DOCUMENT RESUME

ED 051 691 FL 002 266

AUTHOR Williams, Frederick, Ed.; And Others
TITLE Analysis of Production Errors in the Phonetic Performance of School-Age Standard-English-Speaking Children. Final Report.
INSTITUTION Texas Univ., Austin. Center for Communication Research.
SPONS AGENCY Office of Education (DHEW), Washington, D.C.
PUB DATE Dec 70
GRANT OEG-32-15-0050-5010-607
NOTE 98p.

EDRS PRICE EDRS Price MF-$0.65 HC-$3.29
DESCRIPTORS *American English, *Articulation (Speech), Child Development, *Child Language, Elementary School Students, Language Arts, Language Development, Language Patterns, Language Research, Phonetic Analysis, *Phonetics, Speech, *Speech Habits, Speech Tests, Verbal Development

ABSTRACT

This study is concerned with misarticulated speech sounds of children and the phonetic realization of these sounds. The articulation errors of 384 standard-English-speaking school children were analyzed in speech samples obtained by the National Speech and Hearing Survey and were samples of both free speech and of performance on the Goldman-Fristoe Test of Articulation. Error rates and incidence of various types of errors (omissions, distortions, and substitutions) by grade level were noted. The major thrust of the investigation, however, was an attempt to explain the substitution errors in the sample using the constructs of distinctive feature theory and markedness theory. The hypothesis presented in and confirmed by this study is that when substitution errors occur, less complex phonemes will be substituted for more complex ones. The data analyzed in the present study suggest that substitutions are governed in part by a tendency toward ease of articulation with constraints imposed upon substitutions by a tendency to maximize perceptual distinctions in the speech output. The phonetic features themselves were found to be of varying degrees of stability. Tables and charts are included. (Author/RL)

Final Report

Grant No. 32-15-0050-5010(607)

ANALYSIS OF PRODUCTION ERRORS IN THE PHONETIC PERFORMANCE OF SCHOOL-AGE STANDARD-ENGLISH-SPEAKING CHILDREN

Frederick Williams, Editor
Helen S. Cairns
Charles E. Cairns
Dennis F. Blosser

Center for Communication Research
School of Communication
The University of Texas at Austin
Austin, Texas

December, 1970

This research was conducted by the Center for Communication Research, The University of Texas at Austin, under sub-contract with the National Speech and Hearing Survey, Colorado State University, which in turn was supported by contract with the U.S. Office of Education Grant #32-15-0050-5010(607).

The research reported herein was performed pursuant to a grant with the Office of Education, U.S. Department of Health, Education, and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

Office of Education
Bureau of Research

TABLE OF CONTENTS

FOREWORD

Throughout its planning, the directors of the National Speech and Hearing Survey attempted to develop the possibilities for some limited linguistic analyses of their data. In February 1970 a committee met to consider a proposal to do the phonological analysis of standard-English-speaking children described in this report. The research was initiated in June 1970 under sub-contract to the Center for Communication Research, University of Texas at Austin. A second phase -- the analysis of nonstandard-English-speaking children -- is to be initiated in January 1971.

We are indebted to Dr. Forrest Hull, Director of the National Survey, for his cooperation in carrying out this research. Consultants Dr. Roger Shuy and Dr. Walter Stoltz aided in the planning stages. Dr. Helen Cairns undertook the day-to-day management of the project. Dr. Charles Cairns served as the main linguistic consultant. Mr. Dennis F. Blosser managed all computational phases of the project. Graduate assistants serving as typists and phonetic coders included Sharon Barenblat, Roselyn Freeman, Karen Hodges, Devea Lindsey and Kandace Penner.

Frederick Williams
Project Director

December, 1970

ABSTRACT

In this study the articulation errors of 384 standard-English-speaking school children were analyzed. Speech samples were obtained by the National Speech and Hearing Survey and were samples of both Free Speech and of performance on the Goldman-Fristoe Test of Articulation.

Error rates and incidence of various types of errors (omissions, distortions and substitutions) by grade level were noted. The major thrust of the investigation, however, was an attempt to explain the substitution errors in the sample using the constructs of distinctive feature theory in general and markedness theory in particular. Linguistic theories encorporating markedness allow each speech sound to be assigned a value reflecting its complexity on a number of phonetic features. The hypothesis presented in and confirmed by this study is that when substitution errors occur less complex phonemes will be substituted for more complex ones. Furthermore, it was found that the phonetic features which underwent value changes to effect substitution errors usually changed from their more complex (marked) to their less complex (unmarked) value.

The data analyzed in the present study suggest that substitutions are governed in part by a tendency toward ease of articulation with constraints imposed upon substitutions by a tendency to maximize perceptual distinctions in the speech output. The phonetic features themselves were found to be of varying degrees of stability.

SECTION I

Introduction[1]

The articulatory errors of children are typically classified as omissions, distortions or substitutions. Of primary interest to researchers has been an investigation of the speech sounds which are misarticulated, with comparatively little attention paid to the phonetic realizations of these sounds. The present research is concerned with both of these aspects of phonetic errors in a population of school children with normal speech.

1.1. Objectives

The first objective of the present research was to analyze phonetic errors of a sample of children in grades 1-12 and to construct a developmental profile, specifying which speech sounds are missed at each grade level and (in the case of substitution errors) which sounds are substituted for them. The sample was selected from an area of the United States where "Standard English"[2] is spoken. Thus, the error data, the developmental trends, and especially the substitutions themselves, would not be confounded by dialect variables. For each child in the study speech samples of words spoken in isolation as well as segments of connected discourse were available. Thus, the consistency of errors across modes of speech could also be investigated.

The second objective of the present research was to examine the phonetic error data in the light of current linguistic theory. Section 2 of this report presents the linguistic rationale for the study in detail. In general, each phoneme is considered as a bundle of phonetic features, each with a value of + or -. The substitution of one phoneme for another is characterized as a change in value for one or more features of the original phoneme. Thus, the primary unit of the error analysis

---

[1]This section was prepared by F. Williams and H. Cairns.

[2]It is understood that "Standard English" is an idealization which never really exists in any language community; however, the dialect of the area chosen was believed to be as close as possible to this idealization.

was the phonetic feature. It was anticipated that the error data would be relevant to questions about the validity of linguistic complexity measures of phonemes, questions about the relationships among features, and questions about the relative importance (the hierarchical relationship) of the features involved in the analysis.

1.2. Background

Snow (1964) presents consonant substitution data from 438 normal, first grade children from central Indiana. Her data show that the most complex sounds do in fact produce more errors than the less complex ones. Many of the substitutions which she reports do seem to be simplifying substitutions. For example, there are 19 times as many devoicing errors as there are voicing errors in her sample.

Penner (1970) presents an analysis of consonantal substitution data from 20 articulatorily defective 4 and 5-year-olds. Her analysis is on the basis of six distinctive features and is supplemented by a more general analysis of 20 normal children of the same age. The most interesting aspect of this study is the discovery that certain features co-vary, such as continuancy and stridency. When errors occur on strident continuants, significantly more of the substitutions are non-continuant and non-strident than are continuant and non-strident. This suggests a hierarchical relationship between these two features, such that continuancy must be mastered before stridency. A similar suggestion has been made by Menyuk (1968).

It is important to note that while the present analysis utilizes concepts and notation from linguistic theory, no claims are being made about the linguistic competence (Fodor & Garret, 1966) of the children studied. It is impossible to draw any inferences about the competence of any individual from the performance errors of an entire group. Compton (1970) has shown, however, that the performance errors of an individual can yield insights into the structure of his linguistic knowledge. He performed essentially a generative phonological analysis on the output of two children with articulatory disorders and showed how such an analysis can provide insights into appropriate therapy for such children. It is anticipated that, while the results of the present study are not claims about any individual's competence, the knowledge which will be provided about individual features and their inter-relationships will provide a useful guide for future analyses such as Compton's.

1. 3. Organization of the Report

The second section of this report presents the concepts of general linguistic theory which are relevant to the current research. It also makes explicit the anticipated relationships between phonetic error data and linguistic theory. Section 3 and Appendix B present the clerical and computer procedures, respectively, by which the data for this study were analyzed. Section 4 presents the results of all error analyses, and section 5 is devoted to a discussion of the implications of the results, especially with reference to the linguistic issues raised in section 2. The report is organized in such a way that a reader who is uninterested in the linguistic implications of this study may turn immediately to Sections 3 and 4, omitting Sections 2 and 5.

SECTION 2

Linguistic Perspectives[1]

Although the present study involved identification and tabulation of articulatory substitutions, a major theoretical focus was upon the interpretation of the substitutions relative to contemporary phonological theory. Since theories of phonology purport to explain regular aspects of the sound structure of language, it is natural to expect that regular aspects of articulatory errors could be explained in terms of a phonological theory. For reasons which will be discussed below, the theory of generative phonology, as adapted to include the concept of markedness, is judged to be most adequate for this purpose (Chomsky and Halle, 1968, Chapter 9).

2.1. Phonetic Features

2.1.1. Phonetic features in phonological theory. Phonological theory seeks to characterize, for any language, the inventory of phonological segments (phonemes) in that language. Contemporary phonologists generally accept the view that the ultimate unit of phonological analysis should not be the individual phoneme, but rather the phonetic features of which the phonemes are constructed. Table 1 presents brief descriptions of the features used to describe the phonetic content of English phonemes. Notice that many of the features correspond to traditional parameters of phonemic description, such as place and manner of articulation. Table 2 presents a matrix displaying the feature values associated with each consonant analyzed in the present study.

These features frequently refer to the presence or absence of articulatory properties, such as nasality or voicing or the involvement or noninvolvement of the corona of the tongue. In other cases the +/- values reflect the extreme values of a feature (such as backness for the vowels) which range over a continuum and serve to classify phonemes relative to other phonemes. For example, both /u/ and /a/ are classified as [+ back], although /a/ involves more tongue

[1] This section was prepared by C. Cairns and H. Cairns.

Table 1

Phonetic Features

Feature	Description
Consonantal	A speech sound is consonantal if it is produced with a constriction along the center line of the oral cavity. Only the vowels and the glides (/w/, /h/, and /y/) are nonconsonantal.
Vocalic	Vocalic sounds are those which have a largely unobstructed vocal tract. The liquids /l/ and /r/, which are consonantal, are also vocalic. This is true because while there is a central obstruction for the liquids, there is a large unobstructed area to either side of the tongue. Although there is no central obstruction for glides, the most narrow area in the vocal tract during the production is not large enough to qualify them as vocalic. The glides, therefore, are nonvocalic.
Anterior	A sound is anterior if the point of articulation is as far front in the oral cavity as the alveolar ridge. Thus, all the labial and dental sounds are anterior, while sounds produced farther back are nonanterior.
Coronal	A sound is coronal if its articulation involves the front (or corona) of the tongue. A sound is non-coronal if another part of the tongue is used (such as in /k/) or if the tongue is not involved in the production of the sound at all (such as in /p/).

Table 1 (cont'd)

Feature	Description
Continuant	A sound is noncontinuant if it is produced with a complete obstruction in the oral cavity. Only the nasals, stops and affricates are noncontinuant. (The nasals are considered to be noncontinuant because while there is an opening in the nasal cavity, the oral cavity is completely obstructed.)
Strident	A strident sound is produced by an obstruction in the oral cavity which forces the air through a relatively long, narrow constriction. As the air rushes out of the opening of this construction, its turbulence serves as a primary noise source. This turbulent air is then directed against a second obstruction which causes a secondary noise source.
Voice	Voiced sounds are those in which phonation (vibration of the vocal folds in the larynx) takes place as the sound is articulated.
Lateral	A lateral sound is one which involves a contact between the corona of the tongue and some point on the roof of the mouth, along with a simultaneous lowering of the sides of the tongue. In English, /l/ is the only lateral sound, and this feature differentiates it from /r/, the only other liquid, which is nonlateral.

Table 1 (cont'd)

Feature	Description
Nasal	Nasals are characterized by a lowering of the velum, which opens the nasal cavity for sound resonation.
	The above features are used for the description of consonants in English. Hence, they are the only features used for analysis in the present study (cf. Tables 1 & 3). For the sake of completeness, however, the following features for vowel classification are also presented.
High	High vowels are those which involve the highest tongue position, and thus the narrowest constriction in the oral cavity. /u/ and /i/ are the only high vowels; all others are nonhigh.
Low	Low vowels are those which involve the lowest tongue position, /ae/, /a/, and /ɔ/. All other vowels are nonlow. Note how the so-called middle vowels are classed in this system; /e/ and /o/ are nonlow and nonhigh.
Back	The traditional back-front distinction is accounted for the back/nonback distinction. Thus, /u/, /o/, and /ɔ/ are classed as back, while /i/, /ae/, and /e/ are nonback.
Round	As in traditional classifications, the rounding of the lips is a feature for vowel differentiation. Thus, /u/, /o/, and /ɔ/ are round. Others are nonround.

Table 2

Feature Content of Phonemes

Features	z	s	ð	θ	d	t	v	f	b	p	š	ǰ	č	g	k	w	h	y	l	r	m	n
Consonantal	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	+	-	+	+
Vocalic	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-
Anterior	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	+	+	+	+
Coronal	+	+	+	+	+	+	-	-	-	-	+	+	+	-	-	-	-	+	+	+	-	+
Continuant	+	+	+	+	-	-	+	+	-	-	+	-	-	-	-	+	+	+	+	+	-	-
Strident	+	+	-	-	-	-	-	-	-	-	+	+	+	-	-	-	-	-	-	-	-	-
Voiced	+	-	+	-	+	-	+	-	+	-	-	+	-	+	-	+	-	+	+	+	+	+
Lateral	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Nasal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+

retraction than /u/ does. /u/ is classified as [+ back] to distinguish it from /i/ (the only other [+ high] vowel), while /a/ is classified as [+ back] to distinguish it from /ae/ (the only other [+low] vowel). The major point here is that for the purposes of classifying all the phonemes of a language, +/- values are referred to, rather than degrees of realization of individual features.

2.1.2. Phonetic features in the present study. Phonologists have shown that analyzing phonemes as bundles of features leads to more theoretically parsimonious and adequate phonological analyses.[2] A more pertinent question, however, is -- how does the feature approach aid a study such as the present one, which deals with articulatory errors? Suppose that two children misarticulated the phoneme /z/. Child A substituted /s/ for /z/ and Child B substituted /t/ for /z/. If the basic unit of analysis is the individual phoneme, then there is no principled basis for claiming that one substitution is any "closer" to the target phoneme (/z/) than the other, nor is there any general way available to classify the substitutions. Analyzing the substitutions as feature changes, however, is much more informative. Turn to Table 2 and examine the feature content of /z/, /s/, and /t/. The column of pluses and minuses below /s/ differs from that of /z/ by only one cell ([-voice] for /s/; [+voice] for /z/). This means that /s/ and /z/ have the same value for every feature other than [voice]. /t/ and /z/, on the other hand, differ by three feature values. Like /s/, /t/ is [-voice], but, in addition, /t/ is [-strident] while /z/ is [+strident] and /t/ is [-continuant] while /z/ is [+continuant]. (For a description of the features involved, see Table 1.) Therefore, it can be said that /s/ differs from /z/ by only one feature, while /t/ differs from /z/ by three features. The /s/ for /z/ substitution could be said to represent a smaller degree of error than the /t/ for /z/ substitution.

Note that a /d/ for /z/ error is in between the other two substitutions in distance from the target sound, as /d/ differs from /z/ by only two features ([continuant] and [strident]). Thus, use of features seems to provide a metric by which we can judge the degree of an articulatory substitution error.

Another advantage in using the feature approach to interpret articulation errors is that it provides a definition of general classes of errors. (These error classes correspond to "natural classes" of

---

[2] This discussion will not include phonological arguments for the use of feature systems. The interested reader is directed to a classic article on the subject, Halle, 1964.

phonemes in phonological theory, which will be discussed later.) There are, for instance, eight substitutions which involve only a change from [+voice] to [-voice]. They are /s/ for /z/; /θ/ for /ð/; /t/ for /d/; /f/ for /v/; /p/ for /b/; /č/ for /ǰ/; /k/ for /g/; and /h/ for /w/. It is readily apparent that a very large number of classes of errors can be defined using the feature system. Thus, the feature approach provides an informative, quantifiable framework within which to investigate substitution errors.

