To the Graduate Council:

I am submitting herewith a dissertation written by James Hager Bargelt entitled "The Influence of Selected Phonetic and Linguistic Variables on Articulatory Production in Apraxic Speakers." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Speech and Hearing Science.

Harold Peterson
Major Professor

We have read this dissertation
and recommend its acceptance:

Carl W. Asp

Ellen J. Hamby

Merlin D. Johnson

Accepted for the Council:

Vice Provost and
Dean of The Graduate School

THE INFLUENCE OF SELECTED PHONETIC AND LINGUISTIC VARIABLES ON ARTICULATORY PRODUCTION IN APRAXIC SPEAKERS

A Dissertation

Presented for the

Doctor of Philosophy

Degree

The University of Tennessee, Knoxville

James Hager Bargelt

June 1985

ACKNOWLEDGMENTS

This author would like to express his sincere gratitude to Dr. Harold Peterson for directing this project. Dr. Peterson spent countless hours reading this document and provided me with numerous editorial and theoretical suggestions. His guidance, compassion, and friendly advice will always be appreciated.

I would like to thank the three additional members that served on my dissertation committee: Dr. Mike Johnson, for providing interesting insights into this topic; Dr. Carl Asp, a good friend and humanitarian, who always appeared interested in my work and encouraged me to seek excellence; and Dr. J. Ellen Hamby, for being a good adviser, friend, and teacher. Her contribution to my education has been priceless.

Finally, I would like to thank the staff of the Department of Audiology and Speech Pathology at The University of Tennessee, Knoxville, for providing me with a fantastic education, along with those students who are currently (or who have recently finished) working on the Ph.D. in this department. They never get the proper recognition for their efforts. I would like to alleviate this problem by listing their names below: Kendal Bergan and her husband Ernie (a complete lunatic), Hsio Chen, Paul Dagenais, Amy Donahue, Patty and Dennis Earl, Dr. Pearl Gorden, Charlotte Hubbard,

Dr. Sue Hume, Dr. Linda Lilly, Dr. Sumulai Maroonroge (who is the best chef I have ever met), Dr. Dave (the phantom) Mason, Larry Molt, Rick Neely, Dr. Sandi Newsom-Clark, Yoji Takata, and who could forget Fran ("The Liberal") Tucker.

I love all of you (except Pearl).

ABSTRACT

The purpose of this investigation was to measure how sentence voice, grammatical class, and phonetic complexity influence the articulation of eleven apraxic speakers. A set of nonsense CVC and CCVCC syllables were constructed using phonemes that contained either few or numerous marked distinctive features. These syllables were inserted into the subject, verb, and object function locations of both active and passive voice sentences. Later, the entire sentence was presented to these subjects who were required to repeat the nonsense syllable.

Results suggest that for CVC stimuli, grammatical class, sentence voice, and phonetic complexity disrupted the articulation of apraxic speakers. However, the magnitude of these disruptions were not equal for each variable. Also, none of these three variables appeared to interact with each other, indicating that each factor could have a separate influence on the process of articulation. With CCVCC stimuli, only phonetic complexity produced any adverse affect.

These data can also be interpreted in a different manner. While grammatical class, sentence voice, and phonetic complexity were found to be "statistically significant," it is possible that this significance was discovered due to the removal of the between-subject variance in the

statistical model. The result of this action is that small differences between group means may be important only from a statistical viewpoint. From a practical or clinical viewpoint, these differences may be of little importance to the rehabilitative process.

When analyzing individual consonantal errors, it was discovered that apraxic speech is dominated by substitutions, omissions, and additions. Further, the articulatory errors, while being inconsistent, were not unsystematic. The apraxic speakers substituted phonemes with relatively few marked features for those phonemes which contained numerous marked features. Also, a distinctive feature analysis indicated the articulation errors were good approximations of the target phoneme.

It was suggested that the available theories of articulation were not adequate to describe the apraxic productions. A modified version of Roy's model of motor production was presented to account for the small influence of the linguistic and phonetic variables.

TABLE OF CONTENTS

CHAPTER		PAGE
I.	INTRODUCTION	1
	Review of Literature	2
	Phonological Variables Which Influence Apraxic Speech	3
	Linguistic Variables Which Influence Apraxic Speech	9
	Summary and Rationale	15
	Statement of Purpose	21
II.	EXPERIMENTAL PROCEDURES	24
	Subjects	24
	Stimulus Composition	25
	Equipment	27
	Experimental Test Paradigm	28
III.	RESULTS	30
	Reliability	30
	Scoring	32
	Statistical Model	32
	Linguistic Variables	36
	Sentence Voice and Grammatical Class	36
	Articulatory Variables	45
	Phonetic Complexity	45
	Articulatory Performance of Single Phonemes	47
	Manner of Production	52
	Articulatory Accuracy as a Function of Phoneme Position	55
	Consonantal Accuracy in Cluster and Noncluster Environments	59
	Phoneme Error Patterns and Distinctive Feature Errors	63
	Phoneme Markedness Fluctuations	77
	Summary of Results	81
IV.	DISCUSSION	84
	Linguistic Variables	85
	Stimulus Accuracy in Isolation and Sentences	85
	Sentence Voice	87

CHAPTER PAGE

Grammatical Class 91
CCVCC Stimuli 97
Phonetic Variables 98
Feature Markedness 99
Markedness Fluctuations 100
Articulatory Performance for Vowels and Consonants 101
Consonant Accuracy as a Function of Phoneme Position and Environment 106
Disadvantages of Using a Repeated Measures Design with Apraxic Subjects 109
Theoretical Implications for Apraxia of Speech 113
Therapeutic Implications 119
Limitations of the Study 120
Suggestions for Future Research 121

V. SUMMARY AND CONCLUSIONS 123

BIBLIOGRAPHY 125

APPENDICES 130

Appendix A 131
Appendix B 138

VITA 144

LIST OF TABLES

TABLE		PAGE
1.	Distinctive Feature Ratings for Individual Consonants in English	19
2.	Marked and Unmarked Values of Nine Distinctive Features for English Consonants	20
3.	Percent Correct Articulation Scores for CVC Stimuli	33
4.	Percent Correct Articulation Scores for CCVCC Stimuli	34
5.	Total Percent Correct Articulation Scores for CVC Stimuli in Sentences Only, Isolation Only, and a Total Comparison Contrasting CVC Scores in Isolation and Sentences	37
6.	Total Percent Correct Articulation Scores for CCVCC Stimuli in Sentences Only, Isolation Only, and a Total Comparison Contrasting CCVCC Scores in Isolation and Sentences	39
7.	Percent Correct Articulation Scores for Individual Consonants Occurring in Consonant-Vowel Stimuli in Isolation and When Embedded in Sentences	49
8.	Percent Correct Articulation Scores for the Five Vowel Stimuli	51
9.	Percent Correct Articulation Scores for Single Consonants in Isolation and Sentences, as a Function of the Manner of Production for CVC and CCVCC Stimuli Combined	53
10.	Percent Correct Articulation Scores for CVC Consonants in Isolation and Sentences for Prevocalic and Postvocalic Positions	56
11.	Percent Correct Articulation Scores for CCVCC Consonants in Isolation and Sentences for Prevocalic and Postvocalic Positions	58

TABLE PAGE

12. A Comparison of the Percent Correct Articulation Scores for Consonants Which Occur in Consonantal Cluster and Non-cluster Environments for Isolated Stimuli in Prevocalic and Postvocalic Positions 60

13. A Comparison of the Percent Correct Articulation Scores for Consonants Which Occur in Consonantal Cluster and Non-cluster Environments for Sentence Stimuli in Prevocalic and Postvocalic Positions 62

14. Percent Distribution of Articulation Errors Among Six Categories for Both Vowel and Consonant Stimuli 65

15. Error Matrix of Substituted Phonemes 67

16. Number and Percent Distribution of Distinctive Feature Errors Present in Consonant Substitutions 69

17. Contribution of Five Distinctive Features to the Consonant Substitutions Exhibited by Apraxic Subjects 71

18. Number and Percent Distribution of Articulatory Placement Errors Present in Consonant Substitutions as a Function of Physical Distance, Within the Oral Cavity, Separating the Substituted Phoneme from the Target Phoneme . . 71

19. Distinctive Feature Substitution Patterns Present in Stop, Friction, Voicing, and Nasality Distinctive Feature Errors 73

20. Number and Proportional Distribution of Addition Errors to CVC and CCVCC Stimuli Which Occurred in Sentences as a Function of Sentence Voice and Grmamatical Function . . . 76

21. Percent Correct Articulation Scores for Phonemes Containing Zero, One, Two, and Three Marked Distinctive Features 78

TABLE PAGE

22. Percentage of Intruded Phonemic Substitutions with More, Less, and the Same Markedness Values as the Target for Phonemes with Markedness Values of 1, 2, and 3 80

B-1. Age, Sex, Auditory Comprehension Capabilities According to Boston Diagnostic Aphasia Examination Scores, Etiology Characteristics, and Time Post Onset Characteristics for Individual Subjects 139

B-2. Analysis of Variance Calculations for CVC Stimuli Embedded in Sentences 140

B-3. Analysis of Variance Calculations for CCVCC Stimuli Embedded in Sentences 141

B-4. Analysis of Variance Calculations for Vowel Stimuli 142

B-5. Analysis of Variance Calculations for Stimuli with Zero, One, Two, and Three Marked Features 143

LIST OF FIGURES

FIGURE		PAGE
1.	Means and Standard Deviation Markers for CVC Stimuli Embedded in Sentences	41
2.	Means and Standard Deviation Markers for CCVCC Stimuli Embedded in Sentences	42
3.	Percent Correct Articulatory Proficiency Values for Single Consonants as a Function of the Manner of Production for CVC and CCVCC Stimuli Combined	54
4.	Proportional Distribution of Articulatory Errors for Vowel and Consonantal Stimuli	66
5.	Hypothetical Model for Articulatory Production in Normal and Apraxic Speakers	118

CHAPTER I

INTRODUCTION

Apraxia of speech is defined as a neurogenic acticulatory disorder characterized by an impaired ability to program the successive articulatory events necessary for motor speech production. Apraxia occurs despite the absence of weakness, paralysis, incoordination, or altered muscle tone within the speech musculature (Shane and Darley, 1978). Numerous investigators have described the phonological characteristics of apraxic speech. The articulatory behaviors which characterize this disorder include imprecise articulation and numerous phoneme substitutions (Johns and Darley, 1970; Trost and Canter, 1974), greater articulatory accuracy when producing consonant singletons rather than consonant clusters (Shankweiler and Harris, 1966; Johns and Darley, 1970), articulatory errors which are frequently within one distinctive feature of the intended target phoneme (Trost and Canter, 1974; Marquardt, Reinhart, and Peterson 1977), and a greater number of articulatory errors on fricatives and affricates (Shankweiler and Harris, 1966; Johns and Darley 1970; LaPointe and Johns, 1975).

While most investigators have concentrated on analyzing specific phonological behaviors, Martin (1974) suggested that apraxia may be related to language disorders and

influenced by different linguistic variables. An etiological investigation supported this hypothesis by demonstrating that lesions positioned in different locations of the left cerebral hemisphere produce both aphasia and apraxia (Tagnola and Vignolo, 1980). Further, those studies which tested linguistic variables demonstrate grammatical class (Deal and Darley, 1972; Dunlop and Marquardt, 1977), word abstraction (Hardison. Marquardt, and Person, 1977; Dunlop and Marquardt, 1977), and sentence voice (Hardison, Marquardt, and Peterson, 1977) significantly influence the phonological abilities of apraxic speakers.

Although the above phonetic and linguistic variables have been shown, in isolation, to influence articulation, relatively little information is available demonstrating how phonetic and linguistic variables combine to affect apraxic speech. This information is needed to both understand the character of apraxia, and to treat those individuals who develop this disorder. The purpose of this study was to determine how different phonetic and linguistic variables interact to influence the articulation of apraxic speakers.

Review of Literature

Articulatory and linguistic information exists which suggests that both phonological and language variables influence apraxic speech. Further, different investigators

argue that phonology and language are too closely interrelated for disturbances to occur in one area without influencing the other ability. Evidence that both phonological and language variables significantly affect articulatory production in apraxic speakers is reviewed.

Phonological Variables Which Influence Apraxic Speech

Apraxia of speech is a neurogenic communicative disorder that is not completely understood. The physical characteristics of apraxic speech indicate that, in the absence of paralysis, the individual is having difficulty controlling the articulatory mechanism. Apraxic speakers demonstrate a variety of deviant articulatory behaviors during speech. They improperly place their articulators in different positions of the oral cavity, avoid difficult phonemes, and visibly struggle to complete difficult phonological sequences.

Shankweiler and Harris (1966) performed one of the first experiments which described the articulatory behaviors in a group of apraxic speakers. Five subjects were presented with 200 meaningful monosyllabic stimuli which contained consonant singletons and clusters in both initial and final word positions. Each subject was required to repeat the test stimuli. Verbal responses were tape recorded and phonetically transcribed.

Shankweiler and Harris (1966) reported that consonant clusters produced more errors than consonant singletons, initial position consonants were less accurately produced than final position consonants, vowels were produced with greater accuracy than consonants, and fricatives and affricates were produced with less accuracy than other phoneme classes. Further, seven phonemes (/θ,v,ʃ,z,ð,tʃ,dʒ/) were identified as being frequently misarticulated by the apraxics. The authors concluded that apraxia of speech is a disorder which influences the entire articulatory apparatus. Further, the disorder is manifested by an inability to accurately coordinate the sequencing of several articulatory structures during the production of phonemes.

Johns and Darley (1970) assessed neurologically impaired adults to identify the phonological characteristics of apraxic speech and determine whether these behaviors distinguish apraxia from other types of neurocommunicative disorders. Ten apraxics, ten dysarthrics, and ten control subjects were tested for accuracy and consistency of phoneme production using nonsense syllables. Production of individual consonants was evaluated by eliciting responses using stimuli which contained phonemes found to influence the speech of apraxic speakers (Shankweiler and Harris, 1966). Additional experimental tasks tested phoneme production when: (1) words were varied in length; (2) the phoneme was

moved to different word positions; (3) sounds were elicited using different presentation modes; and (4) phonemes were produced while reading a standardized passage. Each subject's verbal responses were tape recorded and transcribed using broad phonetic transcription.

Johns and Darley (1970) reported that numerous variables influence phonetic production in apraxic speakers. Specifically, these variables indicate that for apraxic speakers: (1) articulatory proficiency improves when producing real words instead of nonsense syllables; (2) presenting test stimuli through an auditory-visual medium produces greater articulatory proficiency than either auditory or visual presentation modes in isolation; (3) articulatory production improves when subjects are given the opportunity to repeat the target stimulus three successive times rather than only once; (4) consonant clusters produce more articulatory errors than consonant singletons; (5) the phonemes /θ,v,z,dʒ,ʃ,l/ produced more articulatory errors than /p,f,b,k,d,n,h,n/; and (6) errors are characterized primarily by substitutions, repetitions, and intrusion of the schwa /ə/ phoneme. Johns and Darley concluded that, unlike dysarthria, apraxic speech is an articulatory disorder that is inconsistent, unpredictable, and subject to high degrees of variability.

Similar studies have been performed by other investigators. Trost and Canter (1974) presented 130 monosyllabic CVC syllables and stimuli containing consonant clusters to ten aphasics who demonstrated apraxia of speech. Vowels, consonant singletons, and consonant clusters were tested using both spontaneous and imitative response paradigms. The subjects' articulatory responses were recorded and transcribed using narrow phonetic transcription.

Analysis of consonant singleton production indicated six phonemes /v,ʃ,ŋ,ʒ,θ,j/ were the least accurately produced. Also, single phoneme production was significantly influenced by the frequency with which that phoneme occurs in the English language. Further, consonant clusters were produced less accurately than consonant singletons, and initial position consonants were produced with less accuracy than final position consonants.

Trost and Canter (1974) evaluated phoneme error patterns using both conventional error categories and a distinctive feature analysis. Errors on consonant singletons were characterized primarily by substitutions (67.1 percent) while consonant clusters were characterized by omissions (31.2 percent). Unlike consonant singletons, substitutions comprised only 18.2 percent of the errors for consonant clusters. The distinctive feature analysis indicated that approximately 50 percent of the phoneme errors

were within one feature of the intended target phoneme while 88 percent were within two features. Analysis of individual feature characteristics revealed place, manner and voicing errors contributed 60.9, 53.1, and 36.1 percent, respectively, to the total error productions. The authors concluded that their results indicate the error patterns found in apraxic speech are close approximations of the intended phoneme.

LaPointe and Johns (1975) evaluated 13 apraxics for language deficits, articulatory proficiency, and the ability to complete nonspeech oral movements. These authors reported that apraxics produce a significantly greater number of errors on consonants than vowels and more errors on consonant clusters than consonant singletons. Error frequency and phoneme comparisons indicated apraxics were equally proficient at producing phonemes in the initial, medial, and final word positions, thereby contradicting the results of previous investigations (Shankweiler and Harris, 1966; Trost and Canter, 1974). Evaluation of the error patterns for five manners of production indicated that fricatives and affricates resulted in a significantly greater number of errors than glides, nasals, and plosives. Analysis of error patterns for seven places of production indicated that bilabial and lingual alveolar phonemes elicited the lowest percentage of articulatory errors. Finally, the authors

noted that approximately 38 percent of the phoneme substitution errors were defective in two or more distinctive features.

Marquardt, Reinhart, and Peterson (1979) analyzed phoneme substitution error patterns by monitoring changes in the marking patterns associated with individual distinctive features. These authors theorized that error patterns produced by apraxic speakers are inconsistent but not unsystematic. Instead the phoneme substitutions reveal the articulatory behaviors are characterized by an attempt to reduce the phonological complexity of an utterance. Ten apraxic subjects repeated three groups of CVC monosyllables using phonemes that possessed three marked features /θ,v,ʃ,dʒ/, two marked features /z,b,tʃ,g/, or one marked feature /s,d,p,k/ using both the initial and final syllable positions. Substitution errors were analyzed to determine directionality in the marking fluctuations (i.e., substituting phonemes which contain a greater or lesser number of marked features), the stability of the marking patterns for the coronal and voicing features, and the effect of markedness on error frequency.

Marquardt, Reinhart, and Peterson (1979) reported: (1) apraxic speakers produce a significantly greater number of phoneme substitution errors when producing stimuli that contain numerous marked features then stimuli which contain

relatively few marked features; (2) substituted sounds are characterized as containing fewer marked features rather than additional marked features; and (3) the marking characteristics of the voicing feature remain stable whereas the marking properties for the coronal feature are relatively unstable and easily changed. Further, the authors correlated the marking substitution patterns found in apraxic speech with the "ease of articulation" (Locke, 1972) attributed to different phonemes. They reported a significant correlation between the substitution patterns found in apraxic speech and the difficulty with which each phoneme is produced. The authors concluded that apraxic speakers systematically reduce the complexity of an utterance when attempting to approximate a target phoneme.

Linguistic Variables Which Influence Apraxic Speech

Apraxia of speech is a disorder which rarely can be found in a pure form (Trost and Canter, 1974). Instead, apraxia often occurs as a part of a larger language disorder (aphasia). Certain investigators (Alajouanine and Lhermitte, 1963) claim that apraxia is a disorder that can only occur in conjunction with aphasia. This statement has been supported by Wertz, Rosenbek, and Deal (1970) who demonstrated that 65 percent of all apraxics are impaired, to various degrees, by aphasia. In view of such findings,

various researchers (e.g., Martin, 1974) have suggested that apraxia is an articulatory disorder which should be analyzed by measuring the interrelatedness between the process of phonetic production and the linguistic structures of the utterance.

Martin (1974) objected to using the term "apraxia of speech" because it suggested that apraxia is simply an articulatory disorder which is independent, and therefore not influenced by language. Martin argues that speech involves the rapid production of small meaningful articulatory elements termed phonemes. Conversational speech requires that the speaker select and combine phonemes together in logical sequences. Martin writes:

> The selection and concantenation of these phonemes must conform to the rules of language. Thus, even with a postulated mechanism for the production of speech, the operation of this mechanism depends upon rule-ordered language variables. (page 55).

Martin's theory that articulatory production is dictated by language is advanced by the statement:

> When a speaker-listener of a language concantenates a series of phonemes, he must do so in reference to two things. The desired utterance and the phonological rules of language. . . . The important point is that the sequencing of phonemes is part of a combination process. It (the combination process) acts, not in isolation as a purely motor phenomenon, but in reference to other linguistic parameters and is, by itself, a linguistic event. The sequence of a neurological action

> depends on the preceding and following context, which, in turn, is partially determined by the phonological rules of language. (page 56)

The relationship between language and phonology in apraxia has been investigated using apraxic subjects. Deal and Darley (1972) performed a series of experiments designed to test the influence of certain linguistic variables upon phonological production. The linguistic variables tested included word length, expected phoneme difficulty (Johns and Darley, 1970),and grammatical class (noun, verb, etc.). Twelve subjects were tested by asking them to either read a standardized passage or repeat a series of 120 test words.

Deal and Darley (1972) reported that articulatory errors did not occur randomly throughout the reading material. Instead, phoneme errors actually occur in a predictable manner. During the reading condition, both the grammatical class and word length significantly influenced the number of articulation errors. For the repetition task, however, only the word length was significantly related to phonological errors. Deal and Darley theorized that linguistic variables (grammatical class and word length) may create additional articulation errors by placing increased stress on the articulatory system. More specifically, words which carry the greatest amount of content (i.e., nouns, verbs, and adjectives) also carry a greater degree of linguistic and psychological "weight" which is essential for communication.

