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AN ANALYSIS OF DEVELOPMENTAL ARTICULATION ERRORS ON THE BASIS OF ARTICULATORY ATTRIBUTES: A PROCEDURAL STUDY

By

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Chapter 1

INTRODUCTION

Traditional approaches to articulation testing have typically been lacking in specificity and have failed to contribute sufficient diagnostic information. The second edition of the Templin-Darley Tests of Articulation copyrighted in 1969, suggests the following possible categories for recording test responses: correct, substitution, omission, distortion, no response, and production with nasal emission (Templin, Darley, 1969). Snow (1963), in an attempt to provide information concerning the types of "normal" misarticulations, grouped responses as follows: correct, moderate distortion, severe distortion, omission, and substitution. Such schemes cause the loss of detailed information relating to the specific articulatory responses which the individual did make. Further, traditional error categories do not provide information enabling the recognition of any patterns linked to particular phonetic features and extending across several phonemes. A primary reason for this loss of information is that present articulation testing does not utilize a scheme providing sufficiently detailed descriptions of articulatory responses (Prins, 1962). Recent approaches to phonemic theory, which have as their basic non-segmentable unit some kind of sub-phoneme, promise however, a method whereby we may preserve much of the information presently lost in the evaluation of phonological disorders.

There is a multiplicity of such sub-phonemic schemes, many of which are referred to as distinctive feature schemes. Some of these schemes began as attempts to give perceptual labels to features which were seen in sound spectograms (Fant, 1968) while others give evidence of a more motor-articulation orientation (Wickelgren, 1966). None of these schemes are to be considered ideal, but each, because it is concerned with a finer segmentation of speech, can be more precise than traditional approaches to articulation testing which simply recognize departures from phonemic targets. A procedure for articulation testing which uses a scheme of phonetic features for description of misarticulations can provide significantly more detailed diagnostic information. As such, it would have significant advantages over traditional articulation testing schemes. The purpose of the present study was to develop a procedure utilizing the sub-phoneme as the unit by which articulation responses may be analyzed.

REVIEW OF THE LITERATURE

The literature dealing with sub-phonemic theory began with attempts to develop models of speech production, both functional and conceptual, as a means of developing eventually a model of speech perception. Initial studies analyzed speech production through the synthesis of speech using the sound spectograph and patterned playback. Researchers speculated that it might "be of interest to examine the data from the point of view that perception involves a set of binary choices" (Cooper, 1952). Jakobson, Halle, and Fant (1963) in their early writings suggested that a speech sample is composed of a series of minimal distinctions and that these distinctions confront the listener with a series of two-choice situations involving two polar qualities of the same category. These qualities they called distinctive features: they included "grave" and "acute", "compact" and "diffuse", "voiced" and "unvoiced", among others.

A conceptual model of speech production was then developed representing parallel processing systems which utilized binary distinctive features such as the above. The model allowed for parallel commands to be issued to the speech production mechanism with as many processes being available as there are distinctive features (Liberman, 1967).

Henke (1967) then went on to simulate the speech production process by using computer and oscilloscopic techniques. In this model, phonemes are analyzed into sub-phonemic elements called "articulatory attributes" including a finite set of configuration, manner, and strength attributes. In Henke's model these attributes can be excited in parallel and, because they are goal directed, can be changed at discreet points in time.

Selected studies have also been conducted concerning the role distinctive features play in speech sound perception and in short-term memory. Miller and Nicely (1955) concerned themselves with an analysis of the perceptual confusions among English consonants analyzed in terms of the following five non-binary articulatory features or dimensions: "voicing", "nasality", "affrication", "duration", and "place of articulation". They found that "the perception of any one of these five features is relatively independent of the perception of others".

Wickelgren (1965, 1966), in two studies dealing with distinctive features and short-term memory, found evidence indicating that both vowels and consonants are coded in short-term memory as a set of distinctive features, each of which may be forgotten semi-independently, rather than as a unit. He also found that, while each of three distinctive feature schemes was more accurate than chance in making predictions concerning the rank order of different intrusion errors in recall, the most accurate was a system designed by Wickelgren. "This system is a slightly modified version of the conventional phonetic analysis of consonants": "voicing", "nasality", "manner of articulation", and "place of articulation".

Sadanand Singh (1967), too, conducted several studies dealing with the relation between distinctive features and the perception of English phonemes. He found that at least in selective cases, perceptual relations correspond to distinctive feature relations.

Gunner Fant (1968) extended the preliminary set of distinctive features developed with Jakobson and Halle into a system which categorizes "speech production events" and allows for a translation from speech production to "speech wave characteristics". Fant's distinctive feature scheme thus combines a perceptually based scheme of features with a set of features with an articulatory or productive basis.

Various research done in the area of speech pathology would indicate the applicability of sub-phonemic analysis in this area. Crocker (1969), after sub-phonemically describing various phonological observations of the speech of children, suggested that children acquire "not features as such, not the sound as such, but rather hypothesized rules for the manipulation of features to form feature sets which previously had not appeared in his developing phonological system". Haas (1964) too, in discussing a similar phonological analysis of one case of dyslalia, suggested that sub-phonemic analysis and comparison should be useful in developing successful therapeutic techniques. "What we have to teach is not so much sounds themselves, as discriminations among sounds, i.e., distinctions which the child fails to make."

Jack Weber (1970) describes such a sub-phonemic analysis and subsequent experimental treatment of eighteen subjects with moderate to severe articulation disorders. Therapy conducted differed from the traditional approach to speech therapy in two ways: "An entire pattern or category was taught at once rather than teaching one sound at a time; and, the child was taught to consciously contrast the incorrect feature with the correct feature throughout all stages of therapy".

Asp and Williams (1970) report also that in general, distinctive feature "rules" are useful in the diagnosis and remediation of articulation disorders. Using computer analysis to tabulate errors, they summarized consonant misarticulations of 1,373 subjects who had functional articulation problems. They found that alveolar consonants were the most often substituted and that the features of "nasality" and "friction" improved with age. In addition, they described the following rank order for the correct use of articulatory features: "voicing", "nasality", "friction", "duration", "glide", and "liquid".

In a study of ten children with severe functional articulation disorders by McReynolds and Huston (1971), thirteen distinctive features developed by Jakobson, Halle, and Fant and by Chomsky and Halle were used to describe responses to a traditional test of articulation. They found that distinctive feature errors were consistent across phonemes for all of the children and that misarticulations could only be partially described as a function of the absence of certain distinctive features. They also reported that many errors occurred in the way that distinctive features were used in combination with other features.

Tikofsky and McInish (1968) speculated that the development of speech sound discrimination is on the basis of distinctive features.

Subjects were asked to tell if pairs of words and/or nonsense syllables were heard as the same or different. They found that as the difference between two sounds in terms of distinctive features increased, failures of discrimination decreased. Some distinctive features were also found to contribute more to the ease of discrimination than others.

And, finally, Paula Menyuk (1968), in attempting to support the thesis that a universal ordering of phonetic units is possible, compared the development of certain distinctive features in the speech of Japanese and American children. Despite the fact that the children spoke different languages involving differing phonological systems, she found remarkable similarities in the order of development for several distinctive features.

The use of distinctive feature schemes has contributed to increased understanding of the bases for recognizing and discriminating among speech sounds; it seems likely that a distinctive feature approach to the description of misarticulations can be equally as fruitful. It was unfeasible at the inception of this research to determine a system for assessing how fruitful such an approach might be as the specific nature of the information to be acquired as a result of this study was unknown prior to the execution of the research. Thus no research questions or hypotheses as such were formulated. This investigation then was to be a search for an experimental procedure which might prove useful in further studies which would attempt to answer specific research questions and specifically assess the usefulness of a sub-phonemic description of misarticulations.

Chapter 2

PROCEDURE

The purposes of this study were twofold: to develop a procedure for the sub-phonemic analysis of articulation responses using articulatory features, and to demonstrate that such a sub-phonemic analysis could yield more useful information concerning those responses than traditional articulation error classification schemes. Five subjects between the ages of three and seven who had normal articulation skills for their age were administered two picture-word articulation tests: one test was designed by the experimenter and the other was comprised of portions of the _Templin-Darley Diagnostic Test of Articulation_. Twenty-five English consonants were elicited in single-word responses. All testing was video-taped and the video tapes viewed later for the analysis of articulatory responses.

SUBJECTS

Five subjects were used in this study, one at each of the following age levels: three, four, five, six, and seven years. Each child was within plus or minus thirty days of his birthday at the time of testing. To eliminate possible differential effects of sex differences in the development of articulation skills, only male subjects were used. No subject had received speech or language therapy, and all subjects were selected to represent as well as possible typical articulation skills for each age level. To assure this, each prospective subject was administered the _Templin-Darley Screening Test of Articulation_. Results for each prospective subject were then compared with norms available for the appropriate age level on the *Templin-Darley Screening Test*. Those subjects finally selected for use in this study obtained scores on this test which closely compared with these norms (Appendix A).

STIMULUS MATERIAL

A picture-word articulation test was designed by the experimenter and administered to each subject to elicit each of twenty-five English consonants in syllable-initial and syllable-final positions. Consonants tested were /m/, /n/, /ŋ/, /p/, /b/, /t/, /d/, /k/, /g/, /r/, /l/, /f/, /v/, /θ/, /ð/, /s/, /z/, /ʃ/, /ʒ/, /h/, /w/, /M/, /j/, /tʃ/, and /dʒ/. Certain speech sounds were not tested in both positions: for example, /ŋ/, was tested only in the final position and /w/ was tested only in the initial position as these sounds occur only in these positions. All words elicited were monosyllables and free morphemes (Appendix B).

While recent research would indicate that connected speech is more appropriate for determining a child's habitual articulation pattern than isolated word responses (Faircloth, 1970), for ease of test administration and response analysis, isolated words were implemented. Such responses facilitated comparisons between traditional articulation testing schemes and the articulatory attribute scheme used by the experimenter. The primary emphasis of this study was the generation of a procedure for describing articulatory events, and thus, any possible minor systematic differences between the articulatory events described and those occurring in running speech were not an important concern. Testing of sounds in isolation was ruled out because such testing was considered not to compare closely to "usual" articulation testing procedures and to yield data of questionable validity.

The use of syllable-initial and syllable-final positions rather than the traditional word-initial, word-medial, and word-final approach to articulation testing was proposed on the basis of findings which indicate that essentially identical data is yielded whether one tests in terms of word-initial, -medial, and -final or syllable-initial and -final (Jordan, 1960). Thus it was considered unnecessary to test the consonants in the word-medial position. Monosyllabic responses were elicited because evidence indicates some coarticulation effects cross syllable boundaries and thus testing the speech sounds in monosyllabic words might simplify the analysis of the articulation responses (Amerman, Daniloff, and Moll, 1970).

In addition to the administration of the twenty-five consonant test designed by the experimenter, each subject was administered those portions of the Templin-Darley Diagnostic Test of Articulation which elicit the same twenty-five consonants in word-initial, word-medial, and word-final positions.

While every attempt was made to use the same test materials for all subjects and to elicit spontaneous speech responses wherever possible, additional test materials and direct stimulation were employed on rare occasions at the discretion of the experimenter. Direct stimulation was used in eliciting approximately 22% of all responses. More direct stimulation was necessary, of course, with the younger subjects, ages three and four, than with the older subjects.

TEST PROCEDURE

Before entering the test room, each subject was told that he and the experimenter were going to play a game that involved looking at some pictures and naming them. The children were also told that they were going to be on television. Upon entering the room, the experimenter seated herself out of the camera's range to the left and in front of the child. In all cases the subject was positioned so as to maintain, as well as possible, a full-face view of him. The experimenter then pointed out the camera to the child and as he watched the camera, it was brought into focus on the child. With some subjects, particularly the older children, the experimenter asked the child to keep his hands away from his face and to say each word loudly and clearly while looking directly at the camera. The testing was then begun.

The portions of the Templin-Darley Diagnostic Test were administered first in all cases, followed immediately by the administration of the test designed by the experimenter. Frequently, particularly with the younger subjects, the experimenter found it necessary to use direct stimulation to elicit the desired word; whenever this was done, note was made of that fact alongside the description of that response during the experimenter's subsequent analysis. It was also sometimes necessary to ask the subject to repeat a response because of suspected inadequate oral volume, poor positioning, or other factors which would make analysis of the response questionable or impossible. However, in subsequent analysis of responses, the experimenter was able to analyze the subject's first response except in one case where the initial response was extremely unclear.

Pilot study results indicated that it was not often an especially crucial factor whether the view of the subject was other than a full-face view, if at least a profile of the subject's face was in full view of the camera; nevertheless, care was taken by the experimenter and the camera operator to maintain the full-face position.

Because they indicated an interest and because they seemed to enjoy it, each child was allowed to watch part of the video-tape made of him upon the completion of testing.

DATA ANALYSIS

The video-tape of each subject's various test responses constituted the data to be described by the experimenter. The experimenter described each subject's production of the test phonemes through viewing and auditing the video-tape and allowing as many replayings of a recorded response as proved necessary for a complete description. Responses for each subject on the portions of the Templin-Darley Diagnostic Test of Articulation were described first, using the traditional response categories: correct, distortion, substitution, and omission. Where the error was in the form of a distortion, the experimenter attempted to describe the distortion where possible by indicating if the phoneme had been distorted toward another phoneme. In the case of substitutions, the substituted sound was recorded.

Following the description of each child's Templin-Darley responses, the experimenter described the responses of each subject on the experimenter's consonant sound test. Syllable-initiating and syllable-terminating versions (with exceptions previously noted) of each of twenty-five English consonants were carefully described by the experimenter using a set of manner and place articulatory attributes. This scheme for phonetic analysis was an adaption of that developed by Fant (1968). The application of this scheme of articulatory attributes required that the experimenter make judgments concerning the subject's articulatory motor activity on the basis of the experimenter's auditory and visual perceptual data. Thus the manner and place features are described in motor terms but such judgments concerning manner and place were obviously made primarily on the basis of acoustic and optical data. Description of each subject's production of the test phonemes was in relative rather than absolute terms; that is, judgments were made relative to a static description of normal adult production for each test phoneme.

The conventional designation of manner and place of articulation of all test phonemes was expressed in terms of the articulatory feature system previously described; these descriptions constituted the standards against which all test responses were compared. Each phone to be described was then described relative to the articulatory postures and manners of the "standard" General American phoneme which the phone in question most resembled. Thus a high-back, rounded on-glide (resembling /w/), occurring where /r/ was required, was described in terms of its deviation from the standard /r/. Similarly, a mid-front on-glide occurring where /j/ was required was described in terms of any deviation from the attributes comprising the "standard" /j/ since the phone in question resembled the /j/ more than any other General American phoneme.

Chapter 3

PROCEDURAL RESULTS

The development of a preliminary procedure for sub-phonemic description of articulation responses was one of the purposes of this study. This chapter is devoted to a discussion of the evolution of the feature scheme which was ultimately used in the description of the articulation responses of five children. Further, the reliability and validity of the descriptions are evaluated.

EVOLUTION OF THE FEATURE SCHEME

The classification scheme developed through this research began as an adaptation of a scheme proposed by Gunnar Fant (1968). Fant's scheme included two parallel sets of features, one of which described manner and place of production using an articulatory frame of reference, the other of which was designed for use in description of spectographic displays. For our purposes, only the features using an articulatory reference were used and these are replicated in Table One. Segment type features refer to manner of production while segment pattern features refer to place of articulation.

It was determined that while such a feature scheme would generally fit our purposes, adaptations toward a still more motor-articulatory emphasis would be useful. Thus the preliminary set of features listed in Table Two was outlined as an initial classification scheme.

One of the major changes made in the evolution of the feature system was to move from a binary system, which required a feature to be either on or off, to a system which allowed for the notation of features

Table 1. Features Developed by Fant to Describe Manner and Place of Production

	Segment Type Features
	Source Features
1.	Voice
2.	Noise
3.	Transient
	Resonator Features
4.	Occlusive
5.	Fricative
6.	Lateral
7.	Nasal
8.	Vowellike
9.	Transitional
10.	Glide
	Segment Pattern Features
11.	Tongue fronted
	a) Prepalatal position
	b) Midpalatal position
12.	Tongue retracted
13.	Mouth-opening (including tongue section and lips) narrow
14.	Lips relatively close and protruded (small lip-opening area)
15.	Retroflex modification
	a) Alveolar articulation
	b) Palatal articulation
16.	Bilabial or labiodental closure
17.	Interdental articulation
18.	Dental or prealveolar articulation
19.	a) Palatal articulation with tip of tongue down
	b) Palatal retroflex articulation .
20.	Velar and pharyngeal articulation
21.	Glottal source

Table 2. Preliminary Modification of Fant's Production Feature Scheme

Manner Features

1. Voicing
   Time of onset
   Time of offset
2. Vowel
3. Lateral
4. Occlusive
   Plus or minus explosion
   Plus or minus aspiration
5. Nasal
6. Fricative
7. Transitional
   Direction
   Speed

Place Features

8. Mouth-opening narrow
9. Lips close and protruded
10. Retroflexion
11. Bilabial or labiodental closure
12. Interdental articulation
13. Dental or prealveolar articulation
14. Palatal articulation with tip of tongue down
15. Velar and pharyngeal articulation
16. Glottal articulation

only partially present or present for only a portion of a phone. For example, the feature nasality was described not only as being present or not present, but the appropriateness of the amount and timing of this feature were also described. In addition, the direction and speed of the transitional phases were indicated.

It was felt at this point that the feature scheme did not provide sufficient information concerning both transition speed and the mouth opening. It also seemed advantageous to provide for greater specificity as well by splitting bilabial and labiodental closure into two distinct features and to include additional place features for the description of tongue part, tongue shape, and tongue elevation. Thus the feature scheme took on the appearance shown in Table Three.

After making one additional change in the place of articulation features, the feature scheme was considered to be in a useful although tentative form for our purposes. Mouth opening was simply described as wide, narrow, or neutral while lip rounding and lip retraction were set off as two distinct features of place of articulation. This feature scheme (Table Four) was then used in the analysis of single phonemes produced in monosyllabic words by two children in a brief pilot study.

As a result of this pilot study, several changes were made in the classification scheme. Timing, including both onset and offset, was set off as a distinct manner feature because it was considered possible at that point that errors in timing would affect manner features other than voicing. The sub-feature of force was also added to the occlusive feature. Among the spatial features, lip rounding and lip retraction were combined into a feature designated simply as lip shape. All places of articulation were listed on a continuum moving from anter-

Table 3. Second Revision of Fant's Production Feature Scheme

Manner Features

1. Voicing
    a) Time of onset
    b) Time of offset
2. Vowel
3. Lateral
4. Occlusive
    a) Plus or minus explosion
    b) Plus or minus aspiration
5. Nasal
6. Fricative
7. Transition
    a) Direction
    b) Speed
        (1) One vowel to another
        (2) Glide
        (3) Consonant to vowel

Place Features

8. Mouth opening
    a) Small and rounded
    b) Narrow
    c) Narrow and retracted
    d) Neutral
    e) Wide
9. Bilabial closure
10. Labiodental closure
11. Interdental articulation
12. Dental or prealveolar articulation
13. Palatal articulation
14. Velar and pharyngeal articulation
15. Glottal articulation
16. Tongue part
    a) Tip
    b) Blade
    c) Dorsum
17. Tongue Shape
    a) Forward
    b) Retroflex
18. Tongue Elevation

Table 4. Feature Scheme As It Was Implemented in Pilot Study

Manner Features

1. Voicing
    a) Time of onset
    b) Time of offset
2. Vowel
3. Lateral
4. Occlusive
    a) Plus or minus explosion
    b) Plus or minus aspiration
5. Nasal
6. Fricative
7. Transition
    a) Direction
    b) Speed
        (1) One vowel to another
        (2) Glide
        (3) Consonant to vowel

Place Features

8. Mouth opening
    a) Wide
    b) Narrow
    c) Normal
9. Lip rounding
10. Lips retracted
11. Bilabial closure
12. Labiodental closure
13. Interdental articulation
14. Dental or prealveolar articulation
15. Palatal articulation
16. Velar and pharyngeal articulation
17. Glottal articulation
18. Tongue Part
    a) Tip
    b) Blade
    c) Dorsum
19. Tongue shape
    a) Forward
    b) Retroflex
20. Tongue elevation

ior to posterior in the oral cavity and combined into one feature called place. And finally, the sub-feature of tongue groove was added under tongue shape.

The feature scheme was then adapted to the form of a record sheet for ease in analysis of single articulatory responses. This record sheet was set up in such a way that each feature was indicated as being present, not present, or irrelevant to the analysis of the phone in question. In addition, space was provided for descriptive comments pertinent to each feature present (Table Five). It was in this form that we began to use the feature scheme in the analysis of the video-taped responses of the five subjects used in this study.

Throughout the preliminary attempts to analyze subjects' articulatory responses several additional changes were made in the feature scheme. The first of these changes are reflected in Table Six which shows the record sheet as it was before the last revision into its final form. The sub-feature of duration was added to the timing feature; the intent was to use duration primarily to describe entire feature packages as being of a too long, a too short, or an appropriate duration. The manner feature designated as lateral was expanded to direction of air stream which included consideration of whether the air stream was channeled in a lateral or central direction as well as whether the phoneme was produced on inspired or expired air. The sub-feature of force, previously included under occlusive, was removed and designated as a separate manner feature to be used in describing all phonemes, whether occlusion was present or not. In addition, the first of the spatial features, mouth opening, was described instead as mandibular level with three sub-feature descriptions of narrow, neutral, and wide. Prealveolar

Table 5. Articulatory Feature
Scheme and Record Sheet

MANNER FEATURES	+	-	0	Comment
1. Voicing				
2. Time				
a. Onset of Feature				
b. Offset of Feature				
3. Vowel				
4. Lateral				
5. Occlusive				
a. Explosion				
b. Aspiration				
c. Force				
6. Nasal				
7. Fricative				
8. Transition				
a. Direction				
b. Speed				
1) vowel to vowel				
2) glide				
3) consonant to vowel				
SPATIAL FEATURES				
1. Mouth Opening				
a. Wide				
b. Narrow				
c. Neutral				
2. Lip Shape				
a. Rounded				
b. Retracted				
3. Place				
a. Bilabial				
b. Labiodental				
c. Interdental				
d. Dental				
e. Prealveolar				
f. Palatal				
g. Velar				
h. Pharyngeal				
i. Glottal				
4. Tongue Part				
a. Tip				
b. Blade				
c. Dorsum				
5. Tongue Shape				
a. Forward				
b. Retroflex				
c. Grove				
6. Tongue Elevation				

Table 6. Revision of Articulatory
Feature Scheme and Record Sheet

MANNER FEATURES

1. Voicing
2. Time
    a. Onset (1-3)
    b. Offset (1-3)
    c. Duration (1-3)
3. Vowel
4. Direction of air stream
    a. Central, Lateral
    b. Expiration, Inspiration
5. Occlusive
    a. Explosion
    b. Aspiration
6. Nasal
7. Fricative
8. Transition Speed
    a. vowel to vowel (1)
    b. glide (2)
    c. consonant to vowel (3)
9. Force (1-3)

SPATIAL FEATURES

1. Mandibular Level
    a. Narrow (1)
    b. Neutral (2)
    c. Wide (3)
2. Lip Shape
    a. Rounded
    b. Retracted
3. Place
    a. Bilabial
    b. Labiodental
    c. Interdental
    d. Dental
    e. Alveolar (1-3)
    f. Palatal (1-3)
    g. Velar (1-3)
    h. Pharyngeal
    i. Glottal
4. Tongue Part
    a. Tip
    b. Blade (1-3)
    c. Dorsum (1-3)
5. Tongue Shape
    a. Forward
    b. Retroflex
    c. Groove
6. Tongue Elevation (1-3)

was also changed to read simply as <u>alveolar</u>.

One of the most useful alterations made in the feature scheme took place at this stage of its evolution as well. Previous to this point, an attempt was made to make descriptions of articulatory responses in absolute terms; that is, to describe specifically what the child did without comparisons being made relative to what the child was required to do to produce a correct adult phoneme. Such absolute descriptions were difficult if not impossible to make so the feature scheme was adapted so that descriptions could be made relative to the adult phoneme most closely resembling the response of the child. Thus various features were scaled 1-3, a scale value of two indicating the correct place, proper amount, proper time; a scale value of one indicating too far forward in the oral cavity, too early, not enough; and three indicating too far back in the oral cavity, too late, or too much of any particular feature. On this particular record sheet such rankings were limited to the following features: <u>time</u>, <u>force</u>, <u>mandibular level</u>, <u>tongue elevation</u>, and certain <u>place</u> and <u>tongue part</u> sub-features.

One final change was made in the record sheet at this point. Rather than indicating that a feature was present, not present or relevant to the target phoneme, appropriate notation was simply made that a feature was relevant to a complete and accurate relative description of the articulation response of the child.

Table Seven illustrates the record sheet and thus the feature scheme in the final form used for analysis of articulation responses in this study. It represents as well several final changes in the classification scheme. As only consonants were being tested in syllable-

Table 7. Articulatory Attribute Scheme
and Record Sheet in Final Form

MANNER FEATURES

1. Voicing		
2. Time		
a. Onset (1-3)		
b. Offset (1-3)		
c. Duration (1-3)		
3. Syllable Function		
a. Initiating (1)		
b. Nucleus (2)		
c. Terminating (3)		
4. Direction of air stream		
a. Central (1) Lateral (2)		
b. Expiration (1) Inspiration (2)		
5. Occlusive (1-3)		
a. Explosion (1-3)		
b. Aspiration (1-3)		
6. Nasal (1-3)		
7. Fricative (1-3)		
8. Transition Speed		
a. Vowel to vowel (1)		
b. Glide (2)		
c. Consonant to vowel (3)		
9. Articulator Tension (1-3)		

SPATIAL FEATURES

1. Lip Shape		
a. Rounded (1-3)		
b. Retracted (1-3)		
2. Place		
a. Bilabial (1-3)		
b. Labiodental (1-3)		
c. Interdental (1-3)		
d. Dental		
e. Alveolar (1-3)		
f. Palatal (1-3)		
g. Velar (1-3)		
h. Pharyngeal		
i. Glottal		
3. Tongue Part		
a. Tip (1-3)		
b. Blade (1-3)		
c. Dorsum (1-3)		
4. Tongue Shape		
a. Forward		
b. Retroflex		
c. Groove Width (1-3)		
d. Groove Depth (1-3)		
5. Tongue Elevation (1-3)		

initial and -final positions, it was considered more useful to change the nature of the manner feature number three from a simple indicator that vowel-like properties were present to a feature which would describe the function in the syllable of the phoneme being described. Three usually considered functions existed: syllable initiating, syllable nucleus, and syllable terminating (Stetson, 1951). Two other relatively minor changes were made in the manner features. Force was changed to read articulation tension and several additional manner features were scaled one to three.

Under spatial features, mandibular level was deleted as it had thus far in our descriptions proved unnecessary and was thus not particularly useful. The sub-features of groove width and groove depth were indicated so that both could be more easily described and scaled more easily under tongue shape. And finally, where appropriate all spatial features were scaled. It was in this final form that the feature scheme and record sheet were used in describing the articulatory responses of the five subjects.

ABSOLUTE VERSUS RELATIVE JUDGMENTS

It seems pertinent to discuss here in greater detail the reasoning behind the use of relative judgments rather than absolute judgments in our analysis of articulatory responses. In the initial stages of video-tape viewing and phonemic analysis, the experimenter attempted to make decisions concerning all features absolutely, to describe in concrete and specific terms on the basis of optical and auditory data how much friction was present, how tense the articulators were, exactly where the tongue was, its actual height, etc. In the process of making such judgments, more often than not we were forced to resort to reproducing what the child had done in producing his aberrant response and then to translating this in terms relative to our own articulatory systems, into an absolute description. It was determined then that since we were making what actually amounted to relative decisions, we might better adapt the classification scheme and our use of it to provide for more accurate and more consistent relative judgments. In addition, as each articulatory response was to be analyzed in terms of that General American standard English phoneme it most closely resembled, each of the 25 English consonants under scrutiny in this study was described using the feature scheme as it would be correctly produced by the average adult speaker. These descriptions of correct adult production are summarized in Table Eight. It was at this point that the final revision of the feature scheme and record sheet was made. Phonemic analyses made prior to this point were then redone and further descriptions were undertaken.

RELIABILITY AND VALIDITY OF THE FEATURE SCHEME

While it was not the purpose of this study to determine the reliability of use of the feature scheme which evolved, but to develop that scheme and demonstrate the additional information it could provide, an attempt was made to make a preliminary and limited estimation of the classification scheme's reliability. Consequently, following the completion of all video-tape viewing and articulation response analysis by the experimenter, one individual, felt to be representative of the graduate student population at this institution, was chosen to use the feature scheme in describing sounds previously described by the experi-

Table 8. Articulatory Attribute Description of Adult Phoneme Production

Articulatory Attributes	Phonemes											
Manner features	m	n	ŋ	p	b	t	d	k	g	r	l	f
1. Voicing 1-3	2 2	2 2	2		2 2		2 2		2 2	2 2	2 2	
2. Time: a. Onset 1-3	2 2	2 2	2	2 2	2 2	2 2	2 2	2 2	2 2	2 2	2 2	2 2
b. Offset 1-3	2 2	2 2	2	2 2	2 2	2 2	2 2	2 2	2 2	2 2	2 2	2 2
c. Duration 1-3	2 2	2 2	2	2 2	2 2	2 2	2 2	2 2	2 2	2 2	2 2	2 2
3. Syl. function 1-3	1 3	1 3	3	1 3	1 3	1 3	1 3	1 3	1 3	1 2	1 2	1 3
Air Stream 4. a. central 1, Lateral 2	1 1	1 1	1	1 1	1 1	1 1	1 1	1 1	1 1	1 1	2 2	1 1
b. exp. 1, Insp. 2	1 1	1 1	1	1 1	1 1	1 1	1 1	1 1	1 1	1 1	1 1	1 1
5. Occlusive 1-3				2 2	2 2	2 2	2 2	2 2	2 2			
a. explosion 1-3				2 2	2 2	2 2	2 2	2 2	2 2			
b. aspiration 1-3				2 2	2	2 2	2	2 2				
6. Nasal 1-3	2 2	2 2	2									
7. Fricative 1-3												2 2
8. Trans. speed 1-3	3 3	3 3	3	3 3	3 3	3 3	3 3	3 3	3 3	2 1	2 1	3 3
9. Artic. Tension 1-3	2 2	2 2	2	2 2	2 2	2 2	2 2	2 2	2 2	2 2	2 2	2 2
Spatial features												
1. Lip shape a. round 1-3												
b. retracted 1-3												
2. Place a. bilabial 1-3	2 2			2 2	2 2							
b. labiodental 1-3												2 2
c. interdental 1-3												
d. dental												
e. alveolar 1-3		2 2				2 2	2 2				2 2	
f. palatal 1-3										2 2		
g. velar 1-3			2					2 2	2 2			
h. pharyngeal												
i. glottal												
3. Tongue part. a. tip 1-3		2 2				2 2	2 2				2 2	
b. blade 1-3										2 2		
c. dorsum 1-3			2					2 2	2 2			
4. Tongue shape a. forward		✓ ✓	✓			✓ ✓	✓ ✓	✓ ✓	✓ ✓		✓ ✓	
b. retroflex										✓ ✓		
c. groove width 1-3												
d. groove depth 1-3												
5. Tongue elevation 1-3		2 2	2			2 2	2 2	2 2	2 2	2 2	2 2	

Table 8. Continued.

Articulatory attributes	Phonemes																					
Manner features	v		θ		ð		s		z		ʃ		ʒ		h	w	ʍ	j	tʃ		dʒ	
1. voicing 1-3	2	2			2	2			2	2			2	2		2		2			2	2
2. TIME a. Onset 1-3	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2
b. Offset 1-3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
c. Duration 1-3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3. Syl. function 1-3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	1	1	1	1	3	1	3
4. Air stream a. central-1, lateral-2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
b. exp.-1, insp.-2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5 occlusive 1-3																			2	2	2	2
a. explosion 1-3																			2	2	2	2
b. aspiration 1-3																			2	2		2
6. Nasal 1-3																						
7. Fricative 1-3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2		2		2	2	2	2
8. Trans-speed 1-3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2	3	3	3	3
9. Artic. tension 1-3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Spatial features																						
1. a. round lip 1-3											2	2	2	2		2	2		2	2	2	2
b. retracted lip 1-3																						
2. Place a. bilabial 1-3																2	2					
b. labiodental 1-3	2	2																				
c. interdental 1-3			2	2	2	2																
d. dental																						
e. alveolar 1-3							2	2	2	2									2	2	2	2
f. palatal 1-3											2	2	2	2				2	2	2	2	2
g. velar 1-3																2	2					
h. pharyngeal																						
i. glottal															✓							
3. Tongue part a. tip 1-3			2	2	2	2	2	2	2	2									2	2	2	2
b. blade 1-3											2	2	2	2				2	2	2	2	2
c. dorsum 1-3																2	2					
4. Tounge shape a. forward			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓
b. retroflex																						
c. groove width 1-3			2	2	2	2	2	2	2	2	2	2	2	2					2	2	2	2
d. groove depth 1-3			2	2	2	2	2	2	2	2	2	2	2	2					2	2	2	2
5. Tongue elevation 1-3			2	2	2	2	2	2	2	2	2	2	2	2		2	2	2	2	2	2	2

menter. She was trained by the experimenter in the application of the feature scheme and then asked to analyze 24 articulatory responses chosen randomly across subjects from among those already described by the experimenter. Her analyses as represented by her completed record sheets were then compared with those of the experimenter and the proportions of judgments in agreement for each feature, for each child, and across all children were computed.

