. The investigators reported that the speech pattern of the apraxic speakers was characterized by a high degree of inconsistent initial consonant production consisting predominantly of substitutions, repetitions, and additions. The investigators also reported an increment in articulation error with an increase in word length. The investigators observed an improvement in production with consecutive trials of response and facilitation of correct articulation through particular modes of stimulus presentation. Further, the investigators noted marked prosodic disturbance without phonatory and resonatory changes. However, these disturbances in prosody were not investigated in the course of the study.

Trost and Canter (1974) studied phoneme production accuracy and error patterns of Broca's aphasics with apraxia of speech. From analyses of their data, the investigators concluded that presentation mode, phoneme position, and phoneme frequency of occurrence affected

articulation proficiency, and that the majority of substitution and distortion errors made by the speakers were a close approximation of the target phoneme.

Further delineation of the phonological characteristics of apraxic speakers was completed by LaPointe and Johns (1975). From phonemic analyses of the articulation of apraxic speakers, the researchers reported that consonant clusters were more susceptible to error than consonant singletons, and more errors were produced on consonants than vowels. In contrast to previous findings (Shankweiler and Harris, 1966; Trost and Canter, 1974), the investigators reported that phoneme position did not significantly affect articulation. Analysis of error, according to manner and place of production, revealed that affricatives and fricatives were significantly more impaired than all other manner categories, and lingua-alveolar and bilabial phonemes were more frequently correct than sounds produced at other places. Further analysis of phonemic production indicated that substitution errors were predominantly anticipatory in nature and often bore little resemblance to the target phonemes.

Research has been conducted to investigate specific features of the articulatory disturbances manifested in apraxia of speech. Marquardt, Reinhart, and Peterson (1979) utilized markedness analysis to determine whether phoneme substitution patterns of apraxic speakers were systematically patterned. The authors reported that the apraxic speakers produced significantly more substitution errors on phonemes high in markedness and that the intruded consonants were significantly

more often less marked than their feature targets. In addition, error frequency and directional changes in markedness were positively correlated with ease of articulation. The investigators interpreted their findings as "a systematic effort by the apractic speakers to reduce the complexity of articulatory gestures required to produce phonemes."

Sands, Freeman, and Harris (1978) conducted a longitudinal case study to analyze the changes in articulatory pattern in verbal apraxia as a function of time and therapeutic intervention. The investigators reported that there was a marked reduction in errors of omission, place, and manner, while voicing errors predominated the residual errors.

Freeman, Sands, and Harris (1978) tested the hypothesis that the voicing errors in an apraxic patient's speech were related to impairments in the temporal coordination of phonation and articulation. Data were obtained in the study by measurement of voice onset time for initial stops. The researchers reported that the apraxic productions were markedly different from those of normal subjects in voicing lead for voiced stops and in lag times for both voiced and voiceless stops. The investigators concluded that the voicing errors produced by the apraxic speaker were related to temporal incoordination.

Several investigations have been directed toward examining the effects of selected language variables on the articulatory accuracy of apraxic speakers. Deal and Darley (1972) reported that the combination of grammatical class and word length significantly contributed to the generation of phonemic errors in apraxic speakers. Dunlop and Marquardt

(1977) reported a significant relationship between word abstraction and error production in apraxic subjects. Hardison, Marquardt, and Peterson (1977) examined the effects of sentence voice, noun phrase position, and word abstraction on the articulatory performance of apraxic speakers. From the results, the investigators concluded that selected linguistic variables significantly influenced programming of sequential speech movements.

Studies of Perceptual Dysfunction

Investigators have recently reported that auditory and sensory perceptual dysfunction also may accompany apraxia of speech. In an assessment of auditory perception of sequenced words, Aten, Johns, and Darley (1971) compared the performance of apraxic patients with a matched group of control subjects. The authors reported that the apraxic speakers demonstrated significantly more perceptual errors as a group, but varied considerably in individual level of performance. Impairment in the retention of the second and third syllable consonant elements in three word sequences appeared to be the major deficit in the apraxic group. The investigators concluded that apraxia of speech can occur in relatively pure form in the absence of auditory impairment, or in conjunction with reduced auditory retention span.

Rosenbek, Wertz, and Darley (1973) administered three tests of oral sensation and perception to patients with apraxia of speech, to patients with aphasia and no apraxia of speech, and to normal subjects. Although not all patients with apraxia of speech demonstrated impaired oral sensation and perception, their performance, as a group, was

significantly inferior to that of the aphasic and normal groups. The investigators noted that the more severe the apraxia of speech, the more profound the oral sensory-perceptual deficit.

Studies of Prosody

Prosodic disturbances have been recognized as a characteristic feature of apraxic speakers. Johns and Darley (1970) noted alterations in the prosodic patterns of apraxic subjects in contextual speech. The investigators reported that the apraxic subjects' rate of speech tended to be reduced, even, and hesistant as they effortfully groped for the correct production. The researchers interpreted the alterations in prosody as compensatory adjustments to gain articulatory control.

Darley, Aronson, and Brown (1975) reached similar conclusions regarding the prosodic disturbances in apraxia of speech. The authors stated: "As patients struggle to avoid articulatory error by careful programming of muscle movements, they slow down, space their words and syllables evenly, and stress them equally. Thus the prosody of their speech is altered as well as their articulation" (p. 250).

Tonkovich et al. (1977) examined the ability of apraxic and normal speakers to imitate a wide range of suprasegmental patterns. Resulting measurements from the Test of Rhythm and Intonation Patterns (Koike, 1977) revealed that the apraxic subjects' performance was significantly inferior to that of the normal group. The investigators inferred that "apraxic speakers have difficulty with the temporal patterning of rhythmic sequences" (p. 7).

Rationale

From a review of the literature, it is evident that considerable research interest has been directed toward obtaining descriptive criteria to differentiate apraxia of speech from other expressive neurological disorders. As researchers have attempted to define and describe the disorder, certain features have been recognized as primary symptoms. Current definitions of the disorder denote an impairment in articulation and prosody in the absence of significant weakness, paralysis, or incoordination of the speech musculature.

Apparently, in the past, most investigators have regarded apraxia of speech primarily as a distinctive articulatory disorder. This classification has influenced considerably the investigation, description, and ultimately the diagnosis of the disturbance. The majority of research has focused on specification of the articulatory characteristics of apraxic speakers. Investigators have relied on segment error data to develop descriptive criteria to differentiate the disorder. Consequently, diagnostic techniques have emphasized assessment of the pattern of articulatory performance.

Generally, the prosodic disturbances associated with apraxia of speech have received minimal research attention. Research contributions related to the study of disturbed prosody in apraxia of speech have consisted predominantly of observations made during the course of investigations of articulation. In these reports, authorities have inferred that the alterations in prosody are compensatory in nature, reflecting the apraxic speakers' attempt to cope with articulation

difficulties. In one study, investigators reported that apraxic speakers' ability to imitate suprasegmental patterns is significantly poorer than that of normal subjects.

Due to the limited amount of research conducted to examine the nature and extent of prosodic disturbances in apraxia of speech, relatively inadequate descriptions of the alterations in prosody comprise the bulk of information published in the literature. In consideration of the view that disturbed prosody is a primary symptom manifested in apraxia of speech, the information presently contained in the literature is insufficient. Further investigation of the prosodic disturbances in apraxia of speech would enhance the understanding of the disorder and may provide information of special importance for differential diagnosis and treatment.