2. 2. The Concept of Markedness

As was discussed above, the use of a feature analysis of individual phonemes allows the researcher to distinguish classes of phonemes (and classes of substitution errors). For example, one can refer to the class of "all voiced sounds," i. e. all those phonemes which are [+voice]. In the terminology of phonological theory this grouping by features is referred to as the grouping of the phonemes into "natural classes." Phonologists expect that the phonemes grouped into "natural classes" by features will also evidence similar behavior in phonological processes. That is, phonological rules will apply to all the phonemes which are members of a natural class. A phonological rule would never apply only to /k/, for instance, but to all other voiceless stops as well.[3] Analogously, one would expect that classes of phonemes would be similarly affected by substitution errors. Unfortunately, however, the use of +/- values for features often leads to unsatisfactory groupings into natural classes.

A large natural class defined by +/- feature values is the class of all voiced segments (all phonemes which are [+voiced]). This class includes all voiced obstruents (obstruents are phonemes which are [+consonantal], [-vocalic], and [-nasal], cf. Table 4), all nasals, glides (/w/ and /h/), liquids (/r/ and /l/) and vowels. (Nasals, glides, liquids and vowels are referred to as "sonorants.") It is expected, then, that the voiced obstruents and the sonorants,

---

[3]An excellent example of the unitary phonological behavior of members of a natural class is word-final devoicing in German. All members of the class of voiced obstruents change from [+voice] to [-voice] when they appear in word-final position. Thus, the morpheme "Bad" (bath) becomes /bat/ when there is no inflectional ending. The presence of a stem-final /d/ in the underlying representation of this stem is revealed by the phonetic form when there is an inflectional ending, e. g., /baden/ (plural form).

since they form a natural class of all voiced segments, would function similarly in phonological processes and in articulation errors. This is not the case, however. Phonologically, voiced obstruents behave as a class and participate in phonological processes not involving the sonorants (cf. footnote 2). In articulatory errors, devoicing (a change from [+voice] to [-voice], as in the /s/ for /z/ substitution) is only associated with the voiced obstruents. Vowels, glides, nasals and liquids are never devoiced. In fact, very few languages of the world contain voiceless sonorants in their phonemic inventories. A system is needed which will allow the voiced obstruents and the voiced sonorants to be separated into two different natural classes. It would not do, however, to eliminate the +/- feature system entirely, because the +/- values are necessary to *describe the phonetic content* of phonemes.

The solution is to add another system which will describe the relationship between a particular feature and the other features in the phoneme within which it occurs. Consider again the feature [voice]. Articulatorily, the production of voicing in obstruents involves more articulatory complexity than does the production of voicing in sonorants. This is so because for phonation (voicing) to take place there must be a stream of air passing through the larynx. The production of an obstruent, however, involves the creation of an obstruction in the oral cavity, coupled with the closure of the velum, (recall that obstruents are [+consonantal], [-vocalic], and [-nasal]) thus creating an impediment to the stream of air. Since the introduction of an obstruction in the oral cavity and the closure of the velum causes supra-glottal air pressure to rise as air passes through the larynx, phonation during the production of an obstruent requires extra articulatory effort. In the case of the sonorants, however, there is a large open cavity above the glottis (the oral cavity in the case of vowels, glides and liquids -- the nasal cavity in the case of nasals), so supra-glottal air pressure does not increase as air passes through the larynx, and voicing occurs spontaneously, with no extra effort on the part of the speaker. In fact, the suppression of voicing requires extra articulatory effort. Thus, a voiced obstruent is a more complex phoneme than a voiced sonorant.

The system which has been devised to capture relationships of this sort is the system of *marking* (Cairns, 1969; Chomsky and Halle, 1968, Chapter 9). In this system each feature is assigned a marked (*M*) or unmarked (*U*) value. Table 3 presents the same phonemes as those presented in Table 2, with M/U feature values specified, rather than +/- values. Notice that obstruents which are [+voice] on Table 2 (/z/, /ž/, /d/, /v/, /b/, /ǰ/, and /g/) are [M voice] on Table 3. On the other hand, the sonorants which are [+ voice] on Table 2 (/w/, /j/, /l/, /r/, /m/, and /n/) are [U voice] on Table 3. (If vowels were

Table 3

M/U Feature Values of Phonemes

Features	z	s	ð	θ	d	t	v	f	b	p	š	ǰ	č	g	k	w	h	y	l	r	m	n
Consonantal[a]	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	+	+	+	+
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

[a]Note that the feature 'consonantal' does not take on marked and unmarked values. This is because the conversion of M's to U's for all features is dependent upon the +/- value of the feature 'consonantal'. See the Interpretative Conventions presented in Table 4 (page 16).

included in these two tables, they would be [+voice] on Table 2 and [U voice] on Table 3.) Table 2, then, reflects a +/- value system which describes the phonetic content of the phonemes while Table 3 reflects a marking system which expresses the relationship of the individual features to the phonemes in which they occur. The assignment of [M voice], therefore, is made whenever the articulatory adjustment to produce or suppress voicing involves more articulatory effort on the part of the speaker. (Recall that voiced obstruents and voiceless sonorants are [M voice], while voiceless obstruents and voiced sonorants are [U voice].)[4] The marking system of Table 3 also provides a natural class (all those phonemes which are [M voice]) including voiced obstruents and another natural class (all those phonemes which are [U voice]) which includes voiced sonorants.

Consider the previous example of an /s/ for /z/ substitution. Table 2 revealed that the substitution represents a change of one feature value ([+ voice] to [-voice]). Consultation of Table 3 shows that the value change is also from [M voice] to [U voice]; thus, the +/- system indicates that the substituted phoneme is only one feature distant from the target phoneme, while the M/U system indicates in addition that the substitution is a simplifying substitution. This is true because /s/ has fewer <u>M</u>'s in its total inventory than does /z/ and also because the feature of [voice] is changed from its more complex to its less complex value. It is important to notice that the substitution is <u>not</u> simplifying just because the feature changes from a + to a - value. If an /h/ had been substituted for a /w/, this would also be a change of [+voice] to [-voice], but Table 3 reveals that such a substitution would not be a simplifying one, as it would involve a change from [U voice] to [M voice]. (Recall that /h/, which is voiceless, is marked for voicing because it is a sonorant; see footnote 4.)

2.2.1. <u>A perceptual basis for marking</u>. Marking may also reflect increased complexity attributable to perceptual factors. Three classes of phonemes are relevant to this discussion: (1) strident fricatives -- these are obstruents which are [+ continuant] and [+ strident] (/s/, /z/, /š/); (2) nonstrident (mellow) fricatives -- these are obstruents which are [+ continuant] and [- strident] (/ð/, /θ/, /f/, and /v/); and (3) pure (nonaffricated) stops -- these are obstruents which are [- continuant] and [- strident] (/d/, /t/, /b/, /p/, /g/, and /k/). The main perceptual cue indicating the presence of a pure stop seems to be a brief

[4] Notice that the one voiceless sonorant under consideration, /h/, is in fact marked [M voice] on Table 2.

period of silence during the time of closure. Fricatives, on the other hand, are signaled by the presence of noise during the time of the consonantal obstruction, and strident fricatives are noisier than nonstrident fricatives. Therefore, the perceptual distinction between strident fricatives and stops is greater than that between nonstrident fricatives and stops. Thus, one might say that strident fricatives are optimal fricatives, whereas nonstrident fricatives are nonoptimal because their nonstridency tends to attenuate the perceptual distinction between the fricatives and the stops (Jakobson, 1941).

Note that in Table 3 the nonstrident fricatives are [M strident], while the strident fricatives are [U strident]. This marking reflects the fact that the nonstrident fricatives are nonoptimal and are more perceptually complex. The pure stops, of course, are [U strident]; their lack of stridency makes them perceptually optimal.[5]

Among the nonstrident fricatives, /f/ and /θ/ (and their voiced counterparts /v/ and /ð/) are distinguished from each other by point of articulation. According to the feature system employed here /θ/ and /ð/ are [+coronal], while /f/ and /v/ are [-coronal]. /f/ and /v/ are classified here as [M coronal], whereas /θ/ and /ð/ are [U coronal].[6] Although this assignment of Ms and Us is not as certain as those assignments discussed above, there does seem to be some evidence for this marking. Among the evidence is the fact that several languages exist which contain an /f/ and a /v/ but do not contain a /θ/ and a /ð/, whereas few languages have a /θ/ and a /ð/, but not /f/ and /v/. Another consideration is the general opinion of speech therapists that labials are easier to articulate than lingual consonants.

2.2.3. Complexity. Since the assignment of an M value to a feature reflects relative articulatory or perceptual complexity, the

---

[5]This illustrates an important point which must be borne in mind as Tables 2 and 3 are compared with each other. A feature which has a + value for a particular phoneme on Table 2 will not necessarily be marked with an M on Table 3 (nor will - values on Table 2 correspond invariably to a U on Table 3). If this were the case then there would be no point in having the marking system.

[6]The feature values serve to distinguish the phonemes from each other. The reader will notice that in both the M/U and the +/- matrices no two phonemes have the same set of feature values.

total number of Ms assigned to a particular phoneme can be said to characterize the total complexity of that phoneme. Moreover, the relative complexity of phonemes can be determined by comparing the number of M assignments of each, so that a phoneme with more Ms is more complex than one with fewer Ms. The bottom row of Table 3 displays the complexity value for each phoneme on the chart, derived by simply counting the number of Ms assigned to that segment.

2.2.4. Universal interpretative conventions. As was discussed above, the +/- system and the M/U system for assigning feature values are designed to reflect different kinds of facts about the individual features. It is apparent, however, that the two systems are not independent of whether its descriptive value is + or -. In phonologicial theory, therefore, there must be some description of the relationships between the two systems. That description must hold for all languages of the world (that is, it must be universal) or the M/U assignments could be made up separately for any individual language which was being studied. Table 4 presents the set of universal interpretative conventions which relate the M/U values of Table 3 to the +/- values of Table 2. The conventions are presented both in the formal notation of phonological theory mainly for the purpose of illustrating that notation. They are also verbally described in the same table.

2.3. Phonetic Features and Markedness as Related to the Present Study

It should be valuable to view articulatory substitutions as feature changes rather than as the substitution of one unitary phoneme for another. If this is the correct approach, an analysis of errors should indicate that many features of the target phoneme are retained and only a few are changed when a substitution occurs. This was discussed above as "degree of error" of the substitution. Using the feature as the primary unit of analysis allows the description of an error to include a statement about the "distance" of the substituted phoneme from the target phoneme.

The use of the M/U system to characterize feature values should make it possible to explain many substitution errors. One would expect that within phonemic classes more errors would be associated with the more complex (more marked) phonemes than with the less marked ones. It also seems reasonable to expect that when a substitution occurs, the substituted phoneme will be less marked (have fewer Ms) than the target phoneme which it replaces. When the individual features of the substitution are considered, the theory of complexity presented here predicts that the value changes which effect the substitution will be from M to U.

Table 4

Interpretative Conventions

Convention[a]	Formal Notation
1. The unmarked value of 'vocalic' is the opposite value of consonantal.	$[\text{U voc}] \rightarrow [-\alpha\ \text{voc}] / \begin{bmatrix} \overline{\quad} \\ \alpha\ \text{cns} \end{bmatrix}$
2. The unmarked value of 'nasal' is - .	$[\text{U nas}] \rightarrow [-\text{nas}]$
3. For all consonantal sounds, the unmarked value of 'anterior' is + .	$[\text{U ant}] \rightarrow [+\text{ant}] / \begin{bmatrix} \overline{\quad} \\ +\text{cons} \end{bmatrix}$
4. For true consonants (i. e. all [+cons] [-voc] sounds), the unmarked value of 'continuancy' is - .	$[\text{U cnt}] \rightarrow [-\text{cnt}] / \begin{bmatrix} \overline{\quad} \\ +\text{cns} \\ -\text{voc} \end{bmatrix}$
5. The unmarked value of 'stridency' is the same as the continuancy feature for all nonnasal, true consonants (i. e., all obstruents). It is - for all other sounds.	$[\text{U str}] \rightarrow [\alpha\ \text{str}] / \begin{bmatrix} \overline{\quad} \\ +\text{cns} \\ -\text{voc} \\ -\text{nas} \\ \alpha\ \text{cnt} \end{bmatrix}$
6. The unmarked value of 'coronal' is - for continuant, nonstrident sounds and for nonanterior sounds. It is + for all other sounds. (That is, /θ/ and /d/ are marked for coronal, although /t/, /d/, /s/, and /z/ are not. /f/ and /v/ are also not marked for coronal. The point is that /f/ and /v/ are the unmarked nonstrident continuants.	$[\text{U cor}] \rightarrow \left\{ \begin{matrix} [-\text{cor}] / \left\{ \begin{matrix} \begin{bmatrix} \overline{\quad} \\ +\text{cnt} \\ -\text{str} \end{bmatrix} \\ \begin{bmatrix} \overline{\quad} \\ -\text{ant} \end{bmatrix} \end{matrix} \right\} \\ \\ [+\text{cor}] \end{matrix} \right\}$

Table 4 (cont'd)

Convention[a]	Formal Notation
7. An obstruent (i. e., a [+cns] [-voc] [-nas] sound) is unmarked for voicing when it is [-voi] all other sounds are [+voi] in the unmarked state.	$[\text{U voi}] \rightarrow \left\{ \begin{matrix} [\text{-voi}] / \left[\begin{matrix} \overline{\quad\quad} \\ \text{+cons} \\ \text{-voc} \\ \text{-nas} \end{matrix} \right] \\ [\text{+voi}] \end{matrix} \right\}$
8. The unmarked value of 'lateral' is - .	[U lat] → [-lat]

[a]Note that these conventions must apply in the order in which they are written. For example, '1' must have applied to give a '+' or a '-' value for the feature 'vocalic' before conventions '2,' '5,' or '7' can apply.

The interpretative conventions are written in terms of the <u>U</u> value for each feature. The <u>M</u> value assumes exactly the <u>opposite</u> +/- value from that assumed by the <u>U</u> value. Thus, for example, in convention #8, [U lat] is related to [-lat] and [M lat] is related to [+ lat].

A point which has not been mentioned is the importance of the individual features. All the discussion up to this point has seemed to indicate that [strident], for instance, is as important a feature as [anterior]. Actually, very little is known about the relative importance of the features, but one might speculate that a feature like stridency, which is very distinctive perceptually, might be more important (or carry more information) than the features which specify place of articulation. This is the sort of information which could be provided by a study of articulatory substitutions. If some features seem more vulnerable to value changes than others, then the more stable ones can be characterized as more important. The vulnerability of a feature will probably be related to whether it is marked (since feature changes are expected to be from an M value to a U value) and also to the values of other features with which it interacts.

SECTION 3

Data Collection and Initial Tabulation[1]

3.1. National Speech and Hearing Survey Data Collection

During the school year 1968-1969 the National Speech and Hearing Survey (NSHS) obtained speech samples from 38,802 United States school children. NSHS is based at Colorado State University, under the direction of Dr. Forrest Hull. The sample of 38,802 was drawn from the 41,088,138 member population of United States school children (1968-69 census). Samples were obtained from 100 school districts in 9 census divisions. A minimum sample of 384 children was tested from each district, evenly divided among grades 1-12, with the sample from each grade equally divided by sex.

The speech sample obtained from each child consisted of the Goldman-Fristoe Test of Articulation (Appendix A), a few minutes of connected discourse, selected speech sounds elicited in a vowel context, and the repetition of a set of four sentences. The present study utilized the first two of these speech samples. Segments of connected discourse (free speech) were elicited in various ways, depending on the age level of the subject. Children in grades 1-3 were given the Goldman-Fristoe Sounds in Sentences Test; children in grades 4-9 were asked to make up stories in response to pictures; children in the upper grades were asked standardized questions to stimulate free speech. The testing of subjects was done in specially equipped soundproof vans by trained NSHS staff members. All speech samples were tape recorded.

3.2. Procedure for the Present Study

3.2.1. The sample. For the present study the researchers obtained all speech samples obtained by NSHS from the school district located in Marshalltown, Iowa -- a total of 384 samples (32 subjects per grade). As was discussed in Section 1, this school district was selected because the language spoken there is close to the ideal of

[1] This section was prepared by H. Cairns.

"Standard American." Of the 384 subjects in the Marshalltown smple, 186 had articulation errors of some sort.

3.2.2. Coding and tabulation of errors. The free speech sample for each subject was transcribed into English orthography by typists. Phonetic coders[2] then listened to the Goldman-Fristoe test and to each subject's free speech sample. If no errors were found for a subject, his transcript was placed in a special file. Articulation errors were recorded for each subject on a separate "coding sheet" in the following way: The target phoneme and its position were indicated; the substituted phoneme[3] was noted; the features by which the substituted phoneme differed from the target phoneme were listed, with the value for each. Thus, if a /t/ were substituted for a /d/, the target phoneme would be /d/, the substituted phoneme /t/ and the substitution was coded as a [-voice] error (see Table 2, Section 2 for a list of phonemes with feature content specified). Additional information was tabulated for errors occurring in the free speech samples. The number of occurrences of a misarticulated target phoneme in the free speech sample was recorded, as well as the number of occurrences of errors associated with that target phoneme. What was needed was a frequency of errors relative to occurrences for every phoneme of interest. In some cases a subject would produce more than one substitution for a given target phoneme. Therefore, the number of occurrences of each recorded substitution was noted. After the data were tabulated they were transferred to computer cards. The coding format followed the arrangement of the "Data Base Description" given in Appendix B.