As will be noted in Table Nine, the proportion of agreement between judges across features ranged from .46 for *occlusion* to 1.00 for *place-bilabial*. The average proportion of agreement across all judgments was found to be .81. Features which showed the poorest interjudge reliability included *occlusion*, *lip shape*, *tongue tip*, and *tongue forward*. Several other features showed a proportion of agreement which was less than the average: *time-onset*, *central-lateral*, *aspiration*, *transition speed*, *alveolar*, *palatal*, *velar*, *tongue blade*, *groove width*, and *depth*, and *tongue elevation*. In general, an increase in the proportion of judgments in agreement was found as the age of the subjects increased. This latter point was probably due in part to the fact that as the age of the subject increased, the number of his feature errors decreased. His articulation responses thus became somewhat easier to describe and in fact required fewer fine discriminations to be made by the listener.

The variability of agreement across features seemed due in part to one over-riding factor: a lack of adequate training and experience in the use of the feature scheme on the part of the reliability judge. Three features in particular, *occlusion*, *central-lateral*, and *tongue-shape forward*, were used in such a manner by the reliability judge as to

Table 9. Reliability of Articulatory Attributes. Proportion of Agreement Between Experimenter and Reliability Judge.

Feature	Proportion of Agreement
Bilabial	1.00
Function-Initiating	.96
Function-Terminating	.96
Labiodental	.96
Glottal	.96
Voicing	.92
Function-Nucleus	.92
Nasal	.92
Dental	.92
Retroflex	.92
Time-Offset	.87
Expiration-Inspiration	.87
Explosion	.87
Fricative	.87
Dorsum	.87
Central-Lateral	.83
Interdental	.83
Articulation Tension	.79
Blade	.79
Aspiration	.75
Transition Speed	.75
Velar	.75
Groove Width	.75
Time-Onset	.71
Alveolar	.71
Palatal	.71
Groove Depth	.71
Tongue Elevation	.71
Lips Retracted	.67
Lips Rounded	.62
Tip	.62
Forward	.58
Occlusive	.46

Table 10. Reliability of Judgments by Subject. Proportion of Agreement Between Experimenter and Reliability Judge.

Subject	Proportion of Agreement
Three-year-old	.75
Four-year -old	.82
Five-year-old	.76
Six-year-old	.84
Seven-year-old	.86

suggest that her definition and understanding of these features differed considerably from that of the experimenter. In addition, the reliability judge had not had the repeated exposure to the use of the feature scheme in making fine discriminatory decisions that the experimenter had. It might also be postulated that the experimenter had had an additional set of experiences with the feature scheme as it evolved to its final experimental form. This background the reliability judge did not enjoy.

Additional inferences concerning certain portions of the feature scheme developed in this study can be made by examining the results of other research completed recently (Heaton, 1971). In this latter study, the purpose of which was to examine the reliability and validity of descriptions of certain articulatory features, the following features were examined: time, transition speed, place of articulation, tongue part, tongue shape, and tongue elevation. These features were chosen as they allowed description from an x-ray of the oral region as well as description from full-faced video-tape viewing.

Sixteen graduate students in speech pathology and audiology were trained in using the above named articulatory features in the analysis of articulation responses presented in full-face and x-ray video-tapes. Their judgments of eight misarticulated phones were then analyzed for inter-judge and intra-judge reliability and validity. On the basis of limits set by Heaton prior to the analysis of judgments, three articulatory features were found to have adequate reliability. Time-onset, -nucleus, and -offset showed the highest reliability while tongue shape and tongue elevation also fell within the range necessary for adequate reliability. Place, tongue part, and transition speed were not found to have acceptable reliability with the discrepancies between judges being greatest with the place feature. Poor reliability with these features was felt to be primarily the result of inadequate judge training.

The validity of each of the six features examined by Heaton was determined by comparing full-face judgments with x-ray judgments. Findings similar to those for feature reliability were derived: judges were able to make valid judgments concerning time-onset, -nucleus, and -offset, tongue shape and tongue elevation while poorer validity was found for the features transition speed, place, and tongue part. Here too it was suggested by Heaton that more intensive judge training in the use of the feature scheme would have provided for better feature validity results.

Chapter 4

RESULTS AND IMPLICATIONS

In addition to developing a preliminary classification scheme for the sub-phonemic analysis of articulatory responses, the results of this research demonstrate how such a scheme can be used to obtain more information concerning those responses. This chapter is devoted to a presentation of the articulatory information obtained from each of the five subjects using both the traditional categories of error classification and the sub-phonemic scheme of description discussed in the preceeding chapter. Also discussed herein is the method used for summarizing the descriptive data on each subject as well as suggestions concerning the implications of such data.

SUMMARY OF DATA

Following the completion of all video-tape viewing, the record sheets for each child were ordered by phoneme and the process of summarizing the information contained therein was begun. On each record sheet any feature judged to be in error in terms of the target phone was circled. These errors were then transferred to charts which provided for easier enumeration and summary of errors. One chart was completed for all ages on each feature and on each of the phonemes, both syllable-initial and syllable-final. Each feature error was thus charted twice, by feature and by phoneme.

From these charts, counts of errors per feature or per phone for each subject were made and summarized in table form. Subsequently, from these tables of feature error counts, the proportion of features in error per phoneme and per feature were computed.

The number of errors in any one feature for any one child over all syllable-initial phones was divided by the number of phones tested (twenty-four) and the resulting proportion listed in the table. The same process was used to compute the proportion of errors which were syllable-final and the total proportion of errors involving each particular feature. These proportions were derived because a simple graphing of the number of syllable-initial and syllable-final feature errors per child would have been misleading as twenty-four phonemes were tested in the syllable-initial position while only twenty-one phonemes were tested in the syllable-final position. These proportions were then graphed by age for each feature (Figures 1-34).

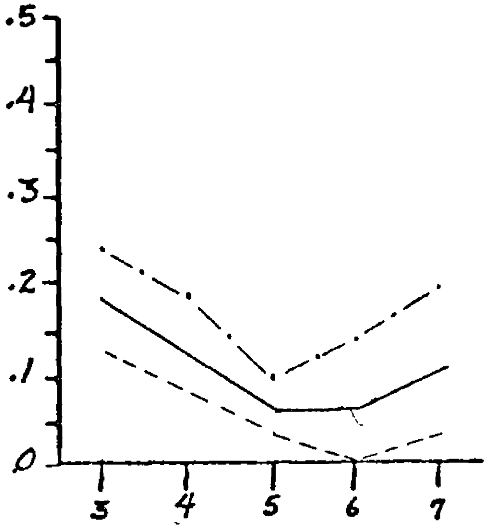
A similar summary of the data by phone was completed. While it was not necessary to compute proportions here, this was done to lend uniformity to the data. The proportion of feature errors by age for each phone was then graphed (Figures 35-59).

In addition, two attempts to group and describe the data by error type were completed. The first such grouping involved placing each of the 585 feature errors into one of five categories: (1) intrusion - the incorrect feature was intruded; (2) addition - the correct feature was present but more than expected; (3) substitution - the feature was present but a different value was substituted and it was not possible to describe that value as too much or too little; (4) subtraction - the correct feature was present but less than expected; and (5) omission - an expected feature was omitted. The number of each type of error for each phone for each child was then counted and listed in an appropriate table. The total number of each type of error for each child

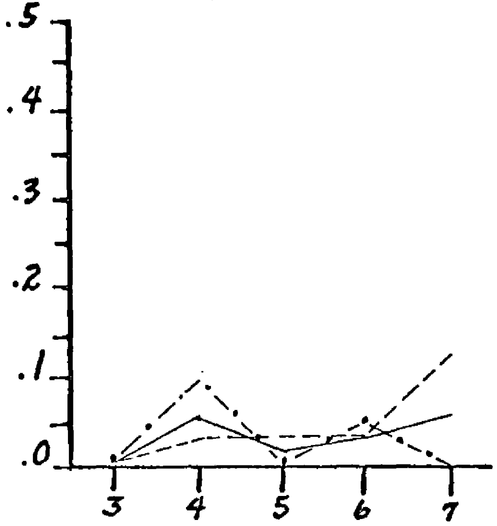
Figures 1-6. Proportion of Errors per Feature by Age.

(Legend: Figures 1-59; Syllable-initial------; Syllable-final ·—·—·; Mean ———)

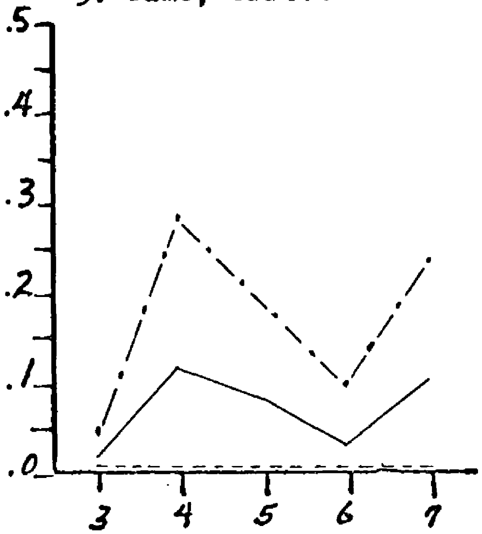
1. Voicing



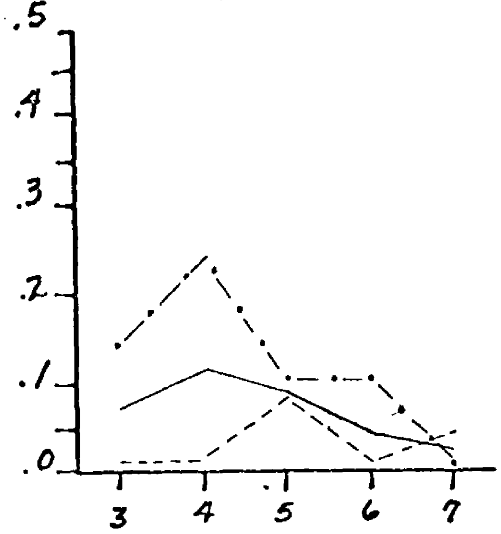
2. Time, onset



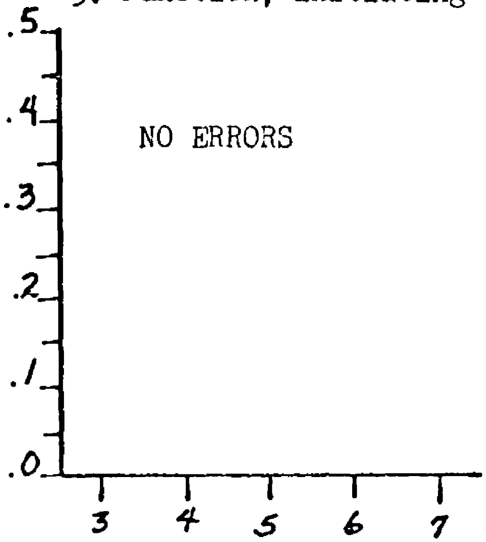
3. Time, offset



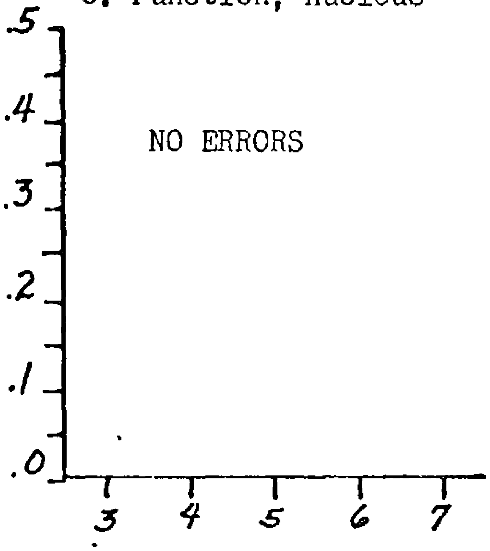
4. Time, duration



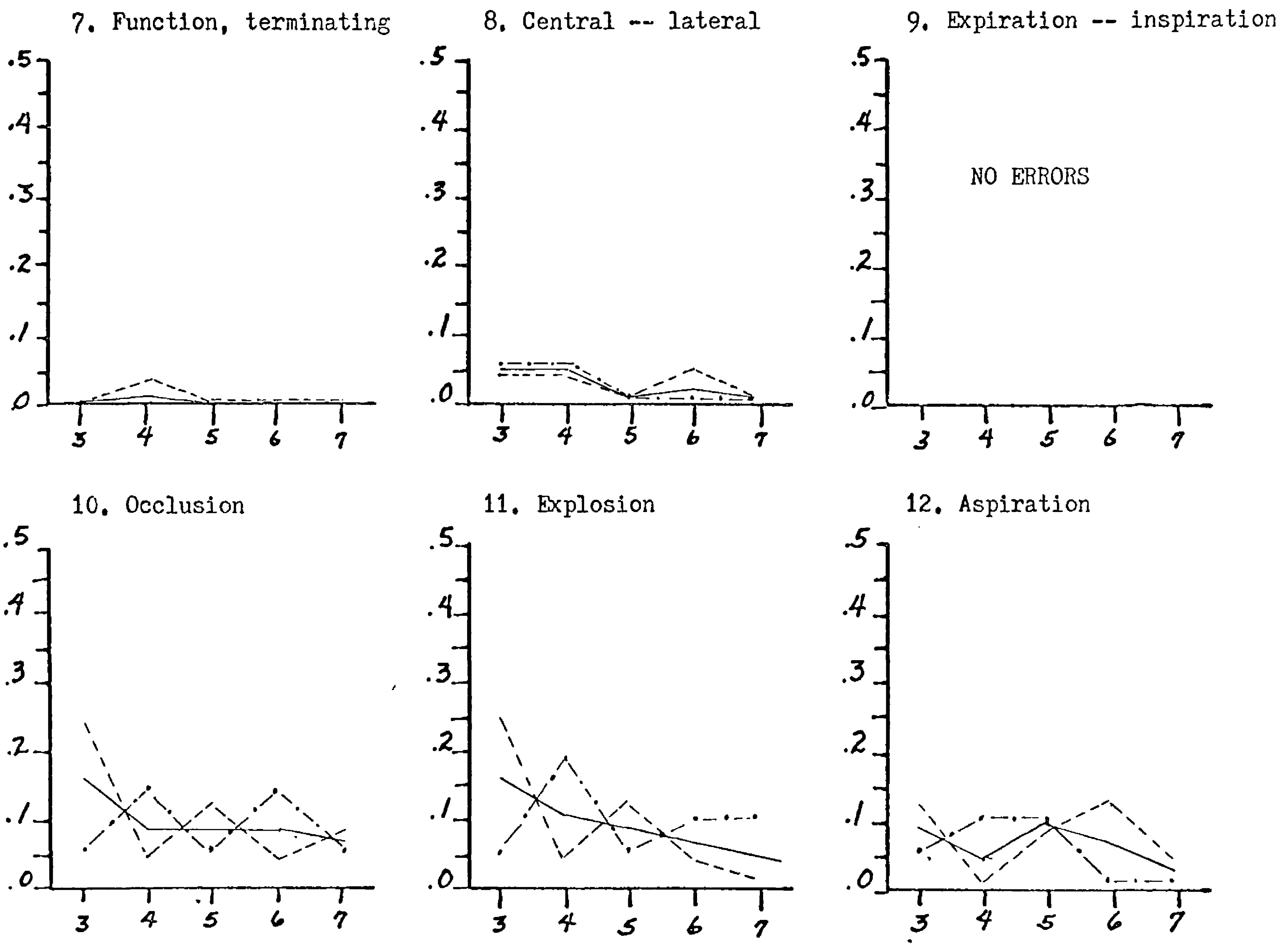
5. Function, initiating



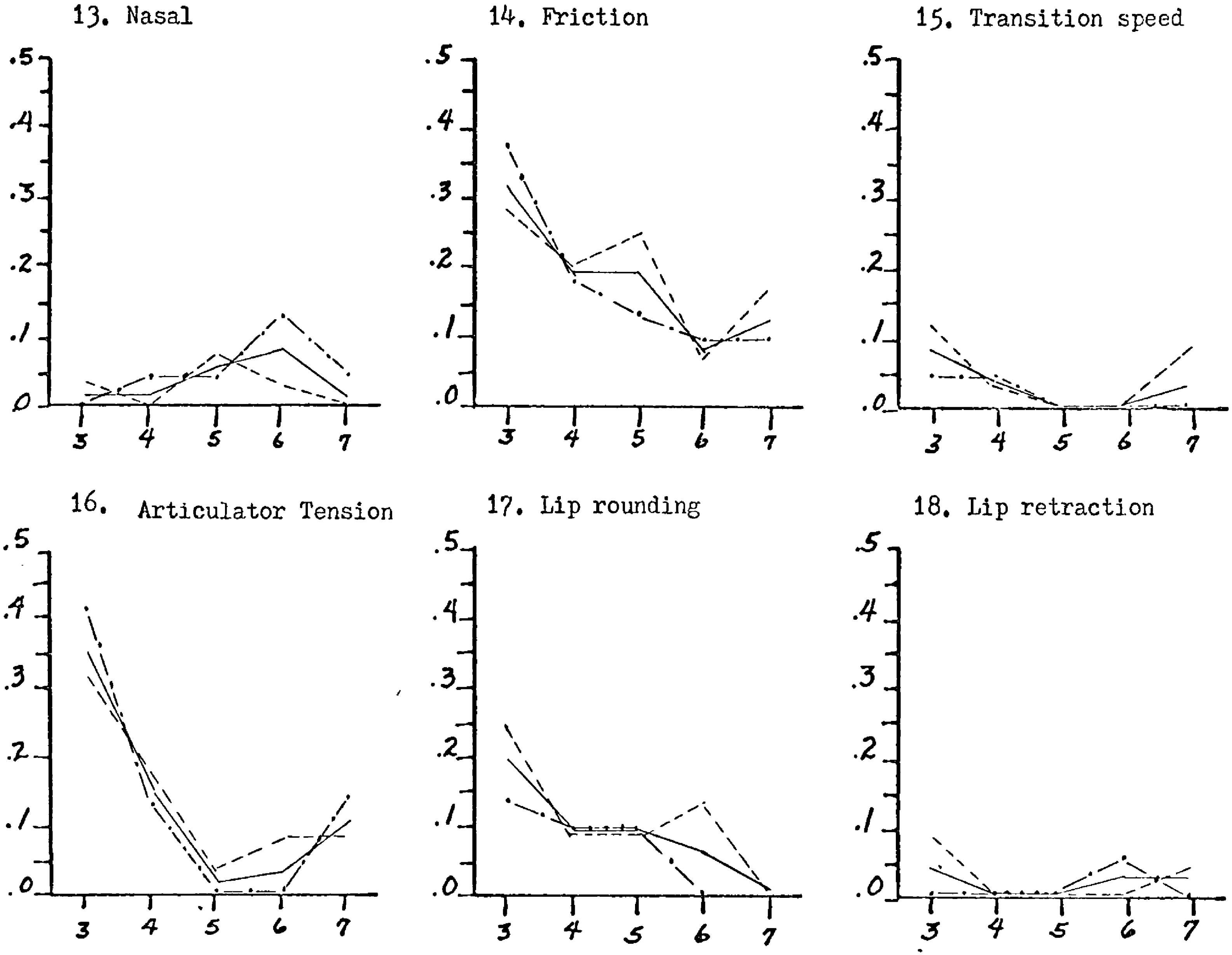
6. Function, nucleus



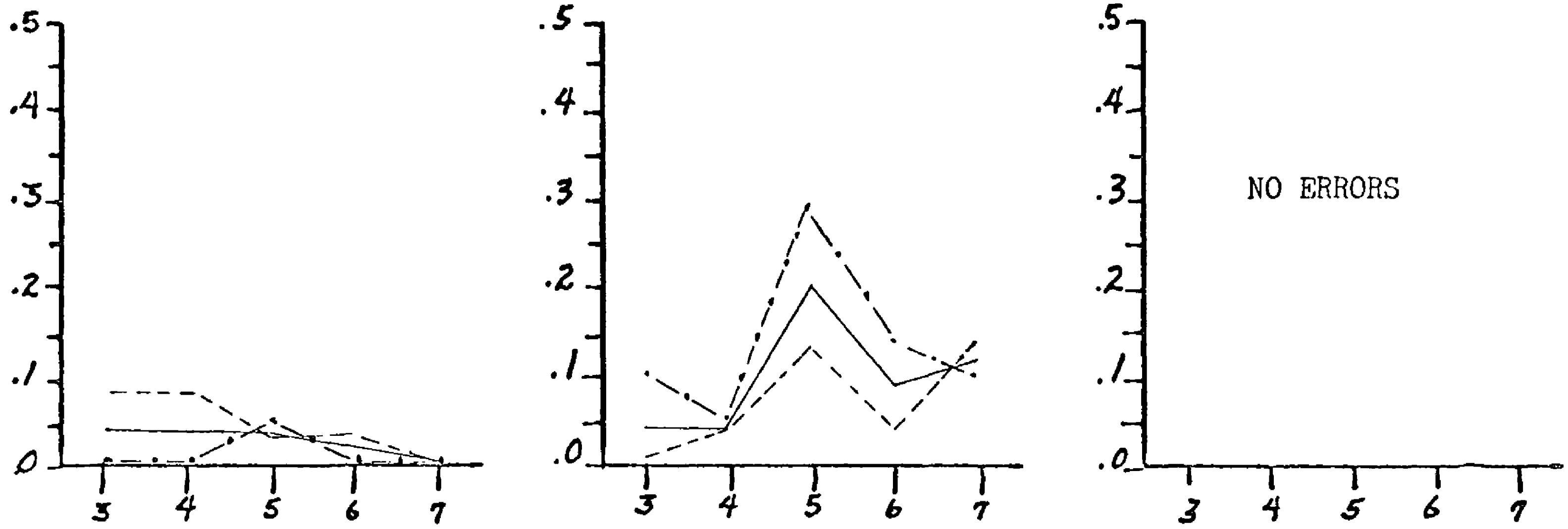
Figures 7-12. Proportion of Errors per Feature by Age



Figures 13-18. Proportion of Errors per Feature by Age.

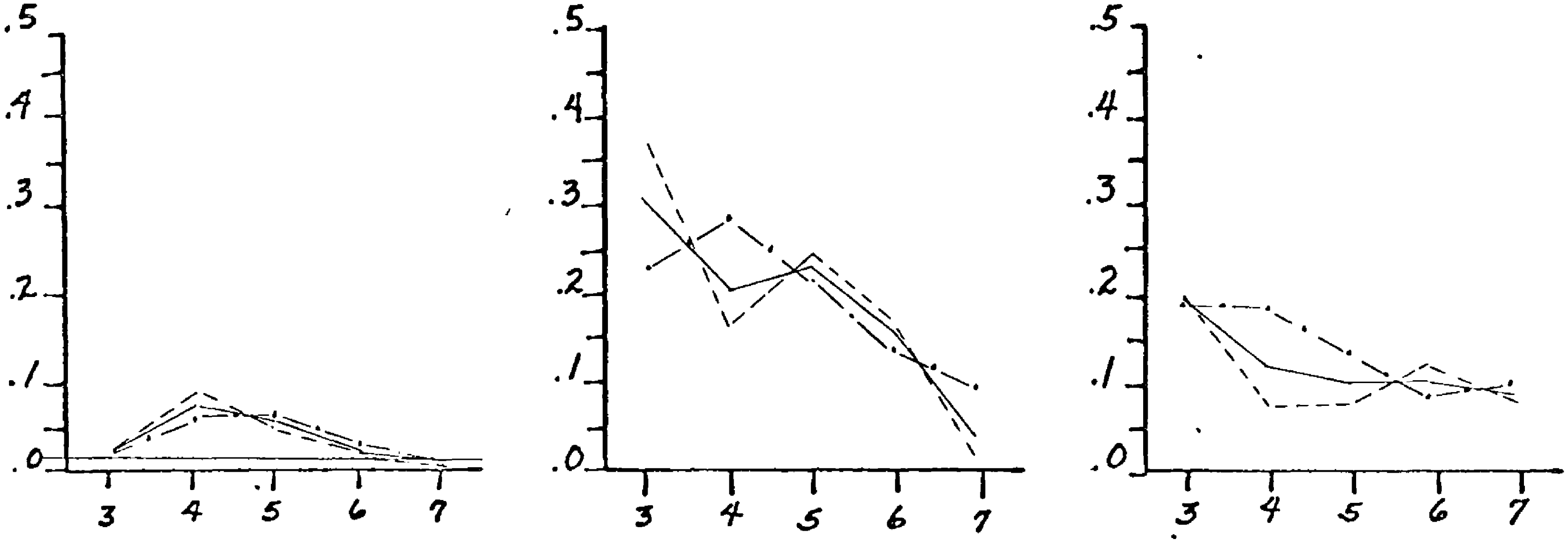


Figures 19-24. Proportion of Errors per Feature by Age.


19. Bilabial

20. Labiodental

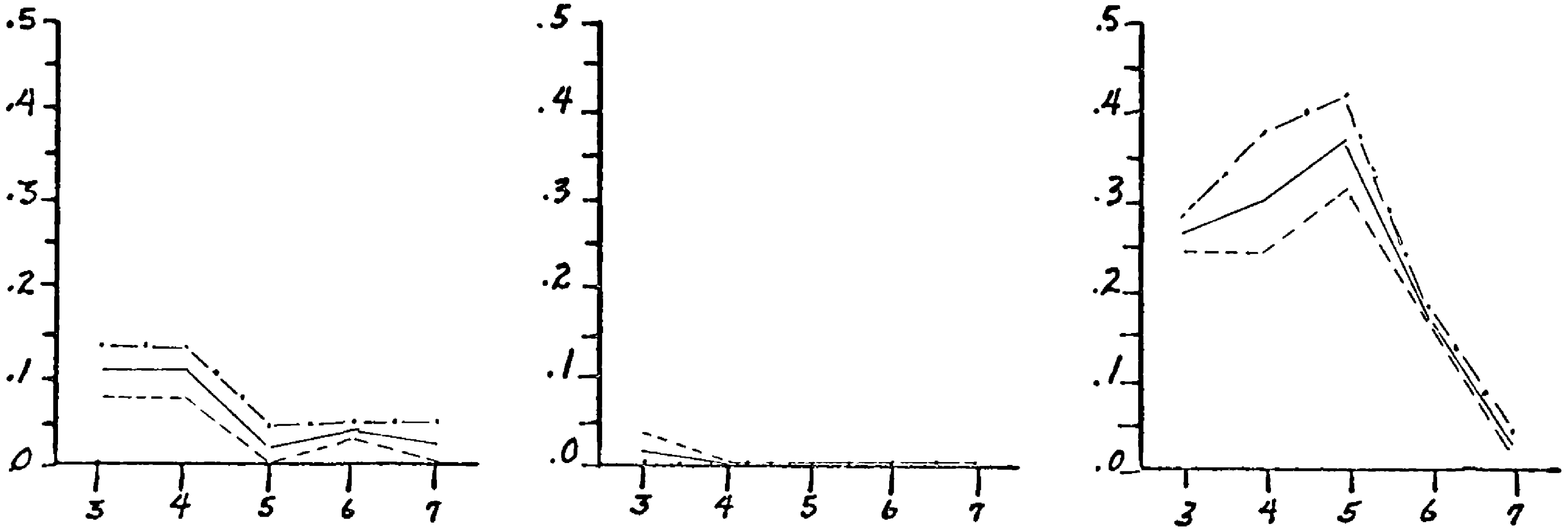
21. Interdental

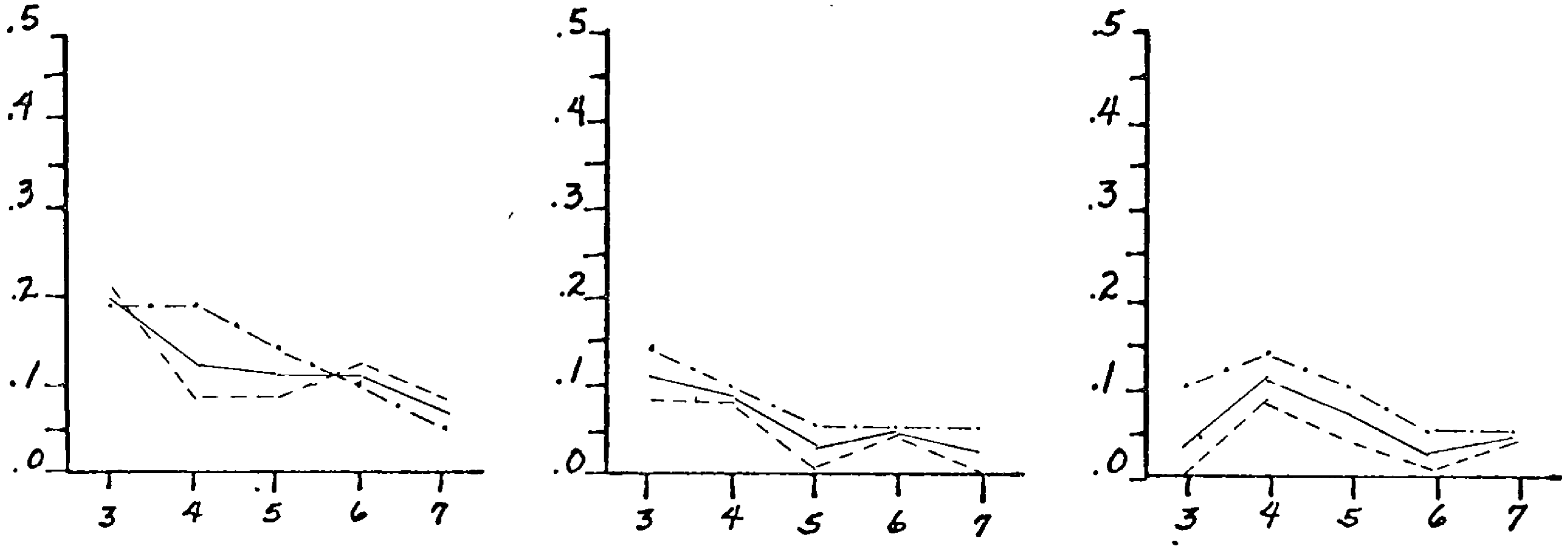

22. Dental

23. Alveolar

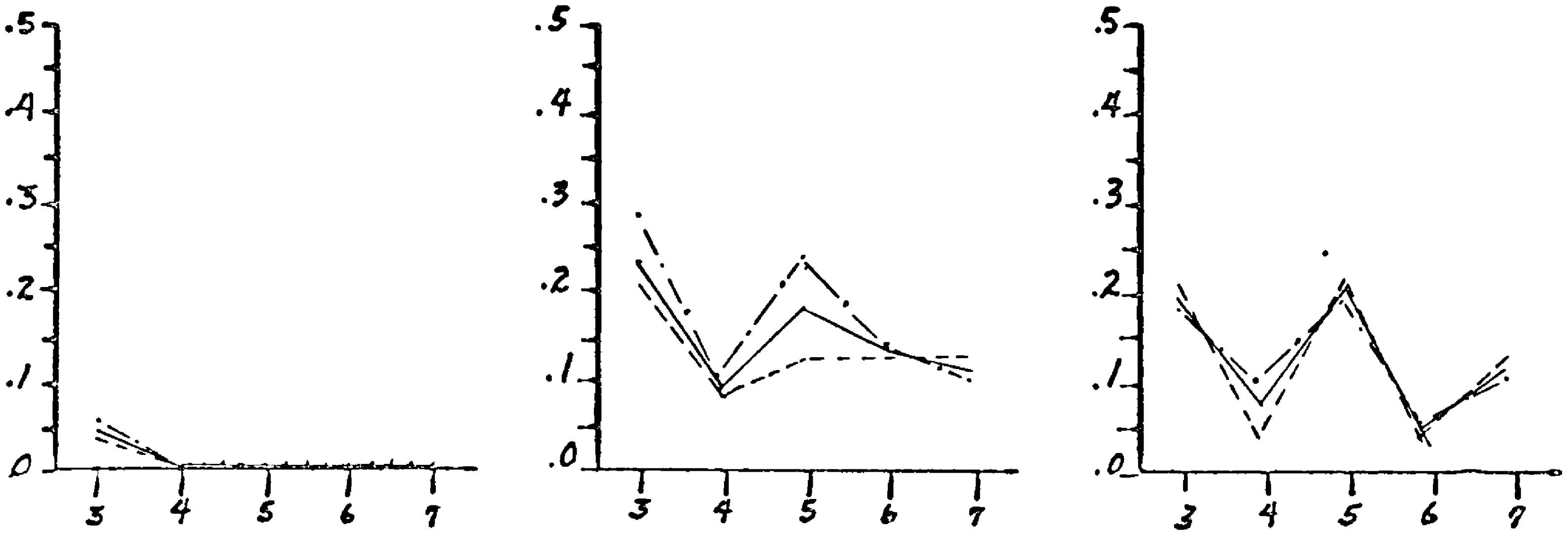
24. Palatal

Figures 25-30. Proportion of Errors per Feature by Age.

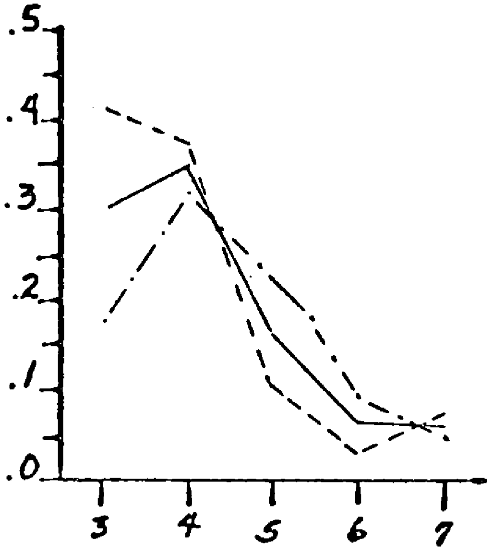

25. Velar 26. Glottal 27. Tongue tip


28. Tongue blade 29. Tongue dorsum 30. Forward

Figures 31-34. Proportion of Errors per Feature by Age.