Purpose of the Study

Prosody is defined as the physical attributes of speech that signal linguistic qualities such as stress and intonation. It includes the fundamental frequency of the voice, the intensity of the voice, and the duration of the individual speech sounds (Nicolosi, Harryman, and Kresheck, 1978). The purpose of this study was to examine one aspect of prosody in the apraxic speakers' speech pattern, that of duration. More specifically, through an analysis of selected consonant and vowel durations in specific nonsense disyllables, answers to the following questions were sought:

1. Are there differences in the durations of selected consonants produced by normal and apraxic speakers?

2. Are there differences in the durations of selected vowels produced by normal and apraxic speakers?

Definition of Terms

The following definitions of terms were those accepted for use in this study:

Consonant duration referred to the time elapsed, in milliseconds, from the termination of the acoustical characteristics of the vowel preceding that consonant to the initiation of the acoustical characteristics of the succeeding vowel.

Vowel duration referred to the time elapsed, in milliseconds, from the termination of the consonantal burst preceding that vowel to the termination of the acoustical characteristics for that vowel.

CHAPTER II

METHOD

Subjects

Five normal speakers and five apraxic speakers participated in this study. All subjects were native speakers of English and demonstrated normal hearing sensitivity as determined by puretone hearing thresholds not exceeding 20 decibels in the better ear (ANSI, 1969) at 500, 1000, and 2000 Hertz. In addition, the normal speakers presented no evidence of a speech, language or neurological disorder, and the apraxic speakers met the following criteria:

1. A medically diagnosed history of nonprogressive left hemisphere brain damage incurred no less than three months prior to this investigation.
2. Articulatory characteristics consistent with a diagnosis of mild to moderate apraxia of speech (LaPointe and Johns, 1975), as judged by responses to tasks for assessing apraxia of speech (Darley, Aronson, and Brown, 1975; Goodglass and Kaplan, 1972).
3. A mild expressive aphasia and no significant auditory comprehension deficits as judged by responses to the Conversational and Expository Speech and Auditory Comprehension subtests of the Boston Diagnostic Aphasia Examination (Goodglass and Kaplan, 1972).

4. No reported premorbid communication impairments nor structural speech mechanism anomalies.

The normal speakers ranged in age from 48 to 66 years, with a mean age of 58.5 years, while the range of ages for the apraxic speakers was 48 to 66 years, with a mean age of 58.4 years. There were three males and two females within each group of subjects. Individual subject information is presented in Appendix A.

Stimuli

The stimuli utilized in the speech task consisted of three CVCV disyllables, /pɑkə/, /tɑpə/, and /kɑtə/. The consonants /p/, /t/, and /k/ were chosen because it is reported that apraxic speakers' production of voiceless plosives is more frequently correct than their production of other consonant sounds (Shankweiler and Harris, 1966; Johns and Darley, 1970; Trost and Canter, 1974). The nonsense disyllables were constructed so that each consonant occurred in a stressed and unstressed syllable. This sequence provided a means of assessing differences in consonant duration in stressed and unstressed syllables.

For presentation purposes, each disyllable was embedded in the carrier phrase, "You will say _____." A recording was made as a trained, male, adult speaker produced each of the three stimulus phrases ten times. The phrase productions were recorded randomly for presentation with the restriction that a stimulus condition not be repeated more than twice in succession. The prerecorded utterances were

utilized subsequently to elicit imitative productions from each of the subjects.

Equipment

A Sony (Model TC377) tape recorder was utilized for prerecording and presenting the stimuli. In addition, a Sony (Model TC377) tape recorder was used to obtain recordings of each stimulus presentation and each subject's experimental productions. Each subject's recorded disyllabic productions were replayed from the Sony (Model TC377) tape recorder into a Nicolet (Model Explorer II with the 2090-2 main frame and 206-2 plug in module) digital storage oscilloscope to obtain duration measurements of the signals. Additionally, a MFE Plotamatic (Model 715M) was utilized to record tracings of the waveform produced by the oscilloscope for each of the recorded disyllabic productions.

Experimental Procedures

Each subject was seated in a quiet room facing the examiner. A training session consisting of eight practice items was completed to familiarize the subject with the task. Then, the thirty stimulus phrases were presented to the subject. The subject was given one model to imitate and was allowed two consecutive attempts to produce the desired response. The subject was instructed to repeat the entire speech sample following the presentation. A condensor microphone was situated approximately six inches from the subject. The thirty prerecorded stimuli were presented (Sony, Model TC377) in the sound

field at 75 decibels with a 25 decibel signal to noise ratio. The stimulus phrase and the subject's response were recorded on a second tape recorder (Sony, Model TC377).

The subjects' responses were judged by a speech pathologist to determine the accuracy of articulation in the imitative productions. The responses were judged to be accurate reproductions when they were phonetically identical to the stimulus presentation. Only those responses which were considered to be correct imitative productions of the stimuli were included in the analyses. Five reproductions of each nonsense disyllable for each of the ten subjects were selected for the duration analyses.

Duration Analysis

The recorded responses were replayed from the tape recorder (Sony, Model TC377) into the digital storage oscilloscope (Nicolet, Model Explorer II) to obtain signal waveforms for analysis and measurement. One disyllable was stored on the digital storage oscilloscope at a time so that the investigator could examine the waveform. Hardcopies of the waveforms, from the X-Y plotter (MFE Plotamatic, Model 715M) were utilized to define where initiation and termination of each speech segment occurred. Initiation and termination of each speech segment were designated as the first and last observable change in the pattern of the waveform for the segment of interest. The duration of each phoneme was determined from measurement of the defined initiation and termination characteristics on the waveform. Duration measurements for

the consonants and vowels were expressed in milliseconds. These measures were obtained from the direct read of the digital storage oscilloscope.

CHAPTER III

RESULTS

Tape recordings of five normal and five apraxic subjects' productions of three nonsense disyllables were analyzed and measured to determine the durations of selected consonants and vowels. A total of 150 utterances were analyzed for the ten subjects, consisting of five productions of each disyllable by each subject. The duration measurements for each normal and apraxic subject are presented in Appendices B and C, respectively. From these measures, means, standard deviations, and ranges were computed for each speaker, as well as for the normal and apraxic groups as a whole. These group means, standard deviations, and ranges were compared to determine differences between the groups in consonant and vowel durations. The duration measurements for each individual apraxic subject also were compared with measures from the normal group to determine whether individual speakers followed the trend evidenced by the apraxic group as a whole.

Reliability

Intra-Examiner Reliability

Intra-examiner reliability was established by remeasuring the consonant and vowel durations of fifty randomly selected responses. The duration measurements were compared to the measurements obtained for the same utterances in the initial analyses. A standard error was computed

for the two sets of consonant duration measurements and the two sets of vowel duration measurements by using the following formula:

$$S.E. = \sqrt{\frac{\Sigma(X_1 - X_2)^2}{2n}}$$

where X_1 = initial duration measurements

X_2 = repeated duration measurements

n = the number of measurements taken

The standard error of measurement for the consonant durations was 4.1 ms. For the vowel durations, the standard error of measurement was 6.5 ms. Gay (1978) reported duration measurements accurate within the range of ± 10 ms.