---

[2] There were three phonetic coders, all graduate students in Speech Pathology. An inter-judge reliability test indicated .78 reliability among the three coders for judgments that an articulation error had occurred. Given that a speech sound was judged to be an error, there was a .87 inter-judge agreement on the identification of the substituted phoneme. Since the error identification reliability seemed a bit low, about a third of the tapes were re-listened to by a coder who had not heard the tape previously. These were tapes on which there was some discrepancy between the scoring by the phonetic coder and the original scoring of the National Speech and Hearing Survey staff. When disagreements in error and substitution judgments were discovered during this re-listening procedure, a third coder was called in to listen to the tape in question and assist in the final decision.

[3] Omission and distortion errors were also noted.

3.2.3. An example. Table 5 presents the tabulated data for one of the Marshalltown children -- subject #13, a female, in the first grade. The Goldman-Fristoe data appear in the column on the left of the page, the Free Speech data on the right. This subject omitted a /p/ in final position on the Goldman-Fristoe test, but did not miss it (N/E = no error) in free speech even though she did have some final /p/ sounds correctly articulated. She also missed /v/ in initial position on the Goldman-Fristoe test, for which she substituted a /w/. That substitution was the result of the change of two features, /w/ being [-consonantal] (whereas /v/ is [+consonantal]), and [-anterior] (whereas /v/ is [+anterior]): /b/ was substituted for /v/ in final position on the Goldman-Fristoe test, with a change of one feature, /b/ being [-continuant]. The "N/O" notation indicates that there was no opportunity for error of this type in the free speech, as no initial or final /v/ occurred. A /d/ for /ð/ error in initial position is coded like the other Goldman-Fristoe errors. The notation in the free speech section indicates that there were 23 occurrences of initial /ð/, with 15 of them misarticulated. Of the 15 misarticulations, 13 were /d/ substitutions and 2 were omissions (indicated by the null sign 'ø'). There were, in addition, 4 occurrences of medial /ð/ in free speech, with one error, a /d/ substitution.

3.3. Two Excluded Phonemes

With two exceptions all the phonemes and clusters tested by the Goldman-Fristoe Test (cf. Appendix A) were evaluated in the error analysis. The excluded phonemes were /wh/ and /ŋ/. The substitution of /w/ for /wh/ is without exception the error associated with the /wh/ phoneme. This substitution is not correlated with articulatory disorders, and is extremely common in English. Many linguists feel that the distinction between /w/ and /wh/ is dying in English, since it carries a very low functional load. That is, there are very few minimal pairs utilizing this distinction (e.g. 'wail'/whale') and those usually involve words which are different parts of speech. Therefore, the distinction almost never affects the meaning of a word embedded in an English sentence. It was decided that the inclusion of /w/ for /wh/ substitutions would distort the error data and magnify the number of errors inappropriately, as there were 120 subjects who produced only /w/ for /wh/ errors.

The /n/ for /ŋ/ substitution was left out of consideration because its distributional characteristics differ from any other phoneme in the language. /ŋ/ patterns more like a cluster than like an individual phoneme, e.g. it usually occurs only in word-final position. When it is not in word-final position it is in stem-final position at a morpheme

Table 5

Sample Tabulation Sheet from One Subject

Subject # 13 Grade 1 Sex F City MSHLTN

G. F. position	G. F. substitution	G. F. features	F. S. position	RF of error	F. S. substitution	F. S. features	RF of substitution
final	p/ø		final		N/E p		
initial	v/w	[-cns] [-ant]	initial		N/O v		
final	b	[-cnt]	final		N/O		
initial	ð/d	[-cnt]	initial	15/23	ð/d	[-cnt]	13
					ø		2
			medial	1/4	d	[-cnt]	1

boundary (e.g. 'sing'/'singer', where there is obviously a morpheme boundary after the /ŋ/ in 'singer'.) In 'finger', where there is no evidence for a morpheme boundary following the /ng/ cluster, the intervocalic /ŋ/ is disallowed by the rules of English. Of course, /ŋ/ frequently occurs in clusters before a /k/ or a /g/, usually as a positional variant of /n/ (e.g. 'congress'/'congressional', where stress is one of the determining characteristics of the assimilation). The distribution of /ŋ/ is similar to the distribution of the clusters /mb/ and /nd/ in that none of these three may occur in word-initial position. Thus, to have treated /ŋ/ like any other phoneme, especially like any other nasal phoneme, would have been highly misleading at best. Therefore, if it had been analyzed, it should have been treated as a cluster. However, the only clusters treated were those occurring in word-initial position. Hence, /ŋ/ could not have been treated on that basis. Adding to the difficulty with /ŋ/ is the fact that the vast majority of /ŋ/ errors occur as an /n/ for /ŋ/ substitution associated with the 'ing' morpheme in progressive and gerundive constructions. The /ŋ/ occurring in the 'ing' morpheme and the /ŋ/ discussed above (which behaves as a stem-final cluster) are phonologically very different. To have collapsed the two types of /ŋ/ as one phoneme for analysis would have simply added to the confusion.

SECTION 4

Results[1]

In this section the results of analyses of the project data will be presented in detail. The linguistic implications of the results will be discussed in Section 5.

4.1. Presentation of Over-All Error Data

4.1.1. Goldman-Fristoe. Table 6 presents all errors produced on the Goldman-Fristoe articulation test. The columns of the table are grades. The rows are target phonemes, ordered by frequency of total errors. *N* for each grade is the number of subjects contributing error data from that grade. Each cell reports *n*, the number of subjects misarticulating the row phoneme in the column grade; *f*, the number of errors occurring on the row phoneme in the column grade; and *%*, the percent of the total errors occurring in the column grade accounted for by the row phoneme. In addition, a list of the errors associated with the target phoneme and the frequency of occurrence of each are entered in each cell of the table. Omission errors are represented by the symbol *Ø*; distortions are entered as *dist*; for substitution errors, the substituted phoneme is noted.

4.1.2. Free speech. Table 7 presents all errors produced in the free speech samples of the subjects. The format of presentation is the same as that of Table 6 with one exception. Replacing the percentage of grade errors (*%*) is information about the relative frequency (*rf*) of errors on the row phoneme in the free speech of subjects in the column grade. The method of computation of *rf* was discussed in the preceding section (see also Table 5). Briefly, *rf* represents a ratio of number of errors on a given phoneme divided by the number of occurrences of that phoneme in a subject's free speech sample. The *rf* in a cell of Table 7, then, is a similar ratio computed across all subjects who missed the row phoneme in the column grade in free speech.

---

[1]This section was prepared by H. Cairns and D. Blosser.

Table 6

Over-All Goldman-Fristoe Errors[a]

Target Phoneme	Grade 1 N=30			2 N=24			3 N=25			4 N=15			5 N=24			6 N=22			Jr. High N=26			Sr. High N=20			Total Errors	
	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f
	4	5	8	10	13	13	8	11	23	5	7	29	3	4	10	1	2	9	1	1	3	6	11	41	38	54
z	error		f	error		f	error		f	error		f	error		f	error		f	error		f	error		f		
	s		4	s		11	s		10	s		5	s		4	s		2	d		1	Dist		5		
				ø		1	ø		1	Dist		2										s		5		
				Dist		1																ø		1		
	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f
	3	3	5	6	14	14	7	8	17	2	3	13	6	8	19	2	2	9	2	2	6	1	1	4	29	41
r	error		f	error		f	error		f	error		f	error		f	error		f	error		f	error		f		
	w		3	w		10	w		6	w		2	w		6	ø		1	w		2	w		1		
				ø		4	ø		2	ø		1	ø		2	w		1								

Table 6 (cont'd)

Target	Grade 1			2			3			4			5			6			Jr. High			Sr. High			Total Errors	
	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f
	3	4	7	7	11	11	4	4	9	2	2	8	3	5	12	1	1	5	2	5	16	2	3	11	24	35
θ	error		f	error		f	error		f	error		f	error		f	error		f	error		f	error		f		
	f		2	f		8	f		4	t		1	f		3	t		1	f		4	t		1		
	t		1	s		2				∅		1	s		1				∅		1	∅		2		
	s		1	t		1							∅		1											
	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f
	10	14	23	8	8	8	4	4	9	1	1	4	1	1	2	2	2	9	2	2	6	3	3	11	31	35
v	error		f	error		f	error		f	error		f	error		f	error		f	error		f	error		f		
	b		10	b		6	b		4	b		1	b		1	b		2	b		2	b		3		
	r		2	ƀ		1																				
	ʒ		1	∅		1																				
	w		1																							

Table 6 (cont'd)

Target		Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Jr. High	Sr. High	Total Errors
ʒ	n f %	6 6 10	2 2 2	2 2 4	5 5 21	3 3 7	2 2 9	3 4 13	1 1 4	n f: 24 25
	error f	d 4	d 2	d 2	d 4	d 3	d 2	d 1	n 1	
		v 1			n 1			Ø 1		
		Ø 1						z 1		
								h 1		
l	n f %	1 2 3	4 5 5	0	0	4 6 14	1 1 5	3 3 10	1 1 4	n f: 14 18
	error f	w 2	Dist 1			Ø 4	Ø 1	Ø 2	w 1	
			d 1			w 2		w 1		
			Ø 1							
			y 1							
s	n f %	1 1 2	5 7 7	0	0	2 2 5	1 1 5	2 2 6	1 1 4	n f: 12 14
	error f	Dist 1	Dist 4			Ø 1	Dist 1	Dist 1	Dist 1	
			t 2			θ 1		Ø 1		
			Ø 1							

Table 6 (cont'd)

Target	Grade 1	2	3	4	5	6	Jr. High	Sr. High	Total Errors
	n f %	n f %	n f %	n f %	n f %	n f %	n f %	n f %	n f
	0	2 4 4	1 1 2	1 1 4	3 3 7	0	1 1 3	1 3 11	9 13
š		error f č 2 s 2	error f č 1	error f s 1	error f č 3		error f č 1	error f Dist 2 č 1	
	n f %	n f %	n f %	n f %	n f %	n f %	n f %	n f %	n f
	3 3 5	2 2 2	1 1 2	0	1 1 2	3 4 18	0	2 2 7	12 13
č	error f t 2 š 1	error f ø 1 t 1	error f t 1		error f ǰ 1	error f t 2 š 2		error f š 2	
	n f %	n f %	n f %	n f %	n f %	n f %	n f %	n f %	n f
	4 4 7	5 7 7	1 1 2	0	0	0	0	0	10 12
f	error f θ 1 b 1 p 1 ø 1	error f b 5 ø 1 ð 1	error f ø 1						

Table 6 (cont'd)

Target	Grade																								Total Errors	
	1			2			3			4			5			6			Jr. High			Sr. High				
	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f
	2	2	3	2	2	2	2	2	4	2	2	8	1	1	2		0		2	2	6		0		11	11
ǰ	error	f		error	f		error	f		error	f		error	f					error	f						
	d	1		č	2		š	1		č	2		d	1					d	1						
	Ø	1					d	1											č	1						
	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f
	5	5	8	1	1	1	1	1	2		0			0			0		1	1	3		0		8	8
p	error	f		error	f		error	f											error	f						
	b	4		b	1		b	1											b	1						
	Ø	1																								
	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f
	2	2	3	1	1	1		0		1	1	4	1	1	2		0			0			0		5	5
k	error	f		error	f					error	f		error	f												
	θ	2		f	1					Ø	1		g	1												

Table 6 (cont'd)

Target	Grade																								Total	
	1			2			3			4			5			6			Jr. High			Sr. High			Errors	
	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f
	1	1	2	1	1	1		0			0			0			0		1	1	3		0		3	3
n	error		f	error		f													error		f					
	1		1	1		1													Ø		1					
	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f
		0		1	1	1		0			0			0			0		1	1	3		0		2	2
d				error		f													error		f					
				Ø		1													Ø		1					
	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f
		0			0			0			0			0			0		1	1	3		0		1	1
t																			error		f					
																			Ø		1					
	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f
	1	1	5		0			0			0			0		1	1	5		0			0		1	1
g	error		f													error		f								
	Ø		1													Ø		1								

Table 6 (cont'd)

Target	Grade 1 n	1 f	1 %	2 n	2 f	2 %	3 n	3 f	3 %	4 n	4 f	4 %	5 n	5 f	5 %	6 n	6 f	6 %	Jr. High n	Jr. High f	Jr. High %	Sr. High n	Sr. High f	Sr. High %	Total Errors n	Total Errors f
m		0		1	1	1		0			0			0			0			0			0		1	1
				error		f																				
				ø		1																				
b	1	1	2		0			0			0			0			0			0			0		1	1
	error		f																							
	v		1																							
fl	2	2	3	3	3	3	2	2	4		0			0		2	2	9	1	1	3		0		10	10
	error		f	error		f	error		f							error		f	error		f					
	(f)	p	1	(f)	p	1	(f)		0							(f)		0	(f)		0					
	(l)	ø	1	(l)	w	2	(l)	w	2							(l)	ø	2	(l)	w	1					

Tabe 6 (cont'd)

Target	Grade 1			2			3			4			5			6			Jr. High			Sr. High			Total Errors	
	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f
br	2	2	3	3	3	3		0			0		1	1	2	1	1	5		0			0		7	7
	error		f	error		f							error		f	error		f								
	(b)		0	(b)		0							(b)		0	(b)		0								
	(r)	w	1	(r)	w	3							(r)	Dist	1	(r)	Ø	1								
		Ø	1																							
	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f
kr		0		2	2	2	3	3	6		0		2	2	5		0			0			0		7	7
				error		f	error		f				error		f											
				(k)		0	(k)		0				(k)		0											
				(r)	w	1	(r)	Ø	2				(r)	w	2											
					Ø	1		w	1																	
	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f
tr	1	1	2	2	3	3	2	2	4		0			0			0			0			0		5	6
	error		f	error		f	error		f																	
	(t)		0	(t)		0	(t)		0																	
	(r)	Ø	1	(r)	w	3	(r)	Ø	1																	
								w	1																	

Table 6 (cont'd)

Target	Grade 1			2			3			4			5			6			Jr. High			Sr. High			Total Errors	
	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f
		0		1	1	1	1	1	2	1	1	4	1	1	2		0		1	1	3	1	1	4	6	6
sl				error		f	error		f	error		f	error		f				error		f	error		f		
				(s)		0	(s)		0	(s)	š	1	(s)		0				(s)		0	(s)		0		
				(l)	Ø	1	(l)	Ø	1	(l)		0	(l)	Ø	1				(l)	w	1	(l)	Dist	1		
	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f
		0		2	2	2	2	2	4		0			0		1	1	5	1	1	3		0		6	6
bl				error		f	error		f							error		f	error		f					
				(b)	p	1	(b)		0							(b)		0	(b)		0					
				(l)	w	1	(l)	Ø	2							(l)	Ø	1	(l)	w	1					
	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f
	1	1	2	1	2	2	1	1	2		0			0		1	1	5		0			0		4	5
dr	error		f	error		f	error		f							error		f								
	(d)		0	(d)	g	1	(d)	b	1							(d)	g	1								
	(r)	Ø	1	(r)	Ø	1	(r)		0							(r)		0								

Table 6 (cont'd)

Target	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Jr. High	Sr. High	Total Errors
	n f %	n f %	n f %	n f %	n f %	n f %	n f %	n f %	n f
skw	1 1 2	2 2 2	0	1 1 4	1 1 2	0	0	0	5 5
	error f (s) 0 (k) 0 (w) Ø 1	error f (s) Ø 1 (k) 0 (w) Ø 1		error f (s) 0 (k) 0 (w) Ø 1	error f (s) 0 (k) 0 (w) Ø 1				
	n f %	n f %	n f %	n f %	n f %	n f %	n f %	n f %	n f
kl	0	0	0	0	2 2 5	1 1 5	1 1 3	0	4 4
					error f (k) 0 (l) Ø 1 w 1	error f (k) 0 (l) Ø 1	error f (k) 0 (l) w 1		
	n f %	n f %	n f %	n f %	n f %	n f %	n f %	n f %	n f
st	0	1 1 1	1 1 2	0	0	0	0	1 1 4	3 3
		error f (s) Dist 1 (t) 0	error f (s) 0 (t) Ø 1					error f (s) Dist 1 (t) 0	

Table 6 (cont'd)

Target	Grade 1			Grade 2			Grade 3			Grade 4			Grade 5			Grade 6			Jr. High			Sr. High			Total Errors	
	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f	%	n	f
pl	1	1	2	1	1	1		0			0			0			0		1	1	3		0		3	3
	error		f	error		f													error		f					
	(p)		0	(p)		0													(p)		0					
	(l)	r	1	(l)	w	1													(l)	w	1					
Total Errors		61			100			47			24			42			22			31			28			

[a]For each cell entry n is the number of subjects who misarticulated the row phoneme in the column grade; f is the number of errors; % indicates the percentage of total errors for the column grade accounted for by the row phoneme. Errors are reported as the substituted phoneme for substitution errors, 'Dist' for a distortion error, and 'Ø' for omission errors.