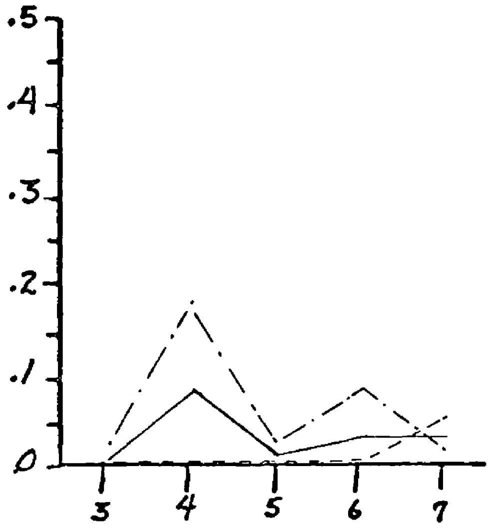

31. Retroflex 32. Groove width 33. Groove depth

34. Tongue elevation

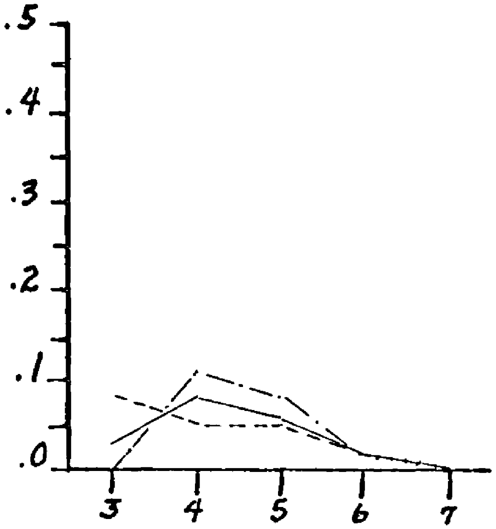


Figures 35-40. Proportion of Feature Errors per Phoneme by Age.

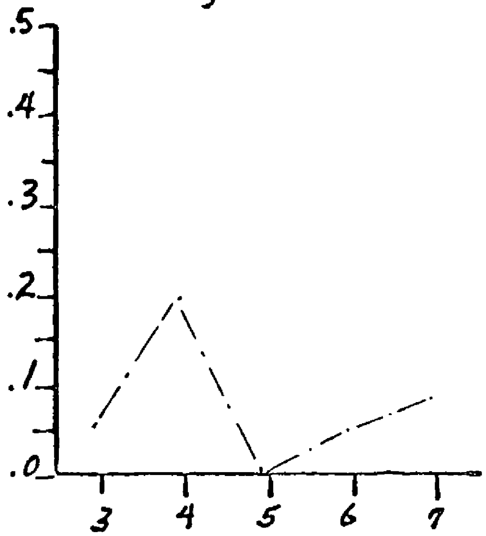
35. /m/



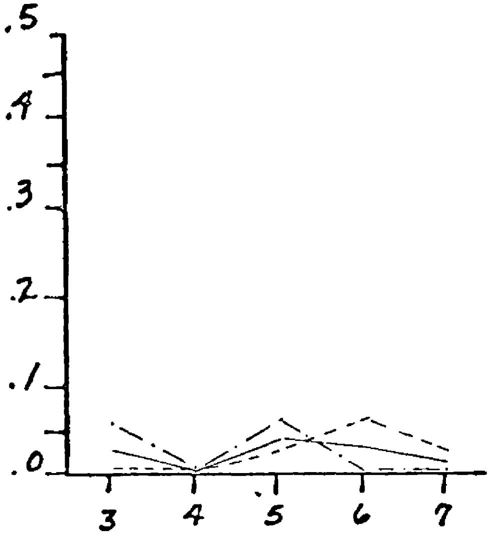
36. /n/



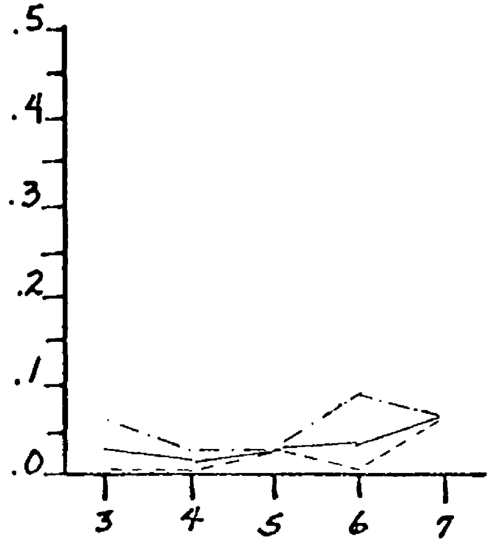
37. /ŋ/



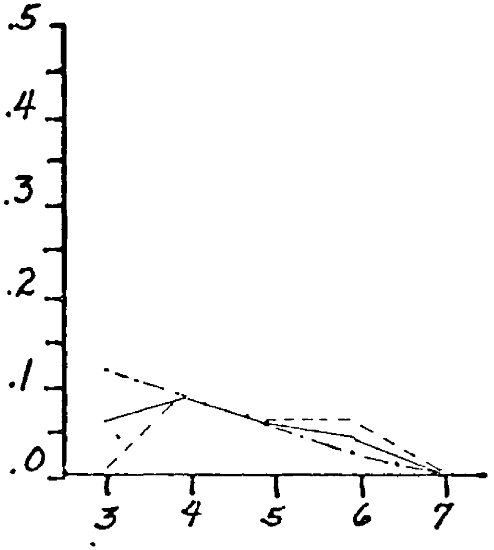
38. /p/



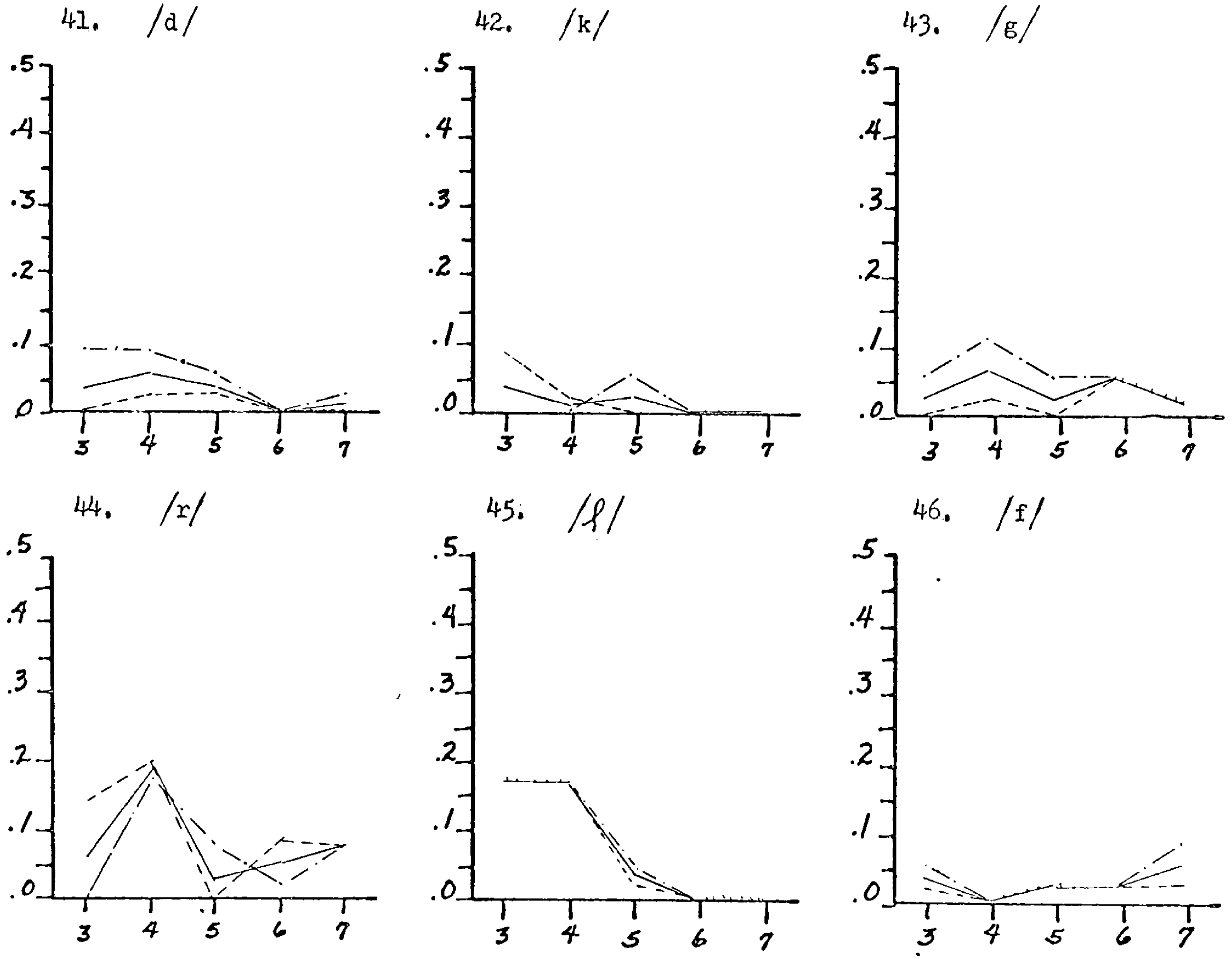
39. /b/



40. /t/

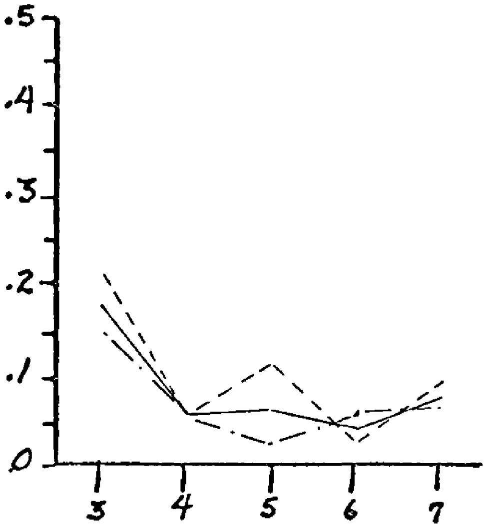


Figures 41-46. Proportion of Feature Errors per Phoneme by Age.

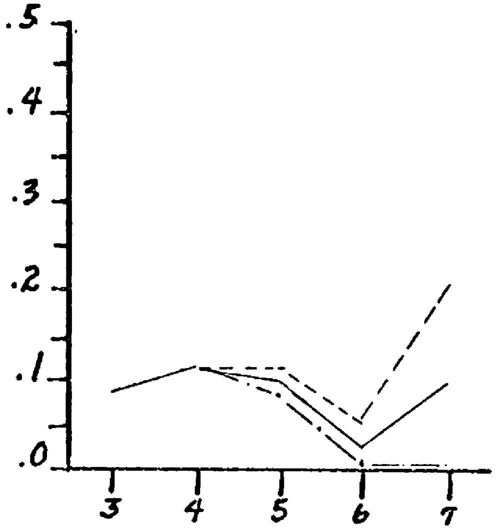


Figures 47-52. Proportion of Feature Errors per Phoneme by Age.

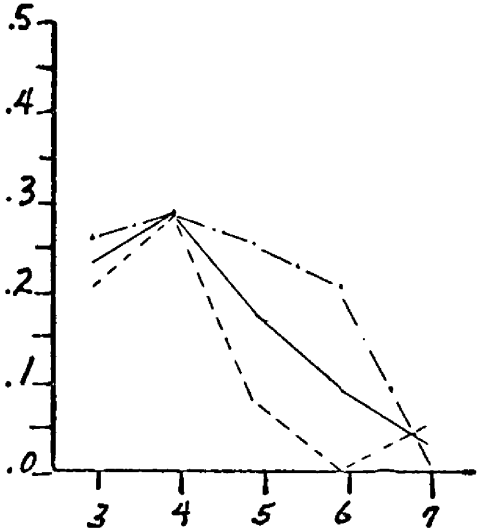
47. /v/



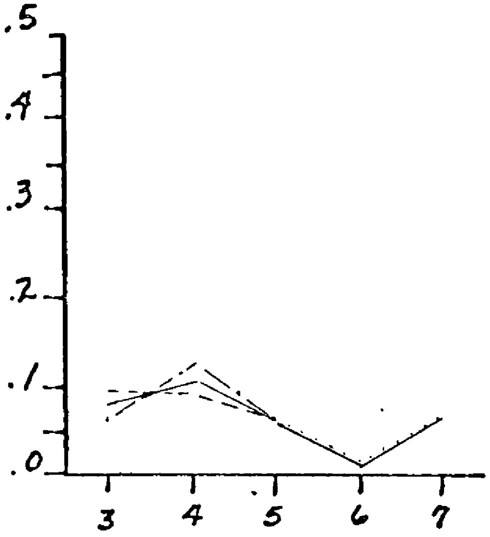
48. /θ/



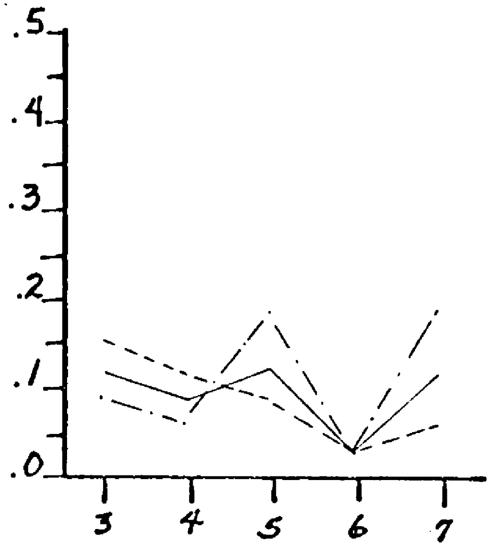
49. /ð/



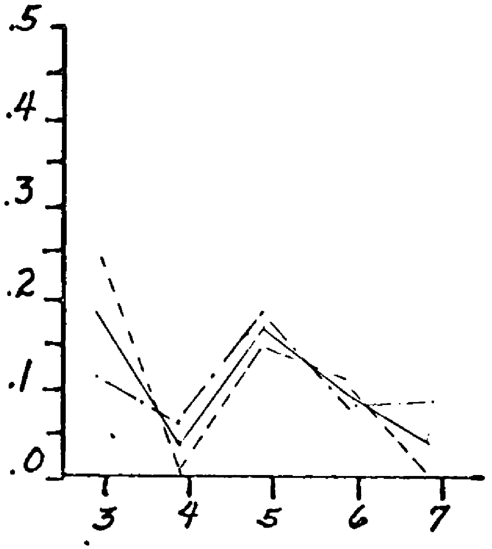
50. /s/



51. /z/

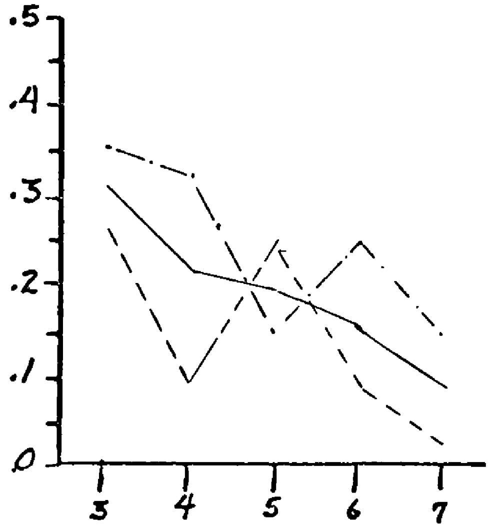


52. /ʃ/

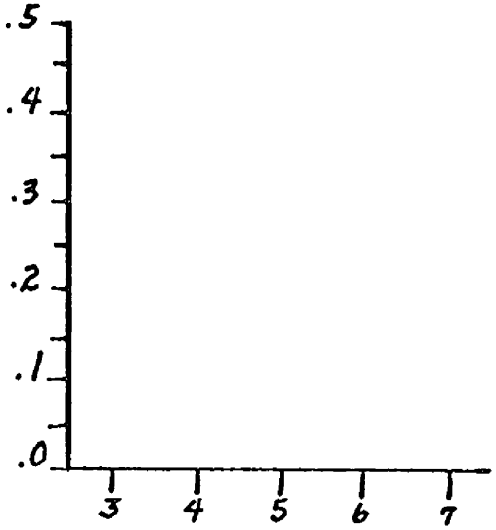


Figures 53-58. Proportion of Feature Errors per Phoneme by Age.

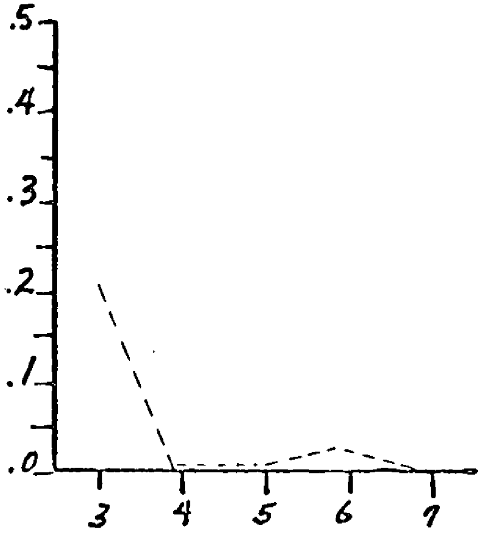
53. /ʒ/



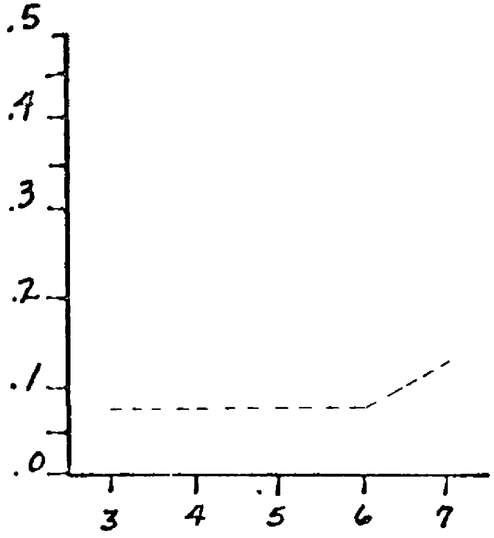
54. /h/



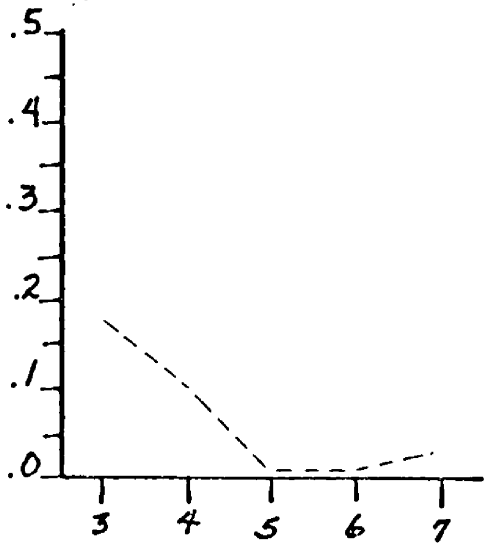
55. /w/



56. /M/



57. /j/



58. /tʃ/

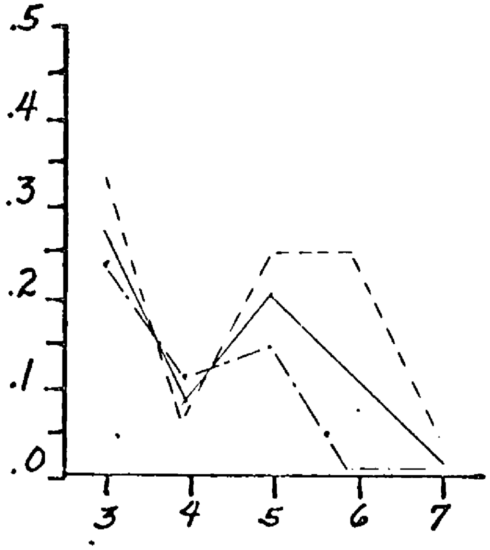
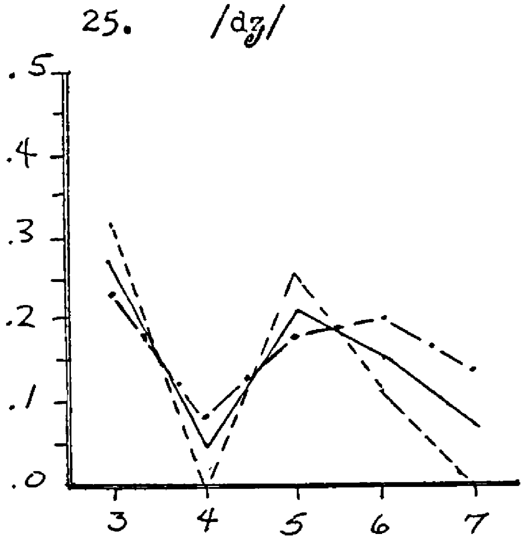


Figure 59. Proportion of Feature Errors per Phoneme by Age.



was divided by his total number of errors; the resulting proportions for each type of error were then graphed by age (Figure 60).

A similar process was used to divide the total errors into the following three categories: (1) hypertonic articulation, (2) hypotonic articulation, and (3) unable to classify. The number of each type of error for each phone for each child was then also counted and listed in an appropriate table. Proportions of each type of feature error for each age were then computed and the results graphed (Figure 61).

One final set of proportions was also computed. The total number of errors for each feature, for each phone, and for each child, were divided by the overall total of errors. These proportions were then ranked. These measures best indicated those features most often misproduced, those phonemes where the most feature errors occurred, and the overall decrease in feature errors with the age of the subjects.

USE OF TRADITIONAL AGE NORMS

Subjects were chosen in part for this study on the basis of the score they obtained on the *Templin-Darley Screening Test of Articulation*. Each child's score approached the mean score available on this test for each age group, and each child was felt to be reasonably representative of the age group he was chosen to represent. In the case of two subjects in particular, it is interesting to compare their *Templin-Darley Screening* scores with an overall summary of the sub-phonemic analysis of each.

The five-year-old subject obtained a score on the *Templin-Darley Screening Test* of 35, slightly higher than the mean for his age group of 34.7. Yet if one examines his articulatory proficiency as described

Figure 60. Feature Errors by Type. Categories of Substitution, Addition, Subtraction, Omission, Intrusion.

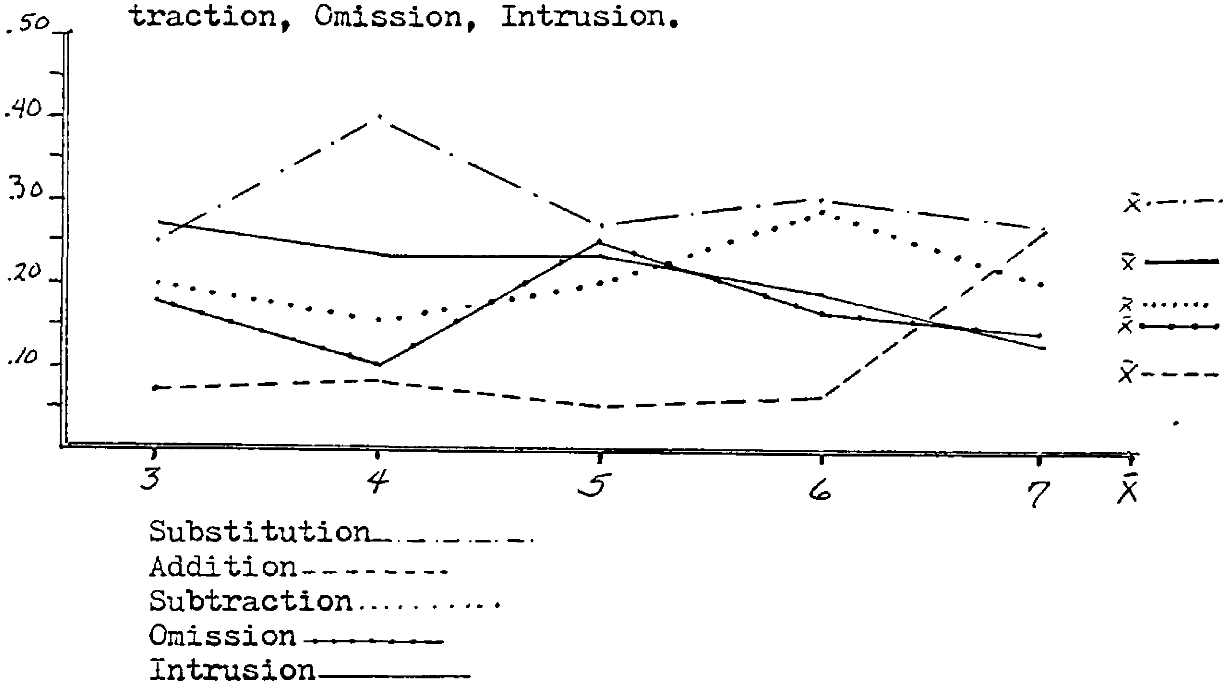
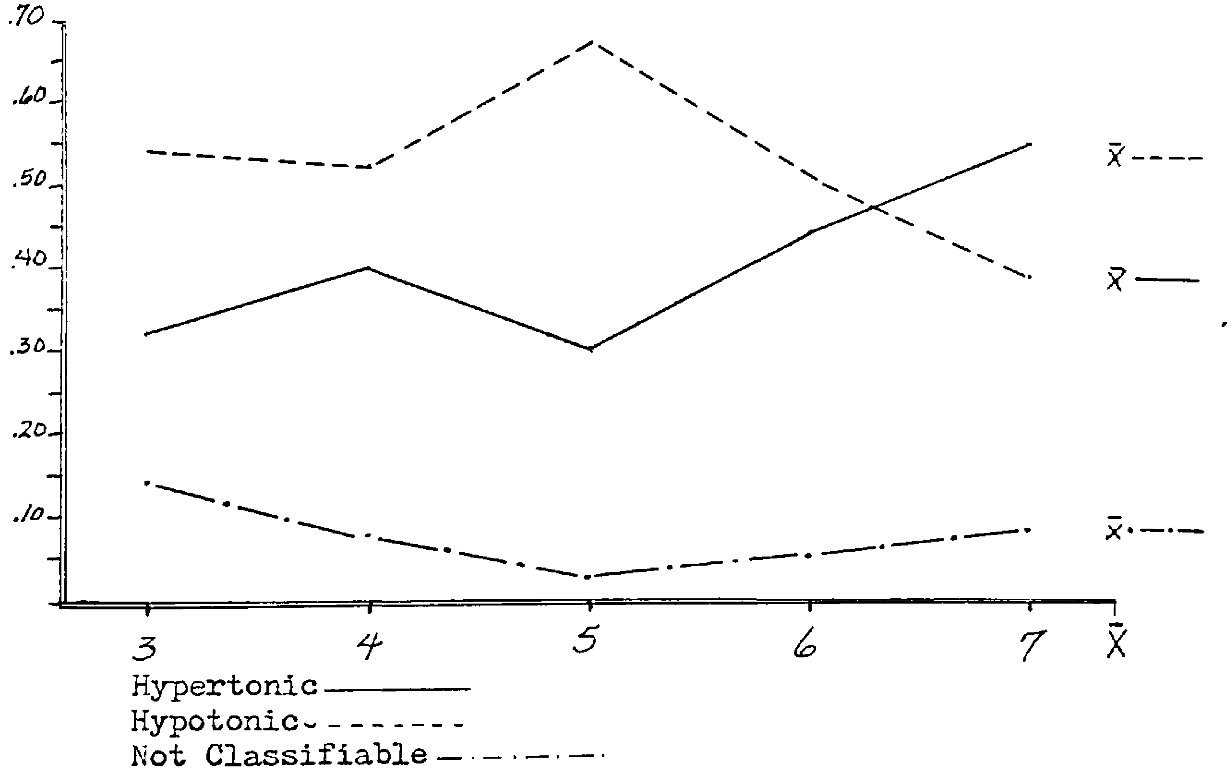


Figure 61. Feature Errors by Type. Categories of Hypertonic Articulation, Hypotonic Articulation, Not Classifiable.



sub-phonemically it becomes apparent that his articulation skills are better than expected from the Templin-Darley Screening Test score and that furthermore this score is due to a rather limited articulatory difficulty. If we examine the by-age graphing of errors on each articulatory feature, in several cases the generally decreasing slope of the graph is interrupted by a sharp dip at age five. For example, note the features of articulation tension, place-velar, voicing, central-lateral, etc. But, these graphs also reveal that this subject in particular had more difficulty with the following features than would be expected by an overall view: friction, place-labiodental, tongue tip, and groove width and depth. This child then appears to have unusual difficulty with labiodental and tongue-tip frictional sounds while his over-all articulation proficiency is better than the Templin-Darley Screening Test reveals.

The seven-year-old subject obtained a score on the Templin-Darley Screening Test of 48, higher than the mean for his age group, 44, and suggesting that his articulatory skills are slightly above average for his age. The graphs of articulatory feature errors by age, however, would suggest the contrary. In the case of several features, among them voicing, time-onset, time-offset, friction, and transition speed, this child had a higher proportion of errors than one would expect from the generally decreasing slope of the graphs.

Such interpretations suggest that traditional articulation tests and their accompanying norms, because of their lack of specificity, are not accurate in describing a child's articulatory proficiency. A child, such as our five-year-old subject, may have a limited articulation difficulty which becomes magnified by a gross error classification scheme. On the other hand such a scheme may not reveal specific though recurrent articulation difficulties, as with our seven-year-old subject.

GENERAL TRENDS

While only five subjects were used in this study, it is interesting to make certain generalizations about those five subjects and to suggest the usefulness of sub-phonemic articulation analysis for further generalizations. Further and more specific statistical analysis of the data obtained was not within the scope of this study.

As one would expect, feature errors graphed by feature or by phone reveal generally that as the age of the subject increases, the number of his errors on any one phone or with any one articulatory feature decreases. Partly because only five subjects' articulatory responses are summarized here, various exceptions to this general trend are apparent. We have already discussed some specific difficulties which the five- and seven-year-old subjects revealed. In addition, the six-year-old subject had a voice quality which would be described as slightly denasal; consequently his proportion of nasality feature errors is higher than would be expected. Both the five- and seven-year-old subjects revealed an unusual amount of difficulty with friction, the five-year-old because of his specific difficulty with labiodental sounds and the seven-year-old because of his missing upper lateral incisors.

The greatest proportion of feature errors across all subjects occurred with the features place-alveolar, tongue-tip, and tongue elevation. A large portion of the consonants in our language are tongue-tip alveolar sounds and this accounts in part for the large number of errors with these two features. In addition, if a place sub-feature or tongue part sub-feature were in error the child had usually erred by moving too far forward; that is, toward the alveolar ridge and toward the tip of the tongue. Finally, if tongue elevation were in error, the child tended to use an elevation lower than that called for, finding it difficult perhaps to move away from a neutral tongue position.

In analyzing the graphs of errors by age for individual features, one can see that features in syllable-initial phones and syllable-final phones may behave quite differently. For instance, no errors in time-offset were recorded for syllable-initial phones. Errors were present in syllable-final phones for this feature, particularly with the four- and seven-year-old subjects. One might hypothesize that as children are acquiring an increasingly complex phonological system and thus learning to regroup articulatory features, they will tend to trail off or prolong certain features at the end of words.

Errors in the time-onset feature occurred both syllable-initial and syllable-final. Here the subjects seemed to have the most difficulty turning voicing on at the appropriate time and affecting velo-pharyngeal closure at the appropriate time.

With both the occlusive and explosion features as well, syllable-initial phones seemed to behave independently of syllable-final phones. While these two features seemed to function together as one, their behavior syllable-initial and -final was such that initial and final errors cancelled themselves out, resulting in a generally decreasing slope.

COMPARISON OF TRADITIONAL AND SUB-PHONEMIC INFORMATION

For purposes of a more consistent comparison, only word-initial and word-final responses on those portions of the *Templin-Darley Diagnostic Test* administered will be referred to here in a discussion of the information obtained from this traditional articulation classification scheme and that obtained from sub-phonemic analysis by articulatory feature.

SEVEN-YEAR-OLD SUBJECT The oldest subject used in this study was judged to have the following errors using the *Templin-Darley* error categories: /f/ for /θ/ substitution initial and final, /ð/ distorted toward a /d/ initial, /s/ distorted both initial and final, and /w/ for /M/ substitution initial. All other articulation responses were judged to be correct. However, sub-phonemic analysis of his articulatory responses indicate that all but the following phonemes had some proportion of articulatory features in error: /n/, /t/, /k/, /l/, /h/, and /w/. Those phonemes, grossly judged to be correct, showed a variety of feature errors, but the following general patterns appeared: too much *articulation tension* and *lip retraction* were present on the right side for bilabial sounds; the lips were too far back on the teeth for labiodental sounds; all errors with *timing* involved *voicing*; all sibilants sounded as if the *tongue groove* were too wide and deep although this was due in fact to missing teeth; *transition speed* tended to be too slow on glides; and if *tongue elevation* were in error, it was usually too low.

SIX-YEAR-OLD SUBJECT The six-year-old subject produced all phonemes, initial and final, correctly on the portions of the *Templin-Darley Test of Articulation* administered with the exception of the following: /f/ distorted toward a /p/ initial; /w/ for /M/ substitution initial; and /ʃ/ for /tʃ/ substitution initial. Sub-phonemic analysis, however, revealed articulatory features in error on all but the following phonemes: /s/, /d/, /k/, /l/, /h/, and /j/. The following patterns appeared in his articulation responses: less *nasality* present than normal where expected; lenis /p/ and /t/ produced initially with insufficient *aspiration*; lips too far forward on the teeth for the labiodental phones; many sibilants produced with a *tongue groove* which was too narrow; if *place* where in error, it tended to be too far forward; *timing* errors usually involved *voicing*; less *lip rounding* than normally present where expected; and several instances were noted where voiceless cognates were substituted for voiced phones.