Other linguistic variables have been shown to influence articulation in apraxic speakers. Dunlop and Marquardt (1977) suggested that the phonological production associated with apraxic speech should not be considered a motor speech act which occurs separately from the influence of language. Ten apraxic subjects were presented with 144 monosyllabic words divided into two separate lists. List 1 contained difficult phonemes (Shankweiler and Harris, 1966) including /v/,/z/,/tʃ/,/ʃ/,/dʒ/, and /θ/. List 2 contained the six phonemes /p/,/b/,/t/,/d/,/k/,and /n/ which are judged to be easier for apraxics to produce. Further, words were assigned to grammatical classes (noun, verb, adjective) and balanced according to their frequency of occurrence in the English language. Test stimuli were placed in a carrier phrase, repeated aloud by the apraxic subjects, and judged for accuracy by the investigators.

Dunlop and Marquardt (1977) reported that an apparent trend (statistically not significant) developed in the apraxic population whereby subjects produced the greatest number of errors on adjectives, followed by verbs and finally nouns. Dunlop and Marquardt analyzed the relationship between abstraction levels for words in noun, verb, and adjective grammatical classes and error productions of the apraxic speakers. They reported that: (1) correlations between articulation errors and word abstraction ratings

decreased as the abstractness of the grammatical class increased; and (2) a low positive correlation exists between the apraxic error scores and single word abstraction ratings. Dunlop and Marquardt concluded that apraxia is integrally related to language, since if it were simply a disorder of motor programming, then the semantic component would not be significantly related to error frequency.

A more extensive investigation of the linguistic variables associated with apraxic speech was performed by Hardison, Marquardt, and Peterson (1977). These authors theorized that there is evidence to suggest that phoneme production is influenced by certain semantic and grammatical factors. Ten apraxic subjects were presented with 60 CVC monosyllables in which the initial and final consonants were reportedly easy to produce. Twenty monosyllables were concrete nouns, 20 were abstract nouns, and 20 were nonsense words. Stimuli were presented in sentences that utilized the combination of three linguistic variables. These included word abstraction, sentence voice (active, passive), and noun phrase position (noun phrase 1, noun phrase 2). The stimuli were presented verbally to each subject whose responses were recorded and analyzed for accuracy.

Hardison, Marquardt, and Peterson (1977) reported that a greater number of articulatory errors occurred on the first noun phrase of each sentence, more errors occurred on

nonsense and abstract nouns than on concrete nouns, and more errors on nouns in passive sentences compared to nouns in active sentences. These authors presented a number of plausible explanations for these results. First, the greater number of errors found on noun phrase 1 may be due to increased syntactical (informational) uncertainty which occurs for words at the beginning of a sentence. A similar explanation may account for the occurrence of more errors for nonsense and abstract words than on concrete nouns. Words which are abstract or nonsensical in nature are more difficult to predict and therefore carry greater informational value. The authors theorized that semantic restrictions may have adversely influenced production of the target phonemes. Finally, the increased number of errors exhibited for passive sentences may have resulted from these stimuli generating a greater memory load and thereby creating additional difficulty for subjects who were burdened by this speech disorder.

A review of the literature demonstrates that apraxic speech is highly influenced by both phonetic and linguistic variables. Still, additional information was needed demonstrating how the grammatical properties of a word (subject, verb, object), sentence voice (active, passive), and the phonetic complexity of a stimulus (few marked features, numerous marked features) interact to influence the articulation of apraxic speakers.

Summary and Rationale

The preceding literature review indicates that numerous phonological and linguistic variables influence acticulatory production in apraxic speakers. Phonetically, apraxic speech is characterized by a preponderance of phoneme substitutions (Johns and Darley, 1970), a greater number of articulatory errors on consonant clusters than consonant singletons (Shankweiler and Harris, 1966; Johns and Darley, 1970; Trost and Canter, 1974), phoneme error patterns which are generally close approximations of the intended sound (Trost and Canter, 1974; Marquardt, Reinhart, and Peterson, 1977), more errors on consonants than vowels (Shankweiler and Harris, 1966; LaPointe and Johns, 1975), more errors on phonemes which contain numerous marked features (Marquardt. Reinhart, and Peterson, 1979), and a tendency to substitute phonemes which contain few marked features (Marquardt, Reinhart, and Peterson, 1977). Linguistically, articulatory production in apraxic speech is influenced by grammatical class (Deal and Darley, 1972; Dunlop and Marquardt, 1977), word abstraction (Hardison, Marquardt, and Peterson; Dunlop and Marquardt, 1977), and sentence voice (Hardison, Marquardt, and Peterson, 1977).

This literature indicates that the articulatory behaviors which characterize apraxic speech are influenced,

to some degree, by both phonetic and linguistic variables. However, relatively little information is available which describes the interrelatedness between these phonetic and linguistic factors. Previous investigators chose to describe apraxia by varying isolated phonetic (Shankweiler and Harris, 1966; Johns and Darley, 1970; Trost and Canter, 1974; LaPointe and Johns, 1975; Marquardt, Reinhart, and Peterson, 1979) or linguistic variables (Deal and Darley, 1972; Dunlop and Marquardt, 1977). Only Hardison, Marquardt, and Peterson (1977) tested the interactive effects between two linguistic variables (noun phrase position and sentence voice). Still, this investigation did not measure the influence of stimuli which varied in phonetic complexity, nor did it evaluate the influence of the verb function.

The limited scope of these investigations indicates that additional information is needed to identify the relationship between the phonetic and linguistic variables which influence articulation in apraxic speakers. More specifically, future investigations should assess the interrelatedness between sentence voice, grammatical class, and phonetic complexity. Additional information describing these relationships would facilitate increased understanding of the links between different linguistic processes and apraxia, and may provide additional information into how language and phonetic complexity influence the physiological mechanisms

associated with articulation. Further, by identifying how both phonetic and linguistic variables, in combination, influence apraxic speech, improved forms of treatment can be developed emphasizing both language and phonology.

Assessing the articulation of apraxic speakers requires using stimuli that differ along specific phonological parameters. Recall that word abstractness/concreteness influences apraxic speech (Dunlop and Marquardt, 1977). This influence can be controlled, however, by using only nonsense syllables. Further, since different phonemes and consonant clusters disrupt articulation in apraxic speakers (Johns and Darley, 1970; LaPointe and Johns, 1975), careful manipulation of consonant clusters, including their length and phoneme choice, should enable the investigator to observe how apraxic speech fluctuates with changes in the difficulty of the phonological combinations. Such information should be helpful in identifying if there are specific systematic patterns of articulatory behaviors used by apraxic speakers when combining phonemes in different consonantal environments.

A variety of techniques are available to describe articulation. Traditionally, investigators described phoneme substitution errors, measured articulatory accuracy according to the place of articulation, and compared the number of errors as a function of the manner of articulation. Analysis of phoneme feature errors involves the use

of both distinctive feature and marking descriptions (Chomsky and Halle, 1968). This technique is based on the assumption that phonemes ace not the smallest units in which a speech sound can be analyzed. Rather, phonemes are bundles of distinct articulatory and acoustic features which can be judged using a binary scoring system (+/-). Speech sounds would thereby be described as including (+) or not including (-) each of the specific features utilized (Table 1). Features can also be characterized as being either marked or unmarked (Chomsky and Halle, 1968). Marking refers to the productive and/or perceptual difficulty with which a feature is produced. Features rated as being marked are more difficult to produce and/or to perceive than unmarked features (Table 2).

Two distinct advantages occur from analyzing phonological patterns using a distinctive feature and making paradigm. First, evaluating changes in distinctive features enables the investigator to identify and analyze the articulatory error patterns employed by a speaker when producing a specific combinations of speech sounds. Finally, analyzing the marking patterns reveals whether these speech errors were produced using substitution patterns which were either elevated or depressed in terms of their perceptual or productive attributes.

Table 1. Distinctive Feature Ratings for Individual Consonants in English.

Features	Consonants																				
	p	b	t	d	k	g	m	n	ŋ	f	v	θ	ð	s	z	ʃ	ʒ	ʧ	ʤ	r	l	w	j
Place	1	1	4	4	6	6	1	4	6	2	2	2	3	3	4	4	5	5	5	5	4	6	5
Voice	-	+	-	+	-	+	+	+	+	-	+	-	+	-	+	-	+	-	+	+	+	+	+
Nasal	-	-	-	-	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Round																				+	-	+	-
Consonantal	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-
Friction	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	-	-	-	-
Stop	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-

*The places of articulation include: (1) bilabial, (2) labial dental, (3) lingual dental, (4) lingual alveolar, (5) palatal, (6) velar.

Adapted from Compton (1975).

Table 2. Marked (M) and Unmarked (U) Values of Nine Distinctive Features for English Consonants.

	Consonants																				
Features	z	s	ʒ	ϴ	d	t	v	f	b	p	ʃ	ʤ	ʧ	g	k	w	h	y	l	r	m	n
Consonantal	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	+	+	+	+
Vocalic	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	M	M	M	M	M	U	U
Anterior	U	U	U	U	U	U	U	U	U	U	M	M	M	M	M	U	U	U	U	U	U	U
Coronal	U	U	M	M	U	U	U	U	M	M	M	M	M	U	U	U	U	M	U	U	M	U
Continuant	M	M	M	M	U	U	M	M	U	U	M	U	U	U	U	U	U	U	U	U	U	U
Strident	U	U	M	M	U	U	M	M	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Voiced	M	U	M	U	M	U	M	U	M	U	U	M	U	M	U	U	M	U	U	U	U	U
Lateral	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	M	U	U	U
Nasal	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	M	M
Complexity	2	1	4	3	1	0	3	2	2	1	3	3	2	2	1	1	2	2	2	1	2	1

Note that the feature "consonantal" does not take on marked and unmarked values. This is because the conversion of all M's and U's for all features is dependent upon the +/- value of the feature "consonantal."

The use of nonsense syllables to assess articulatory control in apraxic speech is enhanced if these stimuli are tested under different linguistic conditions. Recall that those linguistic variables that influence apraxic speech include grammatical class (Dunlop and Marquardt, 1977; Hardison, Marquardt, and Peterson, 1977) and sentence voice (Hardison, Marquardt, and Peterson, 1977). Therefore, to adequately assess articulation, the test stimuli should be inserted into a meaningful sentence and assume the linguistic function of a specific grammatical class. If language variables do affect apraxic speech, then the linguistic function of the target stimulus should interact with the stimuli's phonological complexity to influence the articulatory abilities of the speaker.

Statement of Purpose

The purpose of this study was to measure the phonological changes which occur for apraxic speakers during the articulation of nonsense consonant-vowel (CV) combinations when both the phonological complexity and the linguistic nature of the stimuli were varied. The literature review indicates that the articulatory utterances of apraxic speakers are influenced by the linguistic complexity of the stimulus, and that although apraxic errors may be unpredictable, they are not unsystematic.

Therefore, five questions were asked during this investigation. The first two questions were designed to determine the effect of linguistic variables on apraxic speech. The remaining three questions evaluated the phonological characteristics of apraxic errors. Specifically, the intent of this investigation was:

1. To determine if there were significant differences in the percent correct articulation scores for consonant-vowel nonsense syllables when the syllable was produced in isolation or as part of a sentence.

2a. To determine if there were significant differences in the percent correct articulation scores for nonsense consonant-vowel syllables embedded in sentences that varied as a function of active and passive sentence voice construction.

2b. To determine if there were significant differences in the percent correct articulatory production for nonsense consonant-vowel syllables which served different grammatical functions in a sentence (subject, verb, object).

2c. To determine if there were significant differences in the percent correct acticulatory production for nonsense consonant-vowel syllables which were constructed using phonemes that contained either few or numerous marked distinctive features.

3. To determine if there were significant differences in the percent correct articulation values for individual phonemes.

4. To determine if the percent correct articulation for individual phonemes varied as a function of:

(a) The manner of production,

(b) The relative position (prevocalic, postvocalic) of the phoneme within both CVC and CCVCC stimuli, and

(c) Whether the consonant was positioned in either a consonant cluster (CCVCC) or noncluster (CVC) environment.

5. To determine the distinctive feature and markedness characteristics of the intruded versus the intended phonemes.

CHAPTER II

EXPERIMENTAL PROCEDURES

The experimental procedures involved eleven apraxic subjects producing 16 consonent-vowel combinations in isolation and in active and passive sentence structures. Eight CVC and eight CCVCC stimuli were constructed using phonemes that contained either few (0 to 1) or numerous (2 or 3) marked features. These stimuli were embedded in the subject, verb, and object function locations of a sentence.

Subjects

Eleven apraxic subjects were tested during this investigation. The subjects ages ranged from 50 to 76 years with a mean of 63.13 years (Table B-1, Appendix B). Each subject was a native speaker of English and possessed adequate hearing sensitivity as measured by responses to pure tone stimuli (at least 30 dB in the better ear for 500, 1000, 2000, and 4000 Hertz). Further, each subject:

1. Acknowledged the absence of any premorbid communicative impairment(s);

2. Possessed apraxia of speech without any measurable dysarthria as determined by performance on an oral peripheral mechanism evaluations;

3. Possessed permanent damage to only the left cerebral hemisphere of at least six weeks duration;

4. Possessed auditory comprehension abilities equal to or greater than +0.5 on the four auditory comprehension subtests of the Boston Diagnostic Aphasia Examination (Goodglass and Kaplan, 1972);

5. Possessed premorbid right handedness.

Stimulus Composition

This investigation was designed to measure how apraxic speakers' articulatory patterns fluctuate when influenced by both phonetic and linguistic variables. Three independent variables were manipulated during this investigation. These include: (1) sentence voice (active, passive); (2) grammatical class (subject, verb, object); and, (3) phonetic complexity (few marked features, numerous marked features).

Sentence voice was controlled using twelve active and twelve passive sentences. Active voice sentences were constructed using: article + noun 1 (subject) + verb + article + noun 2 (object). Passive voice sentences were constructed using: article + noun 1 (functional object) + "was" + verb + "by" + article + noun 2 (functional subject).

Grammatical class was controlled by inserting nonsense consonant-vowel stimuli into a sentence formation to serve as the subject, verb, or object function. For example, Appendix A presents 96 stimulus sentences in both the active and passive voice. Sentences 17 through 20 had the nonsense

syllables inserted into the subject function space while sentences 21 through 24 and 25 through 29 were constructed by inserting the nonsense syllables in the object and verb function slots, respectively.

Phonetic complexity was varied by using phonemes which differ along a distinctive feature paradigm. Two separate series of nonsense consonant-vowel combinations were constructed. A list of sixteen CVC and CCVCC syllable combinations is presented in Appendix A. Both of these two consonant-vowel stimulus sets (labeled 1 and 2) were divided into two separate groups (a and b) containing phonemes which differ in the number of marked features they possess. More specifically, both the CVC and CCVCC stimulus sets included two distinct sets of phonemes: consonant sound which contained few (0 or 1) marked features, and consonant phonemes that contained numerous (two or three) marked features.

Consonant clusters were designed using only phoneme combinations which occur in spoken English. Consonant clusters were paired with one of five vowels (/i,E,a,u,æ/) to produce 16 permissible but meaningless consonant-vowel combinations. Appendix A also shows eight CCVCC stimuli constructed using the initial consonant clusters /θr/, /fl/, /sm/, /ʃr/, /tw/, /sn/, /pr/, and /sk/. Each initial consonant cluster was paired with one vowel and one of the following sets of final consonant cluster pairs: /mz/,

/rm/, /rʃ/, /lθ/, /nt/, /ks/, /nd/, and /rp/. Thus, the nonsense stimulus /twEnt/ was constructed placing the initial consonant cluster /tw/ with the vowel /E/ and inserting the final cluster /nt/.

Specific consonant-vowel combinations were constructed using the following procedures. Highly marked CCVCC syllables (set 1a) were balanced by positioning phonemes which contain a total of 15 marked and 16 marked features in the prevocalic and postvocalic positions, respectively. The second CCVCC stimulus group (1b) was balanced using phonemes with few marked phonemes (a total of 7 marked features in both the prevocalic and postvocalic positions). CVC stimuli were constructed using the same technique. Consonant phonemes which contained 2 or more marked features were placed in prevocalic and postvocalic positions (stimulus set 2a). Phonemes which contained 0 or 1 marked features were used to form stimulus set 2b.

Equipment

Articulatory responses were recorded on a Panasonic (Model RQ-323A) cassette recorder. Reliability measurements were conducted using a Nicolet digital oscilloscope (model 206).

Experimental Test Paradigm

Subjects were seated facing the examiner in a well lighted room. Prior to actual testing, verbal instructions were read aloud by the examiner (Appendix A). Following delivery of these instructions, actual test procedures were simulated by introducing two practice sentences accompanied by two nonsense consonant-vowel stimuli (Appendix A). Practice stimuli were repeated, when necessary, until the experimenter was satisfied that the subject comprehended the test procedure. A subject was not tested if he/she failed to appropriately respond to the practice stimuli. Practice stimuli did not include those sentences or nonsense consonant-vowel combinations that occurred during the regular test conditions.

The experimental testing (actual test stimuli are shown in Appendix A) involved two separate procedures. First, the 16 nonsense consonant-vowel combinations were presented to the subject who repeated them. This procedure was repeated later and these 32 isolated productions served as a baseline condition for later comparisons with data obtained while inserting test stimuli into different linguistic environments. Following this procedure, the stimulus sentences (which contained the nonsense consonant-vowel stimuli) were read aloud twice by the examiner to insure that the subject heard and understood the sentence context. Then, the

experimenter repeated the stimulus sentence a third time while omitting the nonsense consonant-vowel combination. The subject's task was to repeat the nonsense consonant-vowel combination. Each subject's responses were audio recorded for later analysis.

Test stimuli were presented at a normal conversational rate. In the middle of the testing procedure, after the 16 nonsense syllables in isolation plus 48 nonsense syllables in the sentence form, the experimenter stopped the testing so that the subject could rest, obtain refreshments, or engage in conversational speech. Testing with the remaining 64 productions was then continued if the subject did not appear fatigued.

Although some of the apraxic subjects did attempt to self-correct their articulatory errors, only the first articulatory utterance was recorded as the scored response. Self corrected responses were not evaluated during the analysis procedures.

CHAPTER III

RESULTS

One hundred and twenty-eight syllable productions (32 in isolation, 96 in sentences) were recorded from each of ten apraxic subjects. Subject 9 produced CVC utterances easily but experienced articulatory difficulty and emotional distress while attempting to articulate the longer, more complex CCVCC stimuli. As a result, only CVC stimuli were recorded for this subject. Phonetic transcriptions for each consonant-vowel combination were recorded by the experimenter during the actual experimental testing. Later, audio recordings of the experimental session were examined by the investigator to refine and, when necessary, correct any errors in the phonetic transcriptions. These transcriptions were used to evaluate the articulatory behaviors of the apraxic subjects.

Reliability

Two different reliability measurements were compiled during this investigation. The first procedure involved calculating the consistency in the average amount of time required for the examiner to present, using live voice, either an active or passive sentence. Twenty-four sentences were measured from each group using a digital oscilloscope.

These calculations indicated the average duration for active and passive sentences were 6.47 (SD = 0.53) and 9.94 (SD = 0.88) seconds, respectively. These long durational values occurred because the test stimuli were produced slowly to facilitate easier recognition by the apraxic speakers.

The next procedure involved measuring interexaminer scoring reliability. The tape recorded responses for subject six (S6) were independently transcribed phonetically by two certified speech-language pathologists. Interexaminer reliability was measured by comparing the original transcriptions of the investigator with those transcriptions compiled by the two independent observers. The percent agreement between the investigator and observer number one was 94.72 percent. The same procedure repeated for observer number two yielded a reliability coefficient of 94.33 percent. When observer number one and two were compared, the agreement equalled 92.86 percent. It was concluded the experimenter's judgments were in agreement with the two independent observers.

Intraexaminer reliability was evaluated by having the investigator rescore the recorded responses from subject eight (S8) and comparing these values to the original transcriptions. The agreement between these two scoring procedures equalled 95.03 percent. It was concluded the experimenter's judgments were consistent.

Scoring

Twelve different levels (2 x 3 x 2 = 12) of the independent variable were tested for each subject in both the CVC and CCVCC calculations. Each of the twelve levels (Tables 3 and 4) were tested by asking each subject to produce four different consonantal-vowel nonsense syllables. For example, test stimuli 17-20, of the 96 sentences listed in Appendix A, involved four CCVCC combinations placed in the subject function location of 12 active sentences using consonants which possess few marked features. Test stimuli 21-24 possess similar characteristics except they are positioned in the object function location. The data reported are in terms of percent correct production of the intended vowel and consonants. For example, when subject 1 produced 17 correct phonemes from he 20 phonemes requested in stimuli 17-20, he received a percentage score of 85 percent (Table 4, first column, first row). The twelve percentage scores calculated for each subject for both CVC and CCVCC stimuli are displayed in Tables 3 and 4, respectively.

Statistical Model

For the stimuli in sentences, the influence of the three independent variables (sentence voice, grammatical class, and phoneme markedness) was measured using two separate three factor (Treatment by Treatment by Treatment

Table 3. Percent Correct Articulation Scores for CVC Stimuli. The Three Independent Variables Include: Active and Sentence Voice; Few (FMF) and Numerous (NMF) Marked Distinctive Features, and Subject (S), Verb (V), and Object (O) Grammatical Class Functions.