Intra-Subject Reliability

Intra-subject reliability was determined by repeating the entire experimental testing procedure one week after the first assessment with two randomly selected subjects, one normal and one apraxic speaker. The responses of each subject were analyzed and measured to determine the consonant and vowel durations for each of the disyllables in the speech task. These consonant and vowel duration measurements for each subject then were compared to the measurements obtained in the initial analyses. In order to determine reliability, a standard error was computed for the two sets of consonant duration measurements and the two sets of vowel duration measurements for each subject. The standard error of measurement for the responses of the normal speaker was 2.9 ms. for consonant durations and 6.3 ms. for vowel durations. For the responses

of the apraxic speaker, the standard error of measurement was 20.6 ms. for consonant durations and 7.0 ms. for vowel durations.

Differences in Consonant Durations

Differences between the Normal and Apraxic Groups

Three selected consonants, /p/, /k/, and /t/, were produced five times in the initial and in the medial positions of disyllables by each of the normal and apraxic speakers. The group means, standard deviations, and ranges for the durations of these consonants in each position are presented in Table I. These data are presented in graphic form in Figure 1. Examination of the table indicates that the mean consonant durations of the apraxic speakers exceeded those of the normal speakers for each of the three consonants in both positions. Further inspection of the means reveals that the greatest differences between the two groups existed in the durations of the initial or stressed consonant of each disyllable. These duration differences between the groups for the initial consonants were consistently in excess of 125 ms. However, differences between the normal and apraxic group means for the durations of the medial consonants were relatively small, 29.6 ms. for /p/, 16.3 ms. for /k/, and 7.1 ms. for /t/. Greater differences in duration between the groups for the initial consonants than for the medial consonants may be accounted for by noting that the mean consonant durations for the normal speakers were relatively stable for both the initial and medial positions. However, for the apraxic speakers there was a large difference in duration according to the position of the

TABLE I

SUMMARY OF GROUP MEANS, STANDARD DEVIATIONS, AND RANGES OF THE INITIAL AND MEDIAL CONSONANT DURATIONS, EXPRESSED IN MILLISECONDS, FOR THE NORMAL AND APRAXIC SUBJECTS

Group	/p/		/k/		/t/	
	I	M	I	M	I	M
Normal						
Mean	144.98	158.46	145.28	133.88	150.28	155.12
SD	21.30	25.75	23.19	18.54	31.94	15.29
Range	119-182	127-204	113-181	113-165	119-210	137-176
Apraxic						
Mean	310.08	188.06	288.26	150.22	325.22	161.22
SD	343.41	47.38	189.43	35.64	171.84	24.45
Range	212-517	122-238	149-662	95-205	207-662	123-188

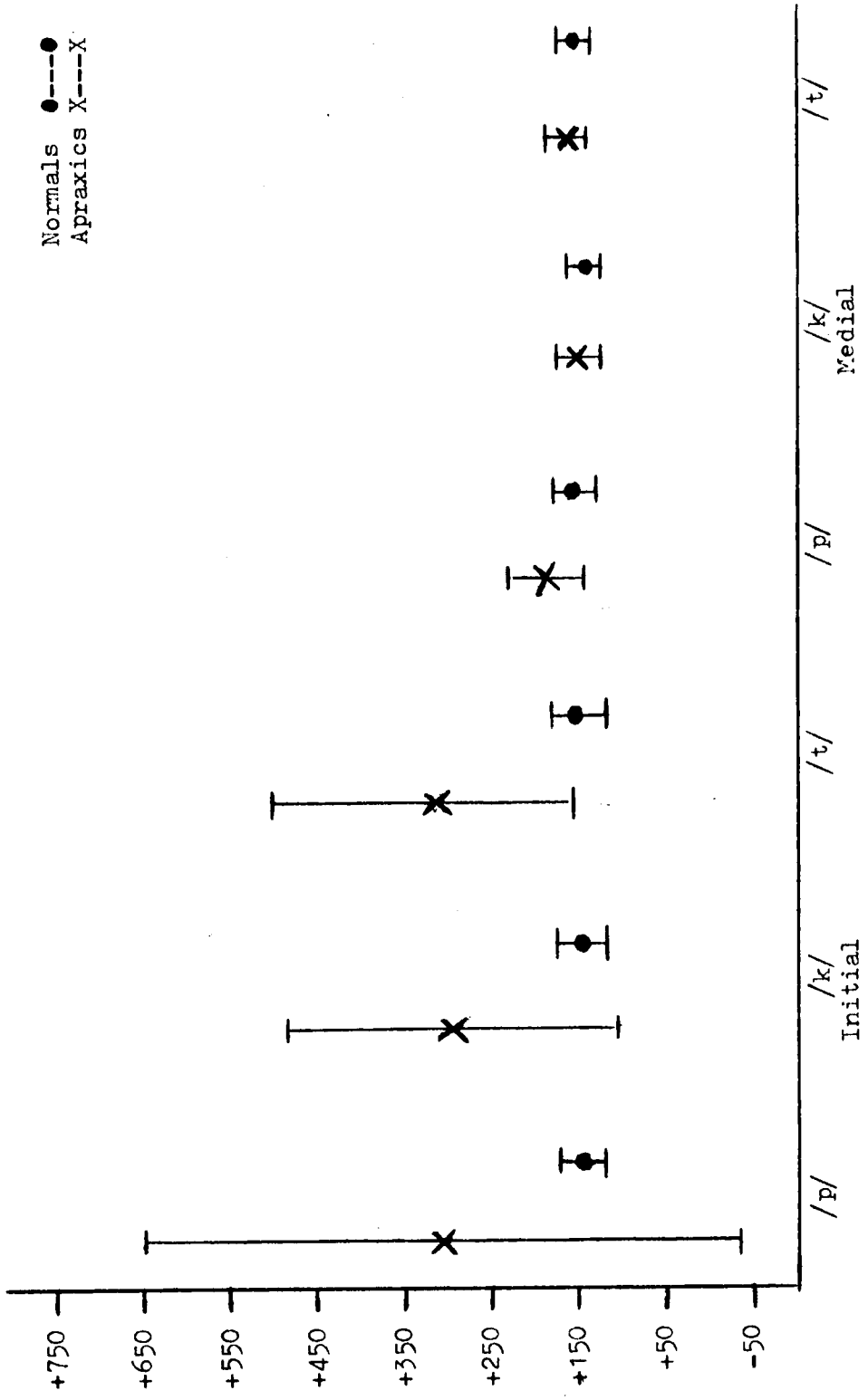


Figure 1. Group Means and Standard Deviations of the Initial and Medial Consonant Durations for the Normal and Apraxic Subjects.

consonant in the disyllable. It is interesting to note from further comparison that the largest and smallest overall differences between the group means occurred in the durations of the initial and medial /t/ phoneme. That is, for the initial /t/, the apraxic group mean duration was 325.22 ms., while the mean duration for the normal group was 150.28 ms. This was the largest difference between the normal and apraxic speakers. In contrast, for the medial /t/, there was less difference between the groups than in any other instance, with the normal and apraxic speakers having group means of 155.12 ms. and 161.22 ms., respectively.

The standard deviations and ranges presented in Table I were utilized to determine group variability in duration. Inspection of this table indicates that the apraxic subjects were considerably more variable than the normal subjects. For example, it can be seen that the standard deviations and ranges of the apraxic group were larger than those of the normal group in every instance. Further examination of these values reveals that there was a greater difference in variation between the two groups for the initial consonants than for the medial consonants because the apraxic group exhibited the greatest amount of variation in the production of these consonants. It is interesting to note that both groups demonstrated the least amount of variation in consonant duration for the same phoneme. That is, the standard deviations and ranges for the normal and apraxic groups were smaller for the medial /t/ phoneme than for any other consonant.