Table 7

Over-All Free Speech Errors[a]

Target Phoneme	Grade 1 N=21	Grade 2 N=21	Grade 3 N=14	Grade 4 N=9	Grade 5 N=15	Grade 6 N=10	Jr. High N=20	Sr. High N=9	Total Errors
	n f rf	n f rf	n f rf	n f rf	n f rf	n f rf	n f rf	n f rf	n f
	1 10 .59	7 19 .16	3 9 .14	3 14 .33	1 2 .25	1 1 .05	1 3 .60	2 9 .38	19 67
z	error	error f	error f	error f	error f	error f	error f	error f	
	s 10	Dist 10	s 9	s 14	s 2	s 1	Dist 3	Dist 6	
		s 7						s 3	
		∅ 2							
	n f rf	n f rf	n f rf	n f rf	n f rf	n f rf	n f rf	n f rf	n f
	3 7 .16	6 54 .56	5 19 .37	2 2 .47	4 6 .33	0	1 1 .20	0	21 89
	error f	error f	error f	error f	error f		error f		
r	∅ 6	∅ 45	∅ 14	w 1	∅ 4		w 1		
	w 1	s 3	w 5	∅ 1	w 2				
		t 2							
		f 2							
		p 1							
		w 1							

Table 7 (cont'd)

Target	Grade																								Total Errors	
	1			2			3			4			5			6			Jr. High			Sr. High				
	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f
	5	8	.33	5	10	.56	3	3	.29	1	1	1.0	1	1	.33	1	1	.33	2	3	.43		0		18	27
θ	error	f		error	f		error	f		error	f		error	f		error	f		error	f						
	t	4		∅	3		∅	2		∅	1		p	1		t	1		f	2						
	f	3		s	3		s	1											t	1						
	∅	1		t	2																					
				f	2																					
	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f
	1	1	1.0	2	2	.33		0			0		2	2	.15	1	1	.33		0			0		6	6
v	error	f		error	f								error	f		error	f									
	∅	1		b	1								b	1		∅	1									
				∅	1								∅	1												
	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f
	20	102	.26	9	43	.25	7	14	.13	7	21	.27	11	21	.12	6	11	.24	13	26	.11	6	13	.11	79	251
ɣ	error	f		error	f		error	f		error	f		error	f		error	f		error	f		error	f			
	d	86		d	32		∅	5		d	14		d	11		d	8		n	10		d	6			
	∅	9		∅	7		d	5		n	4		n	7		∅	2		d	9		∅	4			
	n	7		n	3		n	4		t	2		∅	2		z	1		∅	6		n	2			
				t	1					∅	1		z	1					h	1		t	1			

Table 7 (cont'd)

Target	Grade																								Total	
	1			2			3			4			5			6			Jr. High			Sr. High			Errors	
	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f
	2	5	.36	3	8	.53		0			0		1	5	.39	1	2	.50	1	1	.50	1	5	.71	9	26
l		error	f		error	f								error	f		error	f		error	f		error	f		
		∅	4		∅	6								∅	5		w	1		w	1		∅	5		
		w	1		d	1											∅	1								
					y	1																				
	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f
		0		2	9	.18	2	2	.25		0			0			0		2	4	.18	1	16	.84	7	31
s					error	f		error	f											error	f		error	f		
					Dist	9		z	1											Dist	4		Dist	16		
								∅	1																	
	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f
		0		1	2	1.0	1	1	.33	1	1	.25		0			0			0		1	1	1.0	4	5
š					error	f		error	f		error	f											error	f		
					s	2		č	1		Dist	1											Dist	1		

Table 7 (cont'd)

Target	Grade 1	2	3	4	5	6	Jr. High	Sr. High	Total Errors
č	n f rf 0	n f rf 1 1 .50 error f ø 1	n f rf 0	n f rf 0	n f rf 1 1 .25 error f s 1	n f rf 0	n f rf 0	n f rf 0	n f 2 2
f	n f rf 1 1 .10 error f b 1	n f rf 2 2 1.0 error f w 1 ø 1	n f rf 0	n f rf 0	n f rf 1 1 .33 error f p 1	n f rf 0	n f rf 0	n f rf 0	n f 4 4
ǰ	n f rf 2 3 .20 error f d 3	n f rf 0	n f rf 3 4 .22 error f d 3 ø 1	n f rf 0	n f rf 1 1 1.0 error f d 1	n f rf 0	n f rf 3 4 .50 error f d 3 č 1	n f rf 0	n f 9 12

Tabel 7 (cont'd)

Target	Grade 1			2			3			4			5			6			Jr. High			Sr. High			Total Errors	
	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f
p	2	3	.60	3	4	.50	1	1	.20		0			0			0			0			0		6	8
	error		f	error		f	error		f																	
	b		3	b		3	b		1																	
				d		1																				
	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f
k	1	1	1.0		0			0			0			0			0			0			0		1	1
	error		f																							
	∅		1																							
	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f
n	1	1	.14		0			0			0			0			0			0			0		1	1
	error		f																							
	1		1																							

Table 7 (cont'd)

Target	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Jr. High	Sr. High	Total Errors
	n f rf	n f rf	n f rf	n f rf	n f rf	n f rf	n f rf	n f rf	n f
d	3 3 .30	2 2 .07	1 4 .57	0	1 1 1.0	0	1 1 .25	0	8 11
	error f	error f	error f		error f		error f		
	∅ 3	t 2	∅ 4		∅ 1		∅ 1		
	n f rf	n f rf	n f rf	n f rf	n f rf	n f rf	n f rf	n f rf	n f
t	1 4 .15	4 5 .08	2 8 .42	0	4 5 .08	3 4 .25	5 4 .13	0	19 30
	error f	error f	error f		error f	error f	error f		
	∅ 4	∅ 2 d 1 n 1 ð 1	∅ 8		∅ 3 d 2	∅ 4	∅ 4		
	n f rf	n f rf	n f rf	n f rf	n f rf	n f rf	n f rf	n f rf	n f
g	0	0	0	0	0	1 1 .50	0	0	1 1
						error f			
						∅ 1			

Table 7 (cont'd)

Target	Grade																								Total Errors	
	1			2			3			4			5			6			Jr. High			Sr. High				
	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f
w	2	3	.16		0			0			0			0			0			0			0		2	3
	error		f																							
	∅		3																							
m	2	2	.13		0			0			0			0			0			0			0		2	2
	error		f																							
	∅		2																							
b		0			0			0			0		1	1	.14		0			0			0		1	1
													error		f											
													v		1											

Table 7 (cont'd)

Target	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Jr. High	Sr. High	Total Errors
	n f rf	n f rf	n f rf	n f rf	n f rf	n f rf	n f rf	n f rf	n f
fl	0	1 1 1.0	0	0	0	0	0	0	1 1
		error f (f) 0 (l) w 1							
	n f rf	n f rf	n f rf	n f rf	n f rf	n f rf	n f rf	n f rf	n f
br	0	3 5 .83	1 1 .17	0	0	0	0	0	4 6
		error f (b) 0 (r) w 4 Ø 1	error f (b) 0 (r) Ø 1						
	n f rf	n f rf	n f rf	n f rf	n f rf	n f rf	n f rf	n f rf	n f
kr	0	1 1 1.0	0	0	0	0	0	0	1 1
		error f (k) 0 (r) w 1							

Table 7 (cont'd)

Target	Grade																								Total Errors	
	1			2			3			4			5			6			Jr. High			Sr. High				
	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f
		0		2	2	.50		0			0			0			0			0			0		2	2
tr				error		f																				
				(t)		0																				
				(r)	w	2																				
	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f
		0			0			0			0			0		1	1	1.0		0			0		1	1
sl																error		f								
																(s)		0								
																(l)	w	1								
	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f
	1	1	.50	1	1	1.0		0			0			0			0			0			0		2	2
bl	error		f	error		f																				
	(b)		0	(b)		0																				
	(l)	Ø	1	(l)	Ø	1																				

Table 7 (cont'd)

Target	Grade 1			2			3			4			5			6			Jr. High			Sr. High			Total Errors	
	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f
dr	1	2	1.0	2	2	1.0		0			0			0			0			0			0		3	4
	error	f		error	f																					
	(d) k	1		(d)	0																					
	(r) l	1		(r) w	1																					
				∅	1																					
skw	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f
		0			0			0			0			0			0			0			0		0	0
kl	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f
		0			0			0			0			0		1	1	1.0		0			0		1	1
																error	f									
																(k)	0									
																(l) w	1									
st	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f
		0			0			0			0			0			0			0		1	4	.57	1	4
																						error	f			
																						(s) Dist	4			
																						(t)	0			

Table 7 (cont'd)

Target	Grade 1			2			3			4			5			6			Jr. High			Sr. High			Total Errors	
	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f	rf	n	f
		0		1	1	1.0		0		1	1	1.0		0			0		1	2	1.0		0		3	4
pl				error		f				error		f							error		f					
				(p)		0				(p)		0							(p)		0					
				(l)	w	1				(l)	w	1							(l)	w	2					
					ø	1																				
Total Errors Per Grade	157			174			66			40			47			23			49			48				

[a]Cell entries are exactly the same as those of Table 6 except that % is replaced by 'rf'. 'rf' indicates the "Relative Frequency' of the error, that is, the number of misarticulations of the target phoneme divided by the number of occurrences of the target phoneme.

4.2. Error Analyses

4.2.1. Frequency of misarticulations across grades. The data were first analyzed to ascertain what differences in frequency of articulatory errors could be attributed to differences in Grade level and sex. Two analyses of variance (one for Goldman-Fristoe, one for Free Speech) were performed on the subjects' error scores, with each subject's error score being the number of articulatory errors he produced. (Figure 1 illustrates the relationships for the Goldman-Fristoe data; Figure 2 for the Free Speech.) In both analyses, grade level was highly significant: Goldman-Fristoe, $F(7, 366 = 9.32$, $p < .001$; Free Speech, $F(7, 366 = 11.79$, $p < .001$. Although girls made fewer errors than boys in both Goldman-Fristoe and Free Speech, the difference was not statistically significant.

4.2.2. Performance on individual phonemes by grade. Since it has been shown that the incidence of misarticulations decreases as grade level increases, it is reasonable to wonder if this relationship holds for all phonemes or if the general grade trend is attributable to a few phonemes with high incidences of error. Figure 3 presents a graph showing the incidence of Goldman-Fristoe error associated with individual phonemes in each grade category. The position on the ordinate of the entry for any given grade is the number of errors made on that target phoneme per subject in the original sample. (Recall that the N for the original sample was 32 subjects per grade). Thus, 5 Goldman-Fristoe errors on /z/ in the first grade is expressed as an ordinate value of .156 (5/32) on the first grade point of the /z/ graph in Figure 3. The 9 phonemes which are graphed are those most frequently missed on the Goldman-Fristoe test (cf. Table 6). The incidence of error for individual phonemes in free speech was not analyzed because the differential frequency of occurrence of the phonemes in free speech tends to confound estimates of the error rates of each.

In general all phonemes show a decrease in incidence of error across grade levels. There are, however, some exceptions to this generalization. The error rates for /č/ for example, are quite similar for all grade levels. /z/ is unique in that there is an increase in /z/ errors in the Senior High School group. A surprising finding is that the error rates of several phonemes (/z/, /r/, /l/, /θ/, /s/, and /š/) increase markedly from the first grade to the second. These are all the [+coronal] [+continuant] sounds except /ʒ/, but there seems to be no plausible explanation as to why that class of sounds should be less difficult for first graders than for second graders.