Voice Marking Class	Active						Passive					
	FMF			NMF			FMF			NMF		
	S	V	O	S	V	O	S	V	O	S	V	O
S1	91.66	76.92	76.92	76.92	73.33	91.76	84.62	64.29	84.62	71.43	68.75	84.62
S2	91.66	84.62	100.00	83.33	91.67	83.33	100.00	83.33	83.33	91.67	83.33	84.62
S3	58.33	66.67	83.33	76.92	56.25	92.31	55.56	71.43	52.94	76.92	71.43	92.31
S4	92.31	75.00	91.67	57.14	73.33	91.67	100.00	100.00	50.00	84.62	78.57	69.23
S5	100.00	85.71	92.31	76.92	71.43	83.33	92.31	76.92	92.31	91.67	84.62	84.62
S6	41.67	75.00	91.67	69.23	69.23	91.67	61.54	53.85	57.14	71.43	64.29	53.85
S7	100.00	83.33	83.33	83.33	83.33	100.00	83.33	83.33	83.33	75.00	75.00	83.33
S8	100.00	100.00	91.67	91.67	83.33	91.67	100.00	83.33	83.33	83.33	83.33	83.33
S9	100.00	76.92	64.29	69.23	66.67	71.43	84.62	84.62	91.67	58.33	50.00	66.67
S10	83.33	80.00	76.92	83.33	75.00	83.33	100.00	84.62	84.62	83.33	71.43	69.23
S11	85.71	85.71	91.31	75.00	55.56	83.33	64.29	60.00	71.43	75.00	53.85	41.67
$\bar{X}$	85.88	80.90	85.77	76.64	72.65	86.85	83.45	78.40	75.88	78.43	71.33	73.95
SD	18.16	8.18	9.58	8.81	10.47	7.21	15.36	14.30	14.79	9.37	11.07	14.77

Table 4. Percent Articulation Scores for CCVCC Stimuli. The Three Independent Variables Include: Active and Sentence Voice; Few (FMF) and Numerous (NMF) Marked Distinctive Features, and Subject (S), Verb (V), and Object (O) Grammatical Class Functions.

Voice Marking Class	Active						Passive					
	FMF			NMF			FMF			NMF		
	S	V	O	S	V	O	S	V	O	S	V	O
S1	85.00	85.71	90.00	54.55	77.27	80.00	90.00	61.90	85.00	52.38	54.17	63.64
S2	85.00	85.71	85.00	66.67	68.18	68.18	85.00	80.95	85.00	75.00	63.64	63.64
S3	71.43	72.73	76.19	73.19	68.18	80.95	61.90	77.27	52.17	80.95	77.27	68.18
S4	70.00	90.00	80.95	61.90	60.00	70.00	90.00	85.71	85.00	52.38	59.09	52.38
S5	85.00	80.95	85.00	54.55	71.43	66.67	85.00	95.24	90.00	60.00	75.00	65.00
S6	85.00	52.38	75.00	47.61	55.00	60.00	75.00	59.09	80.00	80.00	55.00	60.00
S7	61.90	70.00	70.00	85.00	66.67	47.62	71.42	80.00	85.00	66.67	50.00	70.00
S8	95.00	95.00	100.00	76.19	90.00	85.00	90.00	95.00	95.00	60.00	61.90	85.00
S9	-	-	-	-	-	-	-	-	-	-	-	-
S10	76.19	90.00	95.00	71.43	65.22	75.00	80.00	76.19	90.00	70.00	71.43	80.95
S11	80.00	76.19	80.00	59.09	85.00	85.00	75.00	81.82	90.00	85.00	76.19	80.00
$\bar{X}$	79.45	79.87	83.71	65.09	70.70	71.84	80.33	79.32	83.72	68.24	64.37	68.88
SD	9.15	11.92	8.82	11.02	10.20	11.30	8.94	11.30	11.23	11.27	9.50	9.76

by Subjects, or repeated measures) analysis of variance (ANOVA) calculations (Bruning and Kintz, 1977). The first ANOVA (Table B-2, Appendix B) evaluated CVC stimuli. The second ANOVA (Table B-3, Appendix B) measured CCVCC stimuli.

This ANOVA was chosen due to the design characteristics of this investigation. In this experiment, sentence voice, grammatical class, and phoneme markedness served as the three independent variables (refer to Tables 3 and 4). Since there were only a limited number (11) of apraxic speakers available for testing, it was necessary to use the repeated measures design whereby every subject was tested under all levels of each independent variable. Another option was a three-way factorial design where different subjects are randomly assigned to each of the twelve (Tables 3 and 4) treatment conditions (Bruning and Kintz, 1977). However, this design was not used because it requires a large number of apraxic subjects, which are only available in larger metropolitan areas.

There are both advantages and disadvantages to using the repeated measures design. The advantages are: (1) the need for fewer subjects, (2) all subjects complete all of the experimental conditions, and (3) the F-ratios are sensitive to small differences within the main effects and interactions. These differences may not be identified in a factorial design that has a large between-subject variance.

The disadvantage of removing the between-subject variance is that the data has to be interpreted with caution. Apraxic speakers possess speech behaviors that are highly variable, both within and between subjects. The repeated measures ANOVA may be too sensitive for apraxic speakers. More specifically, the F-ratios may indicate that the differences between two groups means are "significant," when, in fact, the magnitude of these differences are very small. These limitations will be discussed in further detail later.

Linguistic Variables

Sentence Voice and Grammatical Class

Two different linguistic variables, sentence voice (active, passive) and grammatical class (subject, verb, object), were tested. Initially, to determine whether the sentence environment, regardless of its linguistic structure, influenced articulatory production, accuracy scores were compared using those consonant-vowel stimuli which occurred in isolation with the same stimuli embedded in sentences. Table 5 compares the total percent correct articulation scores for CVC stimuli presented in isolation and sentences. Articulatory accuracy for phonemes in isolation ranged from 74.51 percent (S11) to 97.92 percent (S5) with a mean of 87.68 percent. The articulatory accuracy for CVC stimuli embedded in sentences ranged from

Table 5. Total Percent Correct Articulation Scores for CVC Stimuli in Sentences Only, Isolation Only, and a Total Comparison Contrasting CVC Scores in Isolation and Sentences.

	Sentences Only							Isolation Only		Total Comparison	
	Voice		Markedness		Grammatical Class						
	Active	Passive	FMF	NMF	Subject	Verb	Object	FMF	NMF	*Isolation	*Sentences
S1	80.77	74.70	79.49	77.11	80.77	70.69	84.31	100.00	87.50	93.75	77.63
S2	89.04	87.67	90.41	86.30	91.67	85.75	87.76	96.00	83.33	89.80	88.36
S3	71.79	69.86	63.77	76.83	68.09	65.31	78.18	84.62	92.00	88.24	70.86
S4	79.49	80.26	84.93	75.31	82.69	81.13	75.51	95.83	75.00	85.42	79.87
S5	84.62	87.01	89.74	80.77	90.00	79.63	88.24	100.00	95.83	97.92	85.81
S6	72.97	60.49	63.16	69.62	61.54	65.38	72.55	88.46	83.33	86.00	66.45
S7	88.89	80.55	86.11	83.33	85.42	81.25	87.50	87.50	91.67	89.58	84.72
S8	91.67	87.50	94.44	84.72	91.67	91.67	85.42	100.00	87.50	93.75	89.58
S9	74.36	72.37	85.71	63.64	75.00	69.23	73.08	87.50	68.00	77.55	73.38
S10	80.26	81.82	84.62	77.33	87.50	77.78	78.43	92.31	83.33	88.00	81.05
S11	78.31	61.25	76.19	63.29	75.00	63.33	72.55	74.07	75.00	74.51	69.94
$\bar{X}$	81.11	76.68	81.69	76.20	81.10	75.80	80.31	91.48	83.86	87.68	78.88
SD	6.45	9.38	9.81	7.49	9.49	8.89	6.15	7.68	8.01	6.55	7.52

*Isolated condition involves the combined scores for those CVC stimuli rated as FMF and NMF. Sentence condition includes all CVC stimuli embedded in active and passive sentences, regardless of which grammatical function they assume or the number of marked features they contain.

66.45 percent (S6) to 89.58 percent (S8) with a mean of 78.88 percent. A t-test (Bruning and Kintz, 1968) comparing the articulation scores for CVC stimuli in isolation and sentences indicated the difference between these group means was statistically significant ($t = 4.61$; $df = 10$; $p < 0.001$).

The same analysis was repeated for CCVCC stimuli. Table 6 illustrates percent correct articulation for CCVCC stimuli in isolation ranged from 75.00 percent (S7) to 92.50 percent (10) with a mean of 85.26 percent. Articulatory accuracy for CCVCC stimuli embedded in sentences ranged from 65.16 percent (S6) to 85.54 percent (S8) with a mean of 74.59 percent. A t-test comparing these CCVCC scores indicates the differences between means was statistically significant ($t = 4.49$; $df = 9$; $p < 0.01$). These results illustrate that for both CVC and CCVCC stimulus sets, stimuli embedded in sentence contexts are produced with less articulatory accuracy than stimuli articulated in isolation.

Further measurements were performed to determine whether certain characteristics associated with the sentence environments, specifically sentence voice and grammatical class, influence the articulatory abilities in apraxic speakers. Hardison, Marquardt, and Peterson (1977) reported that apraxic speakers exhibited more articulatory errors on stimuli embedded in passive sentences than in active

Table 6. Total Percent Correct Articulation Scores for CCVCC Stimuli in Sentences Only, Isolation Only, and a Total Comparison Contrasting CCVCC Scores in Isolation and Sentences.

	Sentences Only							Isolation Only		Total Comparison	
	Voice		Markedness		Grammatical Class						
	Active	Passive	FMF	NMF	Subject	Verb	Object	FMF	NMF	*Isolation	*Sentences
S1	78.40	67.19	82.79	63.36	69.87	69.32	79.27	87.50	75.00	81.25	72.73
S2	76.19	75.20	84.43	67.44	77.78	74.42	75.00	80.95	70.45	78.31	75.70
S3	73.85	69.47	68.46	74.81	72.09	73.86	68.97	95.00	87.50	91.25	71.65
S4	72.13	70.40	83.61	59.20	68.29	73.49	71.95	92.50	85.00	88.75	71.26
S5	73.60	82.64	86.89	65.32	70.73	80.72	76.54	95.00	71.43	82.93	78.05
S6	62.30	68.03	70.73	59.50	71.60	55.42	68.75	90.42	87.50	88.89	65.16
S7	66.67	70.49	72.95	64.23	71.08	66.67	67.90	75.00	75.00	75.00	68.29
S8	90.08	80.99	95.00	76.23	80.25	85.19	91.25	95.00	87.50	91.25	85.54
S9	-	-	-	-	-	-	-	-	-	-	-
S10	78.40	78.05	84.43	72.22	74.39	75.29	85.19	100.00	85.00	92.50	78.23
S11	77.24	81.30	80.49	78.05	74.39	79.76	82.50	77.50	87.50	82.50	79.27
$\bar{X}$	74.89	74.38	80.98	68.04	73.05	73.41	76.73	88.89	81.19	85.26	74.59
SD	7.06	5.67	7.69	6.53	3.51	7.89	7.42	7.99	6.90	5.76	5.66

*Isolated condition involves the combined scores for those CVC stimuli rated as FMF and NMF. Sentence condition includes all CVC stimuli embedded in active and passive sentences, regardless of which grammatical function they assume or the number of marked features they contain.

sentences and more errors on the first noun phrase (subject function) than on the second (object function) noun phrase. Both the Table 5 and Figure 1 present the percent correct articulation scores for CVC stimuli in sentences as a function of sentence voice. Articulatory accuracy for stimuli embedded in active sentences ranged from 71.79 percent (S3) to 91.67 percent (S8) with a mean of 81.11 percent. Articulatory accuracy for stimuli embedded in passive sentences ranged from 60.49 percent (S6) to 87.67 percent (S2) with a mean of 76.68 percent. A statistical evaluation indicated the differences between means for active and passive sentences was significant ($F = 5.60$; $df = 1,10$; $p < 0.039$). Further, Table 5 illustrates that eight of the eleven subjects produced lower articulation scores on the passive voice sentences.

The same calculations were performed using CCVCC articulation scores. Both Table 6 and Figure 2 illustrate articulatory accuracy for stimuli embedded in active sentences ranged from 62.30 percent (S6) to 90.08 percent (S8) with a mean of 74.89 percent. Articulatory accuracy for stimuli embedded in passive sentences ranged from 67.19 percent (S1) to 81.30 percent (S11) with a mean of 74.38 percent. The difference between these means was not statistically significant ($F = 0.27$; $df = 1,9$; $p < 0.618$). The results for this investigation partially support the

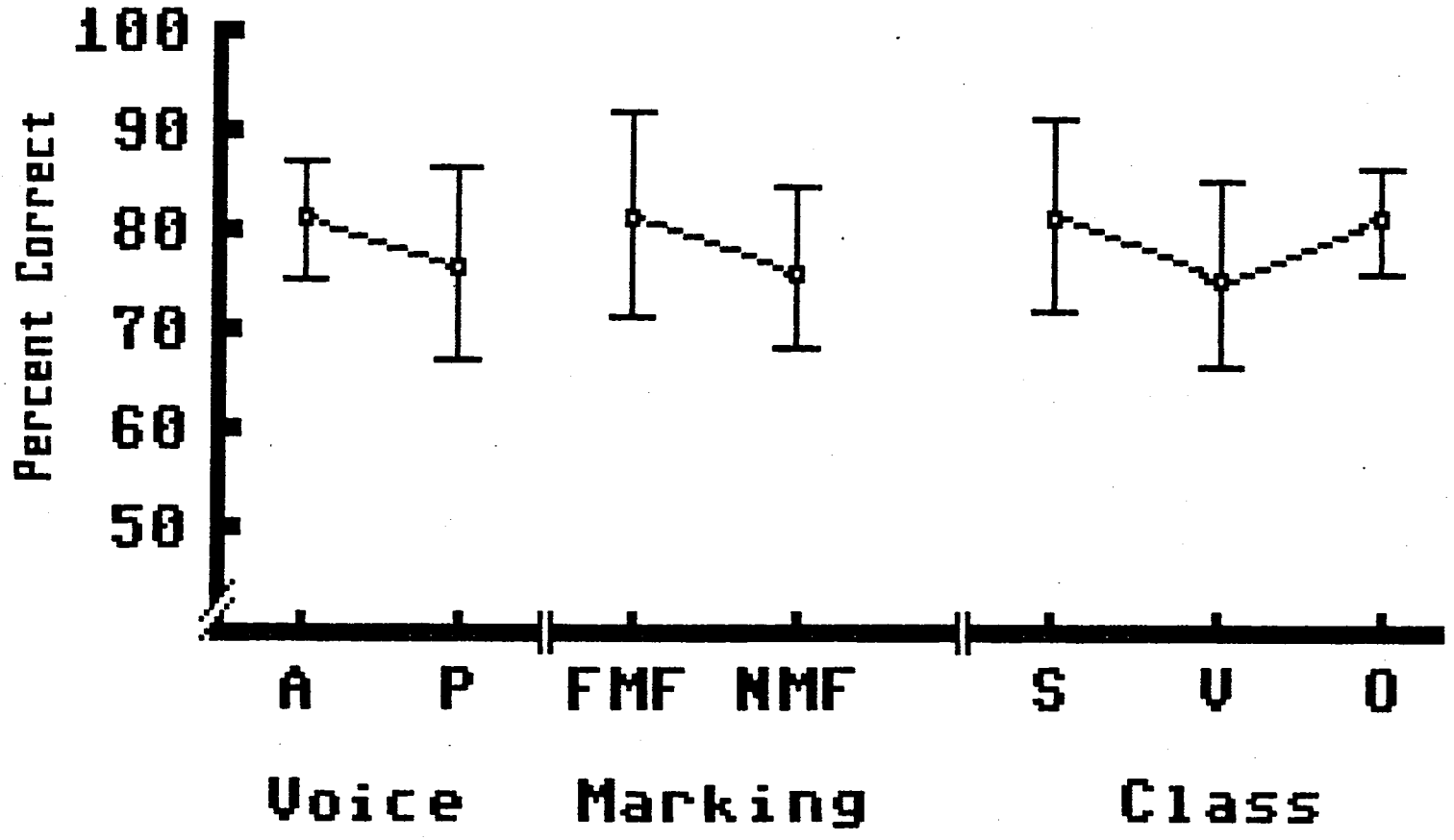


Figure 1. Means and standard deviation markers for CVC stimuli embedded in sentences. Values are plotted for three different conditions: sentence voice, including active (A) and passive (P) construction; phonetic marking, including stimuli which contain few (FMF) and numerous (NMF) marked features; and, grammatical class, including stimuli located in the subject (S), verb (V), and object (O) function locations of the sentence.

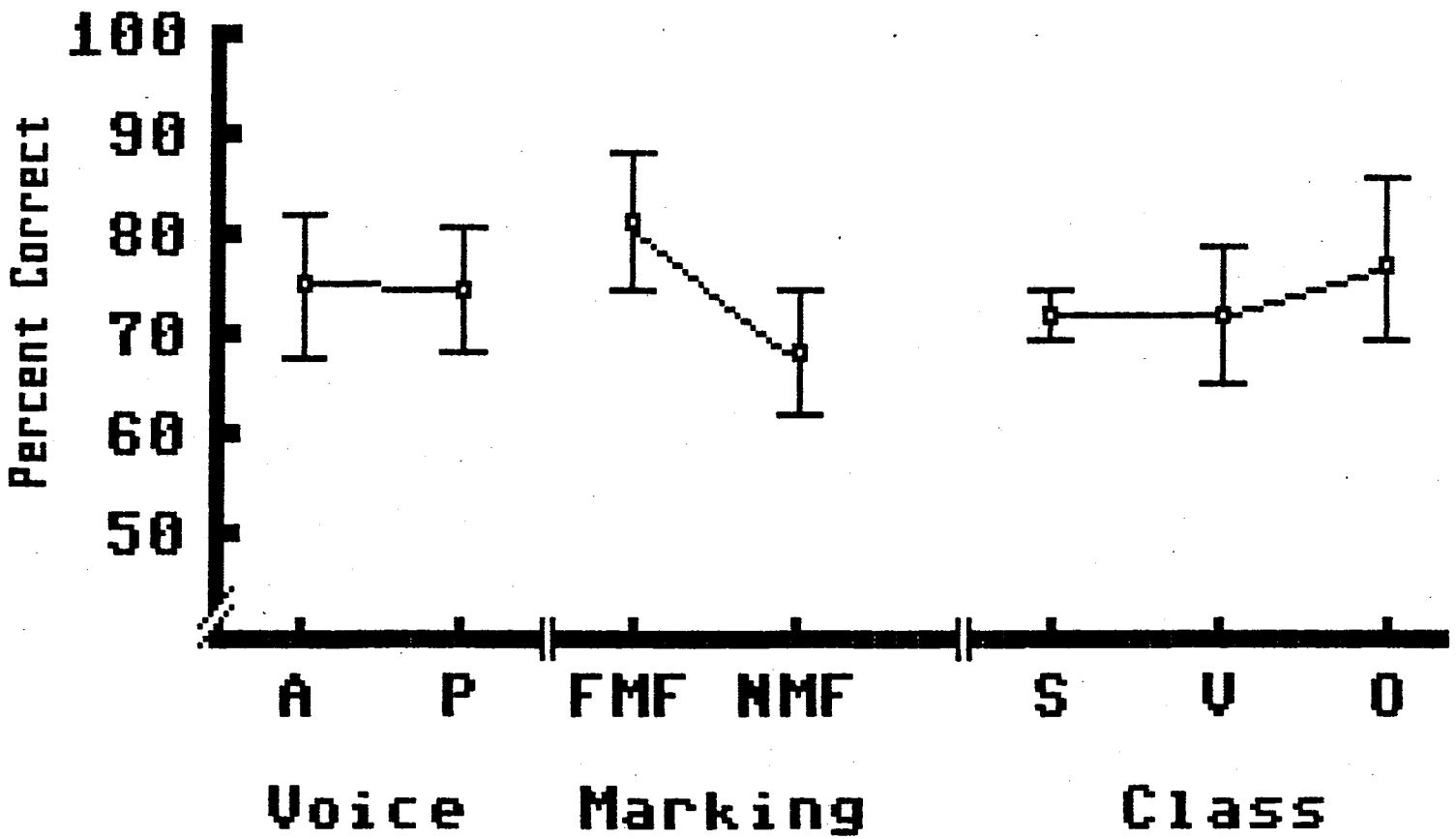


Figure 2. Means and standard deviation markers for CCVCC stimuli embedded in sentences. Values are plotted for three different conditions: sentence voice, including active (A) and passive (P) construction; phonetic marking, including stimuli which contain few (FMF) and numerous (NMF) marked features; and, grammatical class, including stimuli located in the subject (S), verb (V), and object (O) function locations of the sentence.

findings presented by Hardison, Marquardt, and Peterson (1979). Sentence voice only influenced the articulatory accuracy of CVC stimuli. The articulation of CCVCC stimuli, however, did not fluctuate significantly when embedded in active or passive voice sentences.

Table 5, p. 37, and Figure 1 presented the articulation scores for CVC stimuli embedded in different grammatical class (subject, verb, object) locations. Articulatory accuracy in the subject function location ranged in accuracy between 61.54 (S6) and 91.67 percent (Ss 2,8) with a mean of 81.10 percent. Stimuli embedded in the verb function location ranged from 63.33 percent (S11) to 91.67 percent (S8) with a mean of 75.80 percent. Stimuli embedded in the object function location ranged from 72.55 percent (Ss 6,11) to 88.24 percent (S5) with a mean of 80.31 percent. The differences among these means were significant ($F = 4.29$; $df = 2,20$; $p < 0.028$) with a Duncan multiple range test demonstrating the verb function location (75.80 percent) produced significantly lower articulatory accuracy scores than either the subject (81.10 percent) or object (80.31 percent) function locations (whose differences were not significant). Further, close inspection of Table 5 indicates eight of eleven subjects produced lower articulation scores on the verb function stimuli.

Percent correct articulation values for CCVCC stimuli embedded in different grammatical class locations (Table 6 and Figure 1) illustrate articulatory proficiency in the subject function location ranged from 68.29 percent (S4) to 80.25 percent (S8) with a mean of 73.05 percent. Stimuli embedded in the verb function location ranged from 55.42 percent (S6) to 85.19 percent (S8) with a mean of 73.41 percent. Stimuli embedded in the object function location ranged from 67.90 percent (S7) to 91.25 percent (S8) with a mean of 76.73 percent. Statistical evaluation of these means indicates their differences were not significant ($F = 2.10$; $df = 2,18$; $p < 0.15$).