Differences between Individual Apraxic Speakers and the Normal Group

As a group, the apraxic subjects demonstrated longer consonant durations than the normal subjects, particularly for the initial consonants. In order to determine whether this trend was typical of individual apraxic subjects, the initial and medial consonant duration measurements for each apraxic subject were classified into three groups based upon the number of times each value was above, within, or below the range of duration means for the normal subjects. These comparisons are presented in Table II.

As can be seen from Table II, there was a tendency for each apraxic subject to follow the group trend of exhibiting longer durations of the initial consonants as evidenced by the number of individual measurements which exceeded the normal range. The durations of 57 of the 75 (76%) initial consonants produced by the apraxic speakers were longer than those of any normal subject. Moreover, at least 60% of the initial consonants for each individual apraxic speaker were longer than the corresponding normal speakers' durations. However, with the exception of Subject 5 for whom all initial consonant duration measures exceeded the normals' range, the number of measures which surpassed the range of the normal speakers tended to vary among the initial consonants for each subject. For example, the number of initial /p/, /k/, and /t/ durations above the normal range for Subject 3 were 5, 1, and 5, respectively, while for Subject 4 they were 5, 5, and 2, respectively.

Although the initial consonant durations of the apraxic speakers did tend to exceed those of the normal speakers, from Table II it also

TABLE II

COMPARISON OF THE INITIAL AND MEDIAL CONSONANT DURATIONS FOR THE APRAXIC SUBJECTS WITH THE RANGE OF DURATION MEANS FOR THE NORMAL SUBJECTS

		/p/		/k/		/t/	
		I	M	I	M	I	M
Normal Range		119-181	127-204	113-181	113-165	119-210	137-176
Above							
	S1	4	0	4	0	2	1
	S2	4	1	2	5	3	2
	S3	5	0	1	0	5	0
	S4	5	2	5	3	2	2
	S5	5	3	5	1	5	2
	Total	23	6	17	9	17	7
Within							
	S1	1	5	1	5	3	4
	S2	1	4	3	0	2	2
	S3	0	2	3	1	0	1
	S4	0	3	0	2	3	2
	S5	0	2	0	4	0	2
	Total	2	16	7	12	8	11
Below							
	S1	0	0	0	0	0	0
	S2	0	0	0	0	0	1
	S3	0	3	1	4	0	4
	S4	0	0	0	0	0	1
	S5	0	0	0	0	0	1
	Total	0	3	1	4	0	7

can be seen that there was some variation from this trend. Of the remaining eighteen initial consonant durations, seventeen (23%) fell within the range of those produced by the normal speakers, and one initial consonant produced by an apraxic speaker was shorter than those produced by the normals.

As a group, the apraxics' medial consonants also were longer than those of the normals, but this was not always the case for individual subjects. As can be seen from Table II, there was considerable variation from the group trend among the apraxic subjects for the medial consonants. In most instances, there was a greater tendency for the subjects to exhibit durations which fell within (39 of 75, or 52%) the range of durations produced by the normal speakers rather than above (22 of 75, or 29%) it. Additionally, several subjects also demonstrated medial consonant durations which fell below the normal range (14 of 75, or 19%). It is interesting to note the variation in the dispersion of the duration measurements for the apraxic subjects. For example, with one exception, all of the measurements for Subject 1 were within the normal range. The majority of the medial consonant duration measurements for Subject 3 fell below the normal range. The duration measurements for Subjects 2, 4, and 5 were most frequently above or within the normal range, although one measurement was below the range for each subject.

Differences in Vowel Durations

Differences between the Normal and Apraxic Groups

Two selected vowels, /ɑ/, and /ə/, were produced five times in the first and second syllable of each nonsense disyllable by each of the normal and apraxic speakers. Table III presents the group means, standard deviations, and ranges for these vowel durations in each consonant environment. These data are presented in graphic form in Figure 2. Inspection of the table reveals that the mean vowel durations of the apraxic group were larger than those of the normal group in every instance. Further examination of the means indicates a relatively small difference between the two groups in the duration of the first vowel of each disyllable. In contrast to this finding, it can be seen that the apraxic speakers' mean durations for the second vowel considerably exceed those of the normal speakers. It may be noted that this finding is the reverse of the trend noted for differences between groups in consonant durations. In addition, it is interesting to note that the normal speakers' durations of the first vowel tended to exceed that of the second vowel for all of the utterances, while this trend was reversed in the vowel durations of the apraxic group. That is, for the apraxic speakers, the vowel durations tended to be longer in the second syllable than in the first syllable.

Examination of the standard deviations listed in Table III indicates that both groups tended to exhibit a similar amount of variation in the durations of each vowel except in one instance. The exception to this trend was the standard deviation of 77.97 for the

TABLE III

SUMMARY OF GROUP MEANS, STANDARD DEVIATIONS, AND RANGES OF THE FIRST AND SECOND VOWEL DURATIONS, EXPRESSED IN MILLISECONDS, FOR THE NORMAL AND APRAXIC SUBJECTS

Group	/pɑkə/		/kɑtə/		/tɑpə/	
	/ɑ/	/ə/	/ɑ/	/ə/	/ɑ/	/ə/
Normal						
Mean	143.18	123.76	140.88	130.24	136.10	115.22
SD	20.28	37.06	16.66	42.50	16.27	32.24
Range	107-163	82-187	109-155	89-206	106-151	78-165
Apraxic						
Mean	145.82	181.20	155.26	165.06	145.76	164.94
SD	20.69	77.97	13.40	40.59	14.03	36.54
Range	122-179	117-331	129-167	113-225	130-167	104-206