FIVE-YEAR-OLD SUBJECT Eleven articulation errors were noted in the speech of the five-year-old subject, as classified by the *Templin-Darley* error categories: /b/ for /v/ substitution initial; /v/ distorted toward an /f/ final; /s/ for /θ/ substitution initial; /θ/ distorted toward an /s/ final; /s/ for /ʃ/ substitution initial and final; /w/ for /M/ substitution initial; /l/ for /j/ substitution initial; /s/ for /tʃ/ substitution initial, and /dʒ/ distorted initial and final. However, sub-phonemic analysis indicated that articulatory feature errors were present for all but the following phones: /ŋ/, /h/, /w/, and /j/. Errors across the other phones had the following pattern: *labiodental* occlusion was present for bilabially produced /b/ and /p/; generally less *aspiration* was present than expected; there were very few errors with *voicing*, although most *timing* errors involved the *voicing* feature; little consistency was present in *tongue groove* and *tongue elevation* errors; single element sounds were substituted for most two element sounds; errors in *place* and *tongue part* were not consistent; unusual difficulty with *tongue groove*, *tongue tip*, and with *place*-*labiodental*.

FOUR-YEAR-OLD SUBJECT The four-year-old subject had the following errors as classified by the *Templin-Darley* categories: /w/ for /r/ substitution initial; /ŋ/ distorted toward a /k/ final; /θ/ distorted final; /ð/ distorted toward a /d/ initial; /w/ for /M/ substitution initial; /dʒ/ distorted toward a /ʒ/ initial; and /ʒ/ distorted toward a /dʒ/ final. This subject had sub-phonemic errors on all but the following phonemes: /h/, /w/, /p/, and /f/. The following factors characterize this subject's pattern of misarticulations; unusual difficulty with all *timing* sub-features; if *place* or *tongue part* was in error it was usually too far forward; *tongue elevation* was too low if in error usually; errors with *articulation tension* usually involved too much tension; and unusual difficulty was noted with *place-dental*.

THREE-YEAR-OLD SUBJECT The youngest subject used in this study had the following errors as classified by the Templin-Darley categories: /b/ for /v/ substitution initial; /s/ for /θ/ substitution initial; /d/ for /ð/ substitution initial; /ð/ distorted toward an /s/ final; /s/ for /ʃ/ substitution initial and final; /w/ for /M/ substitution initial; /j/ omitted initial; /s/ for /tʃ/ substitution initial; /tʃ/ distorted final; and /dʒ/ distorted final. As one might expect, this child had the most feature errors across all phones, with the following phones being the only ones he produced with no errors: /m/, and /h/. While for most features this subject had the highest proportion of errors, some patterns are still discernable in his articulatory responses: no errors with *time-onset*; fewer errors with *time-offset* than expected; fewer errors with *tongue shape-forward* than expected; an unusual difficulty with *articulation tension*; later learned sounds tended to be too far forward in the oral cavity; if *tongue elevation* was in error, it was usually too low.

CLASSIFICATION OF ERROR BY TYPE

All types of feature errors across all subjects were classified by type, using the two classification schemes previously discussed. That classification scheme which attempted to categorize all features as hypertonic or hypotonic articulation illustrates that for four of the five subjects, hypotonic articulation errors predominated. The exception to this is the seven-year-old subject who had more hypertonic errors of articulation than hypotonic. For some reason, the disparity between the proportion of hypertonic and hypotonic errors is greatest for the five-year-old subject. It is also interesting to note that if the points plotted for this subject on the graph were removed, hypertonic errors would appear to increase with age, while hypotonic errors would appear to decrease with age.

In general, it was found that a rather small static proportion of the subjects' errors were unclassifiable using this system.

It was possible to classify all 585 feature errors using the five categories of intruded feature, subtracted feature, substituted feature, added feature, and omitted feature. Across all subjects the highest proportion of errors fit into the substituted category; the only exception to this was the three-year-old subject. The other categories of errors ranked themselves in the following fashion under substitutions: intrusions, subtractions, omissions, and additions. Errors involving intruded features tended to decrease with age, while errors involving subtracted feature values tended to increase with age. For some reason, the four-year-old subject had a very high proportion of errors involving substituted feature values; in other words, he tended to employ the correct articulatory features but used a value for these features which was incorrect. On the other hand, the seven-year-old subject had a very high proportion of errors involving the addition of a higher value for a feature. This would tend to coincide with the above statement which indicates that this subject made more hypertonic articulation errors than hypotonic articulation errors.

Chapter 5

SUMMARY AND CONCLUSIONS

SUMMARY

Distinctive feature schemes have been developed by linguists and experimental phoneticians in their attempts to understand and describe both speech production and speech perception. The role of distinctive features in short-term memory of speech sounds, in a child's developing phonological system, in the development of speech-sound discrimination, as well as in the description and subsequent remediation of aberrant articulation responses have all been investigated. What was found lacking in previous research, however, was a procedure for the detailed sub-phonemic analysis of articulatory responses using distinctive features or articulatory attributes with a specifically motor-articulation basis.

Traditional articulation testing has proven inadequate in providing sufficiently specific information concerning a child's phonological system. Sub-phonemic analysis offered a means by which such information could be obtained. Thus the purposes of this study were to develop a useful scheme of articulatory attributes and a procedure for their use as well as to demonstrate the advantages of using such a scheme to describe articulation over the use of traditional error classification schemes.

The articulatory responses of five subjects, ages three to seven, were analyzed in this study. Each child used as a subject had articulation skills typical for his age group, as measured by the <u>Templin-Darley Screening Test of Articulation</u>. Each subject was administered portions of the Templin-Darley Diagnostic Test of Articulation and a picture-word articulation test developed by the experimenter. Twenty-five English consonants were tested in single-word responses. All articulatory responses for each subject were video-taped; these responses were later reviewed and described, using the traditional error categories on the portions of the Templin-Darley Test and a scheme of articulatory attributes developed by the experimenter on the test devised for this study. Information concerning each subject's responses on both of the two tests administered was then summarized.

DISCUSSION AND CONCLUSIONS

It was found that traditional articulation error classification schemes do not provide necessarily precise views of a child's general articulation skills and that they tend to magnify limited problem areas and not reveal wide-spread though small articulation problems. Sub-phonemic description of subjects' articulation responses provided more information concerning the child's articulatory proficiency and also revealed patterns present throughout any one child's articulation responses, and across all of the subjects' responses. Such descriptions could be of diagnostic significance in determining if a child's aberrant articulation patterns are maturational or will require remediation.

In general, as age increased, errors per articulatory attribute or phoneme tested decreased. While the articulatory responses of only five children were analyzed in this research, it is interesting to investigate the exceptions to this general trend. Our six-year-old subject had a voice quality characterized by hyponasality and consequently his proportion of errors with the attribute nasal was higher than expected.

Using the traditional error classification scheme, there is no means by which this voice quality can be accurately described; that is, both its nature and its severity. The use of sub-phonemic analysis using some sort of articulatory attribute might therefore prove to be useful in the analysis of and subsequent remediation of aberrant vocal qualities.

One subject, the five-year-old, was found through sub-phonemic description to have articulation skills generally better than preliminary testing indicated. A specific area of articulatory difficulty, labiodental fricatives, was identified in this child. The in-depth description of this child's production of these phonemes is exemplary of how sub-phonemic analysis of aberrant articulation responses can be helpful in the therapeutic process. His misarticulations involved errors with the following features: friction, labiodental, tongue tip, and groove width and depth. Such information could be of great value to the speech clinician planning and implementing a program of therapy with this child. Rather than teaching each phoneme as a whole, she could identify those specific articulatory attributes in error and instruct the child in their correct production, providing for a more efficient therapeutic program. However, further research, using perhaps groups of children with speech disorders and therapists matched as closely as possible, is required to determine if the additional information provided by sub-phonemic analysis is actually valuable to the remediation process.

Certain other general trends are apparent in the summary of articulatory attribute errors for the five subjects. With some features in particular, it is interesting to note that features may behave quite differently in syllable-initial phones and in syllable-final phones. For example, it was found that with syllable-final phones, the children seemed to have some difficulty turning all of the feature package off at the same time, while in syllable-initial phones this difficulty did not appear. It might be suggested that as children are acquiring an increasingly complex phonological system, trailing off at the ends of words is one means by which they may practice certain features.

While relatively few errors with the *voicing* feature were noted across all subjects, all of the children seemed to have the most difficulty with the *timing* of this feature. Menyuk (1968) has indicated that *voicing* is one of the earliest learned features in the developmental process; thus a large proportion of errors would not be expected with this feature. Perhaps the subjects' difficulty with the timing of this feature is as Crocker (1969) suggests, due to the child's difficulty in removing a learned feature from a particular feature package and placing it properly in a newly acquired feature package, or perhaps *voicing* is not learned as early as Menyuk suggests.

As previously discussed, we found that the greatest proportion of feature errors across all subjects occurred with the features *alveolar*, *tongue tip*, and *tongue elevation*. While the proportion of errors with *alveolar* and *tongue tip* are not unexpected considering the great number of tongue-tip alveolar phonemes in the English phonological system, it is interesting to note that where errors existed with other *place* or *tongue part* features, the child usually erred by moving too far forward in the oral cavity; that is, toward the alveolar ridge and toward the tip of the tongue. When a child is in doubt as to where any particular phoneme should be produced, it appears that he will tend to move forward to the familiar place of tongue-tip alveolar. Most errors with *tongue elevation* would also suggest that when a child is acquiring an increasingly complex phonological system, when he is in doubt about the correct tongue height for a particular phoneme, he will tend to stray downward toward the neutral position for the tongue.

Classification of feature errors by type of error was completed, using two classification schemes. That scheme which attempted to describe all feature errors as hypertonic or hypotonic articulation, proved to be the most informative. It was found that as age increases, hypertonic articulation errors increase and hypotonic articulation errors decrease. One might suggest that the apparent shift from hypotonic to hypertonic articulation errors with age found with these five subjects is representative of most children developing toward an adult phonological system. As they are acquiring a more complex system, involving more articulatory attributes and more combinations of these attributes, children seem to be somewhat slow and lazy in their articulation efforts. However, as they become more adept at producing the required features in correct combinations their articulation efforts are more vigorous and exact.

While it was not the purpose of this research to establish either the reliability or validity of the feature scheme developed, a limited investigation of the reliability of the use of the scheme was conducted. In addition, later research (Heaton, 1971) provides us with additional information concerning both the reliability and validity of certain of the articulatory attributes developed in the present study. Relatively acceptable reliability and validity were found for most articulatory attributes; where reliability and validity were not acceptable, this was generally felt due to inadequate judge training procedures. If the sub-phonemic analysis of articulation responses is to become an instrument useful clinically for both diagnostic and therapeutic reasons, additional research is needed in the area of training in the use of sub-phonemic description schemes. The fine discriminatory decisions and the phonetic background required of the listener using such a scheme must be provided for in the training procedure.

The scheme of articulatory attributes and the procedure for its implementation in the description of articulation responses allow for an extremely specific analysis of articulation. It is more time-consuming to complete sub-phonemic analysis of articulation responses, but with the eventual standardization of such a scheme and procedure for its use, it could prove to be a highly useful clinical tool that speech clinicians could be readily trained to use. However, further research is needed to explore several areas. While both auditory and optical information were used in this study in the analysis of articulatory responses, the greatest use was made of auditory information. The comparative validity and reliability of analyses made using both auditory and optical information and auditory information alone should be determined. The possible usefulness of sub-phonemic articulation description for both diagnostic and therapeutic purposes has been suggested. While this study was concerned with the articulation responses of children with articulation skills typical for their age, future studies could investigate children and adults with known articulation or vocal disorders. The therapeutic application of such articulation descriptions should also be further investigated, stressing perhaps therapeutic approaches useful in the remediation of particular patterns of feature errors. Obviously, if sub-phonemic analysis of articulation responses is to become a procedure which is clinically useful, standardized norms for a scheme of articulatory attributes such as was developed by this research must be established. Hopefully too, such research would increase our present body of knowledge concerning the development of articulation skills.

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APPENDIX A

Table 11. Subject Information.

Age	Birthdate	Score - Templin-Darley Screening	Mean for Age Group	Standard Deviation for Age Group
3	4/24/67	14	22.5	13.5
4	4/12/66	35	34.7	11.2
5	5/20/65	35	34.7	14.5
6	5/15/64	46	38.5	13.8
7	4/18/63	48	44.0	8.4

APPENDIX B

Table 12. Words Elicited in
Test Designed by Experimenter.

Phoneme	Initial Position	Final Position
/m/	milk	drum
/n/	nail	train
/ŋ/		swing
/p/	pie	cup
/b/	bed	bib
/t/	tie	boot
/d/	dog	bread
/k/	cow	cake
/g/	gun	pig
/r/	ring	star
/l/	lion	bell
/f/	foot	leaf
/v/	vase	stove
/θ/	thumb	mouth
/ð/	there	smooth
/s/	sun	bus
/z/	zebra	nose
/ʃ/	shoe	fish
/ʒ/	television	garage
/h/	horse	
/w/	worm	
/ʍ/	wheel	
/j/	yo-yo	
/tʃ/	chair	watch
/dʒ/	jar	cage

APPENDIX C

Table 13. Number of Errors per Articulatory Attribute per Child. Syllable-initial, Syllable-final, and Total.

Articulatory Attribute	Three			Four			Five			Six			Seven					
	I	F	T	I	F	T	I	F	T	I	F	T	I	F	T	T	F	T
1. Voicing	3	5	8	2	4	6	1	2	3	0	3	3	1	4	5	7	18	25
2. Time-onset	0	0	0	1	2	3	1	0	1	1	1	2	3	0	3	6	3	9
Time-offset	0	1	1	0	6	6	0	4	4	0	2	2	0	5	5	0	18	18
Time-duration	0	3	3	0	5	5	2	2	4	0	2	2	1	0	1	3	12	15
3. Initiating	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nucleus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Terminating	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1
4. Central-Lateral	1	1	2	1	1	2	0	0	0	1	0	1	0	0	0	3	2	5
Expir.-Inspir.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5. Occlusive	6	1	7	1	3	4	3	1	4	1	3	4	2	1	3	13	9	22
Explosion	6	1	7	1	4	5	3	1	4	1	2	3	0	2	2	11	10	21
Aspiration	3	1	4	0	2	2	2	2	4	3	0	3	1	0	1	9	5	14
6. Nasal	1	0	1	0	1	1	2	1	3	1	3	4	0	1	1	4	6	10
7. Fricative	7	8	15	4	5	9	6	3	9	2	2	4	4	2	6	23	20	43
8. Trans. Speed	3	1	4	1	1	2	0	0	0	0	0	0	2	0	2	6	2	8
9. Artic. Tension	8	9	17	4	3	7	1	0	1	2	0	2	2	3	5	17	15	32
1. Rounded	6	3	9	2	2	4	2	2	4	0	3	3	0	0	0	13	7	20
Retracted	2	0	2	0	0	0	0	0	0	0	1	1	1	0	1	3	1	4
2. Bilabial	2	0	2	2	0	2	1	1	2	1	0	1	0	0	0	6	1	7
Labiodental	0	2	2	1	1	2	3	6	9	1	3	4	3	2	5	8	14	22
Interdental	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dental	0	0	0	2	1	3	1	1	2	0	0	0	0	0	0	3	2	5
Alveolar	9	5	14	4	6	10	6	5	11	4	3	7	0	2	2	23	21	44
Palatal	5	4	9	2	4	6	2	3	5	3	2	5	2	2	4	14	15	29
Velar	2	3	5	2	3	5	0	1	1	1	1	2	0	1	1	5	9	14
Glottal	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
3. Tongue Tip	6	6	12	6	8	14	8	9	17	4	4	8	1	1	2	25	28	53
Blade	5	4	9	2	4	6	2	3	5	3	2	5	2	1	3	14	14	28
Dorsum	2	3	5	2	2	4	0	1	1	1	1	2	0	1	1	5	8	13
4. Tongue Forward	0	2	2	2	3	5	1	2	3	0	1	1	1	1	2	4	9	13
Retroflex	1	1	2	0	0	0	0	0	0	0	0	0	0	1	1	1	2	3
Groove Width	5	6	11	2	2	4	3	5	8	3	3	6	3	2	5	16	18	34
Groove Depth	5	4	9	1	2	3	5	4	9	1	1	2	3	2	5	15	13	28
5. Tongue Elevation	10	4	14	9	7	16	3	5	8	1	2	3	2	1	3	25	19	44
Totals	99	78	177	55	82	137	58	64	122	34	42	80	34	35	69	284	301	585

(I - syllable-initial, F - syllable-final, T - total)

Table 14. Proportion of Errors per Articulatory Attribute for each Child. Syllable-initial, Syllable-final, and Total.

	AGE															TOTAL		
	3			4			5			6			7					
Manner features	I	F	T	I	F	T	I	F	T	I	F	T	I	F	T	N=120	N=105	N=225
1. Voicing	.13	.24	.18	.08	.19	.13	.04	.10	.07	.0	.14	.07	.04	.19	.11	.06	.17	.11
2. a. Time onset	0	0	0	.04	.10	.07	.04	0	.02	.04	.05	.04	.13	0	.07	.05	.03	.04
b. Time offset	0	.05	.02	0	.29	.13	0	.19	.09	0	.10	.04	0	.24	.11	0	.17	.08
c. Time duration	0	.14	.07	0	.24	.11	.08	.10	.09	0	.10	.04	.04	0	.02	.03	.11	.07
3. a. Initiating	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.0 0	.0 0	.0 0
b. Nucleus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.0 0	.0 0	.0 0
c. Terminating	0	0	0	.04	0	.02	0	0	0	0	0	0	0	0	0	.01	0 0	0 0
4 a. central-lateral	.04	.05	.04	.04	.05	.04	0	0	0	.04	0	.02	0	0	0	.03	.02	.02
b. expir. - inspir.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0 0	0 0	0 0
5. Occlusion	25	.05	.16	.04	.14	.09	.13	.05	.09	.04	.14	.09	.08	.05	.07	.11	.08	.10
a. Explosion	25	.05	.16	.04	.19	.11	.13	.05	.09	.04	.10	.07	0	.10	.04	.09	.09	.09
b. Aspiration	.13	.05	.09	0	.10	.04	.08	.10	.09	.13	0	.07	.04	0	.02	.08	.05	.06
6. Nasal	.04	0	.02	0	.05	.02	.08	.05	.07	.04	.14	.09	0	.05	.02	.03	.06	.04
7. Fricative	.29	.38	.33	.21	.19	.20	.25	.14	.20	.08	.10	.09	.17	.10	.13	.19	.19	.19
8. Transition speed	.13	.05	.09	.04	.05	.04	0	0	0	0	0	0	.08	0	.04	.05	.02	.04
9. Artic. tension	.33	.43	.36	.17	.14	.16	.04	0	.02	.08	0	.04	.08	.14	.11	.14	.14	.14
Spatial features																		
1. a. Rounded	.25	.14	.20	.08	.16	.09	.08	.10	.09	.13	0	.07	0	0	0	.11	.07	.09
b. Retracted	.08	0	.04	0	0	0	0	0	0	0	.05	.02	.04	0	.02	.03	.01	.02
2. a. Bilabial	.08	0	.04	.08	0	.04	.04	.05	.04	.04	0	.02	0	0	0	.05	.01	.03
b. Labiodental	0	.10	.04	.04	.05	.04	.13	.29	.20	.04	.14	.09	.13	.10	.11	.07	.13	.10
c. Interdental	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0 0	0 0	0 0
d. Dental	0	0	0	.08	.05	.07	.04	.05	.04	0	0	0	0	0	0	.03	.02	.02
e. Alveolar	.38	.24	.31	.17	.29	.22	.25	.24	.24	.17	.14	.16	0	.10	.04	.19	.20	.20
f. Palatal	.21	.19	.20	.08	.19	.13	.08	.14	.11	.13	.10	.11	.08	.10	.09	.12	.14	.13
g. Velar	.08	.14	.11	.08	.14	.11	0	.05	.02	.04	.05	.04	0	.05	.02	.04	.09	.06
h. Glottal	.04	0	.02	0	0	0	0	0	0	0	0	0	0	0	0	.01	0 0	0 0
3. a. Tip	.29	.25	.27	.25	.38	.31	.33	.43	.38	.17	.19	.18	.04	.05	.04	.21	.27	.24
b. Blade	.21	.19	.20	.08	.19	.13	.08	.14	.11	.13	.10	.11	.08	.05	.07	.12	.13	.12
c. Dorsum	.08	.14	.11	.08	.10	.09	0	.05	.02	.04	.05	.04	0	.05	.02	.04	.08	.06
4. a. Forward	0	.10	.04	.08	.14	.11	.04	.10	.07	0	.05	.02	.04	.05	.04	.03	.09	.06
b. Retroflex	.04	.05	.04	0	0	0	0	0	0	0	0	0	0	.05	.02	.01	.02	.01
c. width	.21	.29	.24	.08	.10	.09	.13	.24	.18	.13	.14	.13	.13	.10	.11	.13	.17	.15
d. Depth	.21	.19	.20	.04	.10	.07	.21	.19	.20	.04	.05	.04	.13	.10	.11	.13	.12	.12
5. Elevation	.42	.19	.31	.38	.33	.36	.13	.24	.18	.04	.10	.07	.08	.05	.07	.21	.18	.20

Table 15. Total Proportion of Errors per Feature in Rank Order

Articulatory Attribute	Proportion of Total Errors
Tongue Tip	.09
Alveolar	.08
Tongue Elevation	.08
Fricative	.07
Articulator Tension	.06
Groove Width	.06
Palatal	.05
Tongue Blade	.05
Groove Depth	.05
Voicing	.04
Occlusive	.04
Explosion	.04
Labiodental	.04
Time-Offset	.03
Time-Duration	.03
Lips Rounded	.03
Time-Onset	.02
Aspiration	.02
Nasal	.02
Velar	.02
Tongue Dorsum	.02
Tongue Forward	.02
Central-Lateral	.01
Transition Speed	.01
Lips Retracted	.01
Bilabial	.01
Dental	.01
Tongue Retroflex	.01
Function-Initiating	.00
Function-Nucleus	.00
Function-Terminating	.00
Interdental	.00
Glottal	.00

APPENDIX D

Table 16. Number of Feature Errors per Phoneme for each Child. Syllable-initial, -final and Total.

Phoneme	Three			Four			Five			Six			Seven					
	I	F	T	I	F	T	I	F	T	I	F	T	I	F	T	I	F	T
/m/	0	1	1	0	6	6	0	1	1	0	3	3	2	1	3	1	12	14
/n/	3	0	3	2	4	6	2	3	5	1	1	2	0	0	0	8	8	16
/ŋ/	-	2	2	-	7	7	-	0	0	-	2	2	-	3	3	-	14	14
/p/	0	2	2	0	0	0	1	2	3	2	0	2	1	0	1	4	4	8
/b/	0	2	2	0	1	1	1	1	2	0	3	3	2	2	4	3	9	12
/t/	0	4	4	3	3	6	2	2	4	2	1	3	0	0	0	7	10	17
/d/	0	3	3	1	3	4	1	2	3	0	0	0	0	1	1	2	9	11
/k/	3	0	3	1	0	1	0	2	2	0	0	0	0	0	0	4	2	6
/g/	0	2	2	1	4	5	0	2	2	2	2	4	1	1	2	4	11	15
/r/	5	0	5	7	6	13	0	3	3	3	1	4	3	3	6	18	13.	31
/l/	6	6	12	6	6	12	1	2	3	0	0	0	0	0	0	13	14	27
/f/	1	2	3	0	0	0	1	1	2	1	1	2	1	3	4	4	7	11
/v/	7	5	12	2	2	4	4	1	5	1	2	3	3	2	5	17	12	29
/θ/	3	3	6	4	4	8	4	3	7	2	0	2	7	0	7	20	10	30
/ð/	7	9	16	10	10	20	3	9	12	0	7	7	2	1	3	22	36	58
/s/	3	2	5	3	4	7	2	2	4	0	0	0	2	2	4	10	10	20
/z/	5	3	8	4	2	6	3	6	9	1	1	2	2	6	8	15	18	33
/ʃ/	9	4	13	0	2	2	5	6	11	4	3	7	0	0	0	18	15	33
/ʒ/	9	12	21	3	11	14	8	5	13	3	8	11	1	5	6	24	41	65
/h/	0	-	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-	0
/w/	7	-	7	0	-	0	0	-	0	1	-	1	0	-	0	8	-	8
/M/	2	-	2	2	-	2	2	-	2	2	-	1	4	-	4	12	-	12
/j/	6	-	6	4	-	4	0	-	0	-	0	-	1	-	1	11	-	11
/tʃ/	12	8	20	2	4	6	9	5	14	9	0	9	2	0	2	34	17	51
/dʒ/	11	8	19	0	3	3	9	6	15	4	7	11	0	5	5	24	29	53
Totals	99	78	177	55	82	137	58	64	122	38	42	80	34	35	69	284	301	585

(I - syllable-initial, F - syllable-final,
T - total)

Table 17. Proportion of Feature Errors per Phoneme for each Child. Syllable-initial, -final, and Total.

	3			4			5			6			7			Total		
	I	F	T	I	F	T	I	F	T	I	F	T	I	F	T	N=170	N=17	N=34
m	0	.03	.01	0	.18	.09	0	.03	.01	0	.09	.04	.06	.03	.04	.01	.07	.04
n	.09	0	.04	.06	.12	.09	.06	.09	.07	.03	.03	.03	0	0	0	.05	.05	.05
ŋ	—	.06	.03	—	.21	.21	—	0	0	—	.06	.06	—	.09	.09	—	.08	.08
p	0	.06	.03	0	0	0	.03	.06	.04	.06	0	.03	.03	0	.01	.02	.02	.02
b	0	.06	.03	0	.03	.01	.03	.03	.03	0	.09	.04	.06	.06	.06	.02	.05	.04
t	0	.12	.06	.09	.09	.09	.06	.06	.06	.06	.03	.04	0	0	0	.04	.06	.05
d	0	.09	.04	.03	.09	.06	.03	.06	.04	0	0	0	0	.03	.01	.01	.05	.03
k	.09	0	.04	.03	0	.01	0	.06	.03	0	0	0	0	0	0	.02	.01	.01
g	0	.06	.03	.03	.12	.07	0	.06	.03	.06	06	.09	.03	.03	.03	.02	.06	.04
r	.15	0	.07	.21	.18	.19	.0	.09	.04	.09	.03	.06	.09	.09	.09	.11	.08	.09
ℓ	.18	.18	.18	.18	.18	.18	.03	.06	.04	0	0	0	0	0	0	.08	.08	.08
f	.03	.06	.04	0	0	0	.03	.03	.03	.03	.03	.03	.03	.09	.06	.02	.04	.03
v	.21	.15	.18	.06	.06	.06	.12	.03	.07	.03	.06	.04	.09	.06	.07	.10	.07	.09
θ	.09	.09	.09	.12	.12	.12	.12	.09	.10	06	0	.03	.21	0	.10	.12	.06	.09
ð	.21	.26	.24	.29	.29	.29	.09	.26	.18	.0	.21	.10	.06	.03	.04	.15	.21	.17
s	.09	.06	.07	.09	.12	.10	.06	.06	.06	0	0	0	.06	.06	.06	.06	.06	.06
z	.15	.09	.12	.12	.06	.09	.09	.18	.13	.03	.03	.03	.06	.18	.12	.09	.11	.10
ʃ	26	.12	.19	.0	.06	.03	.15	.18	.16	.12	.09	.10	0	.09	.04	.11	.09	.10
ʒ	.26	.35	.31	.09	.32	.21	.24	.15	.19	.09	.24	.16	.03	.15	.09	.14	.24	.19
h	0	—	0	0	—	0	0	—	0	0	—	0	0	—	0	0	—	0
w	.21	—	.21	0	—	0	0	—	0	.03	—	.03	0	—	0	.05	—	.05
ʍ	.06	—	06	.06	—	.06	.06	—	.06	.06	—	.06	.12	—	.12	.07		.07
j	.15	—	.18	12	—	.12	0	—	0	0	—	0	.03	—	.03	.06	—	[illegible]
tʃ	.35	.24	.29	.06	.12	.09	.26	.15	.31	.26	0	.15	.06	0	.03	.20	.10	.15
dʒ	.32	.24	.28	0	.09	.04	.26	.18	.22	.12	.21	.16	0	.15	.07	.14	.17	.16

Table 18. Total Proportion of Errors per Phoneme in Rank Order

Phoneme	Proportion of Total Errors
/ʒ/	.11
/ð/	.10
/t /	.09
/dʒ/	.09
/z/	.06
/ʃ/	.06
/r/	.05
/l/	.05
/v/	.05
/θ/	.05
/n/	.03
/t/	.03
/g/	.03
/s/	.03
/m/	.02
/ŋ/	.02
/b/	.02
/d/	.02
/f/	.02
/M/	.02
/j/	.02
/p/	.01
/k/	.01
/w/	.01
	.00

APPENDIX E

Table 19. Number of Feature Errors by Type.
Hypertonic, Hypotonic, and Not Classifiable.

Phoneme	Three			Four			Five			Six			Seven		
	Hyper	Hypo	NC	Hyper	Hypo	NC	Hyper	Hypo	NC	Hyper	Hypo	NC	Hyper	Hypo	NC
/m/	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
	0	1	0	4	1	1	1	0	0	2	1	0	1	0	0
/n/	1	2	0	2	0	0	2	0	0	3	1	0	0	0	0
	0	0	0	2	2	0	0	3	0	0	1	0	0	0	0
/ŋ/	0	2	0	2	5	0	0	0	0	1	1	0	1	2	0
/p/	0	0	0	0	0	0	1	0	0	0	2	0	0	1	0
	0	2	0	0	0	0	1	1	0	0	0	0	0	0	0
/b/	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0
	1	1	0	0	1	0	1	0	0	1	2	0	2	0	0
/t/	0	0	0	2	1	0	1	1	0	0	2	1	1	1	1
	2	2	0	2	1	0	1	1	0	1	0	0	0	0	0
/d/	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
	1	1	1	1	2	0	2	0	0	0	0	0	0	1	0
/k/	0	2	1	0	0	1	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
/g/	0	0	0	1	0	0	0	0	0	2	0	0	0	1	0
	0	1	1	1	3	0	0	1	1	2	0	0	0	1	0
/r/	1	4	0	3	3	1	0	0	0	0	3	0	0	3	0
	0	0	0	0	6	0	2	1	0	0	1	0	2	1	0
/l/	2	2	2	2	3	1	0	1	0	0	0	0	0	0	0
	1	3	2	1	4	1	1	1	0	0	0	0	0	0	0
/f/	0	1	0	0	0	0	0	1	0	0	1	0	1	0	0
	0	2	0	0	0	0	0	1	0	0	1	0	2	0	1
/v/	5	2	0	1	1	0	4	0	0	1	0	0	2	1	0
	3	2	0	0	2	0	0	0	1	0	1	1	1	1	0
/θ/	1	2	0	2	2	0	2	2	0	0	1	1	1	6	0
	1	2	0	3	1	0	2	1	0	0	0	0	0	0	0
/ð/	4	3	0	4	6	0	1	2	0	0	0	0	1	1	0
	1	7	1	3	7	0	3	6	0	2	5	0	0	0	1
/s/	1	2	0	0	3	0	0	2	0	0	0	0	2	0	0
	2	0	0	1	3	0	0	2	0	0	0	0	2	0	0
/z/	3	1	1	1	3	0	1	2	0	0	1	2	2	0	0
	2	0	1	0	1	1	1	5	0	0	0	1	4	1	1
/ʃ/	4	4	1	0	0	0	0	5	0	2	2	0	0	0	0
	0	4	0	0	2	0	1	5	0	2	1	0	0	0	0
/ʒ/	7	1	1	0	3	0	0	7	1	2	1	0	0	1	0
	8	3	1	9	1	1	4	1	0	6	2	0	4	1	0
/h/	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
/w/	0	7	0	0	0	0	0	0	0	0	1	0	0	0	0
/M/	0	1	1	0	1	1	0	1	1	0	2	0	1	2	1
/j/	5	1	0	0	3	1	0	0	0	0	0	0	0	1	0
/tʃ/	0	12	0	1	1	0	0	9	0	1	8	0	2	0	0
	0	7	1	4	0	0	0	5	0	0	0	0	0	0	0
/dʒ/	0	5	6	0	0	0	0	9	0	4	0	0	0	0	0
	0	4	4	2	0	1	2	4	0	6	0	1	4	0	1
Σ_e	56	96	25	55	72	10	36	82	4	35	41	4	38	26	5
%	32	54	14	40	53	7	30	67	3	44	51	5	55	38	7

Table 20. Number of Feature Errors by Type. Intrusion, Addition, Substitution, Subtraction, and Omission.