The results of this analysis partially support the findings presented by Hardison, Marquardt, and Peterson (1977). Specifically, grammatical class significantly influenced the articulatory performance of CVC stimuli. The articulation of CCVCC were not affected. Further, it is interesting to note that CCVCC stimuli were not influenced by the same linguistic variables as CVC stimuli, regardless of the fact that CCVCC stimuli embedded in sentences were produced with lower accuracy than CCVCC stimuli in isolation. Evidently, other linguistic factors, beside sentence voice and grammatical class, affect the articulation of CCVCC stimuli in sentences.

Articulatory Variables

Phonetic Complexity

The influence of phonetic complexity on articulatory production was tested using stimuli that contained phonemes which possessed either few (0 or 1), or numerous (2 or 3) marked distinctive features. Marquardt, Reinhart, and Peterson (1979) reported apraxic substitution errors were characterized by more articulation errors occurring on phonemes containing numerous marked features. During the present investigation, stimuli were originally tested in isolation to serve as a control condition for later comparisons with stimuli embedded in sentences. Table 5, p. 37, presents the articulation scores for CVC stimuli produced in isolation only. Articulatory proficiency for syllables in isolation which contained few marked features (FMF) ranged from 74.07 percent (S11) to 100 percent (Ss 1,5,8) with a mean of 91.48 percent. Articulatory proficiency for stimuli containing numerous marked features (NMF) ranged from 68.00 percent (S9) to 95.83 percent (S5) with a mean of 83.86 percent. A comparison of these means using a t-test revealed that difference was statistically significant ($t = 2.75$; $df = 10$; $p < 0.03$).

The same analysis was performed using CCVCC stimuli in isolation. Table 6, p. 39, reveals articulatory proficiency for stimuli containing few marked features ranged from

75.00 percent (S7) to 100 percent (S10) with a mean of 88.89 percent. Articulatory proficiency for stimuli containing numerous marked features ranged from 70.45 percent (S2) to 87.50 percent (Ss 3,6,8,11) with a mean of 81.19 percent. A comparison of these means revealed that difference was statistically significant ($t = 2.70$; $df = 9$; $p < 0.05$). These results indicate that for both CVC and CCVCC stimulus sets produced in isolation, articulatory proficiency is significantly reduced when articulating phonemes which contain numerous marked features.

Phonetic complexity was tested further by analyzing these phoneme sets (FMF and NMF) in sentences. Both Table 5, p. 37, and Figure 1 contrast the articulation scores for CVC stimuli containing few and numerous marked features. Articulatory accuracy for phonemes containing few marked features ranged from 63.16 percent (S6) to 94.44 percent (S8) with a mean of 81.69 percent. Articulatory accuracy for phonemes containing numerous marked features ranged from 63.29 percent (S11) to 86.30 percent (S2) with a mean of 76.20 percent. Analysis of these means indicates the difference closely approached, but did not reach, statistical significance ($F = 3.51$, $df = 1,10$; $p < 0.09$).

These calculations were repeated using CCVCC stimuli. Both Table 6, p. 39, and Figure 2 illustrate articulatory proficiency for phonemes containing few marked features

ranged from 68.46 percent (S3) to 95.00 percent (S8) with a mean of 80.98 percent. Articulatory accuracy for stimuli containing numerous marked features ranged from 59.20 percent (S4) to 78.05 percent (S11) with a mean of 68.04 percent. The difference between these two means was statistically significant ($F = 18.55$; $df = 1,9$; $p < 0.002$). Further, close inspection of Table 6, p. 39, indicates nine of ten subjects produced lower articulation scores on stimuli containing numerous marked features. These results partially support the findings of previous investigators (Marquardt, Reinhart, and Peterson, 1979). When CVC and CCVCC stimuli are embedded in sentences, articulatory proficiency is significantly reduced when apraxics articulate phonemes containing numerous marked features.

ANOVA calculations were also used to determine whether the three main effects significantly interacted with each other. Close inspection of Tables B-2 and B-3 (Appendix B) illustrate that none of these interactions were significant. This finding indicates that sentence voice, grammatical class, and phonetic complexity influence apraxic speech in separate manners.

Articulatory Performance of Single Phonemes

Articulatory performance for individual phonemes was evaluated by calculating, for the entire subject population, the percent correct articulation for vowels and consonants

in isolation, sentences, and both conditions combined. Different investigators (Shankweiler and Harris, 1966; Johns and Darley, 1970; Trost and Canter, 1974) have reported that certain consonants (/θ,v,ʃ,dʒ,z/) are produced with lower articulatory accuracy by apraxic speakers. For the present investigation, articulation scores for individual consonants are presented in Table 7. Since each phoneme did not occur with equal frequency in this investigation, percent correct values shown at the bottom of Table 7 were calculated using the total number of correct productions divided by the intended number of phoneme occurrences. In isolation, articulatory proficiency ranged from 48.81 percent (/θ/) to 94.23 percent (/m/) with a mean of 84.17 percent. In sentences, articulatory accuracy ranged from 30.00 percent (/z/) to 93.27 percent (/m/) with a mean 76.04 percent. Overall articulatory accuracy ranged from 37.50 percent (/z/) to 93.50 percent (/m/) with a mean of 78.07 percent.

Close inspection of Table 7 indicates that (1) for every phoneme, lower articulatory accuracy occurred when producing consonants in sentences, and (2) the lowest articulation scores occurred when articulating those consonants (/z,ʃ,0/) identified by previous authors (Shankweiler and Harris, 1966; Johns and Darley, 1970; Trost and Canter, 1974; and Marquardt, Reinhart, and Peterson, 1979) as being severely affected in apraxic speech, and

Table 7. Percent Correct Articulation Scores for Individual Consonants Occurring in Consonant-Vowel Stimuli in Isolation and When Embedded in Sentences.

	Number of Marked Features	Condition		
		Overall	Isolation	Sentences
/m/	2	* 93.51 (389/416)	94.23 (98/104)	93.27 (291/312)
/r/	1	87.92 (422/480)	93.33 (112/120)	86.11 (310/360)
/s/	1	84.07 (417/496)	91.94 (114/124)	81.45 (303/372)
/p/	1	83.93 (282/336)	90.48 (76/84)	81.74 (206/252)
/k/	1	83.93 (282/336)	88.09 (74/84)	82.54 (208/252)
/f/	2	83.20 (213/256)	89.06 (57/64)	81.25 (156/132)
/n/	1	82.08 (197/240)	90.00 (54/60)	79.44 (143/180)
/t/	0	79.46 (267/336)	86.90 (73/84)	76.98 (194/252)
/l/	2	79.46 (267/336)	85.71 (72/84)	77.38 (195/252)
/w/	1	70.00 (56/80)	80.00 (16/20)	66.67 (40/60)
/d/	1	66.25 (53/80)	75.00 (15/20)	63.33 (38/60)
/θ/	3	47.32 (159/336)	48.81 (41/84)	46.83 (118/252)
/ʃ/	3	40.00 (64/160)	52.50 (21/40)	35.83 (43/120)
/z/	2	37.50 (30/80)	60.00 (12/20)	30.00 (18/60)
Group Percent Score		78.07 (3098/3968)	84.17 (835/99)	76.04 (2263/2976)

*Numbers in parentheses present the number of correct productions divided by the number of stimulus presentations. These values are presented to demonstrate the unequal proportion of occurrences for phonemes in this investigation.

(3) very low accuracy scores were obtained for phonemes which possessed three marked features (/θ,ʃ/).

Articulatory proficiency for vowel stimuli are shown in Table 8. Vowels were analyzed to determine whether there were any significant differences in articulation between individual phonemes. Very little variation occurred during the production of vowel stimuli across different test conditions (i.e., the CVC and CCVCC stimuli in isolation and sentences). Therefore, Table 8 represents the combined articulatory proficiency scores for each vowel presented in isolation and sentences. Table 8 immediately illustrates that vowels are produced with greater accuracy than consonants (Table 7) supporting the findings of previous investigators (Shankweiler and Harris, 1966; LaPointe and Johns, 1975). Articulatory accuracy for the vowels ranged between 94.84 and 100.00 percent for vowels /i/ and /æ/, respectively. Statistical evaluation of the differences among these five vowel means (Treatment-by-Subjects ANOVA, Table B-3, Appendix B) did not achieve statistical significance ($F = 2.43$; $df = 4,40$; $p < 0.07$).

Analysis of these five vowel stimuli indicates vowels are produced with a relatively high degree of accuracy and apraxic speakers may produce different vowels with various degrees of proficiency. Additional analysis revealed vowel accuracy was not related to either advancement (front-back)

Table 8. Percent Correct Articulation Scores for the Five Vowel Stimuli. Percent Values Represent Scores for CVC and CCVCC Stimuli Combined; Syllables in Isolation and Sentences Combined.

	Vowel				
	/i/	/E/	/ɑ/	/u/	/æ/
S1	100.00	100.00	100.00	100.00	100.00
S2	96.67	100.00	93.33	93.33	100.00
S3	96.67	90.00	100.00	100.00	100.00
S4	80.00	93.33	100.00	100.00	100.00
S5	100.00	96.67	100.00	100.00	100.00
S6	90.00	96.67	80.00	96.67	100.00
S7	96.67	100.00	100.00	100.00	100.00
S8	100.00	100.00	100.00	96.67	100.00
S9	93.33	93.33	100.00	100.00	100.00
S10	93.33	96.67	100.00	100.00	100.00
S11	96.67	96.67	96.67	93.33	100.00
$\bar{X}$	94.84	96.67	97.27	98.18	100.00
SD	5.57	3.17	5.83	2.16	-

or vertical height (high-middle-low) of the tongue, or to the amount of tension (tense-lax) present in the musculature of the oral cavity. Further, articulatory accuracy for individual vowels used did not appear to have differentially affected the consonant articulation.

Manner of Production

Consonants displayed in Table 7 were analyzed by classifying phonemes depending on their means of production to identify if consonantal errors occurred according to any systematic pattern. LaPointe and John (1975) reported fricatives and affricatives resulted in a significantly greater number of errors than glides, nasals, and plosives. In the present investigation, consonant stimuli were classified as being nasal (/m,n/), liquid or glide (/l,r,w/), plosive (/t,d,k,p/), or fricative (s,θ,z,f,ʃ/). Table 9 presents data supporting LaPointe and Johns. Both in isolation and sentences, nasals were produced with the greatest degree of articulatory proficiency, followed by liquids and glides, plosives, and finally fricatives in decreasing order of accuracy. Figure 3 illustrates the same relationship graphically. Specifically, the hierarchical order of articulatory accuracy between these four categories did not change regardless of whether the consonantal stimuli were produced in isolation or sentences.

Table 9. Percent Correct Articulation Scores for Single Consonants in Isolation and Sentences, as a Function of the Manner of Production for CVC and CCVCC Stimuli Combined.

Means of Production	Phoneme	Isolation	Sentences
Nasals	/m/	94.23 (98/104)	93.27 (291/312)
	/n/	90.00 (54/60)	79.44 (143/180)
	Group Percent Score	92.68 (152/164)	88.21 (434/492)
Liquids and Glides	/l/	85.71 (72/84)	77.38 (195/252)
	/r/	93.33 (112/120)	86.11 (310/360)
	/w/	80.00 (16/20)	66.67 (40/60)
	Group Percent Score	89.29 (200/224)	81.10 (545/672)
Plosives	/t/	86.90 (73/84)	76.98 (194/252)
	/k/	88.09 (74/84)	82.54 (208/252)
	/p/	90.48 (76/84)	81.74 (206/252)
	/d/	75.00 (15/20)	63.33 (38/60)
	Group Percent Score	87.50 (238/272)	79.17 (646/816)
Fricatives	/s/	91.94 (114/124)	81.45 (303/372)
	/θ/	48.81 (41/84)	46.83 (118/252)
	/z/	60.00 (12/20)	30.00 (18/60)
	/f/	89.06 (57/64)	81.25 (156/192)
	/ʃ/	52.50 (21/40)	35.83 (43/120)
	Group Percent Score	73.80 (245/332)	64.56 (638/996)

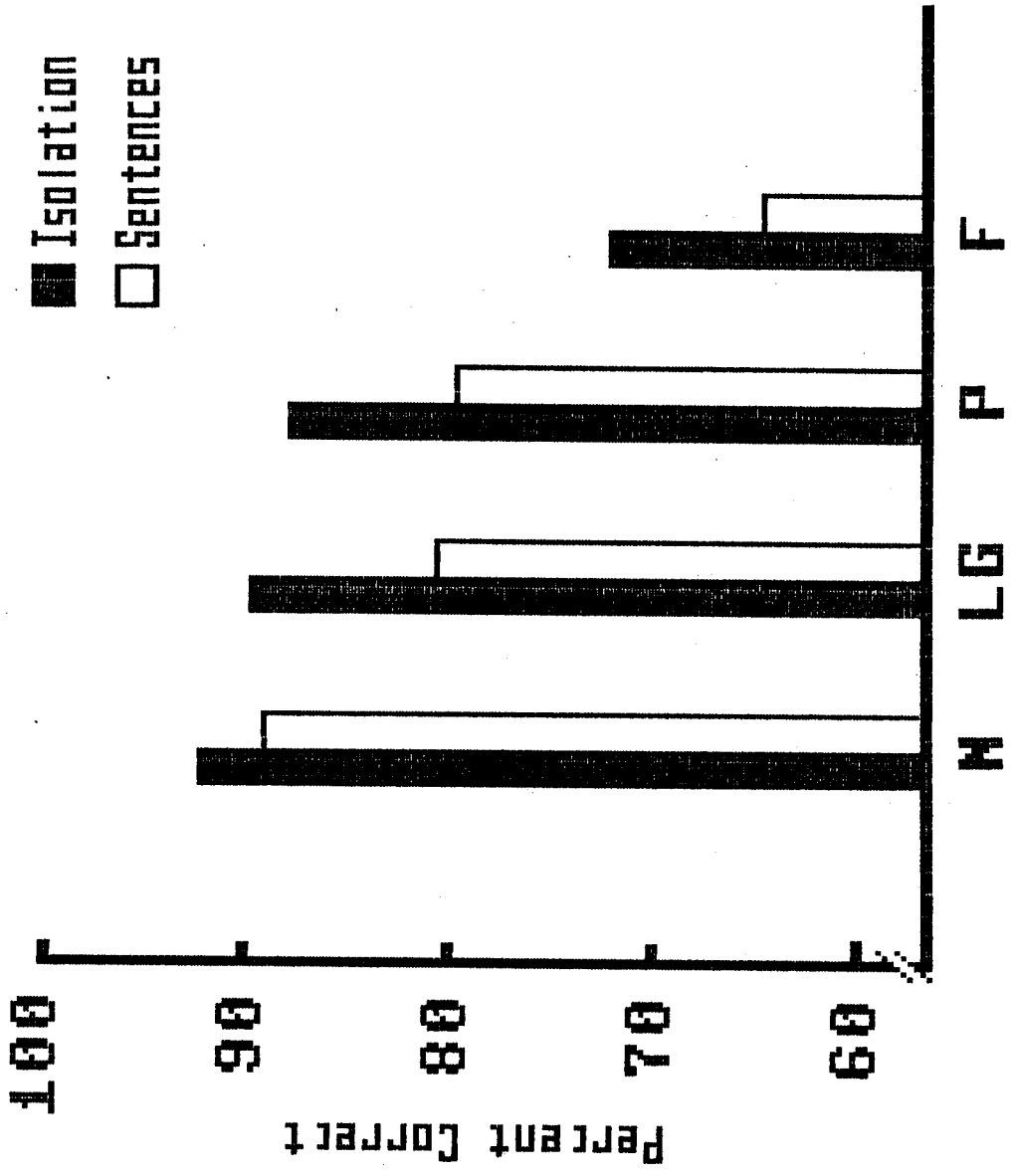


Figure 3. Percent correct articulatory proficiency values for single consonants as a function of the manner of production for CVC and CCVCC stimuli combined. Four manners of production include nasals (N), liquids and glides (LG), plosives (P), and fricatives (F).

Articulatory Accuracy as a Function of Phoneme Position

Ease of production for individual consonants was evaluated according to their relative position in the CVC and CCVCC stimuli. Previous investigators have presented conflicting results describing the influence of phoneme position on articulatory production. Shankweiler and Harris (1966) and Trost and Canter (1974) reported lower articulatory accuracy on initial position phonemes while other investigators (LaPointe and Johns, 1975) discovered equal proficiency at producing phonemes embedded in the initial, medial, and final word positions. For this investigation, consonants were classified as occurring in either the prevocalic or postvocalic position. For prevocalic consonants in isolated CVC stimuli (Table 10), articulatory proficiency ranged from 63.64 percent (/θ/) to 100.00 percent (/p/) with a mean of 89.20 percent. The subjects' articulatory proficiency for postvocalic consonants in isolated CVC stimuli ranged from 40.91 percent (/θ/) to 100.00 percent (/l/) with a mean of 85.22 percent. A statistical evaluation of the differences between prevocalic and postvocalic means indicates these differences were not significant ($t = 0.83$; $df = 7$). Table 10 also compares the articulatory proficiency scores of prevocalic and postvocalic CVC consonants in sentences. For prevocalic consonants, articulatory accuracy ranged from 68.18 percent (/θ/) to 96.97 percent

Table 10. Percent Correct Articulation Scores for CVC Consonants in Isolation and Sentences for Prevocalic and Postvocalic Positions.

	Isolation		Sentences	
	Prevocalic	Postvocalic	Prevocalic	Postvocalic
/t/	81.62 (18/22)	9.45 (21/22)	78.79 (52/66)	71.21 (47/66)
/s/	100.00 (22/22)	95.45 (21/22)	83.33 (55/66)	84.85 (56/66)
/k/	95.45 (21/22)	81.82 (18/22)	95.45 (63/66)	74.24 (49/66)
/p/	100.00 (22/22)	90.91 (20/22)	87.88 (58/66)	95.45 (63/66)
/0/	63.64 (14/22)	40.91 (9/22)	68.18 (45/66)	31.82 (21/66)
/m/	95.45 (21/22)	95.45 (21/22)	96.97 (64/66)	93.94 (62/66)
/f/	90.91 (20/22)	81.82 (18/22)	78.79 (52/66)	72.73 (48/66)
/1/	86.36 (19/22)	100.00 (22/22)	72.73 (48/66)	100.00 (66/66)
Group Percent Scores	89.20 (157/176)	85.25 (150/176)	82.77 (437/528)	78.03 (412/528)

(/m/) with a mean of 82.77 percent. For postvocalic consonants, articulatory accuracy ranged from 31.82 percent (/ɵ/) to 100.00 percent (/l/) with a mean of 78.03 percent. A statistical evaluation of the differences between these means indicates these differences were not significant ($t = 0.708$; $df = 7$).

The same analysis procedures were performed for prevocalic and postvocalic consonants positioned in CCVCC stimuli. Table 11 illustrates articulatory proficiency for prevocalic consonants in isolation ranged from 65.00 percent (/l/) to 95.00 percent (/f/) with a mean of 83.75 percent. Articulatory proficiency for postvocalic consonant ranged from 15.00 percent (/θ/) to 97.50 percent (/m,n/) with a mean of 81.25 percent (260/320). A t-test for independent means revealed this difference was not significant ($t = 0.29$; $df = 22$). Table 11 also presents the percent correct articulation for prevocalic and postvocalic consonants embedded in sentences. Articulatory accuracy for prevocalic consonants ranged from 51.67 percent (/l,ʃ/) to 93.33 percent (/f/) with a mean of 78.02 percent. Articulatory proficiency for postvocalic consonants ranged from 15.00 percent (/θ/) to 94.17 percent (/m/) with a mean of 69.27 percent. A t-test for independent means revealed this difference was not significant ($t = 1.00$; $df = 22$). The results for both CVC and CCVCC stimuli, in isolation and

Table 11. Percent Correct Articulation Scores for CCVCC Consonants in Isolation and Sentences for Prevocalic and Postvocalic Positions.

	Isolation		Sentences	
	Prevocalic	Postvocalic	Prevocalic	Postvocalic
/t/	80.00 (16/20)	90.00 (18/20)	80.00 (48/60)	78.33 (47/60)
/w/	80.00 (16/20)	*	66.67 (40/60)	*
/n/	75.00 (15/20)	97.50 (39/40)	75.00 (45/60)	81.67 (98/120)
/s/	90.00 (54/60)	85.00 (17/20)	87.78 (158/180)	56.67 (34/60)
/k/	80.00 (16/20)	95.00 (19/20)	83.33 (50/60)	76.67 (46/60)
/p/	75.00 (15/20)	95.00 (19/20)	73.33 (44/60)	68.33 (41/60)
/r/	93.33 (56/60)	93.33 (56/60)	83.89 (151/180)	88.33 (159/180)
/d/	*	75.00 (15/20)	*	63.33 (38/60)
/θ/	75.00 (15/20)	15.00 (3/20)	71.67 (43/60)	15.00 (9/60)
/m/	85.00 (17/20)	97.50 (39/40)	86.67 (52/60)	94.17 (113/120)
/z/	*	60.00 (12/20)	*	30.00 (18/60)
/f/	95.00 (19/20)	*	93.33 (56/60)	*
/l/	65.00 (13/20)	90.00 (18/20)	51.67 (31/60)	83.33 (50/60)
/ʃ/	80.00 (16/20)	25.00 (5/20)	51.67 (31/60)	20.00 (12/60)
Group Percent Scores	83.75 (268/320)	81.25 (260/320)	78.02 (748/960)	69.27 (665/960)

*Did not test.

sentences, support the findings of LaPointe and Johns (1975), and Dunlop and Marquardt (1977). There were no significant differences in the articulatory proficiency of consonants located in the prevocalic versus postvocalic position of syllables.