Figure 1

Mean Goldman-Fristoe Errors by Grade and Sex

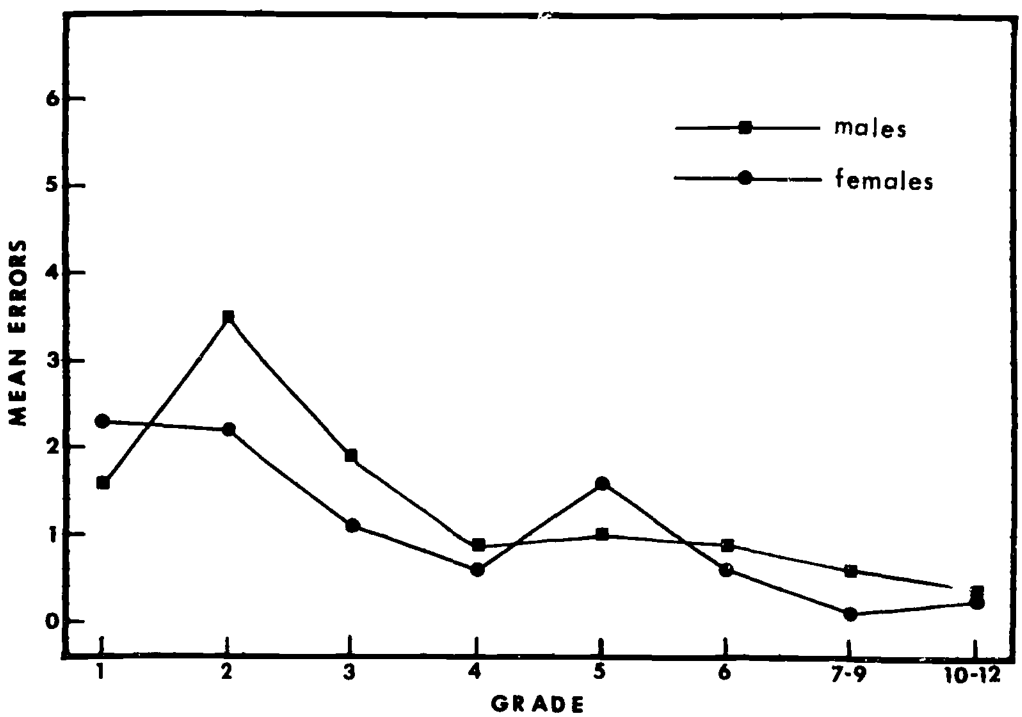


Figure 2

Mean Free Speech Errors by Grade and Sex

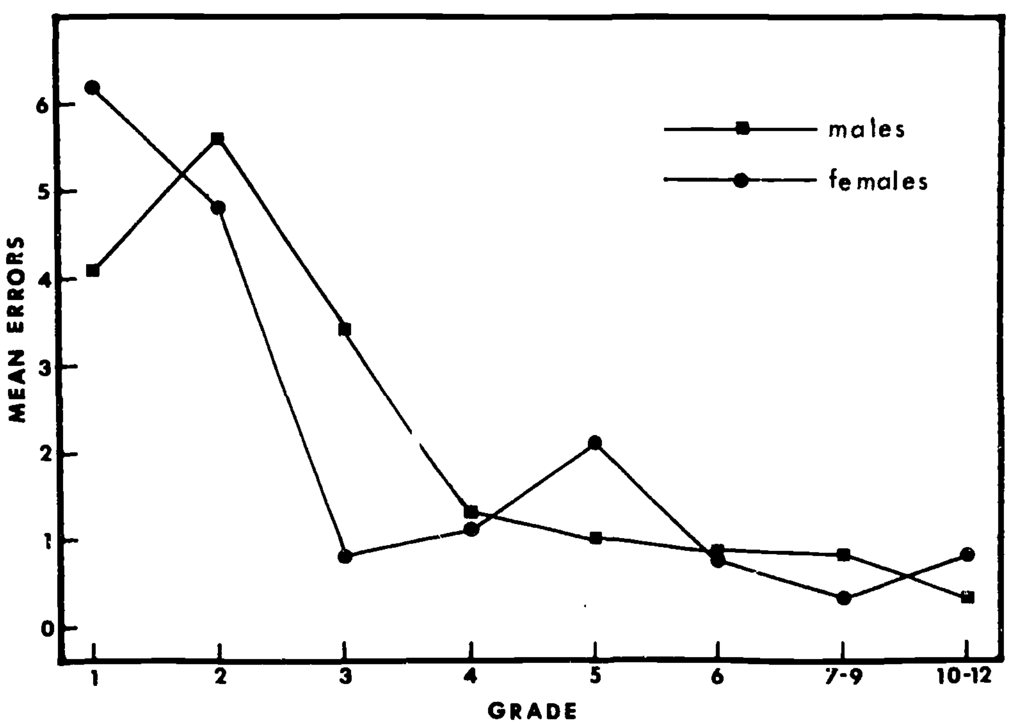


Figure 3

Incidence of Goldman-Fristoe Error by Grade for Individual Phonemes

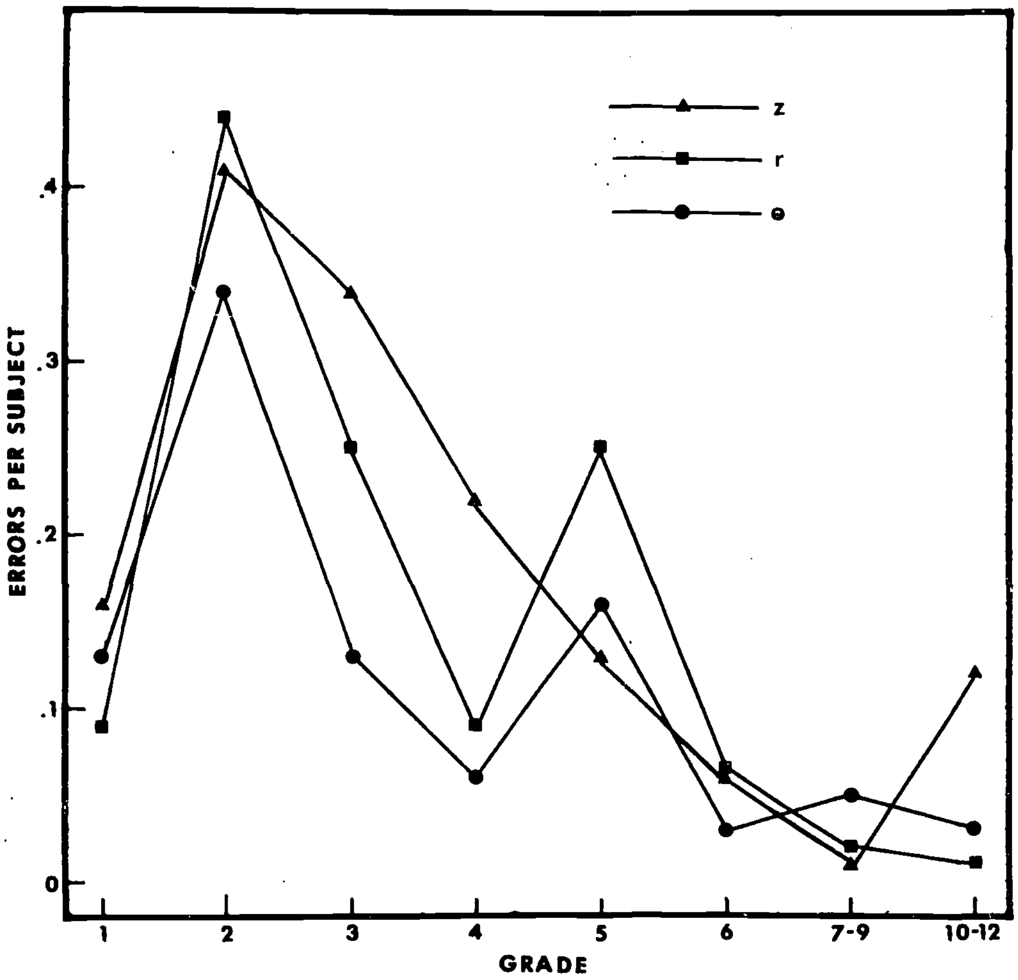


Figure 3 (cont'd)

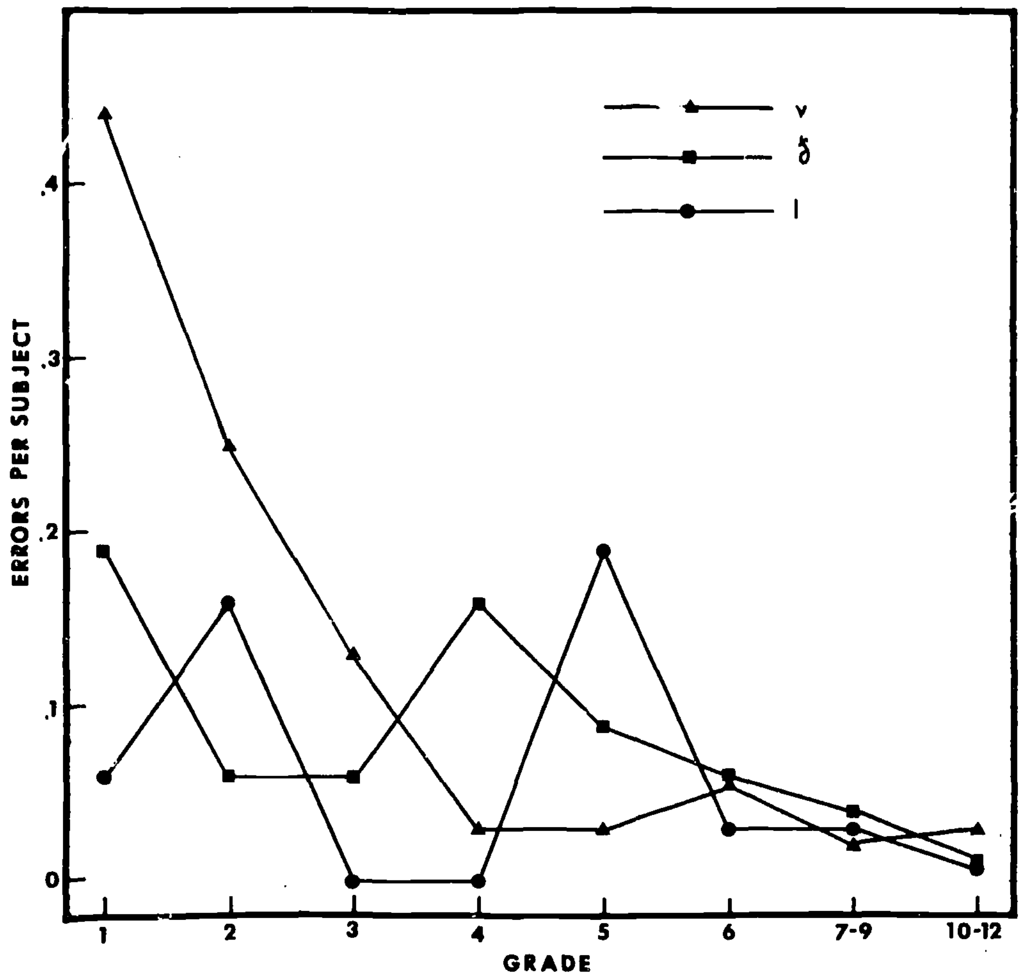
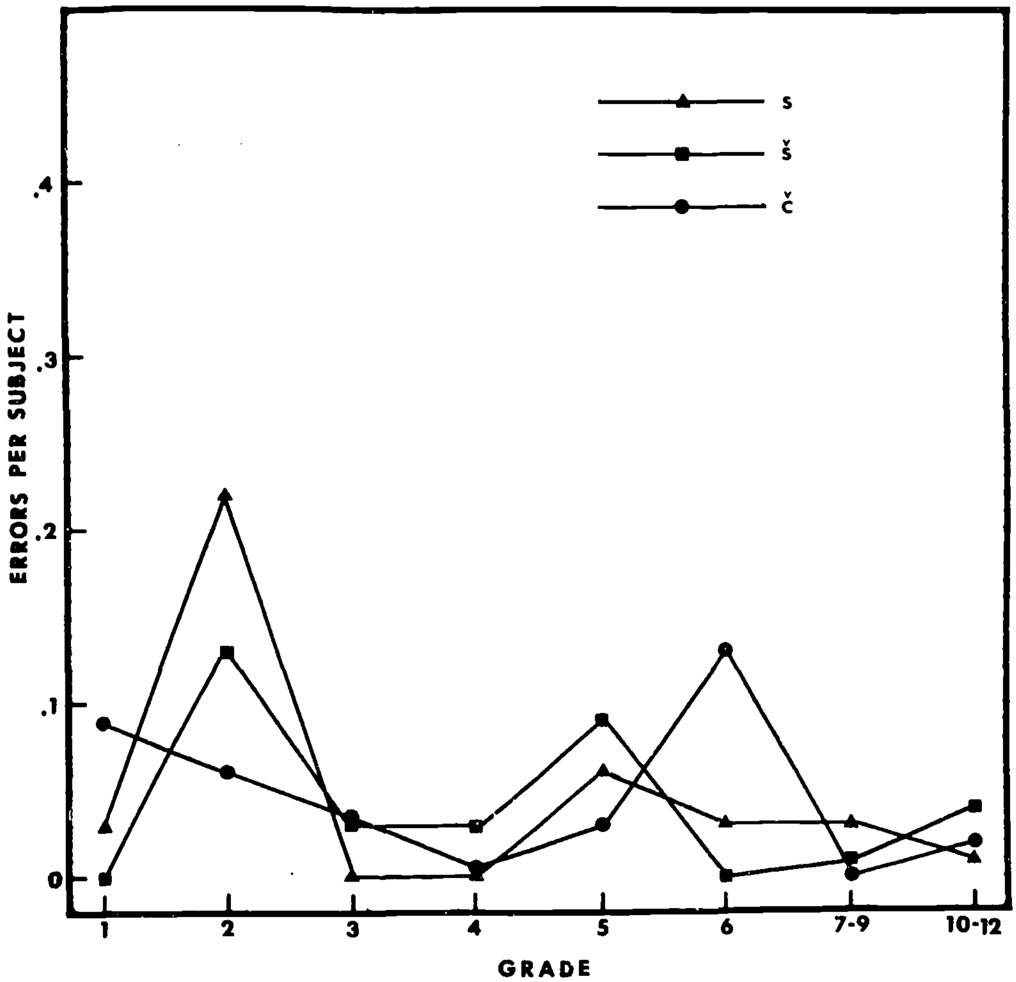


Figure 3 (cont'd)



Two major classes of phonemes are represented in this group of 9 phonemes. /r/ and /l/ are liquids, while the other 7 are obstruents (no nasals appear because they were almost never misarticulated). Notice that /r/ and /l/ seem to behave similarly. While /l/ shows a lower over-all error rate than does /r/, there are increases in error rates in the second and fifth grades for each of these phonemes.

4.2.3. Error type by grade. It has been shown that the absolute number of articulatory errors decreases as grade level increases. The question arises, then, as to whether the same kinds of errors occur at each grade level.

Figure 4 presents the proportion of the total errors for each grade attributable to distortion, substitution and omission. Of the 355 errors in the Marshalltown sample, .699 (248) were substitutions, .237 (84) were omissions, and .065 (23) were distortions. This general pattern seems to obtain in all grade categories except Senior High, when the proportion of substitution errors drops and omissions and distortions rise.

4.2.4. Relationships among the most frequently misarticulated phonemes. In addition to questions about incidence and type of misarticulations it is possible to determine what relationships exist among the individual misarticulated phonemes. Given that a subject makes an error on a particular phoneme, what is the probability that he will misarticulate another specified phoneme. These relationships are displayed in the matrix of Table 8. The rows and columns are the 12 most frequently misarticulated phonemes on the Goldman-Fristoe test. The cell entries are proportions of subjects who missed both phonemes defined by the cell position. Thus, an individual entry represents the proportion of subjects who missed the row phoneme who also missed the column phoneme. The last column shows the proportion of subjects who missed no other phonemes on the Goldman-Fristoe test. An interesting feature of this table is that relationships between the individual phonemes seem to be asymetrical. For instance, a third of the subjects who missed /s/ on the Goldman-Fristoe test also missed /z/, whereas only .128 of the subjects who missed /z/ also missed /s/. Also, errors on some phonemes, notably /ʃ/ and /z/ do not seem to be associated with errors on any other phonemes. For both of these phonemes, nearly half of the subjects who missed them made no other errors.

4.2.5. Relationships between Goldman-Fristoe and Free Speech errors. A probability matrix such as the one presented in Table 8 would be inappropriate for Free Speech error data because of the differential occurrence of the various phonemes in free speech. What is needed is

Figure 4

Relationship of Type of Error to Grade Level

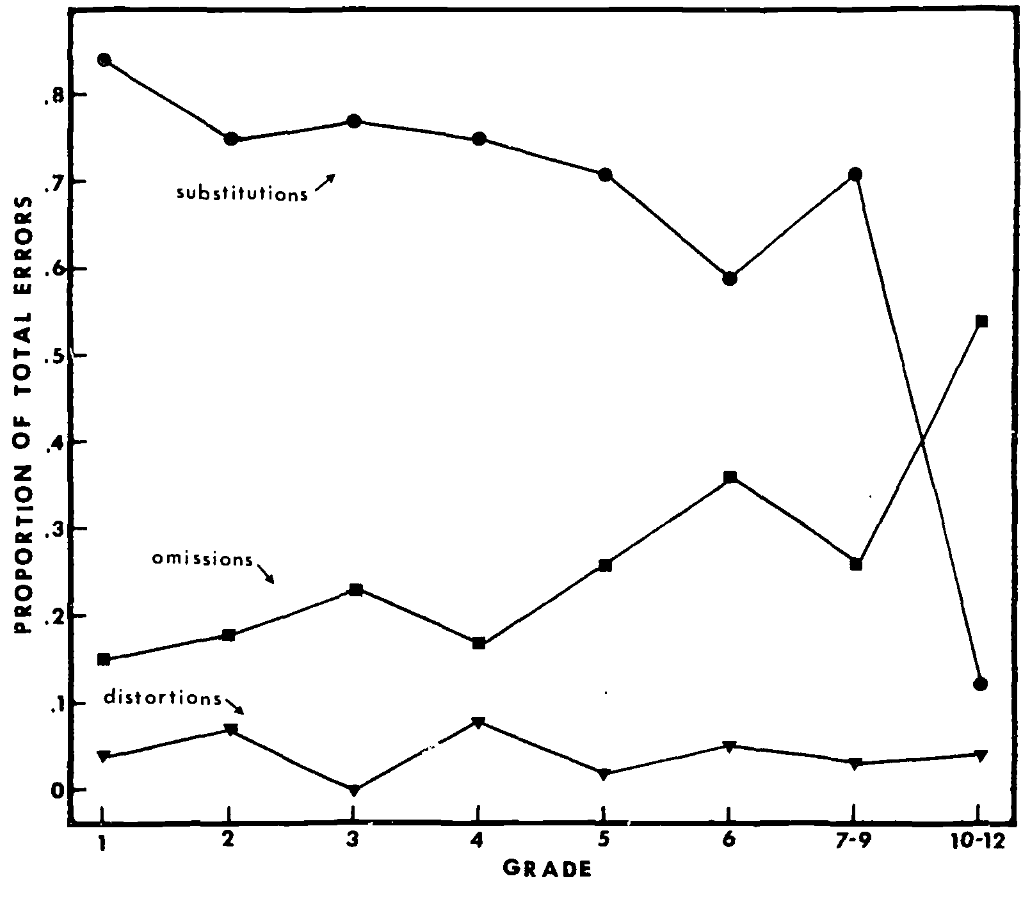


Table 8

Relationships Among Goldman-Fristoe Errors[a]

Phonemes Also Misarticulated on Goldman-Fristoe

Phonemes Misarticulated on Goldman-Fristoe n		z	s	v	ð	θ	š	č	ǰ	r	l	p	f	Nothing Else
38	z	----	.128	.128	.154	.128	.077	.051	.103	.128	.026	.077	0	.436
12	s	.333	----	.250	.166	.333	.166	.083	.333	.166	.166	.083	0	.250
31	v	.193	.096	----	.129	.226	.032	.096	.064	.193	.096	.129	.129	.322
24	ð	.167	.083	.167	----	.167	0	.083	.042	.125	.125	.083	0	.458
24	θ	.208	.167	.333	.167	----	.042	.042	.125	.250	.167	.083	.042	.250
9	š	.444	.222	.111	0	.111	----	.111	.333	.333	.111	0	0	.333
12	č	.167	.083	.250	.167	.083	.083	----	.083	.167	.083	.083	0	.667
11	ǰ	.363	.363	.181	.091	.272	.272	.091	----	.363	.182	.091	0	.091
29	r	.172	.069	.207	.103	.207	.103	.034	.138	----	.207	0	.069	.379
14	l	.143	.143	.286	.214	.286	.071	.071	.143	.429	----	0	.071	.286
8	p	.250	.125	.500	.250	.250	0	.125	.125	0	0	----	0	.125
10	f	.100	0	.400	0	0	0	0	0	.200	0	0	----	.200

[a] Rows and columns are the most frequently misarticulated phonemes on the Goldman-Fristoe test. n is the number of subjects who misarticulated the row phoneme. Cell entries are the proportion of subjects who misarticulated the row phoneme and also the column phoneme.

some indication of the consistency of errors between Goldman-Fristoe and Free Speech performance. Table 9 displays this information. The n of Table 9 is the number of subjects who misarticulated a particular phoneme in either Goldman-Fristoe or in Free Speech (thus the ns will usually be larger in almost every case than the n for that phoneme on either Table 6 or Table 7.) The columns of Table 9 show the number (and proportion) of those total subjects who missed the phoneme of interest (1) only in Goldman-Fristoe and not in Free Speech; (2) both on Goldman-Fristoe and in Free Speech; (3) only in Free Speech and not in Goldman-Fristoe. Consider the subjects who missed the phoneme in Goldman-Fristoe, but not in Free Speech. They did not miss the phoneme in Free Speech either because they articulated it properly or because the phoneme did not occur. Recall from Section 3 that it was noted whether the absence of a free speech error was an N/O error, (i. e. that there was no occurrence of the phoneme in free speech, and, hence, no opportunity for the subject to misarticulate it) or an N/E error (i. e. that the phoneme occurred, but was not misarticulated). Table 9 presents this information for subjects in group (1). The "Goldman-Fristoe error only" column is broken down into those subjects who did not include the phoneme in their free speech (N/O subjects) and those subjects who correctly articulated the phoneme in free speech (N/E subjects).