AGE

PHONEMES	3					4					5					6					7				
	N_i = 177					N_i = 137					N_i = 122					N_i = 80					N_i = 69				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
m	0 0	0 0	0 0	0 1	0 0	0 2	0 1	0 0	0 1	0 2	0 1	0 0	0 0	0 0	0 0	0 0	0 1	0 0	0 2	0 0	0 0	2 1	0 0	0 0	0 0
n	0 0	1 0	2 0	0 0	0 0	0 1	0 0	2 1	0 2	0 0	0 0	2 0	0 2	0 1	0 0	0 0	0 0	0 0	1 1	0 0	0 0	0 0	0 0	0 0	0 0
ŋ	– 0	– 0	– 2	– 0	– 0	– 2	– 0	– 2	– 3	– 0	– 0	– 0	– 0	– 0	– 0	– 0	– 0	– 0	– 2	– 0	– 0	– 0	– 2	– 1	– 0
p	0 0	0 0	0 0	0 2	0 0	0 0	0 0	0 0	0 0	0 0	1 1	0 0	0 0	0 0	0 1	0 0	0 0	0 0	2 0	0 0	0 0	0 0	0 0	1 0	0 0
b	0 0	0 1	0 0	0 1	0 0	0 0	0 0	0 0	0 1	0 0	1 1	0 0	0 0	0 0	0 0	0 2	0 0	0 0	0 1	0 0	0 0	1 1	0 0	1 1	0 0
t	0 0	0 2	0 2	0 0	0 0	0 0	0 0	3 3	0 0	0 0	0 0	0 0	1 1	1 1	0 0	0 0	0 1	0 0	2 0	0 0	0 0	0 0	0 0	0 0	0 0
d	0 0	0 0	0 1	0 1	0 1	0 0	0 0	1 2	0 1	0 0	0 0	0 1	1 1	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 1	0 0
k	2 0	0 0	1 0	0 0	0 0	1 0	0 0	0 0	0 0	0 0	0 0	0 0	0 2	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
g	0 0	0 0	0 0	0 1	0 1	0 0	1 1	0 2	0 1	0 0	0 0	0 0	0 0	0 1	0 1	0 0	0 0	2 2	0 0	0 0	0 0	0 0	0 0	1 1	0 0
r	1 0	0 0	3 0	1 0	0 0	4	1	2 4	1	1	0 0	0 0	0 3	0 0	0 0	0 0	0 0	3 1	0 0	0 0	0 0	0 0	3 3	0 0	0 0
l	4 3	0 0	2 3	0 0	0 0	4 3	0 0	2 3	0 0	0 0	0 1	0 0	1 1	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
f	0 0	0 0	0 1	1 1	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	1 0	0 1	0 0	0 0	0 0	1 1	0 0	0 0	0 1	0 1	1 1	0 0	0 0
v	5 3	0 0	0 0	2 1	0 1	0 0	1 0	0 0	1 2	0 0	3 0	0 0	0 0	0 0	1 1	1 0	0 0	0 1	0 0	0 1	1 0	0 0	1 1	1 1	0 0
θ	1 1	1 1	0 0	1 1	0 0	2 1	0 1	2 1	0 1	0 0	1 2	2 0	1 1	0 0	0 0	0 0	0 0	1 0	1 0	0 0	1 0	1 0	0 0	0 0	5 0
ð	3 1	0 1	1 1	0 1	3 5	4 1	0 2	2 1	1 2	3 4	1 3	0 1	1 1	1 0	0 4	0 1	0 1	0 0	0 0	0 5	1 0	0 0	0 0	1 0	0 1
s	0 0	1 1	1 1	1 0	0 0	0 0	0 0	3 3	0 1	0 0	0 0	0 0	1 2	1 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	2 2	0 0	0 0	0 0
z	0 0	1 2	2 0	1 0	1 1	0 0	1 0	2 1	1 0	0 1	0 1	0 0	2 0	1 0	0 5	0 0	0 0	0 0	1 0	0 1	0 4	2 0	0 1	0 1	0 0
ʃ	5 2	1 0	1 0	2 2	0 0	0 0	0 0	0 2	0 0	0 0	2 2	0 0	0 0	2 3	1 1	2 2	0 0	0 0	2 1	0 0	0 0	0 0	0 0	0 0	0 0
ʒ	4 5	1 1	3 3	1 2	0 1	0 5	0 2	3 2	0 1	0 1	3 4	0 0	1 0	3 1	1 0	2 4	0 0	0 2	1 2	0 0	0 4	0 0	1 1	0 0	0 0
h	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –
w	1 –	0 –	4 –	2 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	1 –	0 –	0 –	0 –	0 –	0 –	0 –
ʍ	1 –	0 –	0 –	1 –	0 –	1 –	0 –	0 –	0 –	1 –	1 –	0 –	0 –	0 –	1 –	0 –	0 –	0 –	2 –	0 –	1 –	1 –	0 –	1 –	1 –
j	5 –	0 –	0 –	1 –	0 –	1 –	0 –	3 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	1 –	0 –
tʃ	0 0	0 0	3 2	3 3	6 3	0 0	1 0	0 4	0 0	0 0	0 0	0 0	2 0	2 1	5 4	0 0	1 0	2 0	1 0	5 0	0 0	0 0	2 0	0 0	0 0
dʒ	0 2	0 0	5 0	2 0	4 6	0 1	0 1	0 0	0 0	0 1	0 0	0 0	2 4	3 2	4 0	0 1	0 1	4 4	0 0	0 1	0 0	0 0	0 4	0 0	0 1
Σ_e	49	15	44	36	33	33	13	56	21	14	29	6	32	25	30	15	5	24	23	13	9	13	18	14	10
%	28	8	25	2	19	24	9	41	15	10	24	5	26	20	25	19	6	30	29	16	13	26	26	20	14

1 - Intrusion
2 - Addition
3 - Substitution
4 - Subtraction
5 - Omission

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Table 19. Total Proportion of Feature Errors per Child in Rank Order

Subject	Proportion of Total Errors
Three-year-old	.30
Four-year-old	.23
Five-year-old	.21
Six-year-old	.14
Seven-year-old	.12

AN ANALYSIS OF DEVELOPMENTAL ARTICULATION ERRORS ON THE BASIS OF ARTICULATORY ATTRIBUTES:

A PROCEDURAL STUDY

By

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Chapter 1

INTRODUCTION

Traditional approaches to articulation testing have typically been lacking in specificity and have failed to contribute sufficient diagnostic information. The second edition of the Templin-Darley Tests of Articulation copyrighted in 1969, suggests the following possible categories for recording test responses: correct, substitution, omission, distortion, no response, and production with nasal emission (Templin, Darley, 1969). Snow (1963), in an attempt to provide information concerning the types of "normal" misarticulations, grouped responses as follows: correct, moderate distortion, severe distortion, omission, and substitution. Such schemes cause the loss of detailed information relating to the specific articulatory responses which the individual did make. Further, traditional error categories do not provide information enabling the recognition of any patterns linked to particular phonetic features and extending across several phonemes. A primary reason for this loss of information is that present articulation testing does not utilize a scheme providing sufficiently detailed descriptions of articulatory responses (Prins, 1962). Recent approaches to phonemic theory, which have as their basic non-segmentable unit some kind of sub-phoneme, promise however, a method whereby we may preserve much of the information presently lost in the evaluation of phonological disorders.

There is a multiplicity of such sub-phonemic schemes, many of which are referred to as distinctive feature schemes. Some of these schemes began as attempts to give perceptual labels to features which were seen in sound spectograms (Fant, 1968) while others give evidence of a more motor-articulation orientation (Wickelgren, 1966). None of these schemes are to be considered ideal, but each, because it is concerned with a finer segmentation of speech, can be more precise than traditional approaches to articulation testing which simply recognize departures from phonemic targets. A procedure for articulation testing which uses a scheme of phonetic features for description of misarticulations can provide significantly more detailed diagnostic information. As such, it would have significant advantages over traditional articulation testing schemes. The purpose of the present study was to develop a procedure utilizing the sub-phoneme as the unit by which articulation responses may be analyzed.

REVIEW OF THE LITERATURE

The literature dealing with sub-phonemic theory began with attempts to develop models of speech production, both functional and conceptual, as a means of developing eventually a model of speech perception. Initial studies analyzed speech production through the synthesis of speech using the sound spectograph and patterned playback. Researchers speculated that it might "be of interest to examine the data from the point of view that perception involves a set of binary choices" (Cooper, 1952). Jakobson, Halle, and Fant (1963) in their early writings suggested that a speech sample is composed of a series of minimal distinctions and that these distinctions confront the listener with a series of two-choice situations involving two polar qualities of the same category. These qualities they called distinctive features: they included "grave" and "acute", "compact" and "diffuse", "voiced" and "unvoiced", among others.

A conceptual model of speech production was then developed representing parallel processing systems which utilized binary distinctive features such as the above. The model allowed for parallel commands to be issued to the speech production mechanism with as many processes being available as there are distinctive features (Liberman, 1967).

Henke (1967) then went on to simulate the speech production process by using computer and oscilloscopic techniques. In this model, phonemes are analyzed into sub-phonemic elements called "articulatory attributes" including a finite set of configuration, manner, and strength attributes. In Henke's model these attributes can be excited in parallel and, because they are goal directed, can be changed at discreet points in time.

Selected studies have also been conducted concerning the role distinctive features play in speech sound perception and in short-term memory. Miller and Nicely (1955) concerned themselves with an analysis of the perceptual confusions among English consonants analyzed in terms of the following five non-binary articulatory features or dimensions: "voicing", "nasality", "affrication", "duration", and "place of articulation". They found that "the perception of any one of these five features is relatively independent of the perception of others".

Wickelgren (1965, 1966), in two studies dealing with distinctive features and short-term memory, found evidence indicating that both vowels and consonants are coded in short-term memory as a set of distinctive features, each of which may be forgotten semi-independently, rather than as a unit. He also found that, while each of three distinctive feature schemes was more accurate than chance in making predictions concerning the rank order of different intrusion errors in recall, the most accurate was a system designed by Wickelgren. "This system is a slightly modified version of the conventional phonetic analysis of consonants": "voicing", "nasality", "manner of articulation", and "place of articulation".

Sadanand Singh (1967), too, conducted several studies dealing with the relation between distinctive features and the perception of English phonemes. He found that at least in selective cases, perceptual relations correspond to distinctive feature relations.

Gunner Fant (1968) extended the preliminary set of distinctive features developed with Jakobson and Halle into a system which categorizes "speech production events" and allows for a translation from speech production to "speech wave characteristics". Fant's distinctive feature scheme thus combines a perceptually based scheme of features with a set of features with an articulatory or productive basis.

Various research done in the area of speech pathology would indicate the applicability of sub-phonemic analysis in this area. Crocker (1969), after sub-phonemically describing various phonological observations of the speech of children, suggested that children acquire "not features as such, not the sound as such, but rather hypothesized rules for the manipulation of features to form feature sets which previously had not appeared in his developing phonological system". Haas (1964) too, in discussing a similar phonological analysis of one case of dyslalia, suggested that sub-phonemic analysis and comparison should be useful in developing successful therapeutic techniques. "What we have to teach is not so much sounds themselves, as discriminations among sounds, i.e., distinctions which the child fails to make."

Jack Weber (1970) describes such a sub-phonemic analysis and subsequent experimental treatment of eighteen subjects with moderate to severe articulation disorders. Therapy conducted differed from the traditional approach to speech therapy in two ways: "An entire pattern or category was taught at once rather than teaching one sound at a time; and, the child was taught to consciously contrast the incorrect feature with the correct feature throughout all stages of therapy".

Asp and Williams (1970) report also that in general, distinctive feature "rules" are useful in the diagnosis and remediation of articulation disorders. Using computer analysis to tabulate errors, they summarized consonant misarticulations of 1,373 subjects who had functional articulation problems. They found that alveolar consonants were the most often substituted and that the features of "nasality" and "friction" improved with age. In addition, they described the following rank order for the correct use of articulatory features: "voicing", "nasality", "friction", "duration", "glide", and "liquid".

In a study of ten children with severe functional articulation disorders by McReynolds and Huston (1971), thirteen distinctive features developed by Jakobson, Halle, and Fant and by Chomsky and Halle were used to describe responses to a traditional test of articulation. They found that distinctive feature errors were consistent across phonemes for all of the children and that misarticulations could only be partially described as a function of the absence of certain distinctive features. They also reported that many errors occurred in the way that distinctive features were used in combination with other features.

Tikofsky and McInish (1968) speculated that the development of speech sound discrimination is on the basis of distinctive features.

Subjects were asked to tell if pairs of words and/or nonsense syllables were heard as the same or different. They found that as the difference between two sounds in terms of distinctive features increased, failures of discrimination decreased. Some distinctive features were also found to contribute more to the ease of discrimination than others.

And, finally, Paula Menyuk (1968), in attempting to support the thesis that a universal ordering of phonetic units is possible, compared the development of certain distinctive features in the speech of Japanese and American children. Despite the fact that the children spoke different languages involving differing phonological systems, she found remarkable similarities in the order of development for several distinctive features.

The use of distinctive feature schemes has contributed to increased understanding of the bases for recognizing and discriminating among speech sounds; it seems likely that a distinctive feature approach to the description of misarticulations can be equally as fruitful. It was unfeasible at the inception of this research to determine a system for assessing how fruitful such an approach might be as the specific nature of the information to be acquired as a result of this study was unknown prior to the execution of the research. Thus no research questions or hypotheses as such were formulated. This investigation then was to be a search for an experimental procedure which might prove useful in further studies which would attempt to answer specific research questions and specifically assess the usefulness of a sub-phonemic description of misarticulations.

Chapter 2

PROCEDURE

The purposes of this study were twofold: to develop a procedure for the sub-phonemic analysis of articulation responses using articulatory features, and to demonstrate that such a sub-phonemic analysis could yield more useful information concerning those responses than traditional articulation error classification schemes. Five subjects between the ages of three and seven who had normal articulation skills for their age were administered two picture-word articulation tests: one test was designed by the experimenter and the other was comprised of portions of the _Templin-Darley Diagnostic Test of Articulation_. Twenty-five English consonants were elicited in single-word responses. All testing was video-taped and the video tapes viewed later for the analysis of articulatory responses.

SUBJECTS

Five subjects were used in this study, one at each of the following age levels: three, four, five, six, and seven years. Each child was within plus or minus thirty days of his birthday at the time of testing. To eliminate possible differential effects of sex differences in the development of articulation skills, only male subjects were used. No subject had received speech or language therapy, and all subjects were selected to represent as well as possible typical articulation skills for each age level. To assure this, each prospective subject was administered the _Templin-Darley Screening Test of Articulation_. Results for each prospective subject were then compared with norms available for the appropriate age level on the Templin-Darley Screening Test. Those subjects finally selected for use in this study obtained scores on this test which closely compared with these norms (Appendix A).

STIMULUS MATERIAL

A picture-word articulation test was designed by the experimenter and administered to each subject to elicit each of twenty-five English consonants in syllable-initial and syllable-final positions. Consonants tested were /m/, /n/, /ŋ/, /p/, /b/, /t/, /d/, /k/, /g/, /r/, /l/, /f/, /v/, /θ/, /ð/, /s/, /z/, /ʃ/, /ʒ/, /h/, /w/, /ʍ/, /j/, /tʃ/, and /dʒ/. Certain speech sounds were not tested in both positions: for example, /ŋ/, was tested only in the final position and /w/ was tested only in the initial position as these sounds occur only in these positions. All words elicited were monosyllables and free morphemes (Appendix B).

While recent research would indicate that connected speech is more appropriate for determining a child's habitual articulation pattern than isolated word responses (Faircloth, 1970), for ease of test administration and response analysis, isolated words were implemented. Such responses facilitated comparisons between traditional articulation testing schemes and the articulatory attribute scheme used by the experimenter. The primary emphasis of this study was the generation of a procedure for describing articulatory events, and thus, any possible minor systematic differences between the articulatory events described and those occurring in running speech were not an important concern. Testing of sounds in isolation was ruled out because such testing was considered not to compare closely to "usual" articulation testing procedures and to yield data of questionable validity.

The use of syllable-initial and syllable-final positions rather than the traditional word-initial, word-medial, and word-final approach to articulation testing was proposed on the basis of findings which indicate that essentially identical data is yielded whether one tests in terms of word-initial, -medial, and -final or syllable-initial and -final (Jordan, 1960). Thus it was considered unnecessary to test the consonants in the word-medial position. Monosyllabic responses were elicited because evidence indicates some coarticulation effects cross syllable boundaries and thus testing the speech sounds in monosyllabic words might simplify the analysis of the articulation responses (Amerman, Daniloff, and Moll, 1970).

In addition to the administration of the twenty-five consonant test designed by the experimenter, each subject was administered those portions of the Templin-Darley Diagnostic Test of Articulation which elicit the same twenty-five consonants in word-initial, word-medial, and word-final positions.

While every attempt was made to use the same test materials for all subjects and to elicit spontaneous speech responses wherever possible, additional test materials and direct stimulation were employed on rare occasions at the discretion of the experimenter. Direct stimulation was used in eliciting approximately 22% of all responses. More direct stimulation was necessary, of course, with the younger subjects, ages three and four, than with the older subjects.

TEST PROCEDURE

Before entering the test room, each subject was told that he and the experimenter were going to play a game that involved looking at some pictures and naming them. The children were also told that they were going to be on television. Upon entering the room, the experimenter seated herself out of the camera's range to the left and in front of the child. In all cases the subject was positioned so as to maintain, as well as possible, a full-face view of him. The experimenter then pointed out the camera to the child and as he watched the camera, it was brought into focus on the child. With some subjects, particularly the older children, the experimenter asked the child to keep his hands away from his face and to say each word loudly and clearly while looking directly at the camera. The testing was then begun.

The portions of the Templin-Darley Diagnostic Test were administered first in all cases, followed immediately by the administration of the test designed by the experimenter. Frequently, particularly with the younger subjects, the experimenter found it necessary to use direct stimulation to elicit the desired word; whenever this was done, note was made of that fact alongside the description of that response during the experimenter's subsequent analysis. It was also sometimes necessary to ask the subject to repeat a response because of suspected inadequate oral volume, poor positioning, or other factors which would make analysis of the response questionable or impossible. However, in subsequent analysis of responses, the experimenter was able to analyze the subject's first response except in one case where the initial response was extremely unclear.

Pilot study results indicated that it was not often an especially crucial factor whether the view of the subject was other than a full-face view, if at least a profile of the subject's face was in full view of the camera; nevertheless, care was taken by the experimenter and the camera operator to maintain the full-face position.

Because they indicated an interest and because they seemed to enjoy it, each child was allowed to watch part of the video-tape made of him upon the completion of testing.

DATA ANALYSIS

The video-tape of each subject's various test responses constituted the data to be described by the experimenter. The experimenter described each subject's production of the test phonemes through viewing and auditing the video-tape and allowing as many replayings of a recorded response as proved necessary for a complete description. Responses for each subject on the portions of the Templin-Darley Diagnostic Test of Articulation were described first, using the traditional response categories: correct, distortion, substitution, and omission. Where the error was in the form of a distortion, the experimenter attempted to describe the distortion where possible by indicating if the phoneme had been distorted toward another phoneme. In the case of substitutions, the substituted sound was recorded.

Following the description of each child's Templin-Darley responses, the experimenter described the responses of each subject on the experimenter's consonant sound test. Syllable-initiating and syllable-terminating versions (with exceptions previously noted) of each of twenty-five English consonants were carefully described by the experimenter using a set of manner and place articulatory attributes. This scheme for phonetic analysis was an adaption of that developed by Fant (1968). The application of this scheme of articulatory attributes required that the experimenter make judgments concerning the subject's articulatory motor activity on the basis of the experimenter's auditory and visual perceptual data. Thus the manner and place features are described in motor terms but such judgments concerning manner and place were obviously made primarily on the basis of acoustic and optical data. Description of each subject's production of the test phonemes was in relative rather than absolute terms; that is, judgments were made relative to a static description of normal adult production for each test phoneme.

The conventional designation of manner and place of articulation of all test phonemes was expressed in terms of the articulatory feature system previously described; these descriptions constituted the standards against which all test responses were compared. Each phone to be described was then described relative to the articulatory postures and manners of the "standard" General American phoneme which the phone in question most resembled. Thus a high-back, rounded on-glide (resembling /w/), occurring where /r/ was required, was described in terms of its deviation from the standard /r/. Similarly, a mid-front on-glide occurring where /j/ was required was described in terms of any deviation from the attributes comprising the "standard" /j/ since the phone in question resembled the /j/ more than any other General American phoneme.

Chapter 3

PROCEDURAL RESULTS

The development of a preliminary procedure for sub-phonemic description of articulation responses was one of the purposes of this study. This chapter is devoted to a discussion of the evolution of the feature scheme which was ultimately used in the description of the articulation responses of five children. Further, the reliability and validity of the descriptions are evaluated.

EVOLUTION OF THE FEATURE SCHEME

The classification scheme developed through this research began as an adaptation of a scheme proposed by Gunnar Fant (1968). Fant's scheme included two parallel sets of features, one of which described manner and place of production using an articulatory frame of reference, the other of which was designed for use in description of spectographic displays. For our purposes, only the features using an articulatory reference were used and these are replicated in Table One. Segment type features refer to manner of production while segment pattern features refer to place of articulation.

It was determined that while such a feature scheme would generally fit our purposes, adaptations toward a still more motor-articulatory emphasis would be useful. Thus the preliminary set of features listed in Table Two was outlined as an initial classification scheme.

One of the major changes made in the evolution of the feature system was to move from a binary system, which required a feature to be either on or off, to a system which allowed for the notation of features

Table 1. Features Developed by Fant to Describe Manner and Place of Production

Segment Type Features

Source Features

1. Voice
2. Noise
3. Transient

Resonator Features

4. Occlusive
5. Fricative
6. Lateral
7. Nasal
8. Vowellike
9. Transitional
10. Glide

Segment Pattern Features

11. Tongue fronted
    a) Prepalatal position
    b) Midpalatal position
12. Tongue retracted
13. Mouth-opening (including tongue section and lips) narrow
14. Lips relatively close and protruded (small lip-opening area)
15. Retroflex modification
    a) Alveolar articulation
    b) Palatal articulation
16. Bilabial or labiodental closure
17. Interdental articulation
18. Dental or prealveolar articulation
19. a) Palatal articulation with tip of tongue down
    b) Palatal retroflex articulation
20. Velar and pharyngeal articulation
21. Glottal source

Table 2. Preliminary Modification
of Fant's Production Feature Scheme

Manner Features

1. Voicing
   Time of onset
   Time of offset
2. Vowel
3. Lateral
4. Occlusive
   Plus or minus explosion
   Plus or minus aspiration
5. Nasal
6. Fricative
7. Transitional
   Direction
   Speed

Place Features

8. Mouth-opening narrow
9. Lips close and protruded
10. Retroflexion
11. Bilabial or labiodental closure
12. Interdental articulation
13. Dental or prealveolar articulation
14. Palatal articulation with tip of tongue down
15. Velar and pharyngeal articulation
16. Glottal articulation

only partially present or present for only a portion of a phone. For example, the feature *nasality* was described not only as being present or not present, but the appropriateness of the amount and timing of this feature were also described. In addition, the *direction* and *speed* of the *transitional* phases were indicated.

It was felt at this point that the feature scheme did not provide sufficient information concerning both *transition speed* and the *mouth opening*. It also seemed advantageous to provide for greater specificity as well by splitting *bilabial* and *labiodental* closure into two distinct features and to include additional place features for the description of *tongue part*, *tongue shape*, and *tongue elevation*. Thus the feature scheme took on the appearance shown in Table Three.

After making one additional change in the *place* of articulation features, the feature scheme was considered to be in a useful although tentative form for our purposes. *Mouth opening* was simply described as *wide*, *narrow*, or *neutral* while *lip rounding* and *lip retraction* were set off as two distinct features of *place* of articulation. This feature scheme (Table Four) was then used in the analysis of single phonemes produced in monosyllabic words by two children in a brief pilot study.

As a result of this pilot study, several changes were made in the classification scheme. *Timing*, including both *onset* and *offset*, was set off as a distinct manner feature because it was considered possible at that point that errors in *timing* would affect manner features other than *voicing*. The sub-feature of *force* was also added to the *occlusive* feature. Among the spatial features, *lip rounding* and *lip retraction* were combined into a feature designated simply as *lip shape*. All places of articulation were listed on a continuum moving from anter-

Table 3. Second Revision of Fant's Production Feature Scheme

Manner Features

1. Voicing
    a) Time of onset
    b) Time of offset
2. Vowel
3. Lateral
4. Occlusive
    a) Plus or minus explosion
    b) Plus or minus aspiration
5. Nasal
6. Fricative
7. Transition
    a) Direction
    b) Speed
        (1) One vowel to another
        (2) Glide
        (3) Consonant to vowel

Place Features

8. Mouth opening
    a) Small and rounded
    b) Narrow
    c) Narrow and retracted
    d) Neutral
    e) Wide
9. Bilabial closure
10. Labiodental closure
11. Interdental articulation
12. Dental or prealveolar articulation
13. Palatal articulation
14. Velar and pharyngeal articulation
15. Glottal articulation
16. Tongue part
    a) Tip
    b) Blade
    c) Dorsum
17. Tongue Shape
    a) Forward
    b) Retroflex
18. Tongue Elevation

Table 4. Feature Scheme As It Was Implemented in Pilot Study

Manner Features

1. Voicing
   a) Time of onset
   b) Time of offset
2. Vowel
3. Lateral
4. Occlusive
   a) Plus or minus explosion
   b) Plus or minus aspiration
5. Nasal
6. Fricative
7. Transition
   a) Direction
   b) Speed
      (1) One vowel to another
      (2) Glide
      (3) Consonant to vowel

Place Features

8. Mouth opening
   a) Wide
   b) Narrow
   c) Normal
9. Lip rounding
10. Lips retracted
11. Bilabial closure
12. Labiodental closure
13. Interdental articulation
14. Dental or prealveolar articulation
15. Palatal articulation
16. Velar and pharyngeal articulation
17. Glottal articulation
18. Tongue Part
    a) Tip
    b) Blade
    c) Dorsum
19. Tongue shape
    a) Forward
    b) Retroflex
20. Tongue elevation

ior to posterior in the oral cavity and combined into one feature called place. And finally, the sub-feature of tongue groove was added under tongue shape.

The feature scheme was then adapted to the form of a record sheet for ease in analysis of single articulatory responses. This record sheet was set up in such a way that each feature was indicated as being present, not present, or irrelevant to the analysis of the phone in question. In addition, space was provided for descriptive comments pertinent to each feature present (Table Five). It was in this form that we began to use the feature scheme in the analysis of the video-taped responses of the five subjects used in this study.

Throughout the preliminary attempts to analyze subjects' articulatory responses several additional changes were made in the feature scheme. The first of these changes are reflected in Table Six which shows the record sheet as it was before the last revision into its final form. The sub-feature of duration was added to the timing feature; the intent was to use duration primarily to describe entire feature packages as being of a too long, a too short, or an appropriate duration. The manner feature designated as lateral was expanded to direction of air stream which included consideration of whether the air stream was channeled in a lateral or central direction as well as whether the phoneme was produced on inspired or expired air. The sub-feature of force, previously included under occlusive, was removed and designated as a separate manner feature to be used in describing all phonemes, whether occlusion was present or not. In addition, the first of the spatial features, mouth opening, was described instead as mandibular level with three sub-feature descriptions of narrow, neutral, and wide. Prealveolar

Table 5. Articulatory Feature
Scheme and Record Sheet

MANNER FEATURES	+	-	0	Comment
1. Voicing				
2. Time				
a. Onset of Feature				
b. Offset of Feature				
3. Vowel				
4. Lateral				
5. Occlusive				
a. Explosion				
b. Aspiration				
c. Force				
6. Nasal				
7. Fricative				
8. Transition				
a. Direction				
b. Speed				
1) vowel to vowel				
2) glide				
3) consonant to vowel				

SPATIAL FEATURES				
1. Mouth Opening				
a. Wide				
b. Narrow				
c. Neutral				
2. Lip Shape				
a. Rounded				
b. Retracted				
3. Place				
a. Bilabial				
b. Labiodental				
c. Interdental				
d. Dental				
e. Prealveolar				
f. Palatal				
g. Velar				
h. Pharyngeal				
i. Glottal				
4. Tongue Part				
a. Tip				
b. Blade				
c. Dorsum				
5. Tongue Shape				
a. Forward				
b. Retroflex				
c. Grove				
6. Tongue Elevation				

Table 6. Revision of Articulatory Feature Scheme and Record Sheet

MANNER FEATURES

1. Voicing
2. Time
    a. Onset (1-3)
    b. Offset (1-3)
    c. Duration (1-3)
3. Vowel
4. Direction of air stream
    a. Central, Lateral
    b. Expiration, Inspiration
5. Occlusive
    a. Explosion
    b. Aspiration
6. Nasal
7. Fricative
8. Transition Speed
    a. vowel to vowel (1)
    b. glide (2)
    c. consonant to vowel (3)
9. Force (1-3)

SPATIAL FEATURES

1. Mandibular Level
    a. Narrow (1)
    b. Neutral (2)
    c. Wide (3)
2. Lip Shape
    a. Rounded
    b. Retracted
3. Place
    a. Bilabial
    b. Labiodental
    c. Interdental
    d. Dental
    e. Alveolar (1-3)
    f. Palatal (1-3)
    g. Velar (1-3)
    h. Pharyngeal
    i. Glottal
4. Tongue Part
    a. Tip
    b. Blade (1-3)
    c. Dorsum (1-3)
5. Tongue Shape
    a. Forward
    b. Retroflex
    c. Groove
6. Tongue Elevation (1-3)

was also changed to read simply as alveolar.

One of the most useful alterations made in the feature scheme took place at this stage of its evolution as well. Previous to this point, an attempt was made to make descriptions of articulatory responses in absolute terms; that is, to describe specifically what the child did without comparisons being made relative to what the child was required to do to produce a correct adult phoneme. Such absolute descriptions were difficult if not impossible to make so the feature scheme was adapted so that descriptions could be made relative to the adult phoneme most closely resembling the response of the child. Thus various features were scaled 1-3, a scale value of two indicating the correct place, proper amount, proper time; a scale value of one indicating too far forward in the oral cavity, too early, not enough; and three indicating too far back in the oral cavity, too late, or too much of any particular feature. On this particular record sheet such rankings were limited to the following features: time, force, mandibular level, tongue elevation, and certain place and tongue part sub-features.

One final change was made in the record sheet at this point. Rather than indicating that a feature was present, not present or relevant to the target phoneme, appropriate notation was simply made that a feature was relevant to a complete and accurate relative description of the articulation response of the child.

Table Seven illustrates the record sheet and thus the feature scheme in the final form used for analysis of articulation responses in this study. It represents as well several final changes in the classification scheme. As only consonants were being tested in syllable-

Table 7. Articulatory Attribute Scheme and Record Sheet in Final Form

MANNER FEATURES

1. Voicing		
2. Time		
a. Onset (1-3)		
b. Offset (1-3)		
c. Duration (1-3)		
3. Syllable Function		
a. Initiating (1)		
b. Nucleus (2)		
c. Terminating (3)		
4. Direction of air stream		
a. Central (1) Lateral (2)		
b. Expiration (1) Inspiration (2)		
5. Occlusive (1-3)		
a. Explosion (1-3)		
b. Aspiration (1-3)		
6. Nasal (1-3)		
7. Fricative (1-3)		
8. Transition Speed		
a. Vowel to vowel (1)		
b. Glide (2)		
c. Consonant to vowel (3)		
9. Articulator Tension (1-3)		

SPATIAL FEATURES

1. Lip Shape		
a. Rounded (1-3)		
b. Retracted (1-3)		
2. Place		
a. Bilabial (1-3)		
b. Labiodental (1-3)		
c. Interdental (1-3)		
d. Dental		
e. Alveolar (1-3)		
f. Palatal (1-3)		
g. Velar (1-3)		
h. Pharyngeal		
i. Glottal		
3. Tongue Part		
a. Tip (1-3)		
b. Blade (1-3)		
c. Dorsum (1-3)		
4. Tongue Shape		
a. Forward		
b. Retroflex		
c. Groove Width (1-3)		
d. Groove Depth (1-3)		
5. Tongue Elevation (1-3)		

initial and -final positions, it was considered more useful to change the nature of the manner feature number three from a simple indicator that vowel-like properties were present to a feature which would describe the function in the syllable of the phoneme being described. Three usually considered functions existed: *syllable initiating*, *syllable nucleus*, and *syllable terminating* (Stetson, 1951). Two other relatively minor changes were made in the manner features. *Force* was changed to read *articulation tension* and several additional manner features were scaled one to three.

Under spatial features, *mandibular level* was deleted as it had thus far in our descriptions proved unnecessary and was thus not particularly useful. The sub-features of *groove width* and *groove depth* were indicated so that both could be more easily described and scaled more easily under *tongue shape*. And finally, where appropriate all spatial features were scaled. It was in this final form that the feature scheme and record sheet were used in describing the articulatory responses of the five subjects.

ABSOLUTE VERSUS RELATIVE JUDGMENTS

It seems pertinent to discuss here in greater detail the reasoning behind the use of relative judgments rather than absolute judgments in our analysis of articulatory responses. In the initial stages of video-tape viewing and phonemic analysis, the experimenter attempted to make decisions concerning all features absolutely, to describe in concrete and specific terms on the basis of optical and auditory data how much friction was present, how tense the articulators were, exactly where the tongue was, its actual height, etc. In the process of making such judgments, more often than not we were forced to resort to reproducing what the child had done in producing his aberrant response and then to translating this in terms relative to our own articulatory systems, into an absolute description. It was determined then that since we were making what actually amounted to relative decisions, we might better adapt the classification scheme and our use of it to provide for more accurate and more consistent relative judgments. In addition, as each articulatory response was to be analyzed in terms of that General American standard English phoneme it most closely resembled, each of the 25 English consonants under scrutiny in this study was described using the feature scheme as it would be correctly produced by the average adult speaker. These descriptions of correct adult production are summarized in Table Eight. It was at this point that the final revision of the feature scheme and record sheet was made. Phonemic analyses made prior to this point were then redone and further descriptions were undertaken.