Consonantal Accuracy in Cluster and Noncluster Environments

The influence of consonant clusters on the articulatory proficiency of single consonants was analyzed by measuring the accuracy for those consonants which occurred in CVC stimuli (without surrounding consonants) with the accuracy scores for the same consonants clustered in CCVCC stimuli. Previous investigations have shown a greater number of articulatory errors occur on consonant clusters than consonant singletons (Shankweiler and Harris, 1966; Johns and Darley, 1970; Trost and Canter, 1974). During this study, the relative difficulty of articulating consonant clusters was not evaluated. Rather, the influence of the consonant cluster environment on the production accuracy of single consonants was measured.

Table 12 indicates that for prevocalic phonemes, articulatory proficiency for consonants positioned in noncluster environments (CVC stimuli) ranged from 63.63 percent (/θ/) to 100.00 percent (/s,p/) with a mean of 89.20 percent. For the same phonemes positioned in clustered

Table 12. A Comparison of the Percent Correct Articulation Scores for Consonants Which Occur in Consonantal Cluster (CCVCC) and Nonclu-ster (CVC) Environments for Isolated Stimuli in Prevocalic and Post-vocalic Positions.

	Prevocalic		Postvocalic	
	CVC	CCVCC	CVC	CCVCC
/t/	81.82 (18/22)	80.00 (16/20)	95.4 (21/22)	90.00 (18/20)
/s/	100.00 (22/22)	90.00 (54/60)	95.45 (21/22)	85.00 (17/20)
/k/	95.45 (21/22)	80.00 (16/20)	81.82 (18/22)	95.00 (19/20)
/p/	100.00 (22/22)	75.00 (15/20)	90.91 (19/22)	95.00 (19/20)
/θ/	63.64 (14/22)	75.00 (15/20)	40.91 (9/22)	15.00 (3/20)
/m/	95.45 (21/22)	85.00 (17/20)	95.45 (21/22)	97.50 (39/40)
/f/	90.91 (20/22)	95.00 (19/20)	*	*
/l/	86.36 (19/22)	65.00 (13/20)	100.00 (22/22)	90.00 (18/20)
Group Percent Scores	89.20 (157/176)	82.50 (165/200)	85.06 (131/154)	83.12 (133/160)

*Did not test.

environments (CCVCC stimuli), articulatory accuracy ranged from 65.00 percent (/l/) to 95.00 percent (/f/) with a mean of 83.75 percent. A statistical comparison of these means indicates these differences closely approached, but did not meet, the predetermined level of significance ($t = 2.09$; $df = 7$; $p < 0.07$). For postvocalic stimuli, articulatory accuracy for consonants in noncluster environments ranged from 40.91 percent (/θ/) to 100.00 percent (/l/) with a mean of 85.23 percent. Phonemes in the cluster environment ranged from 15.00 percent (/θ/) to 97.50 percent (/m/) with a mean of 80.71 percent. A statistical comparison of these means indicates this difference was not significant ($t = 0.92$; $df = 6$).

The same analysis procedure was performed for stimuli embedded in sentences. Table 13 presents articulatory accuracy scores for consonants positioned in prevocalic and postvocalic positions of CVC and CCVCC stimuli. For prevocalic phonemes, articulatory accuracy for consonants in noncluster environments ranged from 68.18 percent (/θ/) to 96.67 percent (/m/) with a mean of 82.77 percent. Phonemes in clustered environments ranged from 51.67 percent (/ʃ/) to 93.33 percent (/f/) with a mean of 78.02 percent. The difference between these scores was not significant ($t = 1.00$; $df = 7$). For postvocalic stimuli, articulatory accuracy for consonants in noncluster environments ranged

Table 13. A Comparison of the Percent Correct Articulation Scores for Consonants Which Occur in Consonantal Cluster (CCVCC) and Noncluster (CVC) Environments for Sentence Stimuli in Prevocalic and Postvocalic Positions.

	Prevocalic		Postvocalic	
	CVC	CCVCC	CVC	CCVCC
/t/	78.79 (52/66)	80.00 (48/60)	71.21 (47/66)	78.33 (47/60)
/s/	83.33 (55/66)	87.78 (158/180)	84.85 (56/66)	56.67 (34/60)
/k/	95.45 (63/66)	83.33 (50/60)	74.24 (49/66)	76.67 (46/60)
/p/	87.88 (58/66)	73.33 (48/60)	95.45 (63/66)	68.33 (41/60)
/θ/	68.18 (45/66)	71.67 (43/60)	31.82 (21/66)	15.00 (9/60)
/m/	96.97 (64/66)	86.67 (52/60)	93.94 (62/66)	94.17 (113/120)
/f/	78.79 (42/66)	93. 33 (56/60)	*	*
/l/	72.73 (48/66)	51.67 (31/60)	100.00 (66/66)	83.33 (50/60)
Group Percent Scores	82.77 (437/528)	80.33 (482/600)	78.03 (412/528)	70.83 (340/480)

*Did not test.

from 31.82 percent (/θ/) to 100.00 percent (/l/) with a mean of 78.03 percent. Phonemes in cluster environments ranged from 15.00 percent (/θ/) to 94.17 percent (/m/) with a mean of 70.83 percent. A comparison of the differences between these means approached, but did not meet, statistical significance ($t = 2.05$; $df = 6$; $p < 0.10$).

The results of these four comparisons indicates that under certain conditions (initial position phonemes in isolated syllables and final position phonemes when target syllables were embedded in sentences) articulatory proficiency apparently decreases when consonants are positioned in clustered environments. Further, although these differences were not significant, close inspection of Tables 12 and 13 indicate that for each of the four comparisons, the consistency of the means suggests a trend whereby consonants positioned in clustered (CCVCC) environments were produced with lower accuracy than nonclustered (CVC) consonants.

Phoneme Error Patterns and Distinctive Feature Errors

Phonetic error patterns, including those fluctuations which occurred across different testing conditions, were analyzed by classifying each error as either a prolongation, substitution, addition, omission, distortion, or a combination of categories. Trost and Canter (1974) reported errors on consonant singletons were characterized primarily by

substitutions (67.10 percent) while consonant clusters were characterized by omissions (31.20 percent). Table 14 illustrates that for this investigation, for both the CVC and CCVCC stimuli sets, substitutions accounted for over half of the total number of errors, and substitutions and additions combined accounted for 75.80 percent of the errors. Further, both Figure 4 and Table 14 illustrate that: (1) vowel errors were characterized by only substitutions (80.00 percent) and omissions (20.00 percent), (2) distortions and prolongations accounted for relatively few errors in consonant error productions, and (3) there was a large shift in the proportion of addition and omission errors between the CVC and CCVCC stimulus sets. In CVC stimuli, addition errors occurred more frequently than omissions, while with CCVCC stimuli, additions and omissions occurred in relatively equal proportions.

Substitution errors were analyzed in greater detail using the error matrix shown in Table 15. Table 15 presents the substitution errors for consonants which occurred in both isolation and sentences. The horizontal axis indicates the intended phoneme. The vertical axis identifies the intruded phonemes. The values presented in this matrix indicate: (1) the number of times the intruded phoneme substituted for the target phoneme, (2) the total number of occurrences in which the intruded phoneme was used as a

Table 14. Percent Distribution of Articulation Errors Among Six Categories for both Vowel and Consonant Stimuli.

Error Category	All Phonemes	CVC Consonants	CCVCC Consonants	Vowels
Substitutions	56.30	51.00	61.75	80.00
Additions	17.76	30.77	13.46	0.00
Omissions	15.24	4.84	17.99	20.00
Distortions	4.03	6.27	4.00	0.00
Prolongations	0.70	0.00	1.13	0.00
Other	5.96	7.12	4.00	0.00

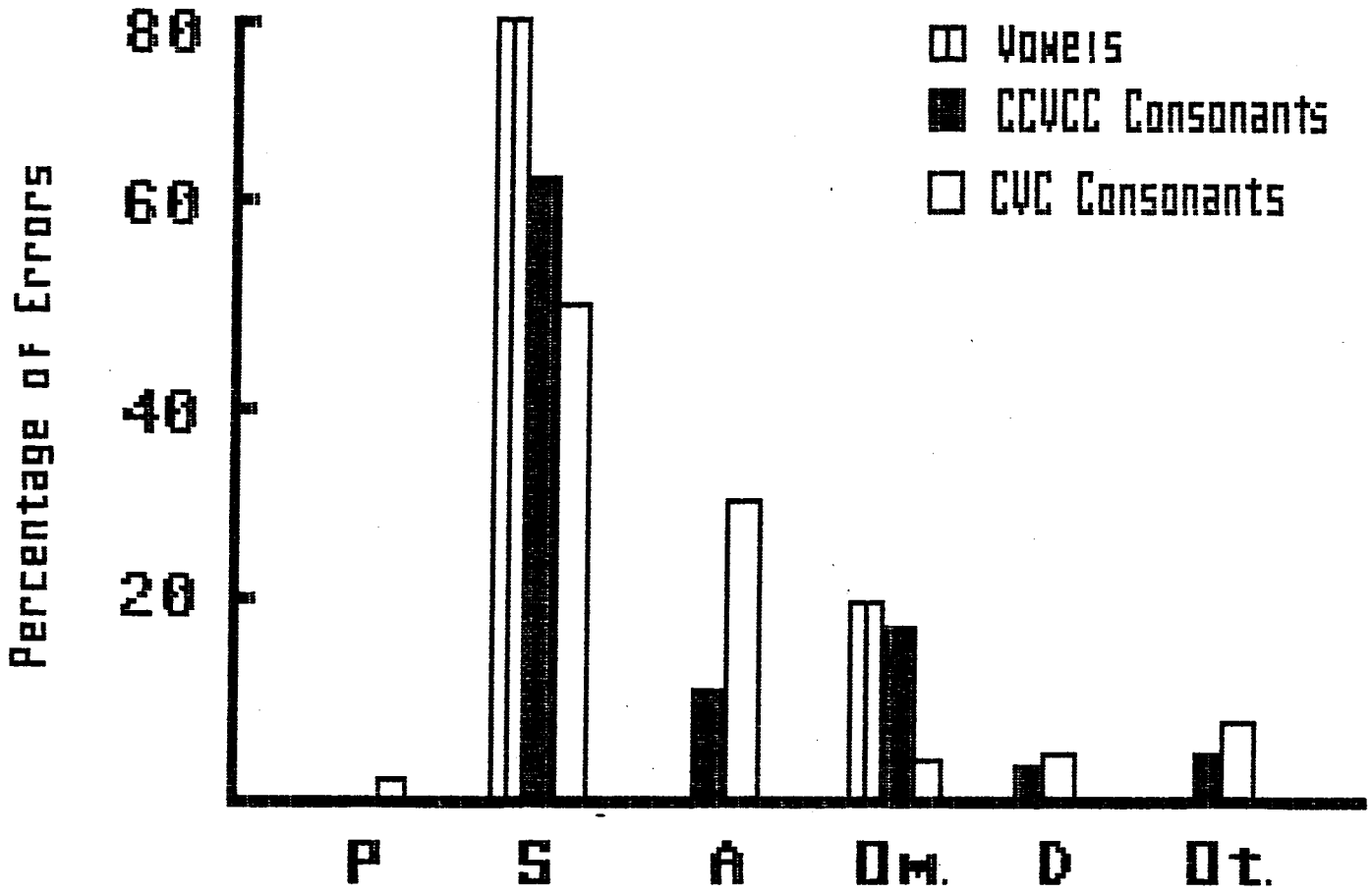


Figure 4. Proportional distribution of articulatory errors for vowel and consonantal stimuli. Error categories include prolongations (P), substitutions (S), additions (A), omissions (Om.), distrotions (D), and other (Ot.).

Table 15. Error Matrix of Substituted Phonemes. Horizontal Axis Presents the Intended Phoneme, the Number of Marked Features Possessed by the Intruded Phoneme, the Number of Times an Intruded Phoneme Was Used as a Substitution, and the Relative Proportion, in Percent, in Which a Single Intruded Phoneme Occurred in the Data. The Vertical Axis Represents the Intruded Phonemes.

Intruded Phoneme	Intended Phoneme														No. Marked Features Intruded Phoneme	No. Substitution Events	Percent Total Errors
	θ	ʃ	m	z	f	l	w	n	s	k	p	r	d	t			
/ð/	1				1										4	2	0.32
/θ/	X	2			14	1			1					7	3	25	4.00
/ʃ/	3	X							6					2	3	11	1.76
/v/					6			1							3	7	1.12
/tʃ/		1							1	1				3	3	6	0.96
/dʒ/			1								1				3	2	0.32
/m/	2		X			5		15			1	14			2	37	5.93
/z/				X											2	0	0.00
/f/	70	5	1		X	2			1	1	14			1	2	95	15.22
/l/	1				1	X						1			2	3	0.48
/b/			2								6				2	8	1.28
/g/			1												2	1	0.16
/w/			1			3	X	1				11			1	16	2.56
/n/			6			1		X		2		1			1	10	1.60
/s/	31	68		32	2				X	1		1	1	5	1	141	22.59
/k/	1							1	2	X	11			15	1	30	4.80
/p/	3		8		7	1		1	5	7	X	3	2	13	1	50	8.01
/r/						24	20	1	1	1		X			1	47	7.53
/d/	5	3	3	6									X	2	1	19	3.04
/t/	35	4			1	2		8	12	32	14		5	X	0	114	18.27

X = correct response.

substitution, (3) the number of marked features possessed by the intruded phoneme, and (4) the relative proportion, in percent, in which a single intruded phoneme occurred in comparison to all of the substituted phonemes present in the data. Table 15 indicates that three phonemes (/s,t,f/) were used extensively for substitutions and constituted 56.08 percent of the intruded phonemes found in apraxic speech. Further, phonemes with zero and one marked feature were more frequently used as substitutions than those phonemes containing two or more marked features.

Consonant substitution errors were analyzed further using a distinctive feature paradigm. Five features were selected for analysis during this investigation. They included place, voicing, stop, nasality, and friction. A total of 624 phoneme substitutions were produced by the eleven subjects. Each substitution was evaluated to determine how many of these features were in error. For example, a p/b substitution had one error feature (voicing) while an f/m substitution produced five error features. Table 16 presents the total number of substitutions, along with their proportional values, which contained from one through five error features. The results indicated that articulatory errors of apraxic speakers closely approximate the target phonemes with 77.88 percent of the phoneme substitutions being within two features of the intended consonants.

Table 16. Number and Percent Distribution of Distinctive Feature Errors Present in Consonant Substitutions.

	Number of Features in Error				
	1	2	3	4	5
Number of Occurrences	431	55	126	9	3
Percentage of Substitutions	69.07	8.81	20.19	1.44	0.48

The number and percent error occurrences for these five features are displayed in Table 17. The place features was the most prevalent error occurring in 83.33 percent of the substitutions. Three features (stop, friction, and voicing) occurred in approximately equal error proportions, while the nasality feature was, evidently, the most resistant to change having occurred in only 8.90 percent of the phoneme substitutions.

The five error features listed were each analyzed separately to identify any consistent patterns in the feature substitution errors. The place feature was evaluated by measuring whether the articulatory substitutions were produced in the same area of the oral cavity as the target phoneme. The oral cavity was divided into six different places of articulation (Table 1, place feature, p. 19): bilabial, labial dental, lingual dental, lingual alveolar, palatal, and velar. A p/f substitution had one place in error (bilabial to labial dental) while a p/k substitution covered five places (bilabial to velar). Table 18 indicates that 57.63 percent of the phoneme substitutions were removed only one place from the location where the intended phoneme was to be articulated. Further, approximately 79 percent of the intruded phonemes were within two places of the intended point of articulation.

Table 17. Contribution of Five Distinctive Features to the Consonant Substitutions Exhibited by Apraxic Subjects.

	Number of Occurrences	*Percentage of Substitutions
Place	520	83.33
Stop	153	24.52
Friction	133	21.31
Voicing	104	16.60
Nasality	55	8.90

*Values add to greater than 100.00% due to many substitutions containing more than one error feature.

Table 18. Number and Percent Distribution of Articulatory Placement Errors Present in Consonant Substitutions as a Function of Physical Distance, Within the Oral Cavity, Separating the Substituted Phoneme from the Target Phoneme.

	Number of Features in Error				
	1	2	3	4	5
Number of Occurrences	302	111	71	20	20
Percent of Substitutions	57.63	21.18	13.55	3.82	3.82

To summarize, the previous distinctive feature analysis for stop, friction, voicing, and nasality errors are displayed in Table 19. Two different error patterns are possible for each feature. Stop feature substitutions can be characterized as shifting from stop (S) to continuant (C), or continuant to stop phonemes. Friction feature substitutions can be characterized as shifting from either friction (F) to nonfriction (NF), or nonfriction to friction phonemes. Voicing feature substitutions can be characterized as changing from voiced (V) to voiceless (VL), or voiceless to voiced phonemes. Finally, nasality errors can be characterized by substitutions that shift from nasal (N) to oral (O), or oral to nasal phonemes.

The results of these measurements indicate: (1) stop feature errors were characterized by substituting stop consonants for continuant consonants (continuant to stop) in 75.16 percent of the substitutions, (2) friction feature errors were characterized by replacing friction consonants with nonfriction consonants (friction to nonfriction) in 66.92 percent of the feature substitutions, (3) voicing feature errors were characterized by voiced phonemes being replaced by voiceless phonemes (voiced to voiceless) in 67.31 percent of the feature substitution, and (4) nasality feature errors were characterized by a similar proportion of nasal to oral (53.57 percent) and oral to nasal (46.43 percent) substitutions. In other words, nonfriction replaced

Table 19. Distinctive Feature Substitution Patterns Present in Stop, Friction, Voicing, and Nasality Distinctive Feature Errors.

Features	Substitution Pattern	
Stop	Stop to Continuant	Continuant to Stop
	24.84	75.16
	(38/153)	(115/153)
Friction	Friction to Nonfriction	Nonfriction to Friction
	66.92	33.08
	(89/133)	(44/133)
Voice	Voiced to Voiceless	Voiceless to Voiced
	67.31	32.69
	(70/104)	(34/104)
Nasality	Nasal to Oral	Oral to Nasal
	53.57	46.43
	(30/56)	(26/56)

friction, unvoiced replaced voiced, stop replaced continuant, and the relatively stable feature of nasality/orality is equivocal.

To summarize, the previous distinctive feature analysis indicates the phoneme substitution patterns that occurred during this investigation were similar to those behavior presented by previous authors. LaPointe and Johns (1975) reported that approximately 62 percent of the phoneme substitutions were defective in less than two distinctive features. The results for this investigation equaled approximately 69 percent. The subphonemic feature analysis closely agrees with the results presented by Trost and Canter (1974). Specifically, the place feature was commonly substituted while nasality was resistant to change, the articulatory placement of error phonemes closely approximated the point of maximal construction for the target phoneme, and fluctuations of the stop, friction, and voicing features followed consistent and predictable substitution patterns.

The 17 percent fluctuation in addition errors (Table 14, p. 65) between CVC and CCVCC suggests these errors may have been a function of the lower articulatory proficiency scores present in CVC passive voice sentences and verb function locations. During the data analysis, it was noticed that a subject would commonly insert an extra

phoneme when articulating a verb function stimulus. For example, the sentence "The girl /θaem/ the machine" often resulted in an additional phoneme (usually /t/) being added to the CVC stimulus. Further analysis of the addition errors for sentence stimuli indicated the verb function received a disproportionate share of these misarticulations. Table 20 reveals that for CVC stimuli (active and passive sentences combined), verb function stimuli were responsible for 50.45 percent of the addition errors while the subject and object function stimuli contributed 23.85 and 25.69 percent, respectively. The same phenomenon occurred for CCVCC stimuli. Verb function stimuli received 51.19 percent of the addition errors while subject and object functions received 27.38 and 21.43 percent, respectively.

The disproportionate number of addition errors occurring in the verb function location led to speculation that addition errors might vary for stimuli embedded in either active or passive voice sentences. Table 20 illustrates that for CVC stimuli, active and passive voice sentences received 44.95 and 55.05 percent of the addition errors respectively, a difference of more than 10 percent. This discrepancy was smaller for CCVCC stimuli. Active and passive sentences received 51.19 and 48.81 percent of the addition errors, respectively, a difference of 2.38 percent. In view of these findings, it could be hypothesized that the

Table 20. Number and Proportional Distribution of Addition Errors to CVC and CCVCC Stimuli Which Occurred in Sentences as a Function of Sentence Voice and Grammatical Function.

Stimulus Set	Sentence Voice	Number of Addition Errors	Percentage of Addition Errors	Grammatical Function	Number of Addition Errors	Percentage of Addition Errors
CVC	Active	49	44.95	Subject	26	23.85
	Passive	60	55.05	Verb	55	50.45
				Object	28	25.69
CCVCC	Active	43	55.19	Subject	23	27.38
	Passive	41	48.81	Verb	43	51.19
				Object	18	21.43

disproportionate number of addition errors presented in passive sentences and verb function locations may be related to the specific phonemes included in the postvocalic positions of these consonant-vowel stimuli. For example, the stimuli /twEnt/ or /prind/ sound as if they could be past tense verbs already, whereas /skarp/ could be interpreted as a present tense verb that would become /skarpt/ in a past tense utterance. Further investigation is needed to substantiate these speculations.

Phoneme Markedness Fluctuations

Subject error scores, including means and standard deviations, for phonemes containing zero, one, two, and three marked features are shown in Table 21. As stated earlier, feature markedness (Table 2, p. 20) describes the perceptual and/or articulatory difficulty of different phonemes. Marquardt, Reinhart, and Peterson (1979) theorized that the phoneme substitutions exhibited by apraxic speakers, while being unpredictable, are not unsystematic. Specifically, by analyzing phoneme markedness fluctuations, it becomes possible to determine if substituted phonemes are more, less, or equal in articulatory difficulty to the target phoneme.

Table 21 illustrates articulatory accuracy for the phoneme containing zero marked features (/t/) ranged from 53.13 percent (S7) to 96.88 percent (S4) with a mean of

Table 21. Percent Correct Articulation Scores for Phonemes Containing Zero, One, Two, and Three Marked Distinctive Features.