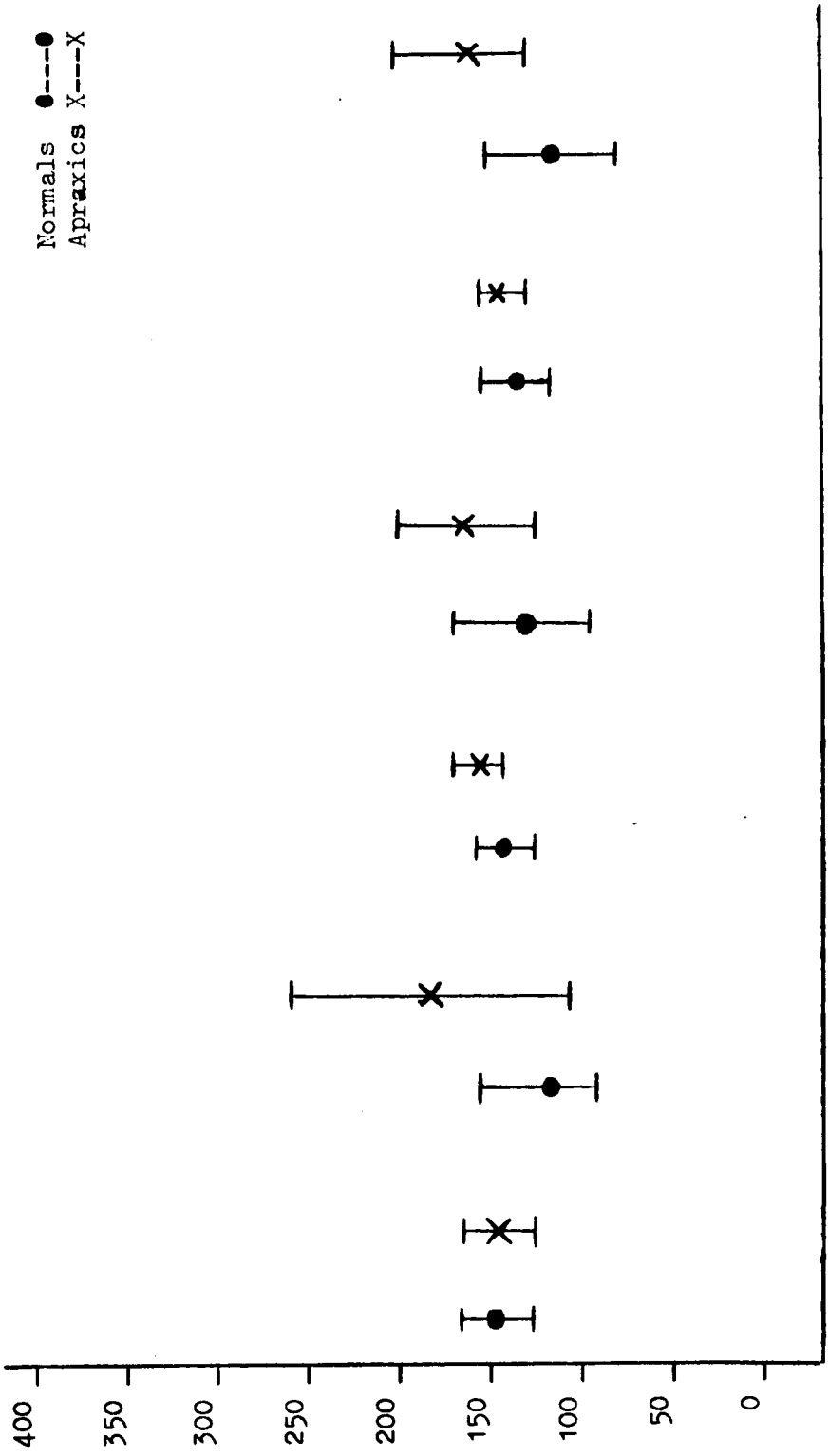


Figure 2. Group Means and Standard Deviations of the First and Second Vowel Durations for the Normal and Apraxic Subjects.

apraxic groups' durations of the /ə/ in /pɑkə/. Further inspection of the standard deviations reveals that both groups were more variable in their durations of the second vowel. Similarly, it can be seen that there was a larger range of durations of this vowel for both groups. Further comparison of these values indicates that the ranges for the apraxic group were equal to or smaller than the ranges of the normal group in every instance but two; these both occurred in the durations of /ə/.

Differences between Individual Apraxic Speakers and the Normal Group

Differences between individual apraxic speakers and the normal group in vowel durations were determined by utilizing the same classification system as previously described for the consonant durations. These comparisons are presented in Table IV. As a group, the apraxic subjects exhibited greater vowel durations than the normal subjects particularly for the second vowel in each disyllable. It can be seen, however, that there was considerable variation from this trend among the subjects. For example, with the exception of Subject 1, longer first vowel durations were not demonstrated frequently by the apraxic subjects. Most of the first vowel duration measurements for Subjects 2, 3, 4, and 5 were within the normal range. However, very few first vowel durations (3 of 75, or 4%) ever fell below the range of those produced by the normal speakers.

Several subjects differed substantially from the group trend in their second vowel durations. For instance, all of the second vowel

TABLE IV

COMPARISON OF THE FIRST AND SECOND VOWEL DURATIONS FOR THE APRAXIC SUBJECTS WITH THE RANGE OF DURATION MEANS FOR THE NORMAL SUBJECTS

		/pɑkə/		/kɑtə/		/tɑpə/	
		/ɑ/	/ə/	/ɑ/	/ə/	/ɑ/	/ə/
Normal Range		107-163	82-187	109-155	89-206	106-151	78-165
Above							
	S1	5	4	4	1	5	5
	S2	0	1	1	1	1	1
	S3	0	0	2	0	2	0
	S4	0	5	3	4	1	4
	S5	0	1	3	0	1	4
	Total	5	11	13	6	10	14
Within							
	S1	0	1	1	4	0	0
	S2	5	4	2	4	3	4
	S3	5	5	3	5	3	5
	S4	5	0	2	1	4	1
	S5	5	2	2	5	4	0
	Total	20	12	10	19	14	10
Below							
	S1	0	0	0	0	0	0
	S2	0	0	2	0	1	0
	S3	0	0	0	0	0	0
	S4	0	0	0	0	0	0
	S5	0	2	0	0	0	1
	Total	0	2	2	0	1	1

duration measurements for Subject 3 and most of the measurements for Subject 2 were within the normal range. Measurements of the second vowel for Subject 5 tended to vary in their dispersion, falling inconsistently above, within, and below the normal range. In contrast to these variations, Subjects 1 and 4 did not greatly differ from the group trend as most of their second vowel durations exceeded the normal range.

Summary of Results

Inspection of the results in this study indicated that there were differences in the durations of selected consonants and vowels produced by the normal and the apraxic speakers. As a group, the apraxic subjects demonstrated longer consonant and vowel durations than the normal subjects in every utterance. Duration differences between the two groups were greater particularly for the initial consonants and the second vowels of each nonsense disyllable. These trends often were less apparent among the consonant and vowel durations for the individual apraxic speakers. However, in most instances, each apraxic subject did exhibit longer initial consonant durations than the normal subjects.

CHAPTER IV

DISCUSSION

The results of this study indicated that the apraxic group demonstrated longer consonant and vowel durations than the normal group, particularly for the initial consonants and second vowels of each nonsense disyllable. Although the group trends were less apparent in the measurements for each apraxic subject, there nonetheless was a tendency for each apraxic subject to demonstrate longer initial consonant durations than the normal subjects. Thus, differences in durations between the normal and apraxic subjects were evident in both group and individual measurement comparisons. Since duration is one component of prosody (Nicolosi, Harryman, and Kresheck, 1978), these differences in durations between the two groups suggest that there were alterations in the prosody of the apraxic speakers' speech patterns. This finding is not a surprising one, and it is consistent with previous reports that disturbances of prosody occur in apraxia of speech (Johns and Darley, 1970; Darley, Aronson, and Brown, 1975; Tonkovich, Asp, Shadden, and Mason, 1977).

Durational Aspects of Prosody

Several of the findings in this study are supportive of statements in previous research reports regarding disturbed prosody in apraxic speakers' speech patterns. Darley, Aronson, and Brown (1975) reported that apraxic speakers frequently alter the prosody of their speech by

stressing their syllables and words equally and excessively. The finding in this study that the apraxic speakers had longer durations particularly for the initial consonants and second vowels suggests that they produced each of the syllables in the disyllabic utterances with excess and equal stress. That is, since the apraxic speakers demonstrated longer durations of one phoneme in each of the syllables, it is highly probable that both syllables were stressed excessively. Hence, this finding appears to support previous investigators' observations of equalization of stress in apraxic speakers' speech patterns.