RELIABILITY AND VALIDITY OF THE FEATURE SCHEME

While it was not the purpose of this study to determine the reliability of use of the feature scheme which evolved, but to develop that scheme and demonstrate the additional information it could provide, an attempt was made to make a preliminary and limited estimation of the classification scheme's reliability. Consequently, following the completion of all video-tape viewing and articulation response analysis by the experimenter, one individual, felt to be representative of the graduate student population at this institution, was chosen to use the feature scheme in describing sounds previously described by the experi-

Table 8. Articulatory Attribute
Description of Adult Phoneme Production

Articulatory Attributes	Phonemes											
Manner features	m	n	ŋ	p	b	t	d	k	g	r	l	f
1. Voicing 1-3	2 2	2 2	2		2 2		2 2		2 2	2 2	2 2	
2. Time: a. Onset 1-3	2 2	2 2	2	2 2	2 2	2 2	2 2	2 2	2 2	2 2	2 2	2 2
b. Offset 1-3	2 2	2 2	2	2 2	2 2	2 2	2 2	2 2	2 2	2 2	2 2	2 2
c. Duration 1-3	2 2	2 2	2	2 2	2 2	2 2	2 2	2 2	2 2	2 2	2 2	2 2
3. Syl. function 1-3	1 3	1 3	3	1 3	1 3	1 3	1 3	1 3	1 3	1 2	1 2	1 3
Air Stream 4. a. central 1, Lateral 2	1 1	1 1	1	1 1	1 1	1 1	1 1	1 1	1 1	1 1	2 2	1 1
b. exp. 1, Insp. 2	1 1	1 1	1	1 1	1 1	1 1	1 1	1 1	1 1	1 1	1 1	1 1
5. Occlusive 1-3				2 2	2 2	2 2	2 2	2 2	2 2			
a. explosion 1-3				2 2	2 2	2 2	2 2	2 2	2 2			
b. aspiration 1-3				2 2	2	2 2	2	2 2				
6. Nasal 1-3	2 2	2 2	2									
7. Fricative 1-3												2 2
8. Trans. speed 1-3	3 3	3 3	3	3 3	3 3	3 3	3 3	3 3	3 3	2 1	2 1	3 3
9. Artic. Tension 1-3	2 2	2 2	2	2 2	2 2	2 2	2 2	2 2	2 2	2 2	2 2	2 2
Spatial features												
1. Lip shape a. round 1-3												
b. retracted 1-3												
2. Place a. bilabial 1-3	2 2			2 2	2 2							
b. labiodental 1-3												2 2
c. interdental 1-3												
d. dental												
e. alveolar 1-3		2 2				2 2	2 2				2 2	
f. palatal 1-3										2 2		
g. velar 1-3			2					2 2	2 2			
h. pharyngeal												
i. glottal												
3. Tongue part. a. tip 1-3		2 2				2 2	2 2				2 2	
b. blade 1-3										2 2		
c. dorsum 1-3			2					2 2	2 2			
4. Tongue shape a. forward		✓ ✓	✓			✓ ✓	✓ ✓	✓ ✓	✓ ✓		✓ ✓	
b. retroflex										✓ ✓		
c. groove width 1-3												
d. groove depth 1-3												
5. Tongue elevation 1-3		2 2	2			2 2	2 2	2 2	2 2	2 2	2 2	

Table 8. Continued.

Articulatory attributes	Phonemes											
Manner features	v	θ	ð	s	z	ʃ	ʒ	h	w	ʍ	j	tʃ	dʒ
1. voicing 1-3	2 2		2 2		2 2		2 2		2		2		2 2
2. TIME a. Onset 1-3	2 2	2 2	2 2	2 2	2 2	2 2	2 2	2	2	2	2	2 2	2 2
b. Offset 1-3	2 2	2 2	2 2	2 2	2 2	2 2	2 2	2	2	2	2	2 2	2 2
c. Duration 1-3	2 2	2 2	2 2	2 2	2 2	2 2	2 2	2	2	2	2	2 2	2 2
3. Syl. function 1-3	1 3	1 3	1 3	1 3	1 3	1 3	1 3	1	1	1	1	1 3	1 3
4. Air stream a. central-1, lateral-2	1 1	1 1	1 1	1 1	1 1	1 1	1 1	1	1	1	1	1 1	1 1
b. exp.-1, insp.-2	1 1	1 1	1 1	1 1	1 1	1 1	1 1	1	1	1	1	1 1	1 1
5 Occlusive 1-3												2 2	2 2
a. explosion 1-3												2 2	2 2
b. aspiration 1-3												2 2	2
6. Nasal 1-3													
7. Fricative 1-3	2 2	2 2	2 2	2 2	2 2	2 2	2 2	2		2		2 2	2 2
8. Trans-speed 1-3	3 3	3 3	3 3	3 3	3 3	3 3	3 3	3	2	2	2	3 3	3 3
9. Artic. tension 1-3	2 2	2 2	2 2	2 2	2 2	2 2	2 2	2	2	2	2	2 2	2 2
Spatial features													
1. a. round lip 1-3						2 2	2 2		2	2		2 2	2 2
b. retracted lip 1-3													
2. Place a. bilabial 1-3									2	2			
b. labiodental 1-3	2 2												
c. interdental 1-3		2 2	2 2										
d. dental													
e. alveolar 1-3				2 2	2 2							2 2	2 2
f. palatal 1-3						2 2	2 2				2	2 2	2 2
g. velar 1-3									2	2			
h. pharyngeal													
i. glottal								✓					
3. Tongue part a. tip 1-3		2 2	2 2	2 2	2 2							2 2	2 2
b. blade 1-3						2 2	2 2				2	2 2	2 2
c. dorsum 1-3									2	2			
4. Tounge shape a. forward		✓ ✓	✓ ✓	✓ ✓	✓ ✓	✓ ✓	✓ ✓		✓	✓	✓	✓ ✓	✓ ✓
b. retroflex													
c. groove width 1-3		2 2	2 2	2 2	2 2	2 2	2 2					2 2	2 2
d. groove depth 1-3		2 2	2 2	2 2	2 2	2 2	2 2					2 2	2 2
5. Tongue elevation 1-3		2 2	2 2	2 2	2 2	2 2	2 2		2	2	2	2 2	2 2

menter. She was trained by the experimenter in the application of the feature scheme and then asked to analyze 24 articulatory responses chosen randomly across subjects from among those already described by the experimenter. Her analyses as represented by her completed record sheets were then compared with those of the experimenter and the proportions of judgments in agreement for each feature, for each child, and across all children were computed.

As will be noted in Table Nine, the proportion of agreement between judges across features ranged from .46 for *occlusion* to 1.00 for *place-bilabial*. The average proportion of agreement across all judgments was found to be .81. Features which showed the poorest inter-judge reliability included *occlusion*, *lip shape*, *tongue tip*, and *tongue forward*. Several other features showed a proportion of agreement which was less than the average: *time-onset*, *central-lateral*, *aspiration*, *transition speed*, *alveolar*, *palatal*, *velar*, *tongue blade*, *groove width*, and *depth*, and *tongue elevation*. In general, an increase in the proportion of judgments in agreement was found as the age of the subjects increased. This latter point was probably due in part to the fact that as the age of the subject increased, the number of his feature errors decreased. His articulation responses thus became somewhat easier to describe and in fact required fewer fine discriminations to be made by the listener.

The variability of agreement across features seemed due in part to one over-riding factor: a lack of adequate training and experience in the use of the feature scheme on the part of the reliability judge. Three features in particular, *occlusion*, *central-lateral*, and *tongue-shape forward*, were used in such a manner by the reliability judge as to

Table 9. Reliability of Articulatory Attributes. Proportion of Agreement Between Experimenter and Reliability Judge.

Feature	Proportion of Agreement
Bilabial	1.00
Function-Initiating	.96
Function-Terminating	.96
Labiodental	.96
Glottal	.96
Voicing	.92
Function-Nucleus	.92
Nasal	.92
Dental	.92
Retroflex	.92
Time-Offset	.87
Expiration-Inspiration	.87
Explosion	.87
Fricative	.87
Dorsum	.87
Central-Lateral	.83
Interdental	.83
Articulation Tension	.79
Blade	.79
Aspiration	.75
Transition Speed	.75
Velar	.75
Groove Width	.75
Time-Onset	.71
Alveolar	.71
Palatal	.71
Groove Depth	.71
Tongue Elevation	.71
Lips Retracted	.67
Lips Rounded	.62
Tip	.62
Forward	.58
Occlusive	.46

Table 10. Reliability of Judgments by Subject. Proportion of Agreement Between Experimenter and Reliability Judge.

Subject	Proportion of Agreement
Three-year-old	.75
Four-year -old	.82
Five-year-old	.76
Six-year-old	.84
Seven-year-old	.86

suggest that her definition and understanding of these features differed considerably from that of the experimenter. In addition, the reliability judge had not had the repeated exposure to the use of the feature scheme in making fine discriminatory decisions that the experimenter had. It might also be postulated that the experimenter had had an additional set of experiences with the feature scheme as it evolved to its final experimental form. This background the reliability judge did not enjoy.

Additional inferences concerning certain portions of the feature scheme developed in this study can be made by examining the results of other research completed recently (Heaton, 1971). In this latter study, the purpose of which was to examine the reliability and validity of descriptions of certain articulatory features, the following features were examined: time, transition speed, place of articulation, tongue part, tongue shape, and tongue elevation. These features were chosen as they allowed description from an x-ray of the oral region as well as description from full-faced video-tape viewing.

Sixteen graduate students in speech pathology and audiology were trained in using the above named articulatory features in the analysis of articulation responses presented in full-face and x-ray video-tapes. Their judgments of eight misarticulated phones were then analyzed for inter-judge and intra-judge reliability and validity. On the basis of limits set by Heaton prior to the analysis of judgments, three articulatory features were found to have adequate reliability. Time-onset, -nucleus, and -offset showed the highest reliability while tongue shape and tongue elevation also fell within the range necessary for adequate reliability. Place, tongue part, and transition speed were not found to have acceptable reliability with the discrepancies between judges being greatest with the <u>place</u> feature. Poor reliability with these features was felt to be primarily the result of inadequate judge training.

The validity of each of the six features examined by Heaton was determined by comparing full-face judgments with x-ray judgments. Findings similar to those for feature reliability were derived: judges were able to make valid judgments concerning <u>time-onset</u>, -<u>nucleus</u>, and -<u>offset</u>, <u>tongue shape</u> and <u>tongue elevation</u> while poorer validity was found for the features <u>transition speed</u>, <u>place</u>, and <u>tongue part</u>. Here too it was suggested by Heaton that more intensive judge training in the use of the feature scheme would have provided for better feature validity results.

Chapter 4

RESULTS AND IMPLICATIONS

In addition to developing a preliminary classification scheme for the sub-phonemic analysis of articulatory responses, the results of this research demonstrate how such a scheme can be used to obtain more information concerning those responses. This chapter is devoted to a presentation of the articulatory information obtained from each of the five subjects using both the traditional categories of error classification and the sub-phonemic scheme of description discussed in the preceeding chapter. Also discussed herein is the method used for summarizing the descriptive data on each subject as well as suggestions concerning the implications of such data.

SUMMARY OF DATA

Following the completion of all video-tape viewing, the record sheets for each child were ordered by phoneme and the process of summarizing the information contained therein was begun. On each record sheet any feature judged to be in error in terms of the target phone was circled. These errors were then transferred to charts which provided for easier enumeration and summary of errors. One chart was completed for all ages on each feature and on each of the phonemes, both syllable-initial and syllable-final. Each feature error was thus charted twice, by feature and by phoneme.

From these charts, counts of errors per feature or per phone for each subject were made and summarized in table form. Subsequently, from these tables of feature error counts, the proportion of features in error per phoneme and per feature were computed.

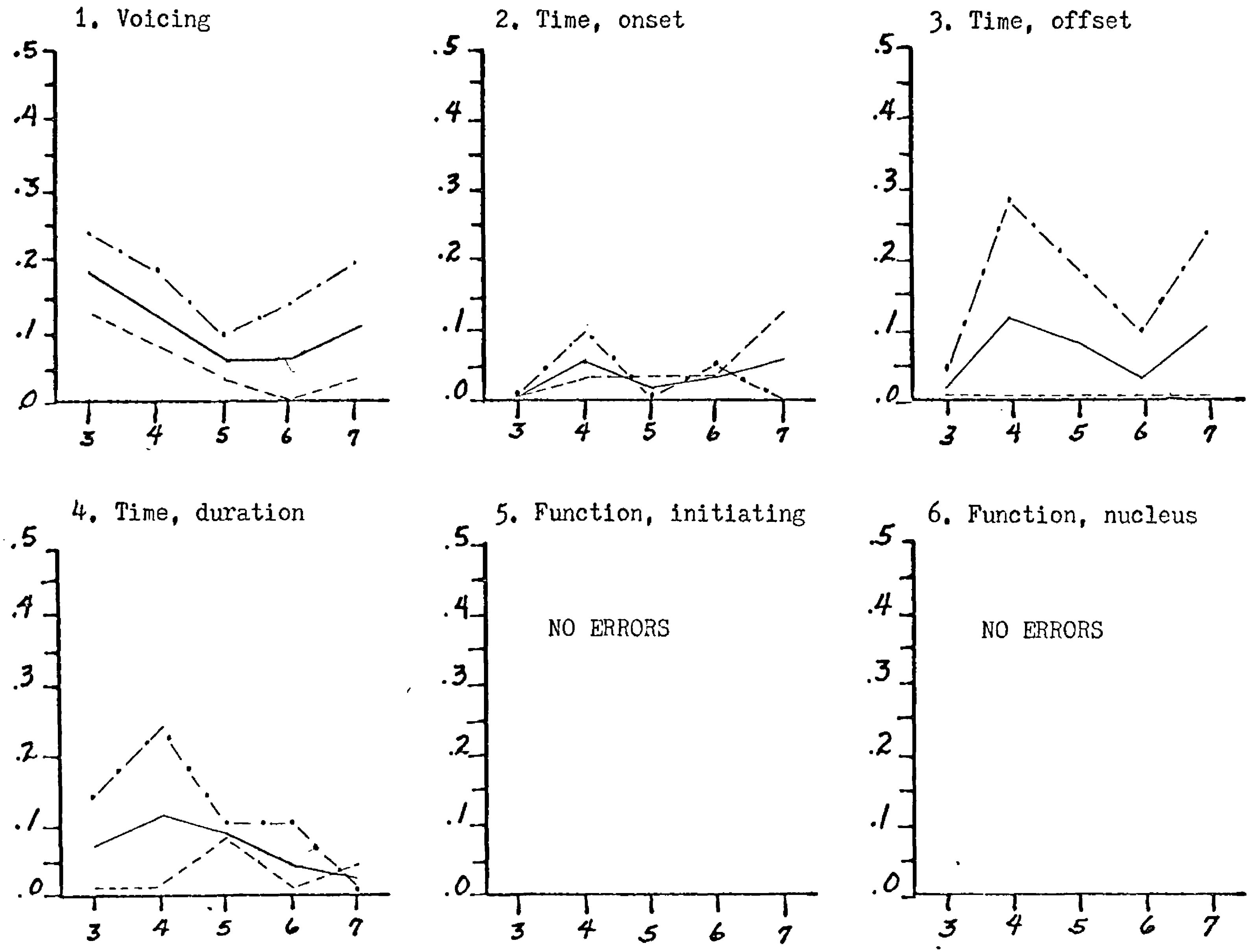
The number of errors in any one feature for any one child over all syllable-initial phones was divided by the number of phones tested (twenty-four) and the resulting proportion listed in the table. The same process was used to compute the proportion of errors which were syllable-final and the total proportion of errors involving each particular feature. These proportions were derived because a simple graphing of the number of syllable-initial and syllable-final feature errors per child would have been misleading as twenty-four phonemes were tested in the syllable-initial position while only twenty-one phonemes were tested in the syllable-final position. These proportions were then graphed by age for each feature (Figures 1-34).

A similar summary of the data by phone was completed. While it was not necessary to compute proportions here, this was done to lend uniformity to the data. The proportion of feature errors by age for each phone was then graphed (Figures 35-59).

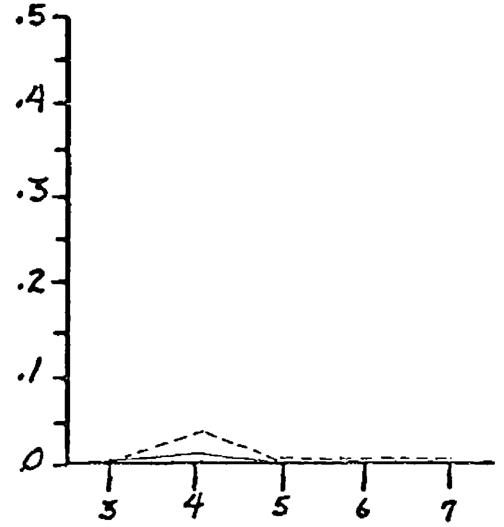
In addition, two attempts to group and describe the data by error type were completed. The first such grouping involved placing each of the 585 feature errors into one of five categories: (1) intrusion - the incorrect feature was intruded; (2) addition - the correct feature was present but more than expected; (3) substitution - the feature was present but a different value was substituted and it was not possible to describe that value as too much or too little; (4) subtraction - the correct feature was present but less than expected; and (5) omission - an expected feature was omitted. The number of each type of error for each phone for each child was then counted and listed in an appropriate table. The total number of each type of error for each child

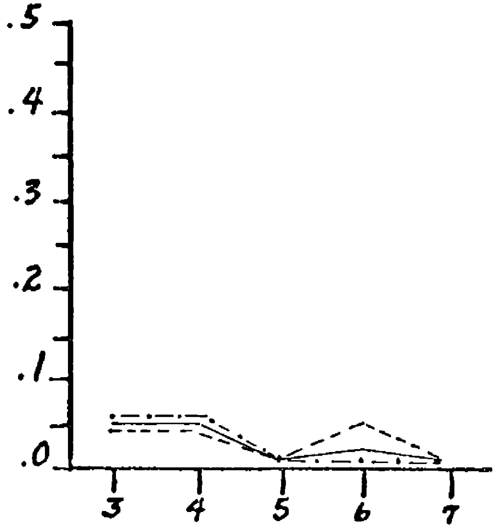
Figures 1-6. Proportion of Errors per Feature by Age.

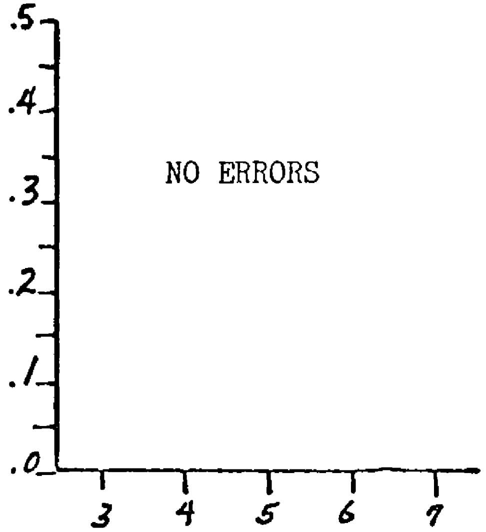
(Legend: Figures 1-59; Syllable-initial------; Syllable-final ·—·—·; Mean ———)

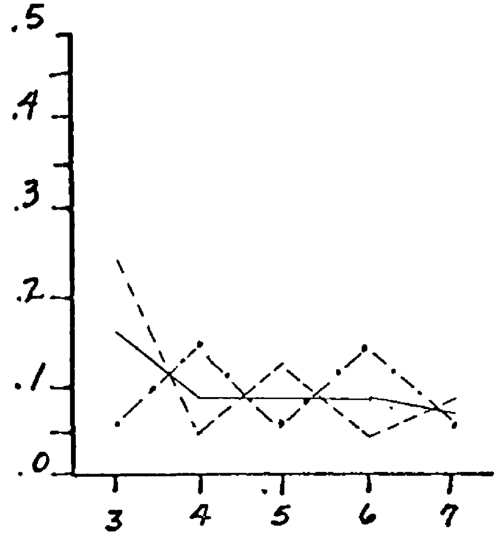


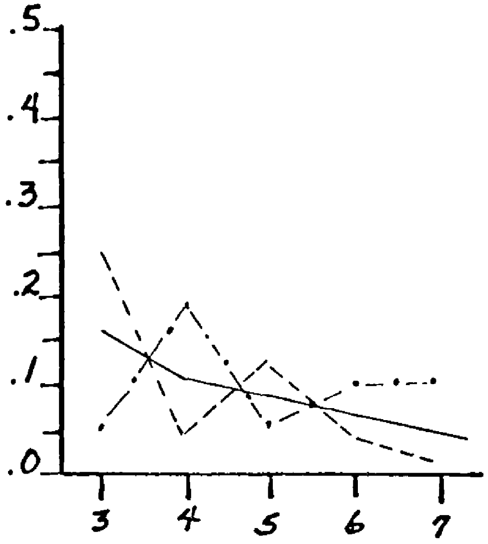
Figures 7-12. Proportion of Errors per Feature by Age

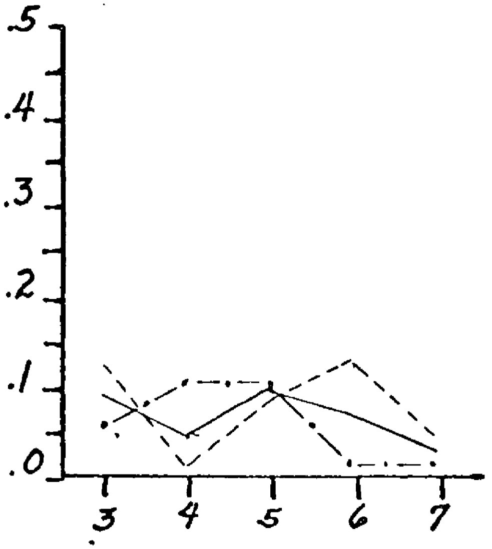

7. Function, terminating


8. Central -- lateral

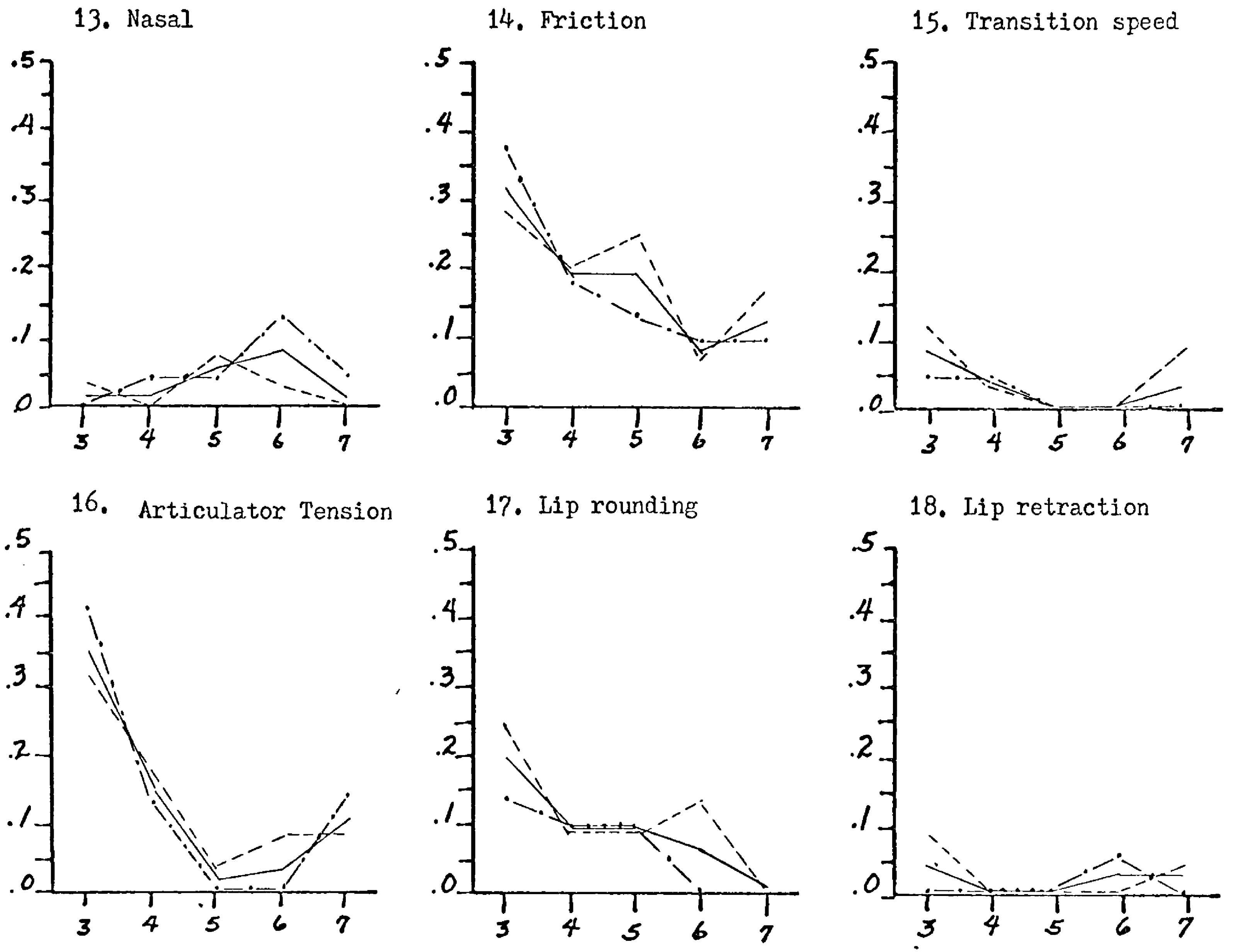

9. Expiration -- inspiration


10. Occlusion


11. Explosion


12. Aspiration

Figures 13-18. Proportion of Errors per Feature by Age.



13. Nasal

14. Friction

15. Transition speed

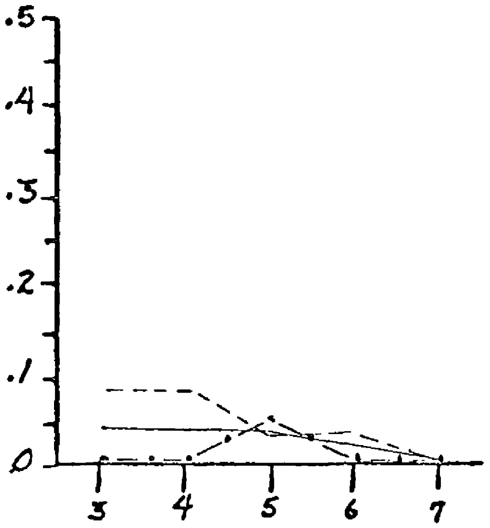
16. Articulator Tension

17. Lip rounding

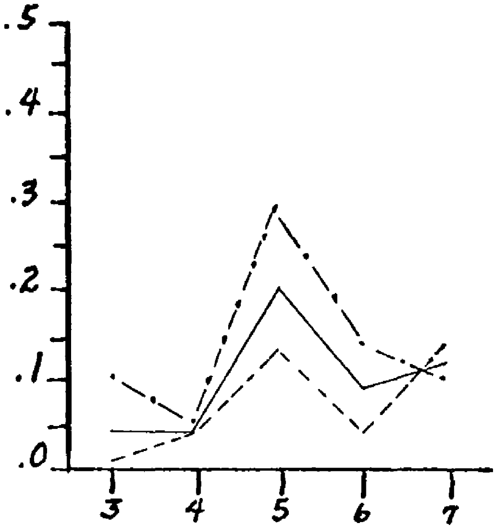
18. Lip retraction

Figures 19-24. Proportion of Errors per Feature by Age.

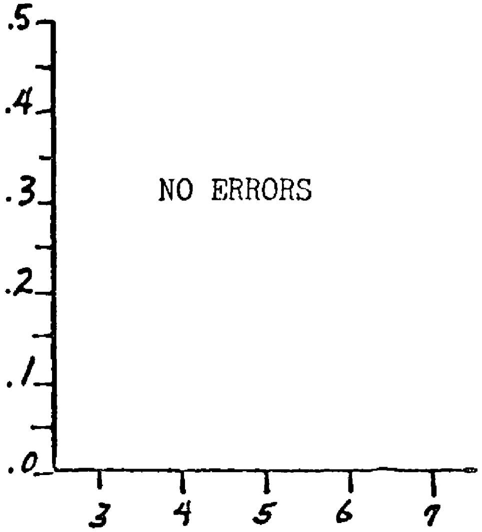
19. Bilabial



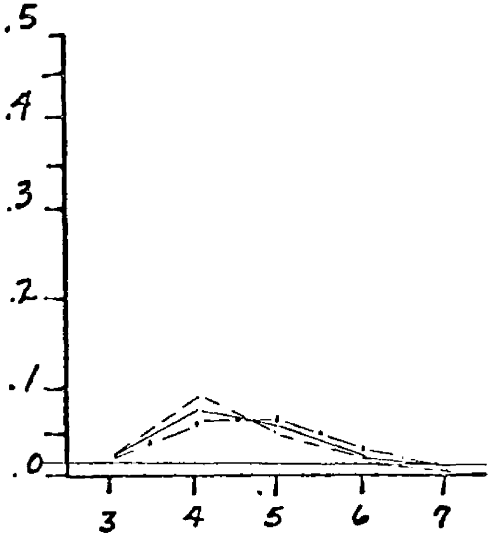
20. Labiodental



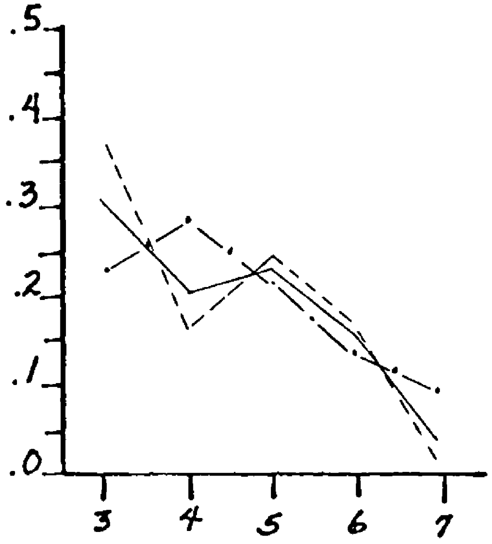
21. Interdental



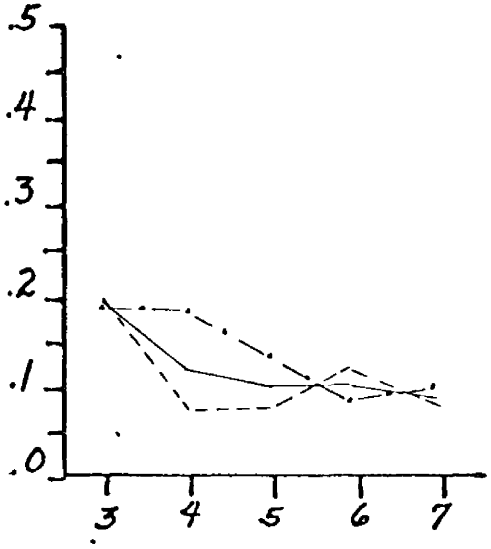
22. Dental



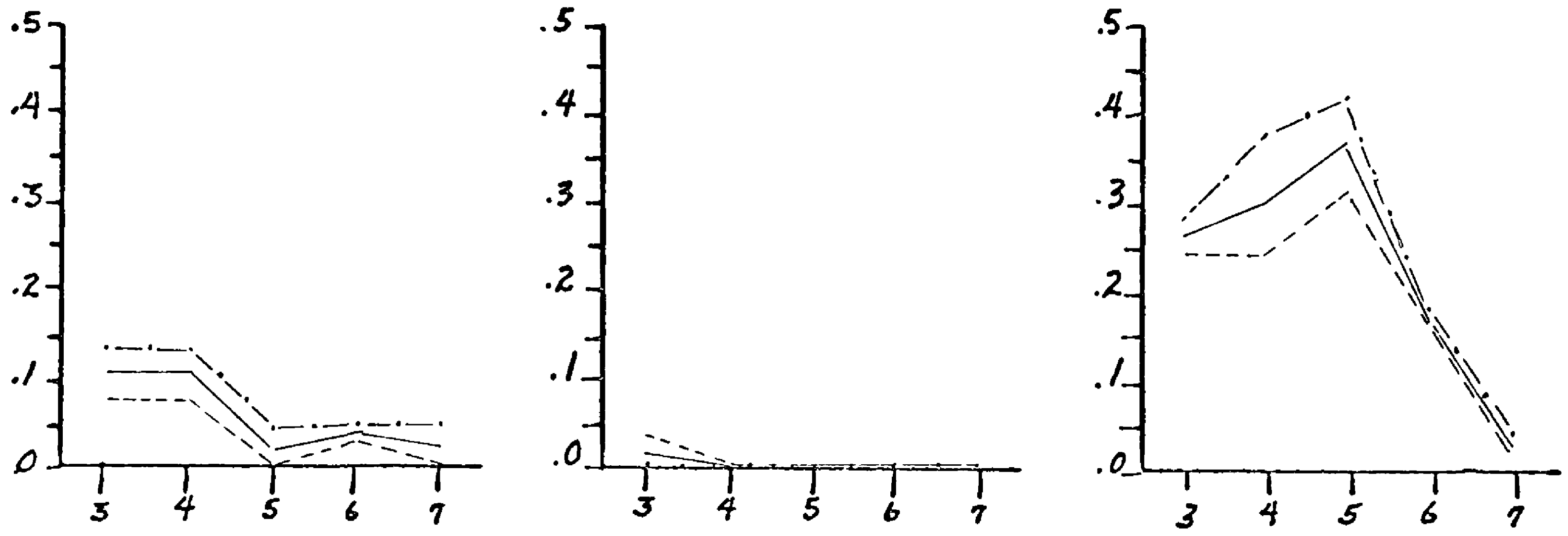
23. Alveolar



24. Palatal

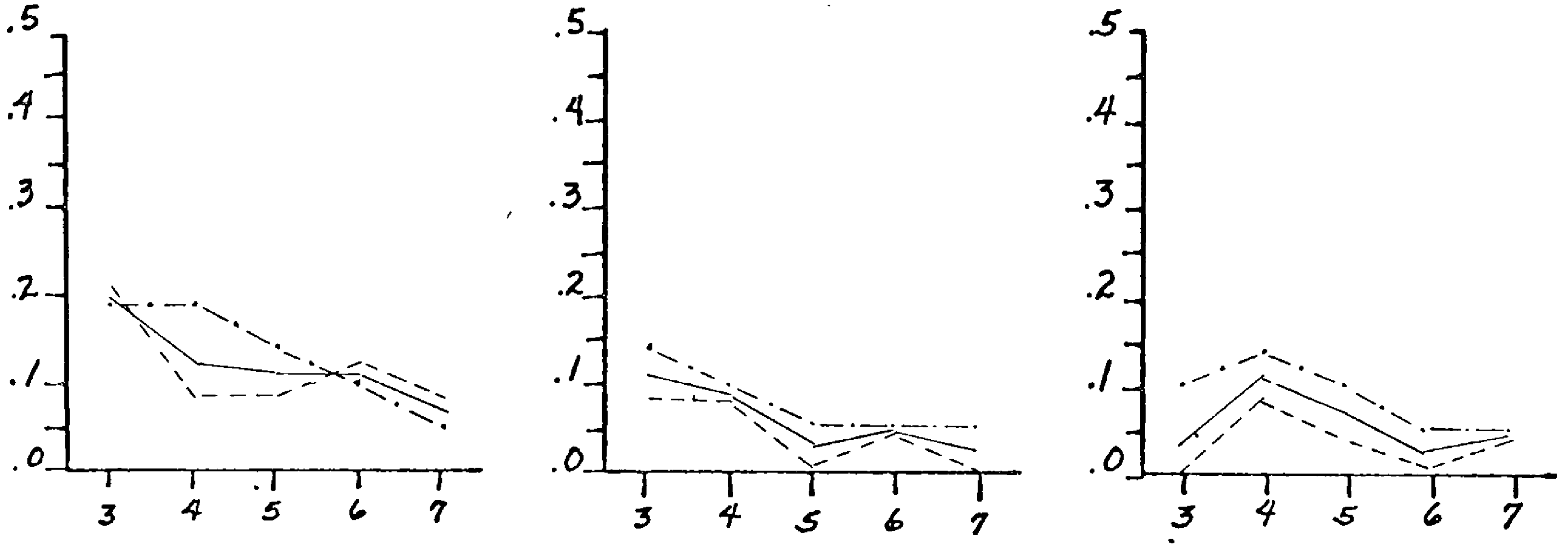


Figures 25-30. Proportion of Errors per Feature by Age.