Subject	0	1	2	3
S1	78.13	84.82	71.09	35.95
S2	96.86	77.23	63.54	46.88
S3	71.88	75.29	84.53	56.25
S4	96.88	75.74	87.08	53.13
S5	90.63	87.20	72.14	43.75
S6	56.25	68.00	76.72	33.32
S7	53.13	63.24	70.05	42.19
S8	87.50	92.26	89.12	51.56
S9	87.50	81.25	70.83	50.00
S10	84.83	89.43	67.45	37.50
S11	59.36	85.27	60.99	62.50
$\bar{X}$	78.41	79.97	74.86	46.64
SD	15.28	8.62	9.20	8.66

78.41 percent. Articulatory accuracy for phonemes containing one marked feature (/w,n,s,k,p,r,d/) ranged from 63.24 percent (S7) to 92.26 percent (S8) with a mean of 79.97 percent. Articulatory accuracy for phonemes containing two marked features (/m,z,f,l/) ranged from 60.99 percent (S11) to 89.12 percent (S8) with a mean of 74.86 percent. Finally, articulatory accuracy for phonemes containing three marked features (/θ,ʃ/) ranged from 37.50 percent (S10) to 62.50 percent (S11) with a mean of 46.64 percent. A Treatment-by-Subjects ANOVA (Table B-5, Appendix B) indicates there is a significant different among these four group means ($F = 27.13$; $df = 3,30$; $p < 0.001$) with a Duncan multiple range test indicating stimuli with three marked features possessing significantly lower articulatory proficiency scores than stimuli with zero, one or two marked features (whose differences are not significant).

Phoneme substitutions which were less marked, more marked, or contained the same number of marked features as the target phoneme are shown in Table 22. Overall, almost 85 percent of the substituted phonemes contained fewer marked features than the target phoneme while the more marked alternative was chosen only 15 percent of the time (68.80 percent less marked, 15.77 percent same markedness, and 15.42 percent more marked).

Table 22. Percentage of Intruded Phonemic Substitutions with More, Less, and the Same Markedness Values as the Target for Phonemes with Markedness Values of 1, 2, and 3.

Markedness of Target Phoneme	Markedness of Produced Phoneme		
	Less Marked	More Marked	Same Markedness
1	34.45 (72/209)	30.62 (64/209)	34.93 (73/209)
2	72.93 (97/133)	18.05 (24/133)	9.02 (12/133)
3	97.02 (228/235)	0.43 (1/235)	2.55 (6/235)
Total	68.80 (397/577)	15.42 (89/577)	15.77 (91/577)

These substitution patterns were analyzed by comparing the observed percentage of substitutions which actually occurred during this experiment, with the percentage of substitutions which could be expected had the articulatory substitutions occurred completely at random. For example, 34.45 percent of the substitutions occurred where a less marked phoneme (0 marked features) was intruded for a phoneme containing one marked feature (first row, first column, Table 22). Since only one phoneme (/t/) contains zero marked features, and 22 English consonants (from a total of 26 consonants which have been rated for markedness) are available for substitution, then only 4.5 percent of the substitutions (1/22 = 4.5 percent) should have occurred in this condition by chance alone. A chi-square analysis comparing the observed and expected phoneme substitutions indicated a significantly large number of apraxic errors ($\chi^2 = 301.41$; $df = 4$; $p < 0.001$) are characterized by intruded phonemes containing fewer marked features than the intended phoneme.

Summary of Results

1. For both CVC and CCVCC stimulus sets, stimuli embedded in sentence contexts are produced with less articulatory accuracy than syllables articulated in isolation.

2. Sentence voice and grammatical function significantly influence the articulatory accuracy of only CVC stimuli embedded in sentences. Although patterns of responses for active versus passive voice and subject, verb, object function for CCVCC stimuli were similar to those of CVC stimuli, the differences in the means for CCVCC stimuli were not statistically significant.

3. For CVC and CCVCC stimuli produced in both isolation and sentences, a greater number of articulatory errors occur when producing phonemes containing numerous marked features.

4. Nasal phonemes are produced with the greatest degree of articulatory accuracy, followed by liquids and glides, plosives, and finally fricatives in decreasing order of proficiency. This order did not change regardless of whether the consonants were produced in isolation or in sentences.

5. There was no significant difference in the articulatory proficiency of phonemes occurring in the prevocalic or postvocalic positions for either CVC or CCVCC stimuli in isolation or in sentences.

6. Although these data did not reach significance, the relative consistency of the values suggests that under certain conditions (initial position phonemes in isolation and final position phonemes in sentences) there is a

possibility that articulatory proficiency may decrease when consonants are positioned in clustered environments.

7. The apraxic speakers articulation errors were characterized primarily by phoneme substitutions in both CVC and CCVCC stimuli. Phoneme additions were more prevalent in CVC than CCVCC stimuli.

8. Relatively few consonants were used as intruded phonemes during consonantal substitutions. Specifically, three phonemes (/s,t,f/) accounted for 56.08 percent of the intruded phonemes during this investigation.

9. Articulatory substitutions closely approximated the physical and acoustic attributes of the target phoneme with 77.88 percent of the phoneme substitutions being within two features of the intended consonants.

10. The distinctive feature "place" is highly susceptible to change in apraxic speech while the feature "nasality" is relatively stable.

11. Phoneme addition errors in CVC stimuli occurred predominantly in the verb function location and on passive voice sentences. Further, these addition errors may be an artifact which contributed to the finding that sentence voice and grammatical class were both significantly affected for CVC stimuli embedded in sentences.

12. Phoneme substitutions are characterized primarily by phonemes which contain few marked features being intruded for phonemes containing numerous marked features.

CHAPTER IV

DISCUSSION

Previous investigators have disagreed whether the phonological characteristics of apraxic speech represent a disruption in language, or a disorientation in the ability to spatially and temporally coordinate the articulators. Martin (1974) argued the phonological errors of aphasics (who possessed apraxia of speech) are very similar in nature, and that the faulty selection and sequencing of phonemes occurs due to a disruption in language. Other authors (Aten, Johns, Deal, and Darley, 1975) strongly disagreed with this premise while subsequent theorists (Roy, 1978) and investigators (Klinch, Ireland, and Weider, 1979; Kent and Rosenbek, 1983; Collins, Rosenbek, and Wertz, 1983) have suggested apraxia is a disruption in the capacity to program the speech musculature. Unfortunately, this controversy has not diminished due to the discovery that both articulatory and linguistic variables hinder the articulation in apraxic speakers.

The purpose of this discussion is to describe how sentence voice, grammatical class, and phonetic complexity each influence the sequencing of phonemes. First, each variable will be analyzed individually to determine how they affect the production of CVC stimuli. The results

from this investigation will be compared with data presented by other researchers to identify any significant discrepancies in the results and discuss why these differences occur. Later, the influence of these three variables on the production of CCVCC stimuli will be discussed. Finally, near the end of this chapter, both the linguistic and articulatory data will be combined with preexisting theories in an attempt to describe the motor speech behaviors in apraxic speech.

Linguistic Variables

Stimulus Accuracy in Isolation and Sentences

Mean articulation scores were originally calculated for consonant-vowel stimuli tested in isolation and in sentences. Recall that these two measurements were originally designed to determine whether the sentence environments, regardless of their linguistic characteristics, affect apraxic speech. For CVC stimuli, mean accuracy scores for stimuli in isolation and sentences were 87.68 and 78.88 percent, respectively. Articulatory accuracy scores for CCVCC stimuli in isolation and sentences were 85.26 and 74.59 percent, respectively. A statistical evaluation of these two conditions indicated the sentence environment significantly influenced the articulation of the test stimuli.

One logical explanation for this finding is that the apraxic speakers possessed, to a limited degree, auditory retention deficits due to the presence of aphasia. As reported earlier, 65 percent of all apraxics are impaired by aphasia (Wertz, Rosenbek, and Deal, 1975). If this finding is correct, then the auditory retention deficits that appear in the aphasic population (Carpenter and Rutherford, 1973) may also exist, to some degree, in apraxic speakers. Aten, Johns, and Darley (1971) partially tested the auditory retention of phonetic stimuli by measuring the speech discrimination abilities for 10 subjects with apraxia of speech. When presented with a three word sequence, these authors reported apraxic speakers made significantly more perceptual errors when attending to words located in the final position of the stimulus. These authors suggested that: (1) apraxic subjects demonstrate, as a group, receptive phonological processing difficulties, and (2) that the speech impediments of certain apraxic speakers may be complicated by a reduced auditory memory.

Partial support for this hypothesis can be obtained by evaluating how isolated and sentence voice stimuli were presented to the apraxic speakers. Recall that during the isolated productions, target stimuli were presented three times to the subject who immediately responded. With sentence stimuli, however, the apraxic subject was required

to delay his/her response (from 6 to 10 seconds for active and passive sentences, respectively) until the carrier phrase was completely delivered. The fact that isolated responses produced greater accuracy scores, combined with the discovery that a number of "no response" errors occurred in the sentence conditions, indicates short-term memory deficits may have contributed to the misperception of the nonsense consonant-vowel combinations. Future investigations could control for this phenomenon by requiring that the apraxic speakers wait 6 to 10 seconds before responding to the isolated stimuli.

Sentence Voice

During this investigation, it was discovered that sentence voice significantly affected the articulatory production of only CVC stimuli. CCVCC stimuli were not affected. For the CVC stimuli, articulatory proficiency in active and passive sentences average 81.11 and 76.68 percent, respectively, a difference of 4.43 percent. These results partially support the findings presented by Hardison, Marquardt, and Peterson (1977). During their investigation, these authors reported that a greater number of articulatory errors (percentage scores were not calculated) occurred when apraxic speakers articulated CVC stimuli embedded in passive voice sentences. CCVCC stimuli were not evaluated.

Decreased articulatory proficiency for stimuli embedded in passive sentences may be explained using the concept of derivational complexity. Mehler (1964) theorized that passive voice sentences are decoded and stored in short-term memory using different linguistic processes than active voice sentences. According to Mehler, a sentence is stored in memory as a simple, active, affirmative, declarative (SAAD) construction, along with markers to represent the interpretive cues in its surface form. Active sentences are stored using only the SAAD construction. For example, the sentence "The girl ran the machine" would be stored in its canonical form as:

actor (girl), action (ran), recipient (machine).

In theory, passive sentences are stored using the SAAD construction plus a marker denoting its passive construction:

agent, action, recipient (+Passive).

Negative passive sentences are stored in memory using the SAAD construction with two additional markers denoting negation and passivity:

agent, action, recipient (+Passive) (+Negation).

Previously, this theory was used to describe why passive voice stimuli were not difficult to learn (Turner

and Rommetveit, 1967; Brown and Hanlon, 1970) and recall (Savin and Perchonock, 1965; Sachs, 1967). In reference to his investigation, this theory suggests that passive voice stimuli require a more complex linguistic decoding process than the active voice stimuli. More specifically, passive voice sentences necessitate the interpretation of both the SAAD structure and marker. Active sentences only require interpretation of the SAAD component. If this theory is true, then the limited cognitive and linguistic abilities possessed by the apraxic speakers may have been overburdened by the added complexity of the passive voice stimuli.

The validity of this theory lies in the assumption that there is a relationship between the decoding of linguistic information and the production (encoding) of phonological stimuli. Both Martin (1974) and Shewan (1983) theorized that the production of phonological units are closely related to the way in which the speaker perceives the speech signal. Stimuli which are improperly decoded will be improperly articulated (encoded). Shewan supported this hypothesis by reporting a high correlation exits ($r = 0.94$) between the articulation errors and the auditory perceptual abilities of apraxic speakers. If the relationship between the decoding and encoding processes is as strong as Shewan suggests, then the added complexity associated with the interpretation of passive voice sentences

may have been reflected by a small (4.43 percent) decrease in the apraxic speaker's articulatory proficiency.

A second, but less plausible explanation is that the difference in the amount of time required for the examiner to verbally present the active and passive sentence stimuli significantly affected the linguistic encoding of the target stimuli. Deal and Darley (1972) reported the articulation of apraxic speakers was not adversely affected when reproducing speech following a delay of 0, 3 and 6 seconds. Specifically, the introduction of a short (up to 6 seconds) response delay did not disrupt the process of articulation. During the present investigation, short response delays did not occur, per se, in the same manner as those time intervals manipulated by Deal and Darley. Instead, the examiner delayed the subjects' responses by presenting sentence stimuli of two different lengths. Recall that active and passive sentence stimuli were presented, by the examiner, with an average duration of 6.47 and 9.94 seconds, respectively. This difference equalled only 3.47 seconds. Since the apraxic speakers were only required to wait and additional 3.47 seconds to respond to the passive voice stimuli, it is unlikely that the additional time delay would have significantly affected the encoding of the phonological information.

Grammatical Class

The results of this investigation indicated that grammatical class significantly affected the production of CVC stimuli apraxic speakers. Articulatory accuracy scores for CVC stimuli embedded in verb function locations (75.80 percent) were produced with lower articulatory accuracy than subject (81.10 percent) or object function (80.31 percent) stimuli. Further, grammatical class did not significantly affect the articulation of CCVCC stimuli. These findings partially support the results presented by Hardison, Marquardt, and Peterson (1979). During their investigation, apraxic speakers produced more errors when articulating CVC stimuli embedded in the first noun phrase (noun function), as opposed to the second noun phrase (object function), of a sentence.

The most logical explanation for the significant influence of the grammatical class function may have been the contamination of the verb function stimuli through the presence of numerous addition errors. As stated earlier, addition errors (Table 20, p. 76) were disproportionately concentrated in the verb function locations. For CVC stimuli, 50.45 percent of the addition errors were located in the verb function location, compared to only 23.85 and 25.69 percent for the subject and object function locations, respectively. Similar results occurred for CCVCC

stimuli. Specifically, 51.19, 27.38, and 21.43 percent of the addition errors occurred on the verb, subject, and object function locations, respectively.

One possible reason was that the subjects confused the consonant-vowel stimuli as being present tense, therefore adding a morphological ending to make it past tense. For example, in the active sentence:

The girl /θaem/ the machine

the CVC stimulus was most likely interpreted as being a present tense regular verb. When the sentence was converted into the passive voice:

The machine was /θaem/ by the girl

the CVC stimulus then could have been interpreted as intending a past tense regular verb. If the speaker viewed the verb as being past tense regular, then the natural tendency would be to add an extra phoneme to the end of the CVC syllable.

Similar phenomena have been reported for children. Turner and Rommetveit (1967) reported the past participle of the verb, especially irregular verbs, generated more errors when children were presented with passive voice sentences. During this investigation, the apraxic speakers may have been confused, due to the use of nonsense syllables, whether the verb function stimuli were past or

present tense. They simply could not distinguish between the two. This confusion manifested itself as a proliferation of addition errors on the verb function stimuli. The morphological rule for this type of confusion would involve adding the phoneme /d/ to produce the utterance /θæmd/. These apraxic speakers frequently used the unmarked addition /t/ (rather than the marked cognate /d/) to produce the utterance /θæmt/.

A second, but equally plausible explanation for this finding is the relative importance of the subject, verb, and object functions to the linguistic processing of the sentence stimuli. Clark (cited in Glucksburg, Trabasso, and Wald, 1973) suggests that there is a hierarchical order of information for subject, verb, and object functions when these categories are decoded in the base structure. For example, in the sentence:

"car hit pole,"

the grammatical class functions can be represented as:

car (X)
pole (Y)
hit (X,Y)

where the verb (hit) serves to relate the subject (car) to the object (pole). Specifically, the verb assumes the critical role in the sentence by providing a description of

the action. Glucksburg, Trabasso, and Wald supported this theory by reporting normal speakers linquistically interpret sentence structures (both active and passive) by first attending to the verb and its actions. Then, the listener matches the verb with the subject and the verb to the object. Finally, the listener evaluates these verb-noun relationships to determine the truth value of the sentence.

These findings relate to the present investigation in the following manner. Recall that both Martin (1974) and Shewan (1983) theorized the decoding and encoding of phonological units are closely related. Stimuli that are improperly perceived will be improperly produced. Further, if the assumption of Glucksburg, Trabasso, and Wald (1972) is also correct, and the verb function stimuli retain a greater linguistic importance than the subject of object function stimuli, then it is possible the added importance associated with these stimuli may have slightly hindered the apraxic speaker's perceptual abilities. This action may have been responsible for the small (5.30 percent) decrease in articulatory accuracy that occurred during the production of the verb function stimuli. Second, the use of nonsense syllables insured that the apraxic speakers were not influenced by an interaction between the syntactic structure of the carrier sentence and the semantic content of the consonant-vowel stimulus. Since this investigation

controlled the semantic content of the test stimuli by using nonsense syllables, then only the stimuli's syntactic structure could have affected the apraxic speakers.

A third explanation for the significance of the grammatical class variable relates to the concept of entropy (Shannon and Weaver, 1962). According to this theory, the informational content of words located within a sentence changes depending on their location. Words located at the beginning of a sentence are less predictable, and more informational, than words located later in the syntactic structure. Also, words positioned in the beginning of the sentence possess fewer syntactic constraints. Therefore, these stimuli may be more difficult to articulate due to their increased informational load, unpredictability, and limited syntactic constraints.

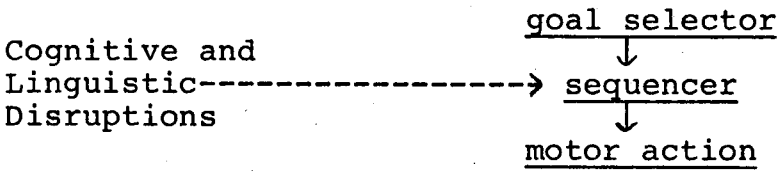
Support for this theory depends on whether the apraxic subjects processed the subject, verb, and object function stimuli in their surface of deep structure forms. For example, if the sentence "The girl ran the machine" was processes in its surface form (subject, verb, object) then entropy would not explain these data since the verb function stimuli (rather than the subject function, which occur in the first position) received the lowest scores. However, if the apraxic subjects acted upon this sentence in its deep structure form (verb, subject, object), then these

data do agree with the concept of entropy. Verb function stimuli usually received the lowest articulation scores. Still, more data are needed to substantiate this theory.

The previous discussion strongly suggests that certain linguistic variables influence phonetic production in apraxic speakers. This, however, does not necessarily indicate that apraxia is a linguistic (Martin, 1975), rather than a phonological impairment. Kent and Rosenbek (1983) argue that linguistic variables are often associated with motoric processes, and that the manipulation of a linguistic factor (e.g., utterance length, stress patterns, or frequency of occurrence) affects motor control.

One method for relating sentence voice and grammatical class to articulation is by using a motor theory which incorporates both cognitive (linguistic) and motoric aspects of speech. Roy (1978) theorized that motor control is hierarchical in nature with the highest function completed by a goal selector that determines the objective for the articulatory act. In conjunction with the selector, there is a subservient motoric sequencer which determines the sequential order of the motor actions. According to Roy, the motor sequencer functions by making decisions using both cognitive and perceptual (i.e., sensory) information. If either cognitive or perceptual deficits occur in the speaker, then the operations of the motor sequencer

will be disrupted. The following diagram illustrates this relationship:



If this theory is true, then linguistic variables affect apraxic speech by interrupting or complicating the means in which the brain sequences motor actions.

CCVCC Stimuli

One interesting result of this investigation was that sentence voice and grammatical class did not influence the articulation of CVC and CCVCC stimuli in the same manner. Both sentence voice and grammatical class affect the production of CVC stimuli. Neither variable significantly affected the production of CCVCC stimuli. Since the only real difference between these two sets of stimuli is the presence of two additional phonemes, these results might indicate: (1) the difficulty in the articulation of the CCVCC stimuli, combined with a lower consistency of production, overshadowed the small influence of the two linguistic variables, or (2) sentence voice and grammatical class functions do not have any significant influence on the longer, more complex CCVCC stimuli. Instead, the phonological sequencing of CCVCC stimuli might be affected by

other linguistic variables that were not tested during this investigation.

Shewan (1980) suggested that apraxic subjects use different articulation strategies when producing CCVCC stimuli. She reported that CVC stimuli were characterized primarily by substitutions while CCVCC stimuli were characterized by both substitutions and omissions. Similar results were seen during this investigation with CCVCC stimuli possessing a greater proportion of omission errors (17.99 percent) than CVC stimuli (4.84 percent). Shewan theorized, and the data from this investigation suggest that the longer phonetic productions placed an additional burden on the speech mechanism, which the apraxic speakers recognize as being too complicated for their limited articulatory abilities. When confronted with an utterance of this nature, instead of actually producing the sequence, the apraxic subject simply "gives up" and omits part of the word.

Phonetic Variables

While some investigators acknowledge that linguistic variables affect apraxic speech, the majority of the researchers (Aten, Darley, Deal, and Johns, 1975; Shane and Darley, 1978; Klinch, Ireland, and Weidner, 1979; and others) suggest that the clinical observations and

scientific evidence indicates apraxia is a motor speech disorder. Collins, Rosenbek, and Wertz (1983) expanded on this concept by describing apraxia as "a neuroprogramming or planning disorder" characterized by a disruption in the timing and coordination of the articulatory sequences.

Results of the current investigation can be applied to this theory. The articulatory characteristics for the 11 subjects in this study included: (1) a predominance of phoneme substitution errors, (2) inconsistent error patterns over repeated trials of the same stimulus, and (3) the presence of phoneme substitutions which were close approximations of the target stimulus (compared to whole word substitutions which characterize aphasia). The following discussion will describe these articulatory characteristics and relate the results of this investigation to data presented by other authors. Later, the data from all of the articulatory comparisons will be combined to form a working theory for articulatory production in apraxic speakers.