It has been reported in the literature that a common prosodic distrubance manifested in apraxic of speech is a reduction in the rate of speech production. Johns and Darley (1970) noted that apraxic speakers' rate of speech tends to be reduced, even, and hesistant. Darley, Aronson, and Brown (1975) also reported that apraxic speakers demonstrate a slowed rate of speech production. It seems likely that longer durations of individual phonemes in the disyllables produced by the apraxic speakers in this investigation would consequently reduce the rate of speech production. Thus, many of the results in this study are supportive of previous reports that apraxic speakers' rate of speech tends to be reduced.

Specific disturbances of the durational aspects of prosody have been reported in the literature. Rosenbek (1978) noted that there is often a distortion of the normal durational relationships between consonants and vowels in apraxia of speech. The finding in this study

that the apraxic subjects exhibited initial consonant durations that exceeded those of the normal subjects and first vowel durations similar to those of the normal subjects suggests that there was a distorted relationship between the consonants and vowels in the disyllables. That is, the durational relationships between the consonants and vowels in the first syllables probably were distorted because the initial consonants generally were excessively longer than the vowels. These findings should be interpreted with caution, however, since the closure phase for each plosive was included in the consonant duration measurement. Nevertheless, this finding appears to be supportive of the durational alterations reported by Rosenbek (1978).

Relationship between Articulation and Duration

Although there were no articulatory errors in the productions analyzed in this study, there nonetheless were definite alterations in the durations of selected consonants and vowels. It is extremely interesting that these alterations frequently occurred in the utterances at points at which previous investigations have predicted there would be articulatory error. That is, based upon studies of articulation in the literature, the apraxic subjects' consonant and vowel durations often were altered when there was greater probability of articulatory error.

In previous reports, investigators have indicated that apraxic speakers' articulatory accuracy tends to be better for frequently occurring words that are meaningful (Deal and Darley, 1972; Dunlop and

Marquardt, 1977; Hardison, Marquardt, and Peterson, 1977). The nonsense disyllables utilized as stimuli to elicit responses from the apraxic speakers in this study were not meaningful units of language. Therefore, there was a high probability that the apraxic subjects would err in their productions. However, this was not the case; rather than evidencing articulatory error, the apraxic subjects demonstrated longer consonant and vowel durations in every utterance. Thus, these disturbances in duration in the apraxic subjects' speech were present when there was greater likelihood of articulatory error.

The findings in this study indicated that there were differences in the durations of particular phonemes for which there was greater chance of articulatory error. A number of investigators have reported that apraxic speakers exhibit a high degree of inconsistent initial consonant production (Shankweiler and Harris, 1966; Johns and Darley, 1970; Trost and Canter, 1974; Darley, Aronson, and Brown, 1975). These investigators also have reported that initial sounds are more likely to be misarticulated than final sounds. In this study, the apraxic subjects frequently demonstrated longer initial consonant durations. In fact, the apraxic subjects' durations of the initial consonants generally were longer than those of any other sounds. Therefore, it seems that the apraxic speakers' difficulty with initial sounds may affect not only their articulation but the durational aspects of the prosody of their speech as well.

Several researchers have reported that apraxic speakers produce significantly more errors on consonants than vowels (Shankweiler and

Harris, 1966; Trost and Canter, 1974; LaPointe and Johns, 1975; Darley, Aronson, and Brown, 1975). The findings in this study indicated that in most instances there were greater deviations from the normal range in the consonant durations rather than the vowel durations for the apraxic speakers. That is, the apraxic speakers' consonant durations generally were altered more frequently and to a greater extent than their vowel durations. Thus, the differences in the durations of the consonants and vowels produced by the apraxic speakers seemed to be related to the possible occurrence of articulatory error.

The Nature of Disturbances in Durations

One possible explanation for the disturbances in the durations of the consonants and vowels in the speech patterns of the apraxic speakers is that these were compensatory adjustments to avoid articulatory error. That is, it is possible that most of the alterations observed in the consonant and vowel durations reflected the apraxic speakers' efforts to compensate for articulatory difficulty. This explanation seems reasonable in consideration of the finding that the alterations in durations occurred when there was greater probability of articulatory error. Thus, it may have been that the apraxic speakers slowed down the rate of their productions in order to correctly articulate the phonemes in the nonsense disyllables.

An alternate interpretation of the data in this investigation is possible. The alterations in durations observed in the apraxic subjects' speech patterns may have occurred because disturbed prosody

is a primary feature of the disorder. That is, the results in this study may be indicative of a primary disturbance of prosody in apraxia of speech. This possibility is enhanced by the finding that some of the apraxic speakers occasionally demonstrated shorter consonant and vowel durations than the normal speakers. Although this result is supportive of previous reports that prosodic disturbances occur in apraxia of speech, it is not consistent with previous investigators' descriptions of the prevailing alterations (Johns and Darley, 1970; Darley, Aronson, and Brown, 1975). That is, the shorter durations do not indicate that there was "effortful groping for correct production" (Johns and Darley, 1970), nor "a slow rate of speech" (Johns and Darley, 1970; Darley, Aronson, and Brown, 1975). In consideration of this, the shorter consonant and vowel durations cannot be accounted for effectively as compensatory adjustments, as it does not seem likely that these would aid in gaining articulatory control.

The finding that the apraxic speakers demonstrated longer durations of the final vowels in the disyllables suggests that these disturbances were independent of articulatory difficulties. The lack of a relationship between the longer durations of the final vowels and difficulty in articulation seems apparent from examination of the reports in the literature. Investigators have reported that apraxic speakers produce significantly more errors on consonants than on vowels (Shankweiler and Harris, 1966; Trost and Canter, 1974; LaPointe and Johns, 1975; Darley, Aronson, and Brown, 1975) and that vowels are produced with greater articulatory ease than are all other manner

categories (Rosenbek, 1978). Therefore, it does not stand to reason that the apraxic speakers would need to compensate for articulatory difficulty in vowel production. Since these disturbances cannot be accounted for adequately as compensatory adjustments, perhaps these alterations in duration are indicative of a primary disturbance of prosody in apraxia of speech.

The finding in this study that in some instances the apraxic speakers' durations were altered when there was greater probability of articulatory error suggests that within very narrow limits there may be impairments in neural function that influence both prosody and articulation. That is, disturbances in prosody and articulation in apraxia of speech may result from faulty temporal patterning of rhythmic and sound sequences. If it is assumed that a central language mechanism programs a neural code of directions which the motor speech programmer utilizes to activate muscle movements, then it is likely that a disorder in the organization or the patterning of the neural codes would result in faulty sequencing of muscle movements. It is also likely that faulty sequencing of muscle movements would result in prosodic and articulatory disturbances. Lebrun (1976) suggested that apraxia of speech results from a disorder of the temporal organization of the articulatory gesture. Tonkovich et al. (1977) suggested that apraxic speakers' difficulty in reproducing certain suprasegmental patterns might be attributable to faulty temporal patterning of rhythmic sequences. This difficulty in timing would influence both the articulatory and the prosodic aspects of speech production. Thus, it

may have been that the disturbances in durations manifested by the apraxic speakers in this study resulted from a disorder of a central mechanism in programming and converting the appropriate neural code of directions for muscle activation.

Several investigators have reported that apraxic speakers demonstrate reduced efficiency in accomplishing the oral postures necessary for phoneme production, and the sequences of those postures for the production of words (Darley, Aronson, and Brown, 1975). Hence, perhaps it may be assumed that there is an impairment in the motor speech programmer which is responsible for muscle activation and the proper execution of muscle movements. It is highly probable that an impairment in the motor speech programmer would affect not only the articulation but also the timing of apraxic speakers' speech patterns, and hence, the durations of individual speech sounds. That is, a disorder in the motor speech programmer would affect the timing of muscle activation, the proper order and the correct duration of the desired speech sounds, and the positioning of the speech musculature.