25. Velar

26. Glottal

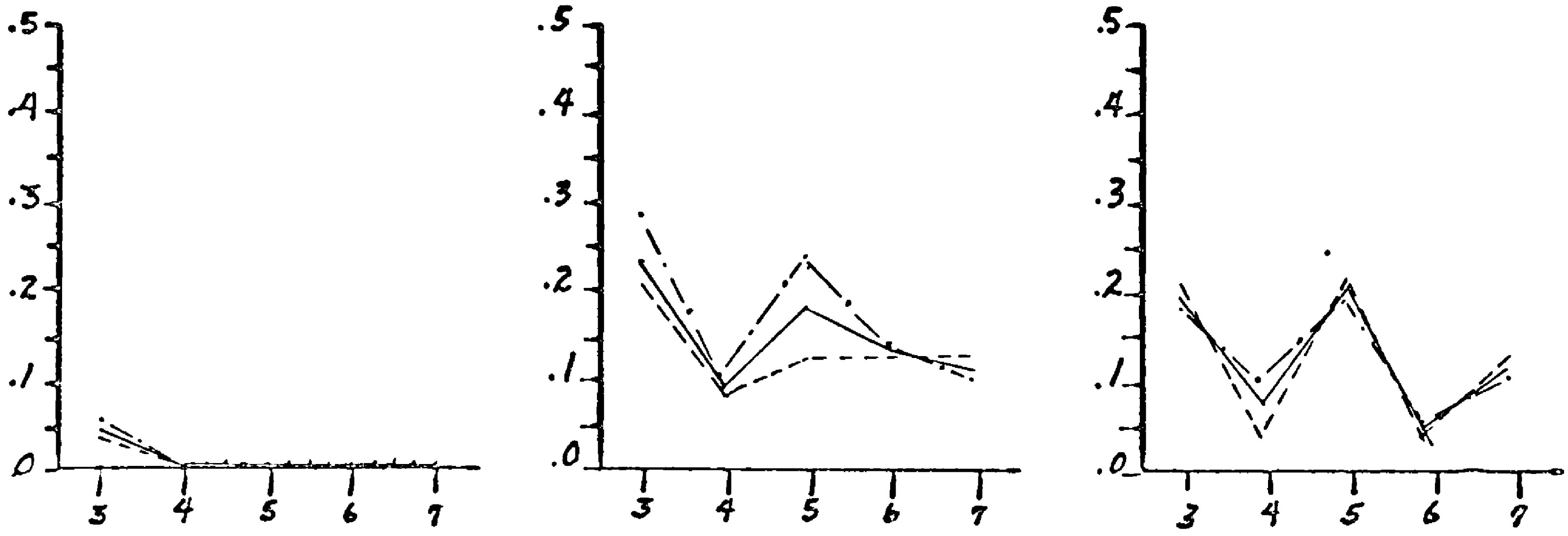
27. Tongue tip


28. Tongue blade

29. Tongue dorsum

30. Forward

Figures 31-34. Proportion of Errors per Feature by Age.

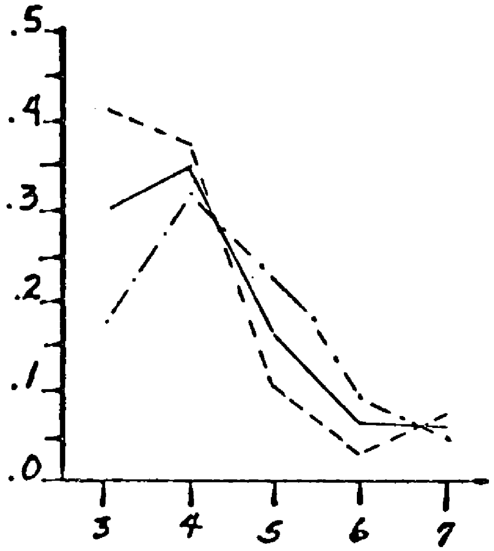


31. Retroflex

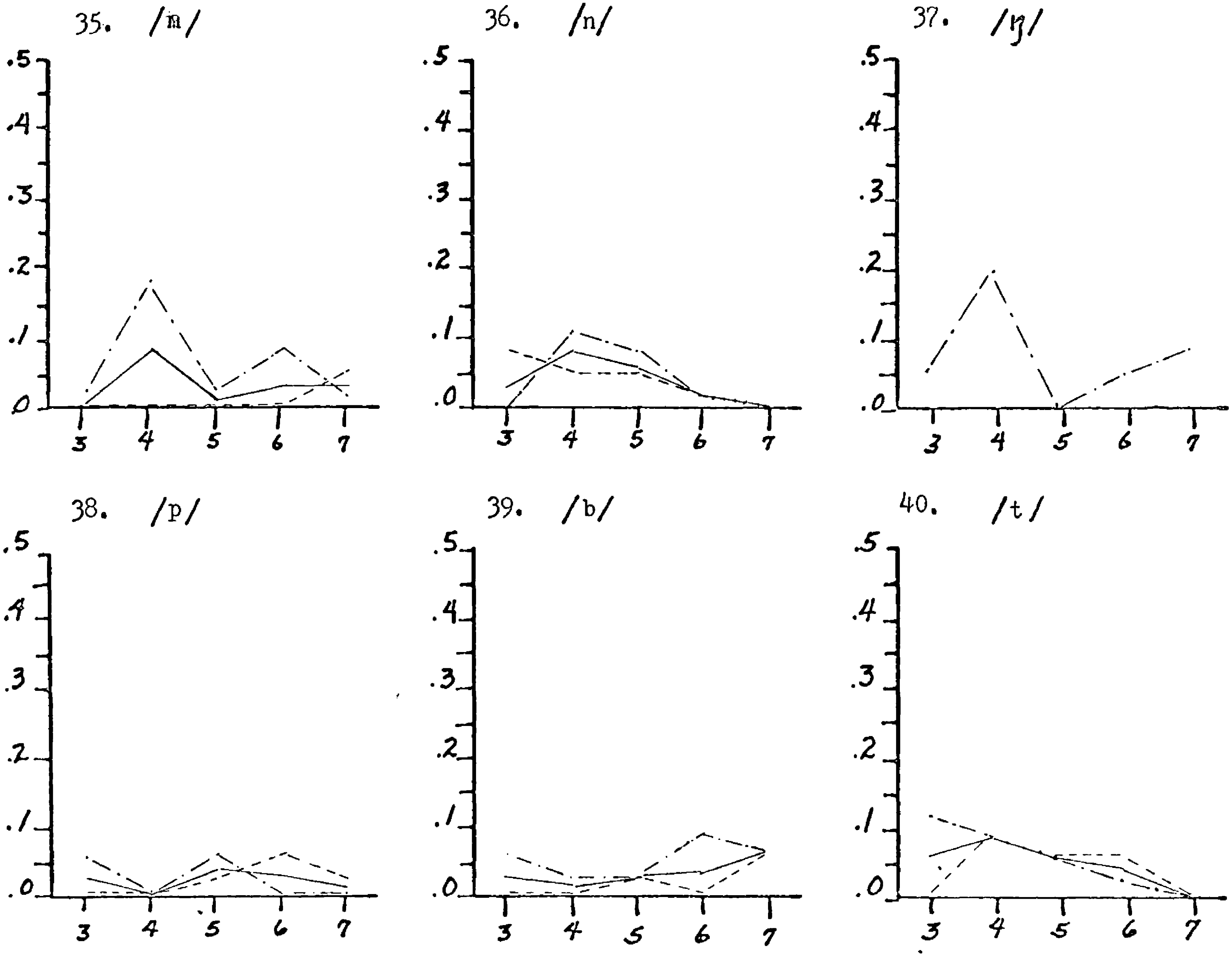
32. Groove width

33. Groove depth

34. Tongue elevation



Figures 35-40. Proportion of Feature Errors per Phoneme by Age.



35. /m/

36. /n/

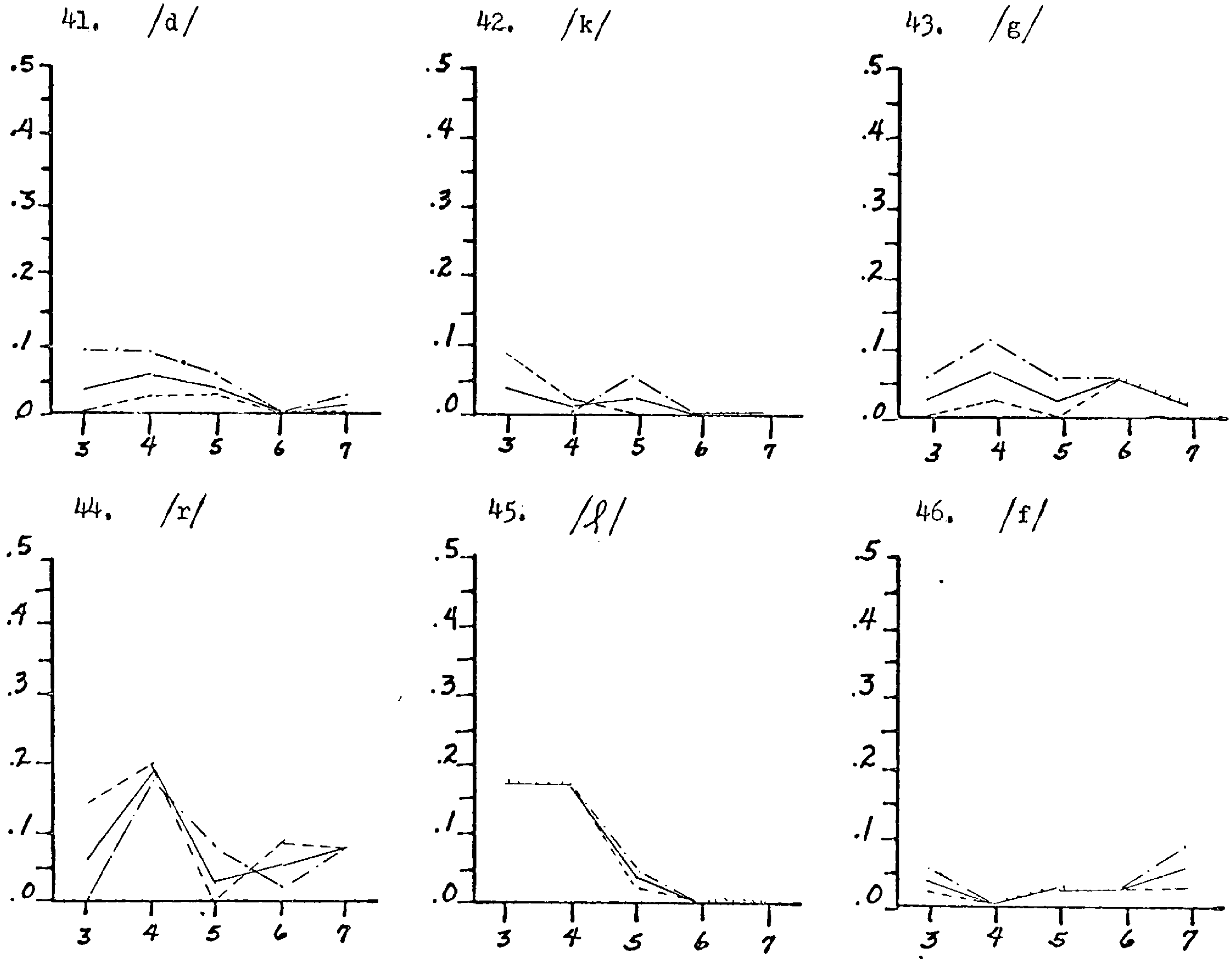
37. /ŋ/

38. /p/

39. /b/

40. /t/

Figures 41-46. Proportion of Feature Errors per Phoneme by Age.


41. /d/

42. /k/

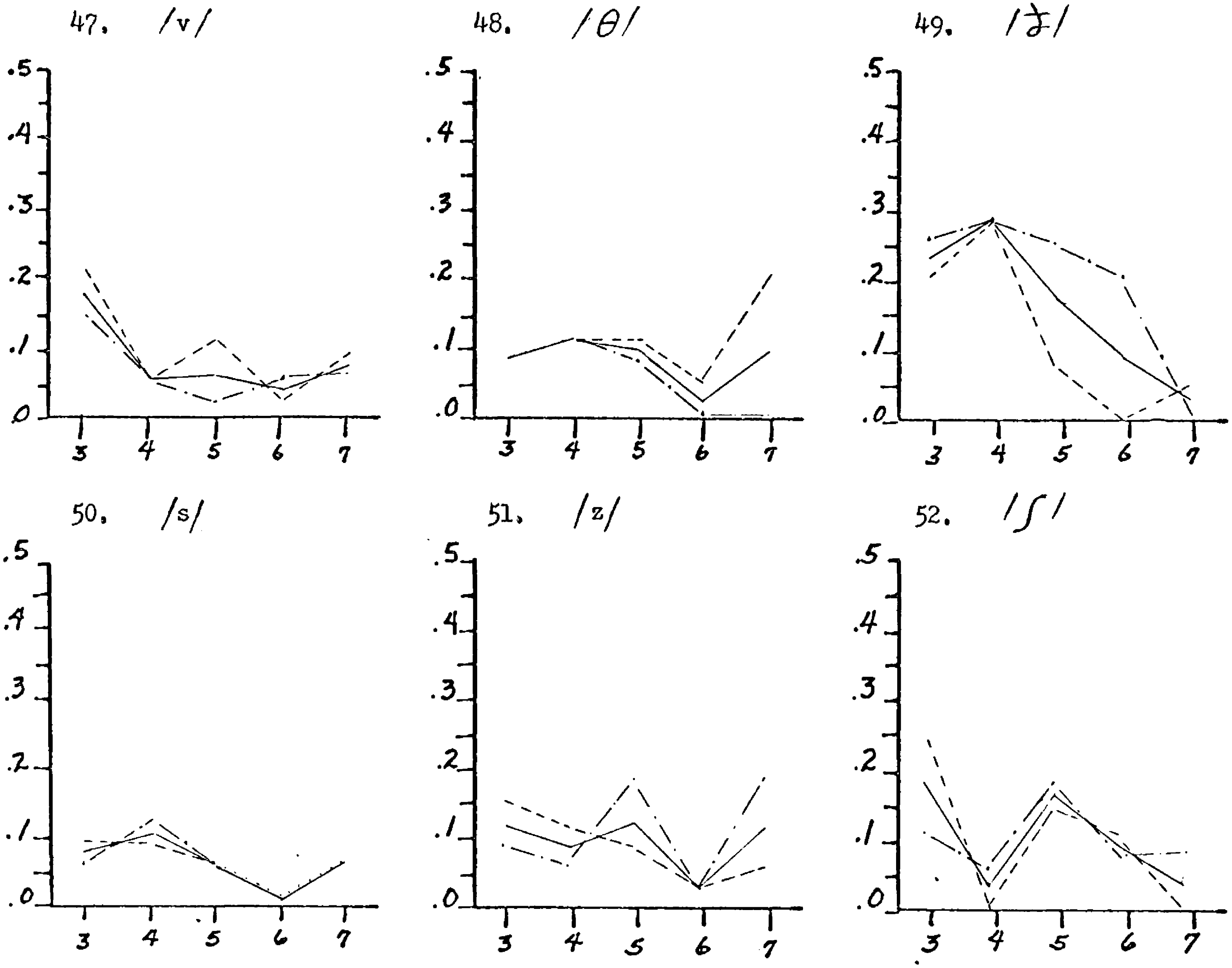
43. /g/

44. /r/

45. /ℓ/

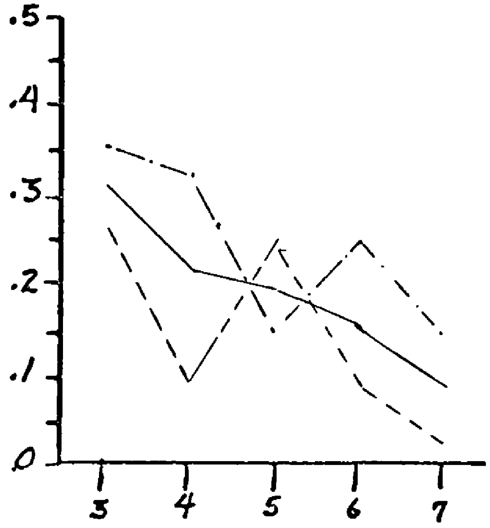
46. /f/

Figures 47-52. Proportion of Feature Errors per Phoneme by Age.

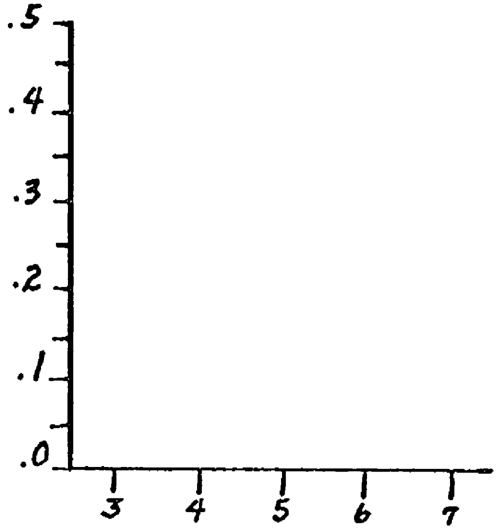


Figures 53-58. Proportion of Feature Errors per Phoneme by Age.

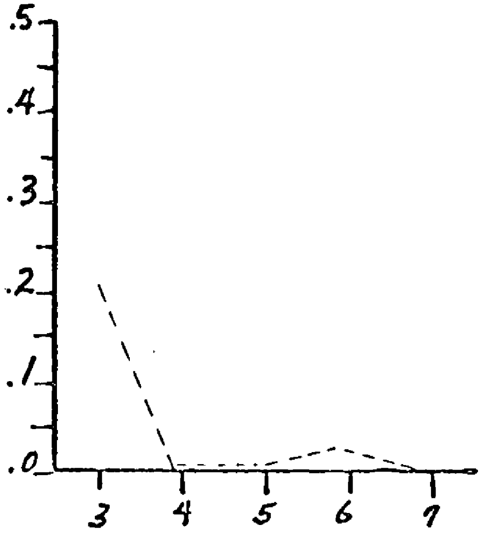
53. /ʒ/



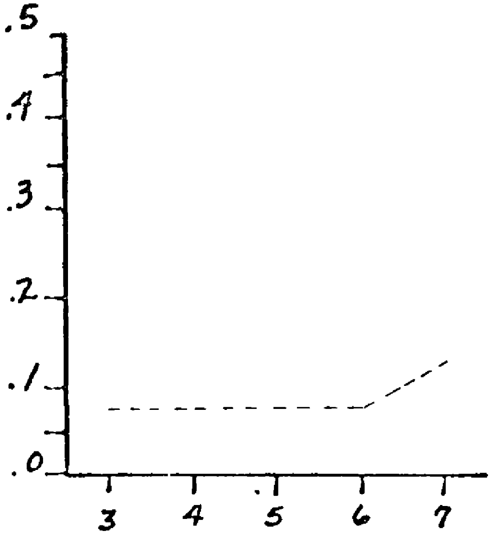
54. /h/



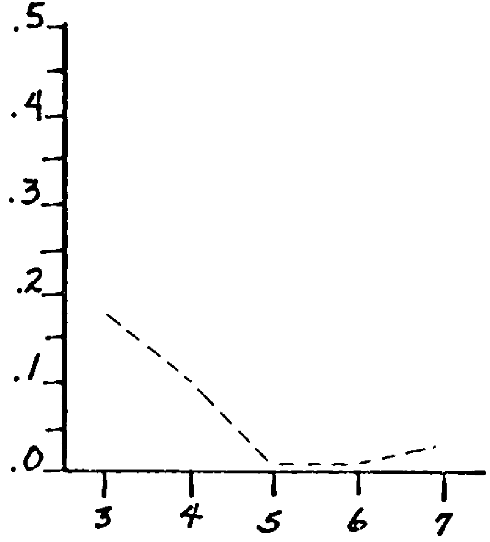
55. /w/



56. /M/



57. /j/



58. /tʃ/

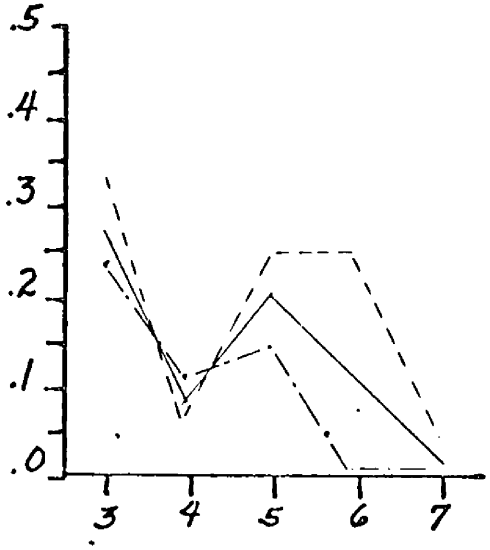
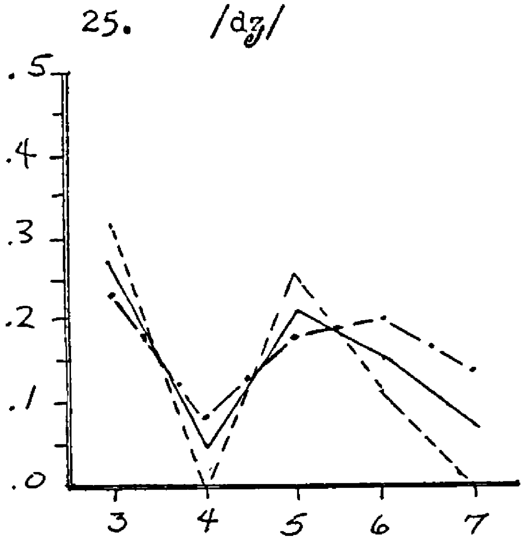


Figure 59. Proportion of Feature Errors per Phoneme by Age.



25. /dʒ/

was divided by his total number of errors; the resulting proportions for each type of error were then graphed by age (Figure 60).

A similar process was used to divide the total errors into the following three categories: (1) hypertonic articulation, (2) hypotonic articulation, and (3) unable to classify. The number of each type of error for each phone for each child was then also counted and listed in an appropriate table. Proportions of each type of feature error for each age were then computed and the results graphed (Figure 61).

One final set of proportions was also computed. The total number of errors for each feature, for each phone, and for each child, were divided by the overall total of errors. These proportions were then ranked. These measures best indicated those features most often misproduced, those phonemes where the most feature errors occurred, and the overall decrease in feature errors with the age of the subjects.

USE OF TRADITIONAL AGE NORMS

Subjects were chosen in part for this study on the basis of the score they obtained on the _Templin-Darley Screening Test of Articulation_. Each child's score approached the mean score available on this test for each age group, and each child was felt to be reasonably representative of the age group he was chosen to represent. In the case of two subjects in particular, it is interesting to compare their _Templin-Darley Screening_ scores with an overall summary of the sub-phonemic analysis of each.

The five-year-old subject obtained a score on the _Templin-Darley Screening Test_ of 35, slightly higher than the mean for his age group of 34.7. Yet if one examines his articulatory proficiency as described

Figure 60. Feature Errors by Type. Categories of Substitution, Addition, Subtraction, Omission, Intrusion.

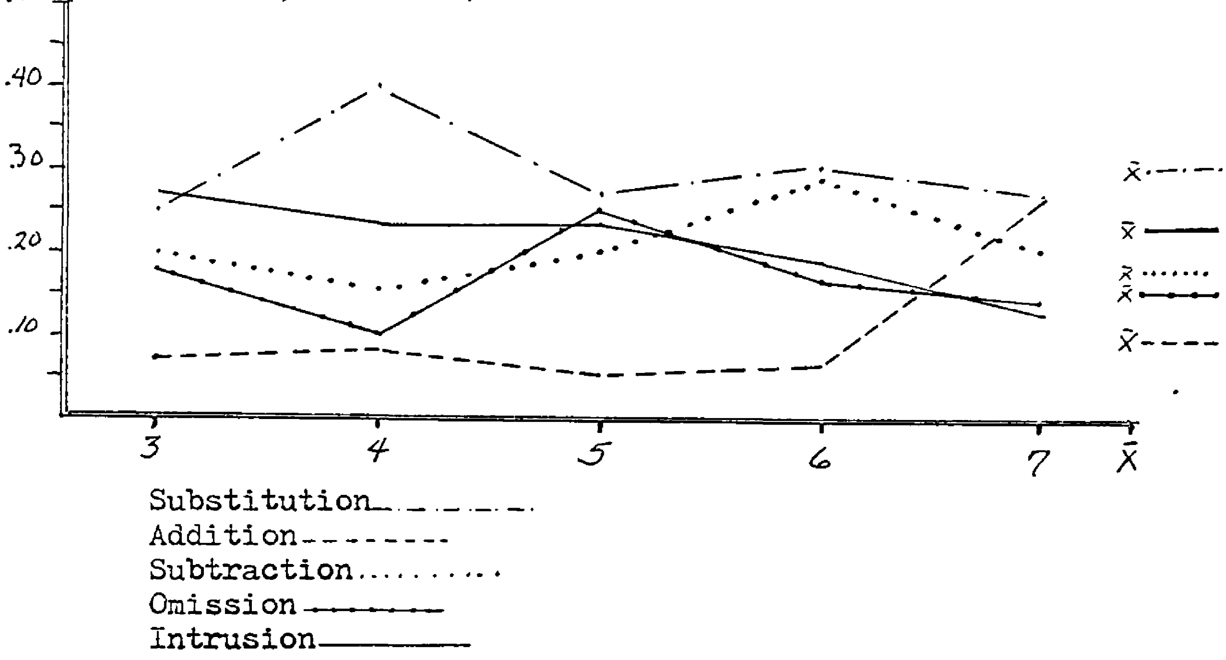
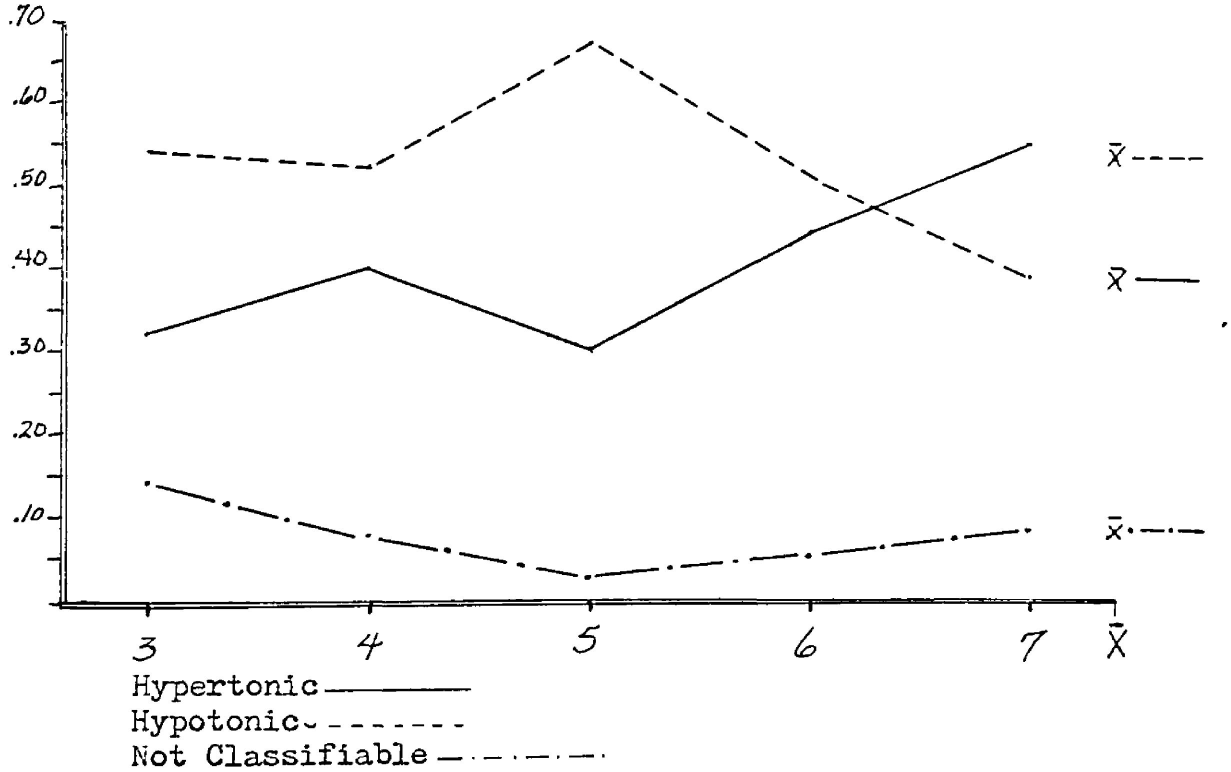


Figure 61. Feature Errors by Type. Categories of Hypertonic Articulation, Hypotonic Articulation, Not Classifiable.



sub-phonemically it becomes apparent that his articulation skills are better than expected from the Templin-Darley Screening Test score and that furthermore this score is due to a rather limited articulatory difficulty. If we examine the by-age graphing of errors on each articulatory feature, in several cases the generally decreasing slope of the graph is interrupted by a sharp dip at age five. For example, note the features of articulation tension, place-velar, voicing, central-lateral, etc. But, these graphs also reveal that this subject in particular had more difficulty with the following features than would be expected by an overall view: friction, place-labiodental, tongue tip, and groove width and depth. This child then appears to have unusual difficulty with labiodental and tongue-tip frictional sounds while his over-all articulation proficiency is better than the Templin-Darley Screening Test reveals.

The seven-year-old subject obtained a score on the Templin-Darley Screening Test of 48, higher than the mean for his age group, 44, and suggesting that his articulatory skills are slightly above average for his age. The graphs of articulatory feature errors by age, however, would suggest the contrary. In the case of several features, among them voicing, time-onset, time-offset, friction, and transition speed, this child had a higher proportion of errors than one would expect from the generally decreasing slope of the graphs.

Such interpretations suggest that traditional articulation tests and their accompanying norms, because of their lack of specificity, are not accurate in describing a child's articulatory proficiency. A child, such as our five-year-old subject, may have a limited articulation difficulty which becomes magnified by a gross error classification scheme. On the other hand such a scheme may not reveal specific though recurrent articulation difficulties, as with our seven-year-old subject.

GENERAL TRENDS

While only five subjects were used in this study, it is interesting to make certain generalizations about those five subjects and to suggest the usefulness of sub-phonemic articulation analysis for further generalizations. Further and more specific statistical analysis of the data obtained was not within the scope of this study.

As one would expect, feature errors graphed by feature or by phone reveal generally that as the age of the subject increases, the number of his errors on any one phone or with any one articulatory feature decreases. Partly because only five subjects' articulatory responses are summarized here, various exceptions to this general trend are apparent. We have already discussed some specific difficulties which the five- and seven-year-old subjects revealed. In addition, the six-year-old subject had a voice quality which would be described as slightly denasal; consequently his proportion of <u>nasality</u> feature errors is higher than would be expected. Both the five- and seven-year-old subjects revealed an unusual amount of difficulty with <u>friction</u>, the five-year-old because of his specific difficulty with labiodental sounds and the seven-year-old because of his missing upper lateral incisors.

The greatest proportion of feature errors across all subjects occurred with the features <u>place-alveolar</u>, <u>tongue-tip</u>, and <u>tongue elevation</u>. A large portion of the consonants in our language are tongue-tip alveolar sounds and this accounts in part for the large number of errors with these two features. In addition, if a <u>place</u> sub-feature or *tongue part* sub-feature were in error the child had usually erred by moving too far forward; that is, toward the alveolar ridge and toward the tip of the tongue. Finally, if *tongue elevation* were in error, the child tended to use an elevation lower than that called for, finding it difficult perhaps to move away from a neutral tongue position.