Feature Markedness

The results of this investigation indicate that for both CVC and CCVCC stimuli in isolation and sentences, more articulatory errors occur when apraxic speakers produce stimuli that use phonemes which contain numerous marked features. Further, phonemes containing three marked

features were produced with significantly lower accuracy than phonemes which contained two, one, or zero marked features, whose differences were not significant. These results are almost in complete agreement with data presented by Marquardt, Reinhart, and Peterson (1979). These authors reported that for consonant stimuli produced in isolation, phonemes which contained numerous marked features were produced with less accuracy than phonemes containing few marked features. Further, when comparing articulation scores for stimuli which contained three, two, or one marked feature, accuracy scores for each group were significantly different with the lowest articulation values occurring on the highly marked stimuli.

Markedness Fluctuations

Changes in the phoneme markedness characteristics were designed to determine whether the intruded errors were more, less, or of the same complexity as the intended phoneme. Marquardt, Reinhart, and Peterson (1979), and Klinch, Ireland, and Weider (1979), reported that apraxic substitutions were characterized by intruding less marked phonemes for highly marked phonemes. The results of the present investigation support these findings. Specifically, when considering all the phoneme substitutions together, 68.80 percent of the substitutions involved a less marked phoneme being intruded for a phoneme containing

numerous marked features. Only 15.42 percent of the substitutions involved highly marked phonemes being intruded for a less marked phonemes.

The most logical explanation for this finding involves the principle of least effort presented by Zipf (1949). Zipf theorized that when individuals engage in complex behaviors (e.g., articulation), those behaviors which are the least complex are used as substitutions for the more difficult behaviors. Locke (1972) suggested the development of articulation in children follows this principle. During his investigation, he reported phoneme substitutions involve intruding an "easy" phoneme (which had been judged for complexity by adults) for a more "difficult" sound. The apraxic speakers tested during this investigation appear to follow the same pattern. Specifically, while the apraxics' substitutions may have been inconsistent, they still involved a systematic process whereby the target phonemes were replaced by consonants which are easier to produce. This suggests that, as a group, apraxic speakers may be characterized by the presence of a strategy to minimize the articulatory effort required to produce speech.

Articulatory Performance for Vowels and Consonants

Mean consonantal accuracy scores were calculated for CVC and CCVCC stimuli produced in both isolation and

sentences. Unfortunately, previous data are not available to directly compare the accuracy scores for CVC and CCVCC stimuli embedded in sentences. Therefore, the only meaningful comparison available is for CVC and CCVCC stimuli articulated in isolation. For CVC and CCVCC stimuli, consonantal accuracy scores (Table 5, p. 37, total comparison-isolation) averaged 87.68 percent, a score much higher than those accuracy values presented by previous authors. Shewan (1980) reported CVC articulation scores in isolation averaged 79.05 percent while Trost and Canter (1974) and Hardison, Marquardt and Peterson (1979) reported accuracy scores of 75.40 and 68.00 percent, respectively. During the isolated production of CCVCC stimuli, consonantal accuracy scores (Table 6, p. 39, total comparison-isolation) averaged 85.26 percent, a value much greater than the 65.56 percent presented by Shewan. Additional analysis of these investigations may explain these differences.

One obvious explanation involves the stimuli used in each study. As reported earlier, Marquardt, Reinhart, and Peterson tested consonantal accuracy using phonemes embedded in the second syllable of disyllabic utterances. Since the target consonants were surrounded on both sides by abutting phonemes, it is possible the coarticulatory effect from adjacent phonemes may have significantly affected the

production of the target consonant. This explanation is substantiated by the findings from this investigation indicating that production of single consonants may be adversely affected by the presence of adjacent consonants in a consonantal cluster (CCVCC) environment. Both Trost and Canter, and Shewan, measured consonantal accuracy using consonant-vowel combinations. Still, no information was presented describing whether these syllables were balanced to include an equal number of phonemes which contained few and numerous marked features. Since the marking content of the stimuli adversely affects articulatory production (Marquardt, Reinhart, and Peterson, 1979), it is possible the lower accuracy scores reported by these authors reflect a disproportionate use of highly marked target phonemes.

A second explanation for these differences involves the subjects included in these three investigations. Trost and Canter tested Broca's aphasics who possessed verbal and auditory comprehension abilities of an unspecified severity. The only description provided was that each subject "showed oral language comprehension superior to oral language expression." Further, no information was provided describing the level of severity for these two abilities, especially articulation. During the present investigation, the apraxic speakers possessed relatively good auditory comprehension ($Z > 0.05$ on the BDAE; Table B-1, Appendix B)

and, with the exception of one subject (S9), the ability to articulate the longer, more complex, CCVCC stimuli.

The different accuracy levels for individual groups of phonemes indicates that certain types of consonants are more severely impaired in apraxic speech. It is not surprising, given the previous literature (Shankweiler and Harris, 1966; Trost and Canter, 1974; Lapointe and Johns, 1975), that fricatives are produced with the lowest degree of accuracy. Klinch, Ireland, and Weidner (1979) suggested that one reason for these differences is that phoneme categories differ according to the amount of constriction present within the oral cavity. Glides and nasals are produced with the least amount of constriction while stops and fricatives involve almost complete closure. Further, each of these four categories are produced with different degrees of motoric complexity with plosives and fricatives using the most sophisticated articulatory gestures. The results of this investigation, when compared with this continuum of constriction and motoric complexity, indicate that those phoneme categories (glides and nasals) that are produced with the least amount of constriction are articulated with the highest degree of accuracy.

One important finding of this investigation is that the articulation errors produced by apraxic speakers are

relatively good approximations of the target phoneme. Detailed phonological analysis demonstrated that during phoneme substitutions, the physical location of the articulators in the oral cavity closely approximate the location designated for the production of the target consonant. Further, additional analysis indicated fluctuations for the voice, friction, and stop distinctive features are consistent and relatively predictable.

These results suggest apraxic speech is lawful and rule governed. Previous investigators (Shankweiler and Harris, 1966) reported apraxic substitutions were unrelated to the target phonemes indicating that apraxic speech is characterized by a disorganized, random encoding of motor sequences associated with articulation. These conclusions are understandable considering that Shankweiler and Harris did not analyze the phonological substitutions using a distinctive feature paradigm. Had these authors measured the subphonemic feature fluctuations which characterize apraxic sound substitutions, it is likely their findings would have agreed with those presented by later investigators (Trost and Canter, 1974; LaPointe and Johns, 1975). Instead, the distinctive feature measurements from this investigation, and others, indicate that apraxic errors are not random, but systematic and patterned.

Consonant Accuracy as a Function of Phoneme Position and Environment

One area of continuing disagreement involves the influence of phoneme position on articulatory accuracy. Results from this investigation indicate that for CVC and CCVCC stimuli, in both isolation and sentences, there is no significant difference in consonantal accuracy when comparing phonemes located in the prevocalic or postvocalic positions. Shankweiler and Harris (1966) and Trost and Canter (1974) reported lower articulatory accuracy on initial position phonemes while other investigators (LaPointe and Johns, 1975) discovered equal proficiency at producing phonemes embedded in the initial, medial, and final word positions.

The most plausible explanation for these differences involves the stimuli used in these investigations. Both Shankweiler and Harris, and Trost and Canter, failed to balance the prevocalic and postvocalic positions using an equal number of phonemes which contained few and numerous marked features. The consequence of this action resulted in one phoneme position containing a disproportionate number of highly marked consonants. During this present investigation, consonants in prevocalic and postvocalic positions were completely balanced in terms of feature markedness (Appendix A). Since the balancing of easy and difficult phonemes is critical to the evaluation of the

effect of phoneme position, then the results of the present investigation could be considered as a more accurate evaluation of the effects of phoneme position.

Analyzing the effect of phoneme position on articulatory accuracy is only one means of describing the phonetic abilities of apraxic speakers. A second procedure is to monitor how the articulatory accuracy of certain target phonemes fluctuate when surrounded by other phonemes. Previous authors (Shankweiler and Harris, 1966; Johns and Darley, 1970; Trost and Canter, 1974) had not measured this phenomenon. Instead, they analyzed the articulation of phonological sequences by simply comparing the accuracy scores for consonant clusters to the articulation scores for consonant singletons. This type of analysis is undesireable because it fails to provide any information describing how individual phonemes are affected when positioned in clustered environments. The only information which is available involves the articulatory production of the entire consonantal cluster. By analyzing the articulation of individual phonemes in different phonetic environments, it becomes possible to analyze how the phonological characteristics of the consonant-vowel stimuli confound the production of individual phonemes.

The results of this investigation strongly indicate that the accuracy of single consonants decrease when

located next to an adjacent consonant. One obvious explanation for this finding is the influence of coarticulation. Coarticulation is defined as the influence of one phoneme on an adjacent phoneme (Daniloff and Hammarberg, 1973). Research with normal speakers indicates the articulation of a phoneme may be influenced by the phonological characteristics of phonemes up to six segments away (Benguerel and Cowan, 1974). If the motor encoding process in apraxic speakers is disrupted, as previous investigators suggest (Shankweiler and Harris, 1966; Johns and Darley, 1970; LaPointe and Johns, 1975; Shane and Darley, 1978), then the accuracy of the target phonemes may be complicated by the phonetic characteristics of abutting vowels and consonants.

A possible explanation for this phenomenon may be the phonetic difficulty of the abutting phonemes. Recall that vowels were produced with greater accuracy than consonants, possibly reflecting the fact that vowels require less muscular effort to articulate. For CVC stimuli, consonants were positioned adjacent to vowels. With CCVCC stimuli, however, a consonant could be positioned either next to another consonant, or next to one consonant and one vowel depending on where the consonant was located in the stimulus. If it is valid to assume that vowels are easier to produce, then those consonants in CVC stimuli are located in the most optimal position for correct production,

followed by initial and final consonants in CCVCC stimuli, with second and fourth position consonants in CCVCC stimuli producing the least optimal conditions. More evidence is needed, however, to adequately test this hypothesis.

Disadvantages of Using a Repeated Measures Design with Apraxic Subjects

Numerous measurements have been performed during this investigation describing how apraxic articulation changes as a function of different speaking conditions. Most of these measurements have involved the use of simple calculations and straight-forward interpretations. The use of the repeated measures ANOVA calculation, however, is more difficult to interpret and provide information that may be of only marginal value to the clinical or scientific community. Therefore, an alternative interpretation will be addressed.

Two separate ANOVA calculations were completed using a repeated measures design. As stated earlier, while this procedure does allow for the testing of fewer apraxic subjects, it does not provide for an opportunity to evaluate the behavior between individuals, or groups of speakers. This occurs because this model removes the between-subject variance when testing the independent variables. While this model may be helpful under certain circumstances, it may hinder the interpretation of certain

calculations presented in this investigation. Specifically, the repeated measures design evaluated how apraxic speakers varied only within themselves (within-subject variance). If the reader is interested in calculating how apraxic speakers fluctuate as a group (between-subject variance), then they will need to perform additional analysis and interpretations that have not been presented in this study. The following example illustrates this weakness.

Table 6, p. 39, and Table B-3, Appendix B, present the percent correct articulation scores and F-ratios for CCVCC stimuli, respectively. The F-ratios indicated that only phoneme markedness significantly affected apraxic speech. Phonemes containing few and numerous marked features were produced with 80.98 and 68.04 percent correct, respectively. This difference equalled 12.94 percent. When this relationship is graphed (Figure 3, p. 54) along with the one standard deviation markers, it appears that a large difference existed between these two sets of stimuli and that very little cross-over occurs between these two data sets. Also, nine of ten subjects had lower (poorer) articulation scores when articulating the stimuli with numerous marked features. Therefore, an evaluation of these data suggested that not only do the ANOVA calculations indicate these differences are "significant," but

Table 6, p. 39, and Figure 3, p. 54, indicate these findings could be important to both how the scientific community views apraxia and how a clinician develops a therapeutic hierarchy during the rehabilitative process.

The data for the CVC stimuli, however, are not as easily interpreted. Table B-2, Appendix B, indicates that, at least statistically, both grammatical class and sentence voice significantly affected articulation in apraxic speech. Phoneme markedness was not statistically significant. If, however, Table 6 is scrutinized more carefully, it becomes apparent that the results of the ANOVA may be misleading.

For CVC stimuli, active and passive voice sentences were produced with 81.11 and 76.68 percent correct, respectively. However, when the means and standard deviations were graphed in Figure 4, p. 66, scores for active and passive voice sentences were found to overlap. The large standard deviations (6.45 and 7.38 percent) for active and passive voice sentences, respectively illustrate that it becomes very difficult to predict how one apraxic's speech will compare to that of a second speaker.

Similar interpretations can be used to describe the grammatical class fluctuations. The F-ratio (Table B-2, Appendix B) indicated that the verb function stimuli (75.80 percent) produced significantly lower articulation

scores than either the subject 81.10 percent) or object (80.31 percent) function stimuli. This difference equalled 5.30 percent. However, Figure 4, p. 66, indicates that the differences between the three grammatical class means, while being consistent within subjects, contains a large degree of between-subject variance. For example, the standard deviation for the verb function stimuli was 8.89 percent. If the data from this investigation were generalized to the apraxic population, 95 percent (two standard deviations) of the apraxic speakers would score between 58.02 and 93.58 percent, a difference totalling 35.56 percent. Similar results occur for the subject and object function stimuli. Obviously, these wide variations between subjects creates difficulty when predicting the speech patterns of two or more apraxic speakers.

The previous discussion illustrates that although certain F-ratio calculations may be sensitive enough to identify small differences within independent variables, this sensitivity occurs due to the removal of the between-subject variance. The use of this analysis procedure may account for the results presented by other investigators. For example, Hardison, Marquardt, and Peterson (1979) reported that a greater number of articulation errors occur when apraxic speakers produce stimuli embedded in passive sentences and the second noun phrase position. Additional

analysis of their data, however, also demonstrates that there is a large difference in the performance levels between individual subjects.

One method for testing sentence voice, grammatical class, and phonetic complexity, while still retaining the information that describes the between-subject variance, is to design a new experiment. As stated earlier, this current investigation used only 11 subjects who were tested in each of the 12 treatment conditions. A new investigation could incorporate as many as 120 subjects, randomly divided into 12 equal groups, with 10 subjects being assigned to only one of these treatment conditions. Each subject would then be tested, a score could be assigned to describe their articulatory proficiency, and these values could be measured using a three factor ANOVA. The only disadvantage to this procedure would be the need for testing a larger group of subjects. However, the advantage from this test paradigm would provide new information describing how these three independent variables affect articulation both within and across different apraxic speakers.

Theoretical Implications for Apraxia of Speech

The results of this investigation indicate linguistic and phonological variables affect articulatory production in apraxic speakers. Both sentence voice and grammatical

class slightly hinder the production of the simpler CVC syllables. The phonetic complexity of the phonemes, represented using consonants that contained few and numerous marked features, affected the articulation of both CVC and CCVCC stimuli. One interesting finding was that none of these three variables significantly interacted with each other to decrease articulatory proficiency, a finding which conforms to the results presented by previous authors (Hardison, Marquardt, and Peterson, 1979). The lack of such an interaction could indicate that linguistic and articulatory variables affect apraxic speech in different manners. Further, any theory of apraxic speech must explain these two separate processes.

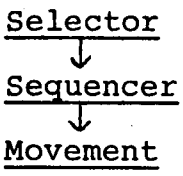
The previous discussion illustrates that not only are apraxic substitutions close approximations of the target phoneme, but that apraxic productions are influenced by the physical characteristics of the surrounding phonemes. Both phenomena are closely related because they highlight the imperfect phonetic sequencing patterns that characterize apraxic speech. MacNeilage (1970) suggested the ballistic movements associated with articulation require a spatial coordinating system that guides the movements or the articulators within the oral cavity. This author theorized articulation is based on a series of targets located within the oral cavity and that the brain codes phonological

productions by specifying these targets. Later, these targets are translated into a series of demands which are placed on the motor control mechanisms which is eventually responsible for guiding the articulators to their appropriate locations. During this investigation, the 83 percent failure in the place feature could have occurred from a breakdown in this system. Specifically, instead of guiding the articulators to the appropriate point of maximal constriction, the apraxic speaker missed the phoneme by slightly overshooting or undershooting the correct articulatory location within the oral cavity.

A space-coordinate model of articulation adequately explains why the place feature is highly susceptible to change. It does not, however, account for the relative stability of other distinctive features (nasality or voicing). One possibility is that the tongue, velum, and larynx operate using different motor command systems (Bell-Berti and Harris, 1981). Oral-nasal contrasts involve closure of the velopharyngeal port. Voiced-voiceless contrasts involve abducting or adducting the vocal folds. Hypothetically, both actions could be carried out by the motor system using a predetermined binary code. Keele (1968) suggested that motor movements are completed using prestructured neural commands which are activated to complete the motor movement. When a speaker either

phonates or closes the velopharyngeal port, theoretically it is possible they complete these actions by activating, at a very specific moment in time, a preprogrammed binary code. In apraxic speakers, it is plausible that errors in voicing or nasality occur due to the improper selection or use of these binary codes.

So far, three different explanations have been presented to describe apraxic speech. Roy's (1978) model, presented earlier, included a hierarchical ordering of events which included the selection, sequencing, and execution of motor movements.



MacNeilage's (1970) space-coordinate system guides the articulators (primarily the tongue) to their proper location within the oral cavity, while the closure of the velopharyngeal port and the vibration of the vocal folds possibly operate on more simplistic, binary motor control systems that involve the execution of preprogrammed neural commands (Keele, 1968). None of these three explanations independently explain the articulatory patterns present in apraxic speech. However, all three of these concepts can

be combined, with modifications, into one motor control program.

Figure 5 presents a theoretical model of the motor programming patterns present in speech. At the two highest levels, there exists the selector and sequencer (Roy, 1978), whose operations have already been discussed. After the utterance has been placed into a motor sequence, then two separate systems operate to control (1) the tongue and its movements (using a space-coordinate system), and (2) the velum and larynx (using preprogrammed binary neural commands). Two feedback loops are also theorized. Connecting the tongue and its motor movements to the sequencer enables the speaker to monitor and, when necessary, change the movements of the tongue. Further, it is theorized a breakdown in the afferent feedback from the tongue will hinder the apraxic's ability to monitor the position of the tongue in the oral cavity (Rosenbek, Wertz, and Darley, 1973). When the subject attempts to reproduce the correct utterance, they use this afferent information to redirect their motor control patterns. During metathesis errors, (inverting two phonemes), the feedback information will return to the sequencer to help reorder the sequencing of the phonemes during the next utterance. During substitutions or omission errors, afferent information will return to the space coordination system to redirect the articulators during the next production.

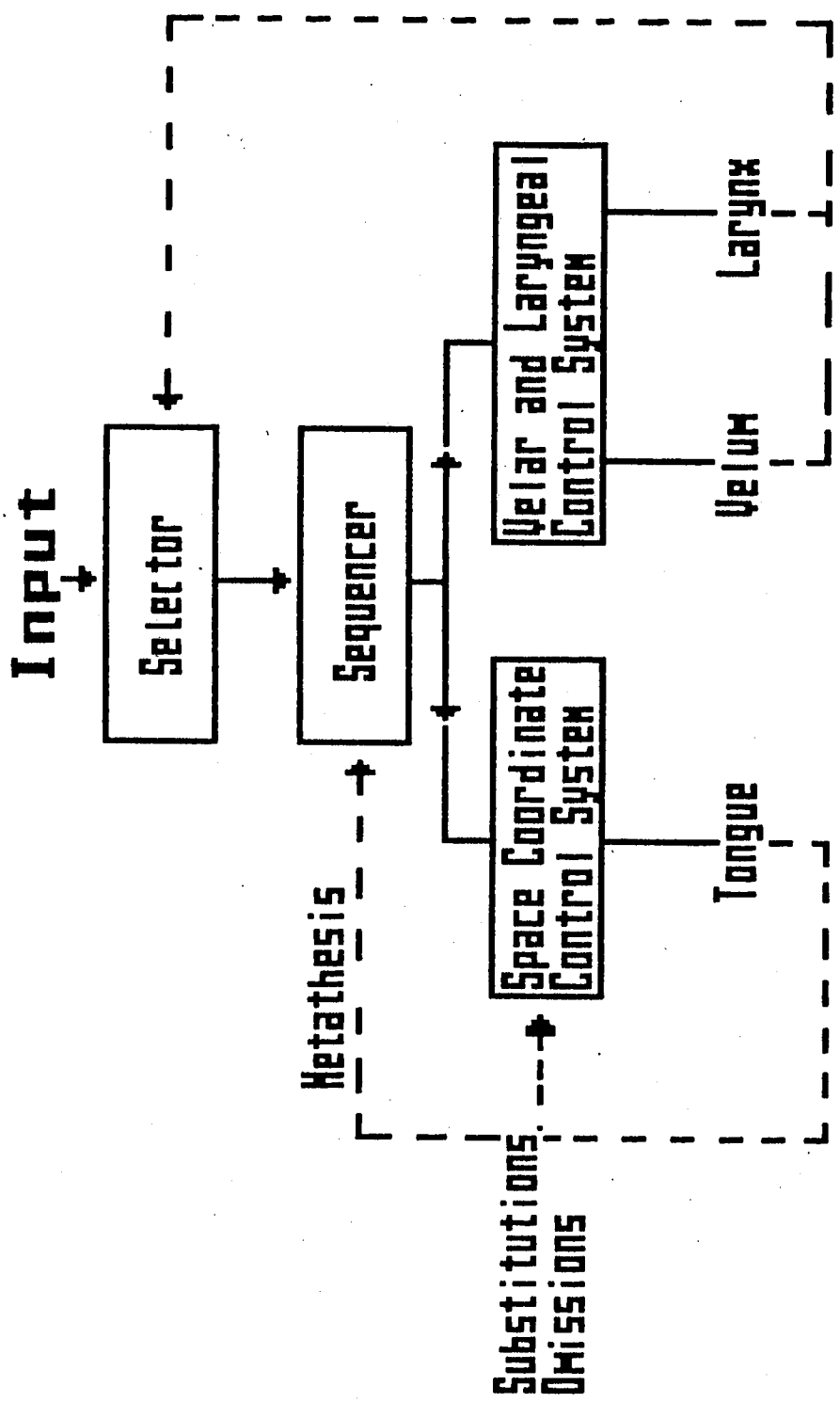


Figure 5. Hypothetical model for articulatory production in normal and apraxic speakers.