From the preceding discussion, it appears possible that there may be an impairment in the central mechanism and/or the motor speech programmer in apraxia of speech. There also seems to be a possibility that the impairment in neural function influences both articulation and prosody independently, but in the same manner. This would explain the finding that the alterations in durations in this investigation often occurred when there was greater probability of articulatory error. It also would suggest that the disturbances in durations observed in the

apraxic speakers' speech patterns may have resulted because this is a primary feature of the disorder.

It is apparent that there is a need for further investigation of the prosodic disturbances demonstrated by apraxic speakers. Research directed toward examining the consonant and vowel durations produced when there is articulatory error may provide further insight. Useful information regarding the prosodic disturbances in apraxia of speech also may be obtained from examination of the consonant and vowel durations produced in words. Further research directed toward examining the nature and extent of prosodic disturbances in apraxia of speech also may provide a better understanding of the disorder.

Limitations of the Study

The results in this study were obtained from the subjects' reproductions of nonsense disyllables which were embedded in a carrier phrase. By utilizing the linguistic environment, the disyllables were produced in a more natural manner. However, it should be recognized that the consonant and vowel durations produced in the experimental task may not be similar to those produced in contextual or conversational speech. Additionally, there may be different results for the durations produced in conversational speech by normal and apraxic speakers.

CHAPTER V

SUMMARY AND CONCLUSIONS

The purpose of this study was to determine if there were differences between normal and apraxic speakers in the durations of selected consonants and vowels. Five normal and five apraxic speakers were presented prerecorded stimuli consisting of the three nonsense disyllables, /pɑkə/, /tɑpə/, and /kɑtə/ embedded within the carrier phrase, "You will say ____." Tape recordings were made as each of the subjects imitatively produced each of the three nonsense disyllables twenty times. The responses were judged for articulatory accuracy, and five productions of each nonsense disyllable for each subject were selected for the duration analyses. The consonant and vowel durations in these utterances were analyzed and measured by use of a digital storage oscilloscope.

The consonant and vowel duration measurements were statistically treated by computing means, standard deviations, and ranges for each speaker as well as for the normal and apraxic groups. The group means, standard deviations, and ranges were compared to determine differences between the groups in consonant and vowel durations. The duration measurements for each apraxic subject also were compared with measures for the normal group to determine whether individual speakers followed the trend evidenced by the group as a whole.

The major findings of this investigation indicated that the apraxic group consistently demonstrated longer consonant durations than the

normal group, particularly for the initial consonants. This trend also was evidenced by each individual apraxic speaker. Further, the results indicated that the apraxic group consistently exhibited longer vowel durations than the normal group, particularly for the final vowels. This trend often was less apparent among the vowel durations for each individual apraxic subject.

From the results of this study, it may be concluded that there are differences in the durations of selected consonants produced by normal and apraxic speakers. Similarly, there are differences in the durations of selected vowels produced by normal and apraxic speakers. These differences in duration are one aspect of the disturbances of prosody in apraxia of speech, and further research is necessary to determine whether these alterations are compensatory in nature or whether they reflect a primary prosodic disturbance in the disorder.

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APPENDICES

APPENDIX A

TABLE V

SUBJECT INFORMATION: SEX, AGE, AND MEAN RAW SCORES ON AUDITORY COMPREHENSION SUBTESTS OF THE BOSTON DIAGNOSTIC APHASIC EXAMINATION

Subject	Sex	Age	Auditory Comprehension
Normal			
S1	F	48.02	
S2	F	66.09	
S3	M	60.00	
S4	M	59.11	
S5	M	58.10	
Apraxic			
S1	F	48.00	29.75
S2	F	66.10	29.25
S3	M	60.03	28.50
S4	M	59.01	28.75
S5	M	59.02	25.25

APPENDIX B

TABLE VI

DURATION MEASUREMENTS, MEANS, AND STANDARD DEVIATIONS OF EACH CONSONANT AND VOWEL OF EACH NONSENSE DISYLLABLE, EXPRESSED IN MILLISECONDS, FOR EACH NORMAL SUBJECT

Stimuli		S1	S2	S3	S4	S5
/p/		138.5	114.5	152.0	157.5	132.0
		160.0	118.5	136.0	159.5	144.0
		163.5	134.0	130.0	189.5	144.0
		136.0	121.5	123.5	147.5	146.5
		151.5	104.5	110.0	253.5	156.5
	Mean	149.9	118.6	130.3	181.5	144.6
	SD	11.0	9.6	13.9	38.6	7.8
/ɑ/		147.5	143.0	156.5	92.5	190.5
		132.5	143.0	164.5	125.0	182.0
		152.5	137.0	164.5	121.5	150.5
		175.0	118.0	148.0	99.0	143.0
		142.0	146.5	161.0	101.5	149.0
	Mean	149.9	137.5	158.9	106.6	163.0
	SD	14.1	10.2	6.1	13.0	19.3
/k/		113.5	102.0	131.5	120.5	110.0
		148.0	101.5	124.0	168.5	111.5
		116.5	112.5	103.0	152.5	159.0
		112.5	130.5	117.0	152.5	168.5
		150.0	117.5	123.5	229.0	172.0
	Mean	128.1	112.8	119.8	164.5	144.2
	SD	17.1	10.8	9.6	35.8	27.7
/ə/		165.0	107.0	184.0	90.0	160.5
		129.0	109.0	132.0	89.0	83.0
		142.0	118.5	177.5	88.0	105.0
		108.5	110.0	202.5	61.5	70.5
		162.5	102.0	238.0	77.5	81.5
	Mean	141.4	109.3	168.8	81.2	100.1
	SD	21.1	5.3	34.5	10.8	32.3

TABLE VI (Continued)

Stimuli		S1	S2	S3	S4	S5
/k/		152.5	114.0	132.0	174.5	115.0
		149.0	117.5	146.0	195.6	136.5
		168.5	110.0	129.5	163.0	155.5
		173.0	103.5	132.5	183.0	148.0
		150.5	118.5	135.0	189.5	138.5
	Mean	158.7	112.7	135.0	181.3	138.7
	SD	10.0	5.4	5.8	11.7	13.7
/ɑ/		156.5	135.5	125.5	103.0	196.5
		159.0	132.0	147.0	115.5	142.5
		141.0	138.0	157.0	112.5	145.0
		150.0	152.5	168.5	116.0	142.5
		129.0	141.5	166.0	99.5	150.0
	Mean	147.1	139.9	152.8	109.3	155.3
	SD	11.0	7.0	15.6	6.8	20.8
/t/		182.0	142.5	175.5	163.5	47.0
		186.0	154.0	140.5	186.0	168.5
		155.5	136.0	129.5	150.0	174.0
		183.5	139.0	121.5	176.5	170.0
		148.0	163.0	116.0	201.5	168.5
	Mean	171.0	146.9	136.6	175.5	145.6
	SD	15.9	10.1	21.1	17.8	49.3
/ə/		132.0	110.0	271.5	64.0	85.0
		164.0	109.0	170.0	87.5	83.5
		131.0	117.5	172.0	74.5	108.0
		119.5	136.5	183.5	103.5	87.5
		158.0	139.0	233.5	114.5	101.0
	Mean	140.9	122.4	206.1	88.8	93.0
	SD	17.0	12.9	38.7	18.4	9.7