Table 9 reveals a counter-intuitive finding in this study. Most researchers assume that words in isolation will be more carefully articulated than those embedded in discourse. If this were true, there should be more errors in Free Speech than there are in Goldman-Fristoe. This expectation is realized, at least in the lower grades (cf. Figures 1 and 2). However, when the incidence of error of individual subjects on individual phonemes is analyzed (as in Table 9) a different picture emerges. The assumption that phonemes are more carefully articulated in isolated words than in connected discourse would lead one to expect that for any individual phoneme there would be more subjects who missed it in Free Speech, but not in Goldman-Fristoe, than who missed it on the Goldman-Fristoe test, but not in Free Speech. This expectation can be evaluated by comparing the "Missed on F-S, but not on G-F" column of Table 9 with the N/E (i. e., correctly articulated in Free Speech, but missed in G-F) column. It turns out that for 9 of the 12 phonemes, more subjects missed it only on Goldman-Fristoe than only in Free Speech (that is, more subjects appear in the N/E column than in the "Missed on F-S, but not on G-F" column). For one phoneme (/θ/) there are equal numbers of subjects in both columns, and for two (/ ð/ and /ǰ/) there are, as expected, fewer subjects in the N/E column.

Table 9

Relationships Among Goldman-Fristoe and Free Speech Errors

Target Phoneme	n[a]	Missed on G-F, but not on F-S		Missed on Both G-F and F-S	Missed on F-S, but not on G-F
		N/E[b]	N/O[c]		
z	40	7 .175	14 .350	18 .450	1 .025
s	15	8 .533	0 0	4 .267	3 .200
v	36	9 .250	21 .583	1 .028	5 .139
ð	85	5 .059	1 .012	18 .212	61 .718
θ	36	12 .333	6 .167	6 .167	12 .333
š	9	3 .333	2 .222	4 .444	0 0
č	13	3 .231	8 .615	1 .077	1 .077
ǰ	19	3 .158	7 .368	1 .053	8 .421
r	36	14 .389	1 .028	14 .389	7 .194
l	19	10 .526	0 0	4 .211	5 .459

Table 9 (cont'd)

Target Phoneme	n[a]	Missed on G-F, but not on F-S		Missed on Both G-F and F-S	Missed on F-S, but not on G-F
		N/E[b]	N/O[c]		
p	12	5 .417	1 .083	2 .167	4 .333
f	10	7 .700	1 .100	2 .200	0 0

[a]n indicates the number of subjects who misarticulated the target phoneme on either Goldman-Fristoe or in Free Speech.

[b]N/E indicates subjects who correctly articulated the target phoneme in Free Speech.

[c]N/O indicates subjects whose Free Speech sample did not include the target phoneme.

In view of these results, perhaps the hypothesis should be entertained that the speech production mechanisms operate more accurately when given an abundance of contextual cues. Under this hypothesis the context provided by a section of discourse provides cues and feedback for the muscles of the vocal apparatus, thus making individual phonemes more likely to be correctly articulated. This situation would be analagous to that of the speech perception mechanisms, which, it is known, operates far better as context introduces redundancy into the speech signal.

4. 3. Analysis of Substitution Errors

4. 3. 1. Presentation of the substitutions. The purpose of analyzing the substitution errors in this sample was to attempt to make some generalizations about substitutions. It was necessary, therefore, to select reasonably consistent substitutions for analysis. All substitutions which occurred more than twice in the Goldman-Fristoe error data were selected for analysis. (Tables 6 and 7 show that similar substitutions are made for phonemes in the Goldman-Fristoe and in the Free Speech samples.) This criterion isolated 15 substitutions which accounted for 196 (87%) of the 225 substitution errors on phonemes on the Goldman-Fristoe.[2] Table 10 presents those 15 substitutions and the frequency of occurrence of each. For convenience the target phoneme which is misarticulated will be referred to as the "victim" of a substitution error. The phoneme which takes its place will be referred to as the "intruder." On Table 10 the intruder is the left-most member of each pair, with the victim appearing in parentheses on the right. The feature changes associated with each substitution are also noted on Table 10. The alteration of both M/U values and +/- values are reported as cells of the matrix. Again, the feature value associated with the intruder is on the left, while the feature value associated with the victim is in parentheses on the right. Thus, when /s/ is substituted for /z/, the value of [voice] changes from M (associated with /z/) to U (associated with /s/) and from + to -.

4. 3. 2. Magnitude of error for substitutions. In Section 2 it was suggested that the use of +/- feature descriptions for phonemes could provide a metric to determine the degree to which an intruder deviates from a victim. The fewer +/- feature changes which take place, the

[2] Of the 62 misarticulations of clusters, 51 (82%) were errors on liquids (47) and glides (4). The same substitution, /w/, occurred for the liquids in clusters as for liquids in a vocalic context.

Table 10

Feature Changes for Substitutions Occurring More Than Twice in Goldman-Fristoe Errors

f	Substitutions[a]	Features: Cns	Voc	Ant	Cor	Cnt	Str	Voi	Lat	Nas
42	s (z)							U(M) -(+)		
4	s (θ)				U(M) +(+)		U(M) +(-)			
8	č (š)					U(M) -(+)				
6	č (ǰ)							U(M) -(+)		
21	f (θ)				U(M) -(+)					
5	t (θ)				U(M) +(+)	U(M) -(+)	U(M) -(-)			
6	t (č)			U(M) +(-)	U(M) +(+)		U(U) -(+)			
18	d (ð)				U(M) +(+)	U(M) -(+)	U(M) -(-)			
3	d (ǰ)			U(M) +(-)	U(M) +(+)		U(U) -(+)			
28	b (v)				M(U) -(-)	U(M) -(+)	U(M) -(-)			
6	b (f)			M(U) -(-)		U(M) -(+)	U(M) -(-)	M(U) +(-)		
7	b (p)							M(U) +(-)		
5	š (č)					M(U) +(-)				
31	w (r)	-(+)	M(M) -(+)	U(U) -(+)	U(U) -(+)					
6	w (l)	-(+)	M(M) -(+)							

[a]The phoneme to the left is the intruder in the substitution. The phoneme to the right in parentheses is the victim. Feature values associated with the victim are also in parentheses, with those associated with the intruder to the lef'.

more features remain common to both the intruder and the victim. Thus, the fewer descriptive, +/- features which are changed, the less the magnitude of error represented by the intruding phoneme. Table 11 groups the 196 substitutions presented in Table 10 according to the magnitude of error in each substitution. Thus, in 9 of the 15 substitutions, accounting for 144 errors, the intruder differed from the victim by only one +/- feature. Three substitutions, accounting for 15 errors, represented a change of two features. To get some idea of the statistical magnitude of the differences in frequency found on Table 11, a chi square test was done, (with 1 df) assuming that the substitutions would have been randomly divided among the four categories. The test produced a $X^2 = 245.4$, $p < .001$. Notice that obstruents were always substituted for obstruents, and, furthermore, that all obstruent errors were effected by one or two feature changes. The 37 errors of a magnitude greater than two features were substitutions of the glide /w/ for liquids. As was mentioned above, this /w/ for liquid substitution (as well as omissions of liquids) occurred frequently in cluster errors. Section 5 will discuss liquid errors in some detail.

4.3.3. Changes in markedness values of features. The relationship between complexity and the M/U value of features was discussed in detail in Section 2. The major hypothesis of the present study, based on theoretical measures of complexity, is that substitutions will be simplifying and that feature values will change from M to U as substitutions are effected. Table 12 presents a summary of the M to U and U to M value changes for individual features involved in the substitutions observed. There are a total of 243 changes in which a feature which is marked for the victim is unmarked for the intruder and 52 in which a feature which is unmarked for the victim is marked for the intruder. For this distribution, with 1 df, $X^2 = 123$, $p < .001$.

Notice that the + to - change for the feature [vocalic] involved in the /w/ for liquid substitutions does not appear on this table because those substitutions do not involve a change in marking for the feature [vocalic] (/w/, /r/ and /l/ are all three marked for the feature [vocalic].) Likewise, the + to - change for the feature [consonantal] for those substitutions does not appear on the table because the feature [consonantal] does not take M/U values in this theory.

Some substitutions (e.g. /s/ for /θ/) are entered on Table 12 because the M/U value of a feature changes ([coronal] in the case of /s/ for /θ/) even though the +/- value remains the same.

4.3.4. A group of consistent intruders is identified. A close examination of Table 10 reveals that a few phonemes serve as intruders

Table 11

Number of +/- Feature Changes Involved in Substitutions Occurring More than Twice in Goldman-Fristoe Errors

Number of +/- Features Changed							
1		2		3		4	
Substitution	f	Substitution	f	Substitution	f	Substitution	f
b (p)	7	b (f)	6	w (l)	6	w (r)	31
s (z)	42	t (č)	6				
b (v)	28	d (ǰ)	3				
f (θ)	21						
s (θ)	4						
d (ð)	18						
č (š)	8						
š (č)	5						
č (ǰ)	6						
	144		15		6		31

Table 12

M/U Value Changes Associated with Substitutions Occurring More than Twice in Goldman-Fristoe Errors

Coronal

M Changed to U: Substitution	f	U Changed to M: Substitution	f
f (θ)	21	b (f)	6
t (θ)	5	b (v)	28
s (θ)	4		
d (ð)	18		
t (č)	6		
d (ǰ)	3		
	57		34

Continuance

M Changed to U: Substitution	f	U Changed to M: Substitution	f
b (v)	28	š (č)	5
t (θ)	5		
d (ð)	18		
č (š)	8		
b (f)	6		
	65		5

Table 12 (cont'd)

Strident

M Changed to U: Substitution	f	U Changed to M: Substitution	f
t (θ)	5	None	
s (θ)	4		
d (ð)	18		
b (f)	6		
b (v)	28		
	61		

Voice

M Changed to U: Substitution	f	U Changed to M: Substitution	f
s (z)	42	b (p)	7
č (ǰ)	6	b (f)	6
	48		13

Anterior

M Changed to U: Substitution	f	U Changed to M: Substitution	f
t (č)	6	None	
d (ǰ)	3		
	9		

Table 12 (cont'd)

Lateral			
M Changed to U		U Changed to M	
Substitution	f	Substitution	f
w (1)	6	None	
	6		

Total M to U changes = 243

Total U to M changes = 52

for a larger class of victims. Moreover, with two exceptions (/č/ and /f/) members of the class of intruders are not themselves intruded upon.[3] Since this phenomenon will be discussed in the next Section, Table 13 has been prepared to facilitate comparisons among the feature values of the groups of intruders and victims. Feature values on Table 13 agree exactly with those of Tables 2 and 3. The columns of phonemes are, however, arranged in groups in Table 13. Each group is set off by a heavy vertical line. The first phoneme of each group is the intruding phoneme, while the other phonemes in the group are the victims of that intruder. Thus, the first group consists of /s/, /a/ and /θ/. /s/ is the intruder of that group and /z/ and /θ/ are both victims for which /s/ is substituted. The frequency of the individual substitution is entered above the symbol for the victim phonemes. In order to get all the relevant information on one table, the M/U value and the +/- value for each feature are entered together in each cell of the matrix.

---

[3] /s/, while it is a frequent intruder, is never the victim of a substitution error. It is a frequently misarticulated phoneme; however, it is only subject to distortion errors.

Table 13

Classes of Intruders and Victims Isolated from Substitution Errors

Features	Intruders and Victims[a]																					
		42	4		8	6		21		5		31	6		5	6		18	3		28	6	7
	s	z	θ	č	š	ǰ	f	θ	š	č	w	r	l	t	θ	č	d	ð	ǰ	b	v	f	p
Consonantal	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+
Vocalic	U -	U -	U -	U -	U -	U -	U -	U -	U -	U -	M-	M+	M+	U -	U -	U -	U -	U -	U -	U -	U -	U -	U -
Anterior	U +	U +	U +	M-	M-	M-	U +	U +	M-	M-	U -	U +	U +	U +	U +	M-	U +	U +	M-	U +	U +	U +	U +
Coronal	U +	U +	M+	M+	M+	M+	U -	M+	M+	M+	U -	U +	U +	U +	M+	M+	U +	M+	M+	M-	U -	U -	M-
Continuant	M+	M+	M+	U -	M+	U -	M+	M+	M+	U -	U +	U +	U +	U -	M+	U -	U -	M+	U -	U -	M+	M+	U -
Strident	U +	U +	M-	U +	U +	U +	M-	M-	U +	U +	U -	U -	U -	U -	M-	U -	U -	M-	U +	U -	M-	M-	U -
Voice	U -	M+	U -	U -	U -	M+	U -	U -	U -	U -	U +	U +	U +	U -	U -	U -	M+	M+	M+	M+	M+	U -	U -
Lateral	U -	U -	U -	U -	U -	U -	U -	U -	U -	U -	U -	U -	M+	U -	U -	U -	U -	U -	U -	U -	U -	U -	U -
Nasal	U -	U -	U -	U -	U -	U -	U -	U -	U -	U -	U -	U -	U -	U -	U -	U -	U -	U -	U -	U -	U -	U -	U -
Complexity	1	2	3	2	3	3	2	3	3	2	1	1	2	0	3	2	1	4	3	2	3	2	1

[a]Groups of phonemes are differentiated by the heavy vertical lines. In each group, the first phoneme is the intruder, the others are the victims of that intruder. The number above the victim indicates the number of occurrences of that substitution.

SECTION 5

Linguistic Implications[1]

This section will deal with the linguistic implications of the substitution errors observed in the present study. In particular, the relationship between substitution errors and markedness theory (as presented in Section 2) will be explored in detail.

5.1. Evaluation of the Central Hypothesis

The major hypothesis presented in Section 2 was that, considering classes of sounds, the more marked ones would be the victims of substitution errors, with the intruder of each substitution being less marked than the victim. Tables 12 and 13 show that this prediction was confirmed by the present study. With only two exceptions (/š/ substituting for /č/, 5 errors; and /b/ for /p/, 7 errors) intruders are less marked than their victims. Furthermore, the vast majority of the feature changes effecting the substitutions were from a marked to an unmarked value for the feature in question.

In general, intruders are drawn from the class of sounds which are never victims (with the exceptions of /š/, /č/ and /f/) of substitution errors. In fact, with the exception of /k/ and /g/, all those sounds which are rarely victimized comprise the class of intruders. That is, /k/ and /g/ are the only sounds which are very rarely victims, yet do not serve as intruders. This is probably due to the fact that /k/ and /g/ are the only dorsal obstruents in English. Thus, if we assume that there is a strong tendency for dorsal sounds not to be substituted for nondorsal ones, then it is evident that /k/ and /g/ do not serve as intruders simply because there are not (in English) any other dorsal obstruents which can serve as their victims. It might be expected that in languages which have a number of dorsal sounds, such as German and the Semitic languages, /k/ and /g/ would also fall into the class of intruders. They would be expected to victimize such sounds as /x/, a velar fricative, or a uvular stop such as /q/. If this prediction were to be confirmed in such languages, then it might be the case that the entire class of sounds which are rarely victimized serves as intruders in substitution errors.