Voicing and nasality errors do not involve errors in the sequencing of phonemes. Rather, the incorrect phoneme was originally chosen. Afferent information in this case could be used by the brain to select a new phoneme for the next attempt at articulation. Hypothetically, it is possible that linguistic and articulatory variables act upon this model in different manners. Roy theorized that cognitive information is used, by the sequencer, to make decisions about the motor control activities of the articulators. If the cognitive capabilities of apraxic speakers are impaired, then the variation of linguistic information may slightly disrupt the phoneme sequencing patterns. The phonetic variables, specifically the easy and difficult phonemes, could differentially interrupt the action of the selector. In this case, the apraxic subject anticipates a difficult articulatory sequence and simply substitutes and easier phoneme in its place (as suggested by Shewan, 1983).

Therapeutic Implications

The results that both linguistic and articulatory variables affect the production of articulatory variables without any significant interactive effect suggest that a careful therapeutic hierarchy should be developed encompassing the syntactic and phonological variations of speech. The therapist should begin by presenting easy and difficult phonemes in isolated syllables. Later, these

phonemes can be inserted into longer, more complex utterances. Near the end of the therapeutic process, the isolated syllables could be inserted into phrases or sentences.

Limitations of the Study

The results of this study apply only to apraxic speakers within the confines of the following limitations. First, a different experimental design could have been used that incorporates and analyzes the variations that exist between different apraxic subject. Second, the results of this study are based upon the responses of a limited number of subjects. Expanding the number of apraxic speakers would provide a more representative measurements of the articulatory behaviors of the entire apraxic population. Third, test-retest reliability measures were not performed to evaluate the consistency in which the apraxic speakers produce the test stimuli. Completing these measurements would have provided useful information describing how apraxic speech fluctuates as a function of time. Finally, the influence of the present and past tense verb functions created a disproportionate number of addition errors to verbs. Future investigations should retest the verb function using stimuli that could be interpreted as being both present and past tense.

Suggestions for Future Research

Further research is needed to investigate those linguistic and articulatory variables which influence apraxic speakers. Specific suggestions for future research include:

1. Careful manipulation of the verb function stimuli to determine whether the formulation of motor units in apraxic speakers are influenced by the syntactic structure surrounding a consonant-vowel stimulus.

2. Measuring the influence of difference consonantal environments on the articulatory accuracy of single consonants. A possible test paradigm for this experiment might include choosing a select group of consonants and then manipulating the surrounding phoneme environment using stimuli which contain both few and numerous marked distinctive features.

3. Determining the relationship between the auditory comprehension and verbal production abilities in apraxic speakers. One means for testing this relationship would be to quantify the auditory deficits using a standardized test (e.g., the Porch Index of Communicative Abilities) and match these scores with the accuracy values for consonants using regression analysis.

4. Measuring whether vowel accuracy can be used as a reliable predictor of articulatory severity in apraxic

speakers. One procedure for testing this relationship would be to measure both vowel and consonantal accuracy fluctuations for individual speakers using a select group of stimuli and then calculate the correlation between the two accuracy scores.

CHAPTER V

SUMMARY AND CONCLUSIONS

The purpose of this investigation was to measure how sentence voice, grammatical class, and phonetic complexity influence the articulation of eleven apraxic speakers. A set of nonsense CVC and CCVCC syllables were constructed using phonemes that contained either few or numerous marked distinctive features. These syllables were inserted into the subject, verb, and object function locations of both active and passive voice sentences. Later, the entire sentence was presented to these subjects who were required to repeat the nonsense syllable.

Results suggest that for CVC stimuli, grammatical class, sentence voice, and phonetic complexity disrupted the articulation of apraxic speakers. However, the magnitude of these disruptions were not equal for each variable. Also, none of these three variables appeared to interact with each other, indicating that each factor could have a separate influence on the process of articulation. With CCVCC stimuli, only phonetic complexity produced any adverse affect.

These data can also be interpreted in a different manner. While grammatical class, sentence voice, and phonetic complexity were found to be "statistically significant," it is possible that this significance was

discovered due to the removal of the between-subject variance in the statistical model. The result of this action is that small differences between group means may be important only from a statistical viewpoint. From a practical or clinical viewpoint, these differences may be of little importance to the rehabilitative process.

When analyzing individual consonantal errors, it was discovered that apraxic speech is dominated by substitutions, omissions, and additions. Further, the articulatory errors, while being inconsistent, were not unsystematic. The apraxic speakers substituted phonemes with relatively few marked features for those phonemes which contained numerous marked features. Also, a distinctive feature analysis indicated the articulation errors were good approximations of the target phoneme.

It was suggested that the available theories of articulation were not adequate to describe the apraxic productions. A modified version of Roy's model of motor production was presented to account for the small influence of the linguistic and phonetic variables.

BIBLIOGRAPHY

BIBLIOGRAPHY

Alajouanine, T., and Lhermitte, F. (1963). Activite's expressives du languge dans l'aphasie. Encephale, 52, 5-45.

Aten, J., Darley, F. L., Deal, J., and Johns, D. (1975). Comment on A. D. Martin's "Some objections to the term apracia of speech." Journal of Speech and Hearing Research, 40, 416-420.

Aten, J. L., Johns, D. F., and Darley, F. L. (1971). Auditory perception of sequenced words in apraxia of speech. Journal of Speech and Hearing Research, 14, 131-143.

Bell-Berti, F., and Harris, K. S. (1981). A temporal model of speech production. Phonetica, 38, 9-20.

Benguerel, A. P., and Cowan, H. A. (1974). Coarticulation of upper lip protrusion in French. Phonetica, 30, 41-55.

Brown, R., and Hanlon, D. (1970). Derivational complexity and the order of acquisition in child speech. In Hayes, H. R. (ed.), Cognition and the Development of Language. New York: John Wiley & Sons.

Bruning, J. L., and Kintz, B. C. (1977). Computational Handbook of Statistics, 2nd ed. Glenview, Illinois: Scott, Foresman.

Carpenter, R. L., and Rutherford, D. R. (1973). Acoustic cue discrimination in adult aphasia. Journal of Speech and Hearing Research, 16, 534-544.

Chomsky, N., and Halle, M. (1968). The Sound Patterns of English. New York: Harper and Row.

Collins, M., Rosenbek, J. C., and Wertz, R. T. (1983). Spectrographic analysis of vowel and word duration in apraxia of speech. Journal of Speech and Hearing Research, 26(4), 224-230.

Compton, A. J. (1975). Generative studies of children's phonological disorders. Cited from Measurement Procedures in Speech, Hearing, and Language (S. Singh, ed.). Maryland: University Park Press.

Daniloff, R. G., and Hammarberg, R. E. (1973). On defining coarticulation. Journal of Phonetics, 1, 239-248.

Darley, F. L., Aronson, A., and Brown, J. (1975). Motor Speech Disorders. Philadelphia: W. B. Saunders.

Deal, J. R., and Darley, F. L. (1972). The influence of linguistic and situational variables on phonemic accuracy in apraxia of speech. Journal of Speech and Hearing Research, 15(3), 639-653.

Dunlop, J., and Marquardt, T. P. (1977). Linguistic and articulatory aspects of single word production in apraxia of speech. Cortex, 13, 17-39.

Glucksberg, S., Trabasso, T., and Wald, J. (1973). Linguistic structures and mental operations. Cognitive Psychology, 5, 338-370.

Hardison, D., Marquardt, T. P., and Peterson, H. A. (1977). Effects of selected linguistic variables in apraxia of speech. Journal of Speech and Hearing Research, 20(2), 334-343.

Johns, D. F., and Darley, F. L. (1970). Phonemic variability in apraxia of speech. Journal of Speech and Hearing Research, 13, 556-583.

Keele, K. S. (1968). Movement control in skilled motor performance. Psychological Bulletin, 70, 387-403.

Kent, R., and Rosenbek, J. C. (1983). Acoustic patterns of apraxia of speech. Journal of Speech and Hearing Research, 26(4), 231-249.

Kertesz, A., and Hooper, P. (1982). Praxis and language: The extent and variety of apraxia in aphasia. Neuropsychologia, 20(3), 275-286.

Klinch, R. J., Ireland, J. V., and Weidner, W. E. (1979). Articulatory and phonological aspects of consonant substitutions in apraxia of speech. Cortex, 15, 451-470.

LaPointe, L. L., and Johns, D. F. (1975). Some phonemic characteristics in apraxia of speech. Cortex, 13, 17-39.

Locke, J. L. (1972). Ease of articulation. Journal of Speech and Hearing Research, 15, 194-200.

MacNeilage, P. F. (1970). Motor control of serial ordering of speech. Psychological Review, 3, 182-196.

Marquardt, T. P., Reinhart, J. B., and Peterson, H. A. (1979). Markedness analysis of phonemic substitution errors an apraxia of speech. Journal of Communicative Disorders, 12, 481-494.

Martin, A. D. (1974). Some objections to the term apraxia of speech. Journal of Speech and Hearing Disorders, 39(1), 53-64.

Mehler, J. (1963). Some effects of grammatical transformations on the recall of English sentences. Journal of Verbal Learning and Verbal Behavior, 2, 246-251.

Olson, D. R., and Filby, N. (1972). On the comprehension of active and passive sentences. Cognitive Psychology, 3, 361-381.

Rosenbek, J. C., Wertz, R. T., and Darley, F. (1973). Oral sensation and perception in apraxia of speech. Journal of Speech and Hearing Research, 16, 22-36.

Roy, E. A. (1978). Apraxia: A new look at an old disorder. Journal of Human Movement Studies, 4, 191-210.

Sachs, J. (1967). Recognition memory for syntactic and semantic aspects of connected discourse. Perception and Psychophysics, 2, 437-442.

Savin, H. B., and Perchonock, E. (1965). Grammatical structure and the grammatical recall of English sentences. Journal of Verbal Learning and Verbal Behavior, 4, 348-353.

Shane, H. C., and Darley, F. L. (1978). The effect of auditory rhythmical stimulation on articulatory accuracy in apraxia of speech. Cortex, 14(3), 444-450.

Shankweiler, D., and Harris, K. (1966). An experimental approach to the problem of articulation in aphasics. Cortex, 2, 277-292.

Shannon, C. E., and Weaver, W. (1962). The Mathematical Theory of Communication. Urbana: University of Illinois Press.

Shewan, C. M. (1980). Phonological processing in Broca's aphasics. Brain and Language, 10, 71-88.

Tagnola, G., and Vignolo, L. (1980). Brain lesions associated with oral apraxia in stroke patients: A clinco-neuroradiological investigation with the CT scan. Neuropsychologia, 18, 257-271.

Trost, J. E., and Canter, G. J. (1974). Apraxia of speech in patients with Broca's aphasia. A study of phoneme production accuracy and error patterns. Brain and Language, 1, 63-79.

Turner, E. A., and Rommetveit, R. (1967). The acquisition of sentence voice and reversibility. Child Development, 649-660.

Wertz, R. T., Rosenbek, J. C., and Deal, J. L. (1970). A review of 228 cases of apraxia of speech: Classification, etiology, and localization. Paper presented at the American Speech and Hearing Association Convention. St. Louis, Missouri.

Williams, F., Cairns, H. S., Cairns, C. E., and Blosser, D. F. (1971). Analysis of production errors in the phonetic performance of school-age standard-English speaking children. Working paper from the Center for Communicative Research, Austin, Texas.

Winer, B. J. (1971). Statistical Principles in Experimental Design. McGraw-Hill Book Company.

APPENDICES

APPENDIX A

CVC and CCVCC Stimulus Sets and the Number of Marked Features in the Prevocalic and Postvocalic Positions

Set 1a. CCVCC Numerous Marked Feature Set

(1) /θrumz/
(2) /flarm/
(3) /smirʃ/
(4) /ʃrElθ/
15-16

Set 1b. CCVCC Few Marked Feature Set

(1) /twEnt/
(2) /snuks/
(3) /prind/
(4) /skarp/
7-7

Set 2a. CVC Numerous Marked Feature Set

(1) /θæm/
(2) /mEl/
(3) /luf/
(4) /fiθ/
9-9

Set 2b. CVC Few Marked Feature Set

(1) /tik/
(2) /kEs/
(3) /put/
(4) /sap/
3-3

*Number shows the value for marked features in prevocalic and postvocalic positions.

Test Instructions

Task #1

I am going to read you 12 strange words. I will repeat each word twice. When I finish, you will repeat the word aloud. Please do not repeat the word until I have presented it twice. Are you ready?

Task #2

I am going to read you a number of short sentences. I will read each sentence three times. I will read the complete sentence twice. On the third reading, I will remove one word. You will repeat that word aloud after I finish with the third sentence. Do you understand? Are you ready?

Practice Stimuli

Practice Nonsense Stimuli

/mut/

/smidz/

Practice Sentence Stimuli

The cat chased the /mut/.

The mouse was /smidz/ by the cat.

Test Stimuli Embedded in Active and Passive Sentences Along with 32 Consonant-Vowel Stimuli in Isolation

1) /θrumz/
2) /flarm/
3) /smirʃ/
4) /ʃrElθ/

5) /twEnt/
6) /snuks/
7) /prind/
8) /skarp/

9) /θæm/
10) /mEl/
11) /luf/
12) /fiθ/

13) /tik/
14) /kEs/
15) /put/
16) /sap/

17) The /twEnt/ ran the machine.
18) The /snuks/ jumped the fence.
19) The /prind/ pushed the car.

CCVCC Few Marked Features Active

20) The /skarp/ caught the mouse.
21) The player threw the /twEnt/.
22) The boys broke the /snuks/.
23) The woman moved the /prind/.
24) The child opened the /skarp/.
25) The author /twEnt/ the story.
26) The lady /snuks/ the book.
27) The truck /prind/ the pole.
28) The maid /skarp/ the house.

29) The machine was run by the /twEnt/.
30) The fence was jumped by the /snuks/.
31) The car was pushed by the /prind/.

CCVCC Few Marked Features Passive

32) The mouse was caught by the /skarp/.
33) The /twEnt/ was thrown by the player.
34) The /snuks/ was broken by the boys.
35) The /prind/ was moved by the woman.
36) The /skarp/ was opened by the child.
37) The story was /twEnt/ by the author.
38) The book was /snuks/ by the lady.
39) The pole was /prind/ by the truck.
40) The house was /skarp/ by the maid.

	41)	The /θrumz/ ran the machine.
	42)	The /flarm/ jumped the fence.
	43)	The /smirʃ/ pushed the car.
CCVCC	44)	The /ʃrElθ) caught the mouse.
Numerous	45)	The player /θrumz/ the ball.
Marked	46)	The boys /flarm/ the window.
Features	47)	The woman /smirʃ/ the chair.
Active	48)	The child /ʃrElθ/ the package.
	49)	The author wrote the /θrumz/.
	50)	The lady read the /flarm/.
	51)	The truck hit the /smirʃ/.
	52)	The maid cleaned the /ʃrElθ/.
	53)	The machine was /θæm/ by the girl.
	54)	The fence was /mEl/ by the dog.
	55)	The car was /luf/ by the men.
CVC	56)	The mouse was /fiθ/ by the cat.
Numerous	57)	The ball was thrown by the /θæm/.
Marked	58)	The window was broken by the /mEl/.
Features	59)	The chair was moved by the /luf/.
Passive	60)	The package was opened by the /fiθ/.
	61)	The /θæm/ was written by the author.
	62)	The /mEl/ was read by the lady.
	63)	The /luf/ was moved by the woman.
	64)	The /fiθ/ was cleaned by the maid.
	65)	The girl ran the /tik/.
	66)	The dog jumped the /kEs/.
	67)	The men pushed the /put/.
CVC	68)	The cat caught the /sap/.
Few	69)	The player /tik/ the ball.
Marked	70)	The boys /kEs/ the window.
Features	71)	The woman /put/ the chair.
Active	72)	The child /sap/ the package.
	73)	The /tik/ wrote the story.
	74)	The /kEs/ read the book.
	75)	The /put/ hit the pole.
	76)	The /sap/ cleaned the house.
	77)	/θrumz/
	78)	/flarm/
	79)	/smirʃ/
	80)	/ʃrElθ/
	81)	/twEnt/
	82)	/snuks/
	83)	/prind/
	84)	/skarp/
	85)	/θæm/
	86)	/mEl/
	87)	/luf/
	88)	/fiθ/

89) /tik/
90) /kEs/
91) /put/
92) /sap/

93) The /tik/ was run by the girl.
94) The /kEs/ was jumped by the dog.
95) The /put/ was pushed by the men.
96) The /sap/ was caught by the cat.

CVC Few Marked Features Passive

97) The ball was /tik/ by the player.
98) The window was /kEs/ by the boys.
99) The chair was /put/ by the woman.
100) The package was /sap/ by the child.
101) The story was written by the /tik/.
102) The book was read by the /kEs/.
103) The pole was hit by the /put/.
104) The house was cleaned by the /sap/.

105) The machine was run by the /θrumz/.
106) The fence was jumped by the /flarm/.
107) The car was pushed by the /smirʃ/.
108) The mouse was caught by the /ʃrElθ/.

CCVCC Numerous Marked Features Passive

109) The ball was /θrumz/ by the player.
110) The window was /flarm/ by the boys.
111) The chair was /smirʃ/ by the woman.
112) The package was /ʃrElθ/ by the child.
113) The /θrumz/ was run by the girl.
114) The /flarm/ was jumped by the dog.
115) The /smirʃ/ was pushed by the men.
116) The /ʃrElθ/ was caught by the cat.

117) The girl /θæm/ the machine.
118) The dog /mEl/ the fence.
119) The men /luf/ the car.

CVC Numerous Marked Features Active

120) The cat /fiθ/ the mouse.
121) The /θæm/ threw the ball.
122) The /mEl/ broke the window.
123) The /luf/ moved the chair.
124) The /fiθ/ opened the package.
125) The author wrote the /θæm/.
126) The lady read the /mEl/.
127) The truck hit the /luf/.
128) The maid cleaned the /fiθ/.

APPENDIX B

Table B-1. Age, Sex, Auditory Comprehension Capabilities According to Boston Diagnostic Aphasia Examination (BDAE) Scores, Etiology Characteristics, and Time Post Onset Characteristics for Individual Subjects.

Subjects	Age	Sex	BDAE Scores	Etiology	Time Post Onset
1	61	M	1	CVA	71 months
2	71	F	1	CVA	125 months
3	76	M	0.5	CVA	2.5 months
4	52	F	0.5	CVA	53 months
5	50	F	1	CVA	46 months
6	69	M	1	CVA	19 months
7	55	F	1	CVA	48 months
8	66	M	1	CVA	65 months
9	56	M	1	CVA	60 months
10	63	M	0.5	CVA	33 months
11	75	M	0.5	CVA	50 months
$\bar{X}$	63.09				
SD	8.68				

Table B-2. Analysis of Variance Calculations for CVC Stimuli Embedded in Sentences.

Source	Type III SS	df	F Value	P F
Voice	678.17	1	5.60	0.039
Marking	850.42	1	3.51	0.090
Voice*Marking	4.82	1	0.06	0.818
G. Class	756.19	2	4.29	0.023
Voice*G.Class	794.43	2	2.54	0.104
Marking*G.Class	358.41	2	1.69	0.209
Voice*Marking*G.Class	73.42	2	0.57	0.576
Subjects	7261.64	10		
Voice*Subjects	1210.74	10		
Marking*Subjects	2422.05	10		
Voice*Marking*Subjects	864.04	10		
G.Class*Subjects	1763.88	20		
Voice*G.Class*Subjects	3128.82	20		
Marking*G.Class*Subjects	2118.48	20		
Voice*Mark*G.Class*Subjects	1296.79	20		
Total	23559.14	131		

Table B-3. Analysis of Variance Calculations for CCVCC Stimuli Embedded in Sentences.

Source	Type III SS	df	F Value	P F
Voice	24.64	1	0.27	0.618
Marking	5025.38	1	18.55	0.002
Voice*Marking	28.46	1	0.38	0.555
G.Class	367.49	2	2.10	0.151
Voice*G.Class	169.50	2	1.31	0.294
Marking*G.Class	13.11	2	0.08	0.919
Voice*Marking*G.Class	93.65	2	0.65	0.534
Subjects	3550.63	9		
Voice*Subjects	835.93	9		
Marking*Subjects	2458.31	9		
Voice*Marking*Subjects	681.43	9		
G.Class*Subjects	1577.57	18		
Voice*G.Class*Subjects	1165.07	18		
Marking*G.Class*Subjects	1398.88	18		
Voice*Mark*G.Class*Subjects	1300.17	18		
Total	18670.24	119		

Table B-4. Analysis of Variance Calculations for Vowel Stimuli.

Source	Type III SS	df	F Value	P F
Vowels	159.00	4	2.43	0.07
Subjects	270.00	10		
Error	654.00	40		
Total	1083.00	54		

Table B-5. Analysis of Variance Calculations for Stimuli with Zero, One, Two, and Three Marked Features.

Source	Type III SS	df	F Value	P F
Phoneme Markedness	8133.78	3	27.13	0.001
Subjects	629.25	10		
Error	2987.71	30		
Total	11750.74	43		

Duncon Comparisons

Zero-One	NS
Zero-Two	NS
Zero-Three	*
One-Two	NS
One-Three	*
Two-Three	*

*Significant at the 0.05 level.

VITA

James Hager Bargelt was born in Los Angeles, California, on April 24, 1959. After completing elementary and high school in that area, he attended the University of California, Santa Barbara, where he was awarded an undergraduate degree in Speech and Hearing Sciences. Following graduation, he entered The University of Tennessee, Knoxville, where he received a M.A. degree in Speech Pathology and a Ph.D. degree in Speech and Hearing Science. Following graduation, James Bargelt was employed as a speech-language pathologist in California.