TABLE VI (Continued)

Stimuli		S1	S2	S3	S4	S5
/t/		127.5	120.5	161.0	227.0	129.5
		162.5	111.5	121.5	206.5	127.0
		142.0	128.5	108.0	228.0	147.5
		169.5	107.5	127.5	176.0	160.0
		165.0	128.0	117.0	210.5	147.5
	Mean	153.3	119.2	127.0	209.6	142.3
	SD	16.0	8.5	18.1	18.9	12.3
/ɑ/		184.5	132.0	132.0	94.5	162.5
		129.5	121.0	170.5	97.5	153.0
		153.5	136.0	145.0	121.5	146.0
		130.5	147.5	142.5	105.0	134.5
		106.5	139.5	166.0	109.0	142.5
	Mean	140.9	135.2	151.2	105.5	147.7
	SD	26.3	8.7	14.7	9.5	9.5
/p/		120.5	169.0	140.0	207.5	141.5
		138.0	147.5	115.0	173.0	151.0
		131.0	155.5	124.5	220.5	177.0
		167.0	149.5	136.0	227.0	163.0
		159.0	172.0	119.0	192.5	165.0
	Mean	143.1	158.7	126.9	204.1	159.5
	SD	17.3	10.0	9.6	19.5	12.2
/ə/		168.0	99.0	157.0	62.5	99.0
		109.5	107.0	132.5	75.5	84.5
		156.5	130.5	192.5	97.0	98.0
		137.5	96.5	196.5	75.0	84.5
		124.0	84.0	147.0	79.5	87.0
	Mean	139.1	103.4	165.1	77.9	90.6
	SD	21.1	15.4	25.2	11.1	6.5

APPENDIX C

TABLE VII

DURATION MEASUREMENTS, MEANS, AND STANDARD DEVIATIONS OF EACH CONSONANT AND VOWEL OF EACH NONSENSE DISYLLABLE, EXPRESSED IN MILLISECONDS, FOR EACH APRAXIC SPEAKER

Stimuli		S1	S2	S3	S4	S5
/p/		175.0	211.5	365.5	332.0	408.5
		664.0	180.5	244.5	192.0	866.0
		227.5	215.0	195.5	203.5	278.0
		234.5	258.5	304.0	264.0	607.5
		252.0	197.0	256.0	195.5	424.5
	Mean	310.6	212.4	273.1	237.4	516.9
	SD	178.6	26.0	57.7	54.0	203.7
/ɑ/		179.5	110.0	153.0	121.0	111.5
		166.5	137.0	147.0	161.5	138.5
		185.5	140.0	158.0	162.0	123.0
		187.0	114.5	158.5	152.0	138.0
		177.0	110.5	144.0	155.0	115.0
	Mean	179.1	122.4	152.1	150.3	125.2
	SD	7.3	13.2	5.8	15.1	11.2
/k/		150.0	216.5	98.0	166.5	184.0
		123.0	200.5	72.5	207.0	123.5
		134.5	200.0	114.5	172.5	164.0
		139.5	181.0	104.0	135.5	140.5
		138.5	225.5	86.5	135.5	142.0
	Mean	137.1	204.7	95.1	163.4	150.8
	SD	8.7	15.3	14.4	26.6	21.0
/ə/		198.5	128.5	139.0	439.5	217.5
		166.5	210.5	114.5	422.0	117.0
		193.0	166.5	98.0	326.5	66.5
		203.0	104.5	136.0	203.0	75.0
		201.0	111.0	118.5	264.0	110.0
	Mean	192.4	144.2	121.2	331.0	117.2
	SD	13.3	39.5	15.0	90.4	53.8

TABLE VII (Continued)

Stimuli		S1	S2	S3	S4	S5
/k/		371.0	205.0	273.5	343.0	467.5
		216.5	202.5	146.5	216.5	714.5
		193.5	151.5	86.5	200.0	587.0
		199.5	142.5	121.5	186.0	1070.0
		167.5	161.0	115.0	198.5	470.0
	Mean	229.6	172.5	148.6	228.8	661.8
	SD	72.4	26.1	65.3	57.9	223.4
/ɑ/		162.0	102.5	142.5	189.0	157.5
		172.0	101.5	149.0	141.5	218.0
		156.0	166.5	181.5	172.5	149.5
		166.0	148.0	154.0	145.0	152.5
		137.0	128.5	159.0	173.0	157.0
	Mean	158.6	129.4	157.2	164.2	166.9
	SD	12.0	25.3	13.3	18.1	25.7
/t/		172.0	177.0	158.0	78.5	174.0
		180.5	226.0	126.0	149.5	121.5
		155.5	172.0	112.0	182.5	273.0
		159.5	131.5	117.0	200.0	202.0
		158.5	156.0	104.5	174.0	169.5
	Mean	165.2	172.5	123.5	156.9	188.0
	SD	9.5	31.0	18.6	42.4	49.8
/ə/		192.0	124.0	91.0	215.5	117.5
		166.0	141.5	129.5	224.5	127.0
		195.0	194.5	112.0	228.5	182.0
		212.0	121.0	119.0	195.0	115.5
		203.0	223.5	112.5	263.0	121.5
	Mean	193.6	160.9	112.8	225.3	132.7
	SD	15.4	40.9	12.6	22.1	25.0

TABLE VII (Continued)

Stimuli		S1	S2	S3	S4	S5
/t/		241.5	314.5	282.0	191.0	845.0
		180.0	357.5	297.0	186.5	585.5
		283.0	248.5	304.0	242.5	395.0
		150.0	161.5	301.0	227.5	693.0
		183.5	161.5	316.0	189.0	791.5
	Mean	207.6	248.7	300.0	207.3	662.0
	SD	47.9	79.2	11.0	23.1	160.2
/ɑ/		181.0	121.0	213.5	156.5	135.0
		164.0	122.0	145.0	147.5	138.5
		182.5	101.0	141.0	125.5	178.0
		157.5	149.5	111.0	131.5	123.5
		159.0	154.5	161.0	132.5	112.0
	Mean	168.8	129.6	154.3	138.7	137.4
	SD	10.8	19.8	33.7	11.4	22.3
/p/		147.0	165.5	131.5	219.5	200.5
		149.0	158.0	141.5	188.0	182.0
		139.0	507.0	122.5	216.0	295.0
		146.5	154.5	103.0	199.0	285.0
		130.0	176.0	112.0	204.0	229.5
	Mean	142.3	232.2	122.1	205.3	238.4
	SD	7.0	137.6	13.7	11.4	44.9
/ə/		198.0	128.0	89.5	222.5	196.0
		190.5	132.5	80.0	204.0	208.0
		244.0	120.0	90.5	195.0	179.5
		202.5	154.0	130.5	161.5	73.0
		192.5	201.5	129.0	194.5	206.5
	Mean	205.5	147.2	103.9	195.5	172.6
	SD	19.7	29.3	21.4	19.8	50.8

VITA

Karen Annita Colson was born in Nashville, Tennessee, on August 13, 1957. She attended elementary school at Saint Bernard's Academy in that city and was graduated from John Overton High School in 1974. The following September she entered Middle Tennessee State University and graduated in May 1978 with a Bachelor of Science degree in Speech and Hearing Therapy.

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