---

[1] This section was prepared by H. Cairns and C. Cairns, with the editorial assistance of F. Williams.

5.2. Evaluation of Errors Associated with Liquids and Glides

Liquids and glides are discussed separately from obstruents for two reasons. First, the great majority of cluster errors involved liquids, so a general discussion of liquids and glides subsumes discussions of clusters as well as the relevant phonemes. Second, the liquids and glides together form a phonological class distinct from the class of true consonants, so it is natural to discuss them together and separately from the consonants.

The liquids and glides form a natural class in that they are the only sounds which are [M vocalic]. The features [vocalic] and [consonantal] are the two features which serve to distinguish the two basic major classes of speech sounds from each other, namely, vowels (which are [-consonantal] and [+vocalic]) and true consonants (i. e., obstruents and nasals, which are [+consonantal] and [-vocalic]). Liquids and glides both hold an intermediate position between these two classes, liquids being [+consonantal] and [+vocalic] and glides being [-consonantal] and [-vocalic]. The features [consonantal] and [vocalic], therefore, are more basic features than the features indicating place and manner of articulation. Thus, as a class, liquids and glides are more highly marked than any other speech sounds even though technically they may be marked for fewer features than some of the other phonemes.

It is an empirical fact often noted by linguists (Greenberg, 1965) that more highly marked classes of phonemes generally contain fewer phonological distinctions than less highly marked classes. For example, the class consisting of all liquids and glides always contains fewer phonemes than do the classes of vowels and true consonants in all the languages of the world. This universal is presumably a result of the fact that the perceptual and/or articulatory apparatus cannot make many distinctions among the liquids and glides because they are, by their very nature, complicated phonemes. It is therefore quite consistent to find that many of the school-aged children surveyed in this study tend to make fewer distinctions among the liquids and glides, thus reducing the total class. They do this by substituting /w/ for /r/ and sometimes for /l/. Markedness theory itself is unable to explain why /w/ is the intruder and /r/ the most common victim. (Note that both /w/ and /r/ have complexity values of 1.) One plausible explanation for this state of affairs is that a labial articulation is less complex articulatorily than the coronal gesture involved in /r/ and /l/. This situation is parallel to that of /θ/ vs. /f/, which was discussed in Section 2 and will be discussed further below. There seems to be a general tendency to avoid coronalness in continuant, nonstrident sounds, to wit, the common substitution of /f/ for /θ/.

5. 3. Substitution Errors Associated with Obstruents

In this section the remaining substitutions presented in Table 10 will be discussed in detail. The discussion will be organized with reference to individual substitutions or groups of substitutions. Recall that Tables 10, 12 and 13 present the feature data which will be discussed in this section.

5. 3. 1. The three substitutions associated with /θ/. The pattern of substitutions of the common victim /θ/ is quite revealing. /θ/ is marked for coronalness, continuancy and stridency (see Table 13). The substitution of /f/ for /θ/ is the most common, occurring 21 out of the 30 times. This is an example of the tendency noted above for nonstrident continuants to become noncoronal (probably for articulatory reasons). In the /f/ for /θ/ substitution, the feature [coronal] changes from its marked to its unmarked value, while the features of continuancy and stridency remain marked.

/t/ substitutions for /θ/ (of which there are 5) change all three of the marked features to unmarked ones, but the only +/- change of these three is in the feature [continuant]. The change in continuancy is probably a result of the simplification of the stridency feature. The substitution of a stop for /θ/ maintains the perceptual cue of nonstridency present in the target phoneme. In fact the appearance of a stop enhances the nonstridency of /θ/. The rarity of this particular substitution, however, seems to indicate that a substitution which preserves the continuancy of /θ/ is more probable. This suggests that there may be a strong tendency to maintain the distinction between continuants and stops. (This tendency is found only in the unvoiced sounds, however, as will be mentioned below when the /d/ for /ð/ substitution is discussed.)

Recall that /θ/ is marked for three features, [coronal], [continuant] and [strident]. When /f/ substitutes for it, the value of the [coronal] feature changes; when /t/ is the substitute, the [continuant] feature changes. The remaining marked feature is [strident] and is in fact altered in four /s/ for /θ/ substitutions.[2]

---

[2]Notice in Table 12 that with the exception of the /s/ for /θ/ substitution all of the substitutions which involve a change in the M/U feature value for stridency are such as to maintain the same +/- value. In particular, they all involve a change from M to U in cases where a stop is substituted for a continuant. Nonstrident continuants are marked for stridency, whereas nonstrident stops are unmarked for stridency. That is why the stridency feature changes from M to U in these cases without a change in the +/- feature value.

In this substitution the distinction between continuants and stops is maintained, as in the /f/ for /θ/ substitution. /s/ for /θ/ is probably more rare than /f/ for /θ/ because /s/ is more difficult to articulate than /f/. The production of /s/ involves a fine adjustment of the muscles internal to the tongue for the formation of the groove necessary for directing a stream of air against the back of the teeth. The /s/ for /θ/ substitution also has the additional disadvantage of destroying the perceptual cue of nonstridency.

/f/ is the most common substitute for /θ/, then, for three reasons: (1) This substitution is common because of the general tendency of nonstrident continuants to become noncoronal. There are no examples of coronal, nonstrident continuants substituting for noncoronal, nonstrident continuants, although the /f/ for /θ/ substitution is common. This suggests that nonstrident continuants which are noncoronal (more specifically, labial) are less complex than those which are coronal. This is consistent with the predictions of markedness theory. (2) The /f/ for /θ/ substitution preserves the distinction between strident and nonstrident continuants, since /f/ is also nonstrident. This is consistent with the apparently strong tendency, discussed in detail below, for speakers to preserve the distinction between strident and nonstrident fricatives by avoiding the substitution of a strident for a nonstrident fricative, and vice versa. (3) This substitution preserves the distinction between stops and continuants. As will be discussed in more detail below, the preservation of this distinction, while prevalent, is secondary to the preservation of the distinction between strident and nonstrident continuants (see 5.3.6. below). The two less frequent (but occurring) substitutions, /t/ and /s/, have only advantages (2) and (3), respectively.

These three /θ/ substitutions illustrate the applicability of markedness theory to a study of articulation errors. In each case, the substituted phoneme is less complex than the victim, /θ/. Furthermore, markedness theory predicts that [coronal], [strident], and [continuant] will be the vulnerable features of /θ/ (because they are the marked features of /θ/). Finally an analysis of the relative frequency of occurrence of the predicted substitutions directs the formation of hypotheses about the articulatory and perceptual bases of the substitutions.

5.3.2. The substitution of /d/ for /ð/. Note that the pattern of substitutions associated with /ð/ is not similar to that of /θ/. One's initial expectation would be that the most common intruder on /ð/ would be /v/ (the voiced counterpart of /f/). In the Goldman-Fristoe data, however, a /v/ for /ð/ substitution only occurred once for one subject in the first grade; and it never occurred in Free Speech. It appears, then, that when voicing is present, maintenance of the distinction between stops and continuants is not as important as for unvoiced sounds. This is reasonable, since phonation reduces intra-oral pressure, so there is little friction present to indicate the presence of a continuant. Because it is voiced, /ð/ comes out, phonetically, very much like a voiced flap. Since it does not seem crucial to preserve the continuance of /ð/, the maintenance of the perceptual cue of nonstridency conditions the substitution of /d/.

The reason that the substitution of /d/ for /ð/ causes a change in its M/U value for the feature [coronal] is because coronal continuants were considered to be marked for [coronal], whereas coronal stops are unmarked for this feature. Notice that in the case of /f/ for /θ/ (where continuance was maintained) the value of the coronal feature was simplified in the +/- feature value of [coronal]. In the /d/ for /ð/ substitution, however, simplification of the feature [coronal] is effected by a change in the value of continuance (i. e., a stop is produced, which is unmarked for [coronal], with the +/- value of [coronal] remaining constant.)

5. 3. 3. The substitutions of /t/ for /č/ and of /d/ for /ǰ/. These substitutions reveal a probable general tendency to simplify affricates by substituting either stops or fricatives for them. /č/ is in fact substituted for by the fricative /š/ 5 times. The voiced counterpart /ž/ is a very rare phoneme in English and is never seen as a substitute for /ǰ/. If /č/ and /ǰ/ were to be converted into homorganic pure stops, palato-alveolar stops would result, which are foreign to English. It is only natural, then, that the speaker would instead substitute the nearby alveolar stops, namely /t/ and /d/ (preserving the appropriate voicing value for /č/ and /ǰ/).

The change in M/U value for the feature [coronal] is a consequence of the shift to an alveolar point of articulation (effected by a change in the feature [anterior]). Nonanterior coronal sounds (such as /č/, /ǰ/ and /š/) are marked for [coronal], whereas coronal anterior sounds are unmarked for coronal. Therefore, the change in the feature [anterior] produces an M/U (although not a +/-) change for the feature [coronal].

5. 3. 4. The substitution of /b/ for /v/. The substitution of /b/ for /v/ is parallel to the substitution of /d/ for /ð/. In both cases a nonstrident voiced continuant is substituted for by its homorganic voiced stop. The hypothesis advanced to explain the /d/ for /ð/

substitution holds equally well for the /b/ for /v/ substitution. That is, for the voiced nonstrident fricatives the substitution tends to preserve the perceptual cue of nonstridency. A more thorough discussion of this substitution is deferred until the discussion of the /s/ for /z/ substitution below.

5. 3. 5. The substitution of /č/ for /š/ and of /š/ for /č/. The interchangeability of /č/ and /š/ appears anomalous. If it were only that /š/ was frequently substituted for /č/, then it could be maintained that the affricate was being victimized by a pure fricative. This would be complementary to the simplification of /č/ to /t/, a pure stop (which was discussed above). However, the substitution of /č/ for /š/ does not fit into this explanation at all. (Note that /č/ is never substituted for /t/ in these data.) The only claim that can be made on the basis of the facts at hand is that the distinction between the strident affricate /č/ and the strident fricative /š/ is frequently weakened, so that the two sounds can substitute for each other. These data show only a slight (8 to 5) tendency toward the /č/ for /š/ over the /š/ for /č/ substitution. It is important to note that this is the only case of a more or less bilateral substitution in this study.

5. 3. 6. The substitution of /b/ for /f/. This relatively uncommon substitution can be seen as another example of enhancement by an intruder of the perceptual cue of nonstridency inherent in the victim. As in the /t/ for /θ/, /d/ for /ð/, and /b/ for /v/ substitutions, this is done at the expense of the feature of continuance. Note also that this 'stop for continuant' substitution is much more rare for the unvoiced victims, /θ/ and /f/, than for the voiced victims, /ð/ and /v/. The hypothesis is that continuance will be less likely to be lost in the unvoiced nonstrident fricatives.

5. 3. 7. The substitution of /s/ for /z/. This is perhaps the most revealing of all the substitutions in these data, especially in comparison with the substitution of /b/ for /f/ and /b/ for /v/. The /s/ for /z/ substitution can be understood as a tendency for the speaker to maximize the distinction between the strident and nonstrident sounds in the speech output. /s/ is more strident than /z/, for the most important perceptual characteristic of strident sounds is the predominance of (band-limited) white noise in the spectrum. In the case of /s/, all of the acoustic energy is contained in white noise. In the case of /z/, however, there is less energy in the noisy portion, while there is some energy in the low frequency voice bar. This is because the presence of phonation causes the inter-oral air pressure to drop somewhat, which causes the stream of air to pass through the tongue groove and hit the back of the teeth with less force than in the

case of the unvoiced /s/. Therefore, in general, the presence of voicing makes a strident sound appear less strident and a nonstrident sound appear more nonstrident. It is significant that among the nonstrident sounds an unvoiced sound is never substituted for a voiced one. This is quite consistent with the explanation presented here, for the substitution of an unvoiced nonstrident sound for a voiced one would tend to minimize the perceptual cue of nonstridency. It is only the strident, voiced victim /z/ which is substituted for by its unvoiced counterpart. Since noisiness is the most salient perceptual characteristic of strident sounds, the absence of noise is the most salient characteristic of nonstrident sounds. Stops are less noisy than fricatives; moreover, voiced stops in English, which are usually nonaspirated, are even less noisy than voiceless stops, which are frequently aspirated and/or exhibit a noise burst upon release. This can explain why /v/ and /f/ are both substituted for by /b/: they are both nonstrident fricatives which are substituted for by the optimally nonstrident (voiced) homorganic sound /b/.

There seems to be ample evidence that the feature of stridency seems to be the least vulnerable feature in this set of substitutions. Notice that when /s/ is misarticulated it is not replaced by an intruding phoneme, but is distorted in some way. In these cases the speaker, unable to produce an /s/ in the normal manner, resorts to other compensatory articulatory gestures, the major goal of which is to produce stridency. Notice that it would not appear plausible to explain the substitution of /s/ for /z/ simply on the basis of articulatory simplicity. If one were to argue that /s/ substitutes for /z/ because /s/ is simpler (in that it does not involve phonation), then one would be at a loss to explain why /f/ never substitutes for /v/ -- still worse, the substitution of /b/ for /f/ would appear entirely anomalous.

5.4. Over-All Interpretation

The data analyzed in the present study suggest that substitutions are governed in part by a tendency toward ease of articulation with constraints imposed upon substitutions by a tendency to maximize perceptual distinctions. The data reveal that stridency is the least vulnerable feature and that speakers tend to intrude those sounds which are the best vehicles for the stridency value of the victim.

Among the voiced sounds, the next least vulnerable feature seems to be continuance. This tendency to preserve continuance explains why /θ/ is victimized by /f/ more often than by /t/.

The feature [coronal] seems to be an extremely vulnerable feature. In the frequent /f/ for /θ/ and /w/ for /r/ substitutions the coronal feature changes from a + to a - value, but there is no substitution in which [coronal] changes value from - to + .

The voicing feature cannot be said to be either vulnerable or stable independent of other features in the same phoneme. [Voice] is vulnerable when it appears in phonemes which are [+strident], stable when it appears in phonemes which are [-strident].

APPENDIX A

Goldman-Fristoe Test of Articulation

h ou s e

t ele ph one

c u p

g u n

kn i f e

w in d ow

wa g on. . . wh eel

chic k en

z i pp er

s ci ss or s

d uc k. . . y e ll ow

v acuum

m at ch es

l amp

sh o v el

ca r

r a bb it

f i sh ing

ch ur ch

fea th er

p en c il. . . th is or th at

ca rr o t. . . oran g e

ba th t u b. . . b a th

th umb. . . f ing er. . . r ing

j umping

pa j ama

air pl ane. . . bl ue

br u sh

dr u m

fl a g

Sa n ta Cl aus

Chr ist m as tr ee

squ irre l

sl eeping. . . be d

st o v e

APPENDIX B

Data Management System[1]

A data corpus as large and complex as that obtained in the NSHS presents a number of serious problems for commonly used management and analysis procedures. The present approach was to use a computer system developed primarily for management of record files. The nature of this system and its utilization for the NSHS data are reviewed in some detail in order to reveal possibilities for similar applications in further phonological or linguistic studies. A second purpose of this section is to describe in more detail the computer treatment of the NSHS data.

Phonological and linguistic studies typically generate large amounts of data. The availability of flexible systems to handle large amounts of data without requiring the data to be coded (i. e., verbal responses may retain their original form) should make practical certain phonological and linguistic studies which otherwise would not be feasible. Furthermore, such computer management of phonological and linguistic data should permit evaluation of larger subject samples than would otherwise be practical.

Problems of Data Management in the NSHS

Probably the most typical way of handling data in the behavioral sciences today is to organize raw data into some convenient written form and to render scores from these data along one to many dimensions for the individual subjects observed. These subject-scores are then punched on cards or stored on magnetic tape and subsequently submitted to "canned" computer programs for statistical analyses. Such typical management and analysis procedures were seen to be unsatisfactory for the NSHS data.

In the case of the NSHS, there was a need to keep the data in a state ready for quick examination at a "raw-data" level, since it was desirable to be able to evaluate frequencies of occurrences of errors subject to contingencies which were not completely specifiable at the outset. Combing through a written form of the data by hand for even

---

[1] This Appendix was prepared by Dennis Blosser.

the most basic predetermined error analyses would have been very costly in terms of both real-time and work time. Standard utilization of the computer would have done little to alleviate the problem of real-time expense.

The following example illustrates the size and complexity of the NSHS data analysis. Th' Goldman-Fristoe articulation test has 73 sound-position items. In a 'ion to knowing which items were missed, specification of the c.a .. nature of each error was desired. Errors were evaluated by what sounds were substituted and the distinctive features involved in each substitution. From the first, it was anticipated that there would be many alternatives in describing the error data -- for example, examination of the types of substitutions which occur throughout given errors on a certain phoneme; or given that an error occurred involving one distinctive feature for a certain sound, determination of what related sounds also had errors associated with that distinctive feature. It was also desirable to be able to reorient the classification approaches as the data led to new hypotheses.

As a solution to these problems, we adopted the use of a general system designed for computerized management of record files.

Remote File Management System

Background. The Remote File Management System (RFMS) was developed by the staff of the University of Texas Computation Center. RFMS is one of a number of similar systems currently evolving in the United States which are oriented to remote time-sharing computer usage. While RFMS was designed for implementation on the Control Data 6600 computer at the University of Texas at Austin, the fact that RFMS is primarily coded in FORTRAN makes adaptation to other systems quite feasible. RFMS is available upon request.

Data organization and storage. The purpose of RFMS is to organize large data files for convenient initial input, storage, updating, and selective retrieval.

Fundamental organization in RFMS is provided by the data base description. The data base description supplies the computer with information concerning the generalized structure of the input data; it is a list of hierarchically organized generic components. Each component is labeled by a numerical tag and the component's name. The type of data the component represents is also specified. In order to make the notion of the data base description more concrete, consider the data base description shown in Table 1, which was used for the NSHS data.

Table 1

Data Base Description

1. Subject number (integer number)
2. Sex (name)
3. Grade (Integer number)
4. City (name)
5. Test result (repeating group)
    6. Name of test (name in 5)
    7. Target sound (repeating group in 5)
    8. Name of target sound (name in 7)
    9. Positions of target sound (name in 7)
    10. Frequency of target sound (integer number in 7)
    11. Frequency of errors for target sound (integer number in 7)
    12. Error evaluation (repeating group in 7)
        13. Substituted sound (name in 12)
        14. Rank of substituted sound (name in 12)
        15. Frequency of substituted sound (integer number in 12)
        16. Features of substitution (repeating group in 12)
            17. Continuant (name in 16)
            18. Strident (name in 16)
            19. Coronal (name in 16)
            20. Anterior (name in 16)
            21. Voiced (name in 16)
            22. Nasal (name in 16)
            23. Consonantal (name in 16)
            24. Vocalic (name in 16)
            25. Lateral (name in 16)

This data base description provided the structure for all articulation data in the NSHS study. Data of appropriate types may be entered for all components of the data base description except repeating groups. Components of the repeating group type act as labels for nodes in the hierarchical structure of the data base. The data base description permits nearly format-free data input under RFMS. That is, data may be entered in any order within a repeating group. This is done by simply listing the component number of the repeating group and the data component numbers to be entered along with the values the components assume. Any components for which values are not available may simply be omitted.

For example, given the data base description shown in Table 1, the data string entered for a subject might look like this.

[1] 026 [2] MALE [3] 4 [4] MARSHALLTOWN

[5] [6] GOLDMAN-FRISTOE

[7] [8] Z [10] 1 [9] INITIAL

[12] [13] D

[16] [17] MINUS [18] MINUS

[END]

Notice that component numbers for the repeating groups are entered without any data immediately following. Numbers for data components are entered in any order within a repeating group (e. g., line three of the example) along with their associated data values. The example has been broken into a number of lines only for clarity. Alternatively, RFMS could accept this subject's data as a continuous string.

In summary, the data organization and data storage functions of RFMS consist of two simple stages. First, a generalized hierarchical description called the data base description is supplied to the computer. Second, subject data values labeled with component numbers from the data base description are read into the computer.

<u>Interrogation of the data base.</u> After the complete data corpus has been loaded into RFMS with respect to the data base description, it is referred to as a <u>data base.</u> RFMS permits interrogation of the data base by a system of English-like requests. These requests can be developed to high degrees of conditionality. A few statistical functions are also available in the retrieval requests.

An elemental form of an RFMS retrieval request is:

PRINT [output list] WHERE [retrieval condition].

(Phrases enclosed in brackets represent descriptive characterizations of elements of the actual retrieval requests.) The output list may be simply a list of names or numbers of components from the data base description to be searched out and printed by RFMS. The retrieval condition may be simply a list of values that components of the data base must assume in order to be accepted by RFMS for retrieval and printout.

An example of a retrieval request to the NSHS data base might be as follows:

PRINT SUBJECT NUMBER, TARGET SOUND WHERE
NAME OF TEST EQ GOLDMAN-FRISTOE;

Such a request would print subject I. D. numbers and a list of the sounds each subject missed on the Goldman-Fristoe test. If a subject had no errors on the Goldman-Fristoe test, his number would not be printed out, since the retrieval condition would not be satisfied.

Instead of listing the component names in a retrieval request, the component numbers alone may be used. This shorter notation is handy when a lengthy retrieval request is used such as in the following example.

PRINT C8, C13 C16 WHERE C6 EQ GOLDMAN-FRISTOE
AND (C8 EQ D OR C8 EQ V OR C8 EQ Z) AND C9 EQ INITIAL;

Referring to Table 1, it can be seen that the above retrieval condition causes cases to be selected where substitutions for initial /d/, /v/, or /z/ occurred on the Goldman-Fristoe. For all such cases there would be a printout of the target sound and the substituted sound (C8 and C13). By calling for the repeating group C16 in the output list, the entire distinctive feature analysis (C17 through C25) will be printed out for each error.

A more complete array of RFMS retrieval capability is shown in Table 2. It can be seen from an inspection of Table 2 that the skeletal form of the retrieval request illustrated above can be expanded and refined considerably. Format options for the output list may be selected which may in some cases put retrieved data into form

Table 2

PRINT <output specifications> (repeatable)* WHERE <retrieval condition>*

<output specifications> (repeatable)*:

- (optional) <output format>
- (mandatory) <output list>, one of:
  - (a) components
    - (1) elements
    - (2) RG's-total information sub-ordinate to RG is output
    - (3) ENTRY
  - (b) functions
    - MAX, MIN, SUM, AVERAGE, SIGMA — plus element one for one
    - COUNT — plus element or RG one for one
  - (c) sorting instructions
    - BY HIGH / BY LOW — plus element one for one (restricted to one level per output list.)
  - (d) combination of a and c

<retrieval condition>*:

<condition> AND <condition>
OR <condition>
NOT <condition>

(AND/OR/NOT <condition>: repeatable and optional; may be grouped by parentheses)

<condition>: <element> relation <values>

- relation: EQ, NE, GT, GE, LT, LE
- <values>:
  - (a) data string
  - (b) generic — EXISTS / FAILS

*Output specifications from a preceding statement may be repeated entirely in following statement by DITTO. (e.g., DITTO WHERE < >;)

*Retrieval conditions of preceding statements may be repeated entirely in following statement by SAME. (e.g., PRINT< > WHERE SAME AND < >;)

suitable for inclusion in a report without retyping. Statistical functions of the values of components which may be selected for output are maxima, minima, sums, means, standard deviations, and frequency counts. Also, retrieved data may be sorted, resulting in an output list ordered on the values of some specified component. Inspection of the left hand portion of Table 2 shows that retrieval conditions may include any combination or grouping of logical/relational specifications desired.

Conclusion

Examples of the data base description, input data, and some retrievals from the NSHS study are shown in the appended section. Study of these examples and the information given in this section should make clear the general nature of RFMS and its applications in the NSHS study.

While it is likely that a system such as RFMS can offer much in future phonological studies and other linguistic studies, the reader is cautioned not to consider this paper as a user's manual. RFMS is easy to use; however, there are many details of its use that have not been included here for the sake of simplicity.

RFMS permitted the accomplishment of a good deal in the NSHS study which otherwise would probably not have been attempted. Additionally, real-time and labor costs have been tremendously reduced by RFMS. It is expected that the availability of systems such as RFMS will significantly expand the scope of phonological and other linguistic studies in the near future.

EXAMPLES OF RFMS OUTPUT FOR
THE NSHS STUDY

EXAMPLE 1

Data Base Definition

```
OLD DATA BASE  NSHS
 1) SUBJECT NUMBER (INTEGER NUMBER)
 2) SEX (NAME)
 3) GRADE (INTEGER NUMBER)
 4) CITY (NAME)
 5) TEST RESULT (RG)
   6) NAME OF TEST (NAME IN 5)
   7) TARGET SOUND (RG IN 5)
     8) NAME OF TARGET SOUND (NAME IN 7)
     9) POSITION OF TARGET SOUND (NAME IN 7)
     10) FREQUENCY OF TARGET SOUND (INTEGER NUMBER IN 7)
     11) FREQUENCY OF ERRORS FOR TARGET SOUND (INTEGER NUMBER IN 7)
     12) ERROR EVALUATION (RG IN 7)
       13) SUBSTITUTED SOUND (NAME IN 12)
       14) RANK OF SUBSTITUTED SOUND (NAME IN 12)
       15) FREQUENCY OF SUBSTITUTED SOUND (INTEGER NUMBER IN 12)
       16) FEATURES OF SUBSTITUTION (RG IN 12)
         17) CONTINUANT (NAME IN 16)
         18) STRIDENT (NAME IN 16)
         19) CORONAL (NAME IN 16)
         20) ANTERIOR (NAME IN 16)
         21) VOICED (NAME IN 16)
         22) NASAL (NAME IN 16)
         23) CONSONANTAL (NAME IN 16)
         24) VOCALIC (NAME IN 16)
         25) LATERAL (NAME IN 16)
```

EXAMPLE 2

Data input string for a subject in the NSHS study. Data are shown with one component per line and indentations corresponding to hierarchical status only for clarity. In practice data would be punched across cards in any suitable fashion. The following pages show examples of input data for other subjects.

```
1) 1
2) M
3) 1
4) MRSHL
   6) G-F
      8) V
      9) I
         13) B
            17) MINUS
            18) MINUS
      8) P
      9) I
         13) B
            21) PLUS
      8) K
      9) M
         13) T
            19) PLUS
            20) PLUS
   6) F-S
      8) V
      9) I
      10) 99
      11) 0
      8) P
      9) I
      10) 99
      11) 0
      8) K
      9) M
      10) 99
      11) 0
```

EXAMPLE 2 (cont'd)

```
1) 16
2) F
3) 1
4) MRSHL
  6) G-F
    8) V
    9) I
      13) R
        18) MINUS
        19) PLUS
        24) PLUS
    8) D-
    9) I
      13) PHI
    8) T-
    9) F
      13) F
        18) PLUS
        19) MINUS
    8) T-
    9) M
      13) T
        17) MINUS
  6) F-S
    8) V
    9) I
    10) 0
    8) D-
    9) I
    10) 14
    11) 3
      13) D
      14) ONLY
      15) 3
        17) MINUS
    8) T-
    9) F
    10) 99
    11) 0
    8) T-
    9) M
    10) 0
```

EXAMPLE 2 (cont'd)

```
1) 13
2) F
3) 1
4) MRSHL
  6) G-F
    8) P
    9) F
      13) PHI
    8) V
    9) I
      13) W
        18) MINUS
        20) MINUS
        23) MINUS
    8) V
    9) F
      13) B
        17) MINUS
        18) MINUS
    8) D-
    9) I
      13) D
        17) MINUS
    8) C
    9) F
      13) SC
        17) PLUS
  6) F-S
    8) P
    9) F
    10) 99
    11) 0
    8) V
    9) I
    10) 0
    8) V
    9) F
    10) 0
    8) D-
    9) I
    10) 23
    11) 15
      13) D
      14) 1
      15) 13
        17) MINUS
      13) PHI
      14) 2
      15) 2
```

EXAMPLE 2 (cont'd)

```
1) 18
2) F
3) 1
4) MRSHL
  6) G-F
    8) F
    9) I
      13) B
        17) MINUS
        18) MINUS
        21) PLUS
    8) F
    9) F
      13) P
        17) MINUS
        18) MINUS
    8) V
    9) M
      13) B
        17) MINUS
        21) PLUS
    8) R
    9) I
      13) W
        19) MINUS
        20) MINUS
        23) MINUS
        24) MINUS
```

EXAMPLE 2 (cont'd)

```
1) 7
2) F
3) 1
4) MRSHL
  6) G-F
    8) C
    9) I
      13) T
        18) MINUS
        20) PLUS
    8) V
    9) I
      13) B
        17) MINUS
        18) MINUS
    8) V
    9) M
      13) B
        17) MINUS
        18) MINUS
  6) F-S
    8) C
    9) I
    10) 99
    11) 0
    8) V
    9) I
    10) 0
    8) V
    9) M
    10) 99
    11) 0
    8) D-
    9) I
    10) 23
    11) 1
      13) D
      14) ONLY
      15) 1
        17) MINUS
```

EXAMPLE 2 (cont'd)

```
1) 24
2) F
3) 1
4) MRSHL
  6) G-F
    8) T-
    9) I
      13) S
        18) PLUS
    8) V
    9) I
      13) B
        17) MINUS
        18) MINUS
    8) V
    9) M
      13) B
        17) MINUS
        18) MINUS
```

EXAMPLE 3

Simple Retrieval Requests and Resulting
Output from RFMS

```
REQUEST...
PRINT C8,C9,C13 WHERE C6 EQ G-F AND C8 EQ D-$
      8) D-
      9) I
        13) D
      8) D-
      9) I
        13) D
      8) D-
      9) I
        13) D

REQUEST...
PRINT C8,C9,C13 WHERE C6 EQ G-F AND C8 EQ T-$
      8) T-
      9) M
        13) PHI
      8) T-
      9) M
        13) F
      8) T-
      9) F
        13) F
      8) T-
      9) M
        13) PHI
      8) T-
      9) F
        13) PHI
      8) T-
      9) I
        13) T
```

EXAMPLE 3 (cont'd)

```
REQUEST...
PRINT C8,C9,C13 WHERE C6 EQ G-F AND C8 EQ D$
 DIAGNOSTIC-C   8 EQ D           UNSATISFIED-NONFATAL
 DIAGNOSTIC- AND IS UNSATISFIED -NONFATAL
 DIAGNOSTIC-WHERE CLAUSE NOT SATISFIED -NONFATAL

REQUEST...
PRINT C8,C9,C13 WHERE C6 EQ G-F AND C8 EQ T$
      8) T
      9) M
        13) PHI

REQUEST...
PRINT C8,C9,C13 WHERE C6 EQ G-F AND C8 EQ V$
      8) V
      9) I
        13) F

REQUEST...
PRINT C8,C9,C13 WHERE C6 EQ G-F AND C8 EQ F$
 DIAGNOSTIC-WHERE CLAUSE NOT SATISFIED -NONFATAL

REQUEST...
PRINT C8,C9,C13 WHERE C6 EQ G-F AND C8 EQ R$
 DIAGNOSTIC-WHERE CLAUSE NOT SATISFIED -NONFATAL

REQUEST...
PRINT C8,C9,C13 WHERE C6 EQ G-F AND C8 EQ P$
      8) P
      9) I
        13) B
      8) P
      9) M
        13) PHI
      8) P
      9) I
        13) B
      8) P
      9) I
        13) B
      8) P
      9) I
        13) B
      8) P
      9) I
        13) B
```

REFERENCES

Cairns, C. E. Markedness, neutralization, and universal redundancy rules. Language, 1969, 45, 863-885.

Chomsky, N. and Halle, M. The sound pattern of English. New York: Harper & Row, 1968.

Compton, A. J. Generative studies of children's phonological disorders. To appear in Journal of Speech and Hearing Disorders.

Fodor, J. and Garrett, M. Some reflections on competence and performance. Psycholinguistic Papers. Lyons, J. and Wales, R. J. (Eds), Edinburgh: University Press, 1966.

Greenberg, J. H. Language universals. The Hague: Mouton & Co., 1966.

Halle, M. Phonology in a generative grammar. Word, XVIII, 1962, 54-72. Reprinted in The structure of language: Readings in the philosophy of language. Fodor, J. and Katz, J. (Eds.), Englewood Cliffs: Prentice Hall, 1964.

Jakobson, R. Kindersprache, Aphasie, und allgemeine Lautgesetze. Stockholm: 1941. Reprinted in Selected Writings, 328-402.

Menyuk, P. The role of distinctive features in children's acquisition of phonology. Journal of Speech and Hearing Research, 1968, Vol. II, No. 1, 138-145.

Penner, K. A distinctive feature analysis of the phonemic description of speech of preschool children. Unpublished Masters Thesis. The University of Texas at Austin, 1970.

Snow, K. A comparative study of sound substitutions by "normal" first grade children. Speech Monographs, 1964, Vol. 31, 135-141.