In analyzing the graphs of errors by age for individual features, one can see that features in syllable-initial phones and syllable-final phones may behave quite differently. For instance, no errors in *time-offset* were recorded for syllable-initial phones. Errors were present in syllable-final phones for this feature, particularly with the four- and seven-year-old subjects. One might hypothesize that as children are acquiring an increasingly complex phonological system and thus learning to regroup articulatory features, they will tend to trail off or prolong certain features at the end of words.

Errors in the *time-onset* feature occurred both syllable-initial and syllable-final. Here the subjects seemed to have the most difficulty turning voicing on at the appropriate time and affecting velo-pharyngeal closure at the appropriate time.

With both the *occlusive* and *explosion* features as well, syllable-initial phones seemed to behave independently of syllable-final phones. While these two features seemed to function together as one, their behavior syllable-initial and -final was such that initial and final errors cancelled themselves out, resulting in a generally decreasing slope.

COMPARISON OF TRADITIONAL AND SUB-PHONEMIC INFORMATION

For purposes of a more consistent comparison, only word-initial and word-final responses on those portions of the *Templin-Darley Diagnostic Test* administered will be referred to here in a discussion of the information obtained from this traditional articulation classification scheme and that obtained from sub-phonemic analysis by articulatory feature.

SEVEN-YEAR-OLD SUBJECT The oldest subject used in this study was judged to have the following errors using the *Templin-Darley* error categories: /f/ for /θ/ substitution initial and final, /ð/ distorted toward a /d/ initial, /s/ distorted both initial and final, and /w/ for /M/ substitution initial. All other articulation responses were judged to be correct. However, sub-phonemic analysis of his articulatory responses indicate that all but the following phonemes had some proportion of articulatory features in error: /n/, /t/, /k/, /l/, /h/, and /w/. Those phonemes, grossly judged to be correct, showed a variety of feature errors, but the following general patterns appeared: too much *articulation tension* and *lip retraction* were present on the right side for bilabial sounds; the lips were too far back on the teeth for labiodental sounds; all errors with *timing* involved *voicing*; all sibilants sounded as if the *tongue groove* were too wide and deep although this was due in fact to missing teeth; *transition speed* tended to be too slow on glides; and if *tongue elevation* were in error, it was usually too low.

SIX-YEAR-OLD SUBJECT The six-year-old subject produced all phonemes, initial and final, correctly on the portions of the *Templin-Darley Test of Articulation* administered with the exception of the following: /f/ distorted toward a /p/ initial; /w/ for /M/ substitution initial; and /ʃ/ for /tʃ/ substitution initial. Sub-phonemic analysis, however, revealed articulatory features in error on all but the following phonemes: /s/, /d/, /k/, /l/, /h/, and /j/. The following patterns appeared in his articulation responses: less *nasality* present than normal where expected; lenis /p/ and /t/ produced initially with insufficient *aspiration*; lips too far forward on the teeth for the labiodental phones; many sibilants produced with a *tongue groove* which was too narrow; if *place* where in error, it tended to be too far forward; *timing* errors usually involved *voicing*; less *lip rounding* than normally present where expected; and several instances were noted where voiceless cognates were substituted for voiced phones.

FIVE-YEAR-OLD SUBJECT Eleven articulation errors were noted in the speech of the five-year-old subject, as classified by the *Templin-Darley* error categories: /b/ for /v/ substitution initial; /v/ distorted toward an /f/ final; /s/ for /θ/ substitution initial; /θ/ distorted toward an /s/ final; /s/ for /ʃ/ substitution initial and final; /w/ for /M/ substitution initial; /l/ for /j/ substitution initial; /s/ for /tʃ/ substitution initial, and /dʒ/ distorted initial and final. However, sub-phonemic analysis indicated that articulatory feature errors were present for all but the following phones: /ŋ/, /h/, /w/, and /j/. Errors across the other phones had the following pattern: *labiodental* occlusion was present for bilabially produced /b/ and /p/; generally less *aspiration* was present than expected; there were very few errors with *voicing*, although most *timing* errors involved the *voicing* feature; little consistency was present in *tongue groove* and *tongue elevation* errors; single element sounds were substituted for most two element sounds; errors in *place* and *tongue part* were not consistent; unusual difficulty with *tongue groove*, *tongue tip*, and with *place-labiodental*.

FOUR-YEAR-OLD SUBJECT The four-year-old subject had the following errors as classified by the *Templin-Darley* categories: /w/ for /r/ substitution initial; /ŋ/ distorted toward a /k/ final; /θ/ distorted final; /ð/ distorted toward a /d/ initial; /w/ for /M/ substitution initial; /dʒ/ distorted toward a /ʒ/ initial; and /ʒ/ distorted toward a /dʒ/ final. This subject had sub-phonemic errors on all but the following phonemes: /h/, /w/, /p/, and /f/. The following factors characterize this subject's pattern of misarticulations; unusual difficulty with all *timing* sub-features; if *place* or *tongue part* was in error it was usually too far forward; *tongue elevation* was too low if in error usually; errors with *articulation tension* usually involved too much tension; and unusual difficulty was noted with *place-dental*.

THREE-YEAR-OLD SUBJECT The youngest subject used in this study had the following errors as classified by the Templin-Darley categories: /b/ for /v/ substitution initial; /s/ for /θ/ substitution initial; /d/ for /ð/ substitution initial; /ð/ distorted toward an /s/ final; /s/ for /ʃ/ substitution initial and final; /w/ for /M/ substitution initial; /j/ omitted initial; /s/ for /tʃ/ substitution initial; /tʃ/ distorted final; and /dʒ/ distorted final. As one might expect, this child had the most feature errors across all phones, with the following phones being the only ones he produced with no errors: /m/, and /h/. While for most features this subject had the highest proportion of errors, some patterns are still discernable in his articulatory responses: no errors with *time-onset*; fewer errors with *time-offset* than expected; fewer errors with *tongue shape-forward* than expected; an unusual difficulty with *articulation tension*; later learned sounds tended to be too far forward in the oral cavity; if *tongue elevation* was in error, it was usually too low.

CLASSIFICATION OF ERROR BY TYPE

All types of feature errors across all subjects were classified by type, using the two classification schemes previously discussed. That classification scheme which attempted to categorize all features as hypertonic or hypotonic articulation illustrates that for four of the five subjects, hypotonic articulation errors predominated. The exception to this is the seven-year-old subject who had more hypertonic errors of articulation than hypotonic. For some reason, the disparity between the proportion of hypertonic and hypotonic errors is greatest for the five-year-old subject. It is also interesting to note that if the points plotted for this subject on the graph were removed, hypertonic errors would appear to increase with age, while hypotonic errors would appear to decrease with age.

In general, it was found that a rather small static proportion of the subjects' errors were unclassifiable using this system.

It was possible to classify all 585 feature errors using the five categories of intruded feature, subtracted feature, substituted feature, added feature, and omitted feature. Across all subjects the highest proportion of errors fit into the substituted category; the only exception to this was the three-year-old subject. The other categories of errors ranked themselves in the following fashion under substitutions: intrusions, subtractions, omissions, and additions. Errors involving intruded features tended to decrease with age, while errors involving subtracted feature values tended to increase with age. For some reason, the four-year-old subject had a very high proportion of errors involving substituted feature values; in other words, he tended to employ the correct articulatory features but used a value for these features which was incorrect. On the other hand, the seven-year-old subject had a very high proportion of errors involving the addition of a higher value for a feature. This would tend to coincide with the above statement which indicates that this subject made more hypertonic articulation errors than hypotonic articulation errors.

Chapter 5

SUMMARY AND CONCLUSIONS

SUMMARY

Distinctive feature schemes have been developed by linguists and experimental phoneticians in their attempts to understand and describe both speech production and speech perception. The role of distinctive features in short-term memory of speech sounds, in a child's developing phonological system, in the development of speech-sound discrimination, as well as in the description and subsequent remediation of aberrant articulation responses have all been investigated. What was found lacking in previous research, however, was a procedure for the detailed sub-phonemic analysis of articulatory responses using distinctive features or articulatory attributes with a specifically motor-articulation basis.

Traditional articulation testing has proven inadequate in providing sufficiently specific information concerning a child's phonological system. Sub-phonemic analysis offered a means by which such information could be obtained. Thus the purposes of this study were to develop a useful scheme of articulatory attributes and a procedure for their use as well as to demonstrate the advantages of using such a scheme to describe articulation over the use of traditional error classification schemes.

The articulatory responses of five subjects, ages three to seven, were analyzed in this study. Each child used as a subject had articulation skills typical for his age group, as measured by the _Templin-Darley Screening Test of Articulation_. Each subject was administered portions of the Templin-Darley Diagnostic Test of Articulation and a picture-word articulation test developed by the experimenter. Twenty-five English consonants were tested in single-word responses. All articulatory responses for each subject were video-taped; these responses were later reviewed and described, using the traditional error categories on the portions of the Templin-Darley Test and a scheme of articulatory attributes developed by the experimenter on the test devised for this study. Information concerning each subject's responses on both of the two tests administered was then summarized.

DISCUSSION AND CONCLUSIONS

It was found that traditional articulation error classification schemes do not provide necessarily precise views of a child's general articulation skills and that they tend to magnify limited problem areas and not reveal wide-spread though small articulation problems. Sub-phonemic description of subjects' articulation responses provided more information concerning the child's articulatory proficiency and also revealed patterns present throughout any one child's articulation responses, and across all of the subjects' responses. Such descriptions could be of diagnostic significance in determining if a child's aberrant articulation patterns are maturational or will require remediation.

In general, as age increased, errors per articulatory attribute or phoneme tested decreased. While the articulatory responses of only five children were analyzed in this research, it is interesting to investigate the exceptions to this general trend. Our six-year-old subject had a voice quality characterized by hyponasality and consequently his proportion of errors with the attribute nasal was higher than expected.

Using the traditional error classification scheme, there is no means by which this voice quality can be accurately described; that is, both its nature and its severity. The use of sub-phonemic analysis using some sort of articulatory attribute might therefore prove to be useful in the analysis of and subsequent remediation of aberrant vocal qualities.

One subject, the five-year-old, was found through sub-phonemic description to have articulation skills generally better than preliminary testing indicated. A specific area of articulatory difficulty, labiodental fricatives, was identified in this child. The in-depth description of this child's production of these phonemes is exemplary of how sub-phonemic analysis of aberrant articulation responses can be helpful in the therapeutic process. His misarticulations involved errors with the following features: friction, labiodental, tongue tip, and groove width and depth. Such information could be of great value to the speech clinician planning and implementing a program of therapy with this child. Rather than teaching each phoneme as a whole, she could identify those specific articulatory attributes in error and instruct the child in their correct production, providing for a more efficient therapeutic program. However, further research, using perhaps groups of children with speech disorders and therapists matched as closely as possible, is required to determine if the additional information provided by sub-phonemic analysis is actually valuable to the remediation process.

Certain other general trends are apparent in the summary of articulatory attribute errors for the five subjects. With some features in particular, it is interesting to note that features may behave quite differently in syllable-initial phones and in syllable-final phones. For example, it was found that with syllable-final phones, the children seemed to have some difficulty turning all of the feature package off at the same time, while in syllable-initial phones this difficulty did not appear. It might be suggested that as children are acquiring an increasingly complex phonological system, trailing off at the ends of words is one means by which they may practice certain features.

While relatively few errors with the voicing feature were noted across all subjects, all of the children seemed to have the most difficulty with the timing of this feature. Menyuk (1968) has indicated that voicing is one of the earliest learned features in the developmental process; thus a large proportion of errors would not be expected with this feature. Perhaps the subjects' difficulty with the timing of this feature is as Crocker (1969) suggests, due to the child's difficulty in removing a learned feature from a particular feature package and placing it properly in a newly acquired feature package, or perhaps voicing is not learned as early as Menyuk suggests.

As previously discussed, we found that the greatest proportion of feature errors across all subjects occurred with the features alveolar, tongue tip, and tongue elevation. While the proportion of errors with alveolar and tongue tip are not unexpected considering the great number of tongue-tip alveolar phonemes in the English phonological system, it is interesting to note that where errors existed with other place or tongue part features, the child usually erred by moving too far forward in the oral cavity; that is, toward the alveolar ridge and toward the tip of the tongue. When a child is in doubt as to where any particular phoneme should be produced, it appears that he will tend to move forward to the familiar place of tongue-tip alveolar. Most errors with tongue elevation would also suggest that when a child is acquiring an increasingly complex phonological system, when he is in doubt about the correct tongue height for a particular phoneme, he will tend to stray downward toward the neutral position for the tongue.

Classification of feature errors by type of error was completed, using two classification schemes. That scheme which attempted to describe all feature errors as hypertonic or hypotonic articulation, proved to be the most informative. It was found that as age increases, hypertonic articulation errors increase and hypotonic articulation errors decrease. One might suggest that the apparent shift from hypotonic to hypertonic articulation errors with age found with these five subjects is representative of most children developing toward an adult phonological system. As they are acquiring a more complex system, involving more articulatory attributes and more combinations of these attributes, children seem to be somewhat slow and lazy in their articulation efforts. However, as they become more adept at producing the required features in correct combinations their articulation efforts are more vigorous and exact.

While it was not the purpose of this research to establish either the reliability or validity of the feature scheme developed, a limited investigation of the reliability of the use of the scheme was conducted. In addition, later research (Heaton, 1971) provides us with additional information concerning both the reliability and validity of certain of the articulatory attributes developed in the present study. Relatively acceptable reliability and validity were found for most articulatory attributes; where reliability and validity were not acceptable, this was generally felt due to inadequate judge training procedures. If the sub-phonemic analysis of articulation responses is to become an instrument useful clinically for both diagnostic and therapeutic reasons, additional research is needed in the area of training in the use of sub-phonemic description schemes. The fine discriminatory decisions and the phonetic background required of the listener using such a scheme must be provided for in the training procedure.

The scheme of articulatory attributes and the procedure for its implementation in the description of articulation responses allow for an extremely specific analysis of articulation. It is more time-consuming to complete sub-phonemic analysis of articulation responses, but with the eventual standardization of such a scheme and procedure for its use, it could prove to be a highly useful clinical tool that speech clinicians could be readily trained to use. However, further research is needed to explore several areas. While both auditory and optical information were used in this study in the analysis of articulatory responses, the greatest use was made of auditory information. The comparative validity and reliability of analyses made using both auditory and optical information and auditory information alone should be determined. The possible usefulness of sub-phonemic articulation description for both diagnostic and therapeutic purposes has been suggested. While this study was concerned with the articulation responses of children with articulation skills typical for their age, future studies could investigate children and adults with known articulation or vocal disorders. The therapeutic application of such articulation descriptions should also be further investigated, stressing perhaps therapeutic approaches useful in the remediation of particular patterns of feature errors. Obviously, if sub-phonemic analysis of articulation responses is to become a procedure which is clinically useful, standardized norms for a scheme of articulatory attributes such as was developed by this research must be established. Hopefully too, such research would increase our present body of knowledge concerning the development of articulation skills.

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APPENDIX A

Table 11. Subject Information.

Age	Birthdate	Score - Templin-Darley Screening	Mean for Age Group	Standard Deviation for Age Group
3	4/24/67	14	22.5	13.5
4	4/12/66	35	34.7	11.2
5	5/20/65	35	34.7	14.5
6	5/15/64	46	38.5	13.8
7	4/18/63	48	44.0	8.4

APPENDIX B

Table 12. Words Elicited in Test Designed by Experimenter.

Phoneme	Initial Position	Final Position
/m/	milk	drum
/n/	nail	train
/ŋ/		swing
/p/	pie	cup
/b/	bed	bib
/t/	tie	boot
/d/	dog	bread
/k/	cow	cake
/g/	gun	pig
/r/	ring	star
/l/	lion	bell
/f/	foot	leaf
/v/	vase	stove
/θ/	thumb	mouth
/ð/	there	smooth
/s/	sun	bus
/z/	zebra	nose
/ʃ/	shoe	fish
/ʒ/	television	garage
/h/	horse	
/w/	worm	
/M/	wheel	
/j/	yo-yo	
/tʃ/	chair	watch
/dʒ/	jar	cage

APPENDIX C

Table 13. Number of Errors per Articulatory Attribute per Child. Syllable-initial, Syllable-final, and Total.

Articulatory Attribute	Three			Four			Five			Six			Seven					
	I	F	T	I	F	T	I	F	T	I	F	T	I	F	T	T	F	T
1. Voicing	3	5	8	2	4	6	1	2	3	0	3	3	1	4	5	7	18	25
2. Time-onset	0	0	0	1	2	3	1	0	1	1	1	2	3	0	3	6	3	9
Time-offset	0	1	1	0	6	6	0	4	4	0	2	2	0	5	5	0	18	18
Time-duration	0	3	3	0	5	5	2	2	4	0	2	2	1	0	1	3	12	15
3. Initiating	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nucleus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Terminating	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1
4. Central-Lateral	1	1	2	1	1	2	0	0	0	1	0	1	0	0	0	3	2	5
Expir.-Inspir.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5. Occlusive	6	1	7	1	3	4	3	1	4	1	3	4	2	1	3	13	9	22
Explosion	6	1	7	1	4	5	3	1	4	1	2	3	0	2	2	11	10	21
Aspiration	3	1	4	0	2	2	2	2	4	3	0	3	1	0	1	9	5	14
6. Nasal	1	0	1	0	1	1	2	1	3	1	3	4	0	1	1	4	6	10
7. Fricative	7	8	15	4	5	9	6	3	9	2	2	4	4	2	6	23	20	43
8. Trans. Speed	3	1	4	1	1	2	0	0	0	0	0	0	2	0	2	6	2	8
9. Artic. Tension	8	9	17	4	3	7	1	0	1	2	0	2	2	3	5	17	15	32
1. Rounded	6	3	9	2	2	4	2	2	4	0	3	3	0	0	0	13	7	20
Retracted	2	0	2	0	0	0	0	0	0	0	1	1	1	0	1	3	1	4
2. Bilabial	2	0	2	2	0	2	1	1	2	1	0	1	0	0	0	6	1	7
Labiodental	0	2	2	1	1	2	3	6	9	1	3	4	3	2	5	8	14	22
Interdental	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dental	0	0	0	2	1	3	1	1	2	0	0	0	0	0	0	3	2	5
Alveolar	9	5	14	4	6	10	6	5	11	4	3	7	0	2	2	23	21	44
Palatal	5	4	9	2	4	6	2	3	5	3	2	5	2	2	4	14	15	29
Velar	2	3	5	2	3	5	0	1	1	1	1	2	0	1	1	5	9	14
Glottal	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
3. Tongue Tip	6	6	12	6	8	14	8	9	17	4	4	8	1	1	2	25	28	53
Blade	5	4	9	2	4	6	2	3	5	3	2	5	2	1	3	14	14	28
Dorsum	2	3	5	2	2	4	0	1	1	1	1	2	0	1	1	5	8	13
4. Tongue Forward	0	2	2	2	3	5	1	2	3	0	1	1	1	1	2	4	9	13
Retroflex	1	1	2	0	0	0	0	0	0	0	0	0	0	1	1	1	2	3
Groove Width	5	6	11	2	2	4	3	5	8	3	3	6	3	2	5	16	18	34
Groove Depth	5	4	9	1	2	3	5	4	9	1	1	2	3	2	5	15	13	28
5. Tongue Elevation	10	4	14	9	7	16	3	5	8	1	2	3	2	1	3	25	19	44
Totals	99	78	177	55	82	137	58	64	122	34	42	80	34	35	69	284	301	585

(I - syllable-initial, F - syllable-final,
T - total)

Table 14. Proportion of Errors per Articulatory Attribute for each Child. Syllable-initial, Syllable-final, and Total.

	AGE																
	3			4			5			6			7			TOTAL		
Manner features	I	F	T	I	F	T	I	F	T	I	F	T	I	F	T	N=120	N=105	N=225
1. Voicing	.13	.24	.18	.08	.19	.13	.04	.10	.07	.0	.14	.07	.04	.19	.11	.06	.17	.11
2. a. Time onset	0	0	0	.04	.10	.07	.04	0	.02	.04	.05	.04	.13	0	.07	.05	.03	.04
b. Time offset	0	.05	.02	0	.29	.13	0	.19	.09	0	.10	.04	0	.24	.11	0	.17	.08
c. Time duration	0	.14	.07	0	.24	.11	.08	.10	.09	0	.10	.04	.04	0	.02	.03	.11	.07
3. a. Initiating	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.0 0	.0 0	.0 0
b. Nucleus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.0 0	.0 0	.0 0
c. Terminating	0	0	0	.04	0	.02	0	0	0	0	0	0	0	0	0	.01	.0 0	0 0
4 a. central-lateral	.04	.05	.04	.04	.05	.04	0	0	0	.04	0	.02	0	0	0	.03	.02	.02
b. expir.-inspir.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0 0	0 0	0 0
5 occlusion	25	.05	.16	.04	.14	.09	.13	.05	.09	.04	.14	.09	.08	.05	.07	.11	.08	.10
a. Explosion	25	.05	.16	.04	.19	.11	.13	.05	.09	.04	.10	.07	0	.10	.04	.09	.09	.09
b. Aspiration	.13	.05	.09	0	.10	.04	.08	.10	.09	.13	0	07	04	0	.02	.08	.05	.06
6. Nasal	.04	0	.02	0	.05	.02	.08	.05	.07	.04	.14	.09	0	.05	.02	.03	.06	.04
7. Fricative	.29	.38	.33	.21	.19	.20	.25	.14	.20	.08	.10	.09	.17	.10	.13	.19	.19	.19
8. Transition speed	.13	.05	.09	.04	.05	.04	0	0	0	0	0	0	.08	0	.04	.05	.02	.04
9. Artic. tension	.33	.43	.36	.17	.14	.16	.04	0	.02	.08	0	.04	.08	.14	.11	.14	.14	.14
Spatial features																		
1. a. Rounded	.25	.14	.20	.08	.16	.09	.08	.10	.09	.13	0	.07	0	0	0	.11	.07	.09
b. Retracted	.08	0	.04	0	0	0	0	0	0	0	.05	.02	.04	0	.02	.03	.01	.02
2. a. Bilabial	.08	0	.04	.08	0	.04	.04	.05	.04	.04	0	.02	0	0	0	.05	.01	.03
b. Labiodental	0	.10	.04	.04	.05	.04	.13	.29	.20	.04	.14	.09	.13	.10	.11	.07	.13	.10
c. Interdental	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0 0	0 0	0 0
d. Dental	0	0	0	.08	.05	.07	.04	.05	.04	0	0	0	0	0	0	.03	.02	.02
e. Alveolar	.38	.24	.31	.17	.29	.22	.25	.24	.24	.17	.14	.16	0	.10	.04	.19	.20	.20
f. Palatal	.21	.19	.20	.08	.19	.13	.08	.14	.11	.13	.10	.11	.08	.10	.09	.12	.14	.13
g. Velar	.08	.14	.11	.08	.14	.11	0	.05	.02	.04	.05	.04	0	.05	.02	.04	.09	.06
h. Glottal	.04	0	.02	0	0	0	0	0	0	0	0	0	0	0	0	.01	0 0	0 0
3. a. Tip	.29	.25	.27	.25	.38	.31	.33	.43	.38	.17	.19	.18	.04	.05	.04	.21	.27	.24
b. Blade	.21	.19	.20	.08	.19	.13	.08	.14	.11	.13	.10	.11	.08	.05	.07	.12	.13	.12
c. Dorsum	.08	.14	.11	.08	.10	.09	0	.05	.02	.04	.05	.04	0	.05	.02	.04	.08	.06
4. a. Forward	0	.10	.04	.08	.14	.11	.04	.10	.07	0	.05	.02	.04	.05	.04	.03	.09	.06
b. Retroflex	.04	.05	.04	0	0	0	0	0	0	0	0	0	0	.05	.02	.01	.02	.01
c. width	.21	.29	.24	.08	.10	.09	.13	.24	.18	.13	.14	.13	.13	.10	.11	.13	.17	.15
d. Depth	.21	.19	.20	.04	.10	.07	21	.19	.20	.04	.05	.04	.13	.10	.11	.13	.12	.12
5. Elevation	.42	.19	.31	.38	.33	.36	.13	.24	.18	.04	.10	.07	.08	.05	.07	.21	.18	.20

Table 15. Total Proportion of Errors per Feature in Rank Order

Articulatory Attribute	Proportion of Total Errors
Tongue Tip	.09
Alveolar	.08
Tongue Elevation	.08
Fricative	.07
Articulator Tension	.06
Groove Width	.06
Palatal	.05
Tongue Blade	.05
Groove Depth	.05
Voicing	.04
Occlusive	.04
Explosion	.04
Labiodental	.04
Time-Offset	.03
Time-Duration	.03
Lips Rounded	.03
Time-Onset	.02
Aspiration	.02
Nasal	.02
Velar	.02
Tongue Dorsum	.02
Tongue Forward	.02
Central-Lateral	.01
Transition Speed	.01
Lips Retracted	.01
Bilabial	.01
Dental	.01
Tongue Retroflex	.01
Function-Initiating	.00
Function-Nucleus	.00
Function-Terminating	.00
Interdental	.00
Glottal	.00

APPENDIX D

Table 16. Number of Feature Errors per Phoneme for each Child. Syllable-initial, -final and Total.

Phoneme	Three			Four			Five			Six			Seven					
	I	F	T	I	F	T	I	F	T	I	F	T	I	F	T	I	F	T
/m/	0	1	1	0	6	6	0	1	1	0	3	3	2	1	3	1	12	14
/n/	3	0	3	2	4	6	2	3	5	1	1	2	0	0	0	8	8	16
/ŋ/	-	2	2	-	7	7	-	0	0	-	2	2	-	3	3	-	14	14
/p/	0	2	2	0	0	0	1	2	3	2	0	2	1	0	1	4	4	8
/b/	0	2	2	0	1	1	1	1	2	0	3	3	2	2	4	3	9	12
/t/	0	4	4	3	3	6	2	2	4	2	1	3	0	0	0	7	10	17
/d/	0	3	3	1	3	4	1	2	3	0	0	0	0	1	1	2	9	11
/k/	3	0	3	1	0	1	0	2	2	0	0	0	0	0	0	4	2	6
/g/	0	2	2	1	4	5	0	2	2	2	2	4	1	1	2	4	11	15
/r/	5	0	5	7	6	13	0	3	3	3	1	4	3	3	6	18	13.	31
/l/	6	6	12	6	6	12	1	2	3	0	0	0	0	0	0	13	14	27
/f/	1	2	3	0	0	0	1	1	2	1	1	2	1	3	4	4	7	11
/v/	7	5	12	2	2	4	4	1	5	1	2	3	3	2	5	17	12	29
/θ/	3	3	6	4	4	8	4	3	7	2	0	2	7	0	7	20	10	30
/ð/	7	9	16	10	10	20	3	9	12	0	7	7	2	1	3	22	36	58
/s/	3	2	5	3	4	7	2	2	4	0	0	0	2	2	4	10	10	20
/z/	5	3	8	4	2	6	3	6	9	1	1	2	2	6	8	15	18	33
/ʃ/	9	4	13	0	2	2	5	6	11	4	3	7	0	0	0	18	15	33
/ʒ/	9	12	21	3	11	14	8	5	13	3	8	11	1	5	6	24	41	65
/h/	0	-	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-	0
/w/	7	-	7	0	-	0	0	-	0	1	-	1	0	-	0	8	-	8
/ʍ/	2	-	2	2	-	2	2	-	2	2	-	1	4	-	4	12	-	12
/j/	6	-	6	4	-	4	0	-	0	-	0	-	1	-	1	11	-	11
/tʃ/	12	8	20	2	4	6	9	5	14	9	0	9	2	0	2	34	17	51
/dʒ/	11	8	19	0	3	3	9	6	15	4	7	11	0	5	5	24	29	53
Totals	99	78	177	55	82	137	58	64	122	38	42	80	34	35	69	284	301	585

(I - syllable-initial, F - syllable-final,
T - total)

Table 17. Proportion of Feature Errors per Phoneme for each Child. Syllable-initial, -final, and Total.

	3			4			5			6			7			Total		
	I	F	T	I	F	T	I	F	T	I	F	T	I	F	T	N=170	N=170	N=340
m	0	.03	.01	0	.18	.09	0	.03	.01	0	.09	.04	.06	.03	.04	.01	.07	.04
n	.09	0	.04	.06	.12	.09	.06	.09	.07	.03	.03	.03	0	0	0	.05	.05	.05
ŋ	—	.06	.03	—	.21	.21	—	0	0	—	.06	.06	—	.09	.09	—	.08	.08
p	0	.06	.03	0	0	0	.03	.06	.04	.06	0	.03	.03	0	.01	.02	.02	.02
b	0	.06	.03	0	.03	.01	.03	.03	.03	0	.09	.04	.06	.06	.06	.02	.05	.04
t	0	.12	.06	.09	.09	.09	.06	.06	.06	.06	.03	.04	0	0	0	.04	.06	.05
d	0	.09	.04	.03	.09	.06	.03	.06	.04	0	0	0	0	.03	.01	.01	.05	.03
k	.09	0	.04	.03	0	.01	0	.06	.03	0	0	0	0	0	0	.02	.01	.01
g	0	.06	.03	.03	.12	.07	0	.06	.03	.06	.06	.09	.03	.03	.03	.02	.06	.04
r	.15	0	.07	.21	.18	.19	.0	.09	.04	.09	.03	.06	.09	.09	.09	.11	.08	.09
l	.18	.18	.18	.18	.18	.18	.03	.06	.04	0	0	0	0	0	0	.08	.08	.08
f	.03	.06	.04	0	0	0	.03	.03	.03	.03	.03	.03	.03	.09	.06	.02	.04	.03
v	.21	.15	.18	.06	.06	.06	.12	.03	.07	.03	.06	.04	.09	.06	.07	.10	.07	.09
θ	.09	.09	.09	.12	.12	.12	.12	.09	.10	.06	0	.03	.21	0	.10	.12	.06	.09
ð	.21	.26	.24	.29	.29	.29	.09	.26	.18	.0	.21	.10	.06	.03	.04	.15	.21	.17
s	.09	.06	.07	.09	.12	.10	.06	.06	.06	0	0	0	.06	.06	.06	.06	.06	.06
z	.15	.09	.12	.12	.06	.09	.09	.18	.13	.03	.03	.03	.06	.18	.12	.09	.11	.10
ʃ	.26	.12	.19	.0	.06	.03	.15	.18	.16	.12	.09	.10	0	.09	.04	.11	.07	.10
ʒ	.26	.35	.31	.09	.32	.21	.24	.15	.19	.09	.24	.16	.03	.15	.09	.14	.24	.19
h	0	—	0	0	—	0	0	—	0	0	—	0	0	—	0	0	—	0
w	.21	—	.21	0	—	0	0	—	0	.03	—	.03	0	—	0	.05	—	.05
ʍ	.06	—	.06	.06	—	.06	.06	—	.06	.06	—	.06	.12	—	[illegible]	.07		.07
j	.15	—	.15	.12	—	.12	0	—	0	0	—	0	.03	—	.03	[illegible]	—	[illegible]
tʃ	.35	.24	.29	.06	.12	.09	.26	.15	.21	.26	0	.13	.06	0	.03	.20	.10	.15
dʒ	.32	.24	.28	0	.09	.04	.26	.18	.22	.12	.21	.16	0	.15	.07	.14	.17	.16

Table 18. Total Proportion of Errors per Phoneme in Rank Order

Phoneme	Proportion of Total Errors
/ʒ/	.11
/ð/	.10
/t /	.09
/dʒ/	.09
/z/	.06
/ʃ/	.06
/r/	.05
/l/	.05
/v/	.05
/θ/	.05
/n/	.03
/t/	.03
/g/	.03
/s/	.03
/m/	.02
/ŋ/	.02
/b/	.02
/d/	.02
/f/	.02
/M/	.02
/j/	.02
/p/	.01
/k/	.01
/w/	.01
	.00

APPENDIX E

Table 19. Number of Feature Errors by Type. Hypertonic, Hypotonic, and Not Classifiable.

Phoneme	Three			Four			Five			Six			Seven		
	Hyper	Hypo	NC	Hyper	Hypo	NC	Hyper	Hypo	NC	Hyper	Hypo	NC	Hyper	Hypo	NC
/m/	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
	0	1	0	4	1	1	1	0	0	2	1	0	1	0	0
/n/	1	2	0	2	0	0	2	0	0	3	1	0	0	0	0
	0	0	0	2	2	0	0	3	0	0	1	0	0	0	0
/ŋ/	0	2	0	2	5	0	0	0	0	1	1	0	1	2	0
/p/	0	0	0	0	0	0	1	0	0	0	2	0	0	1	0
	0	2	0	0	0	0	1	1	0	0	0	0	0	0	0
/b/	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0
	1	1	0	0	1	0	1	0	0	1	2	0	2	0	0
/t/	0	0	0	2	1	0	1	1	0	0	2	1	1	1	1
	2	2	0	2	1	0	1	1	0	1	0	0	0	0	0
/d/	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
	1	1	1	1	2	0	2	0	0	0	0	0	0	1	0
/k/	0	2	1	0	0	1	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
/g/	0	0	0	1	0	0	0	0	0	2	0	0	0	1	0
	0	1	1	1	3	0	0	1	1	2	0	0	0	1	0
/r/	1	4	0	3	3	1	0	0	0	0	3	0	0	3	0
	0	0	0	0	6	0	2	1	0	0	1	0	2	1	0
/l/	2	2	2	2	3	1	0	1	0	0	0	0	0	0	0
	1	3	2	1	4	1	1	1	0	0	0	0	0	0	0
/f/	0	1	0	0	0	0	0	1	0	0	1	0	1	0	0
	0	2	0	0	0	0	0	1	0	0	1	0	2	0	1
/v/	5	2	0	1	1	0	4	0	0	1	0	0	2	1	0
	3	2	0	0	2	0	0	0	1	0	1	1	1	1	0
/θ/	1	2	0	2	2	0	2	2	0	0	1	1	1	6	0
	1	2	0	3	1	0	2	1	0	0	0	0	0	0	0
/ð/	4	3	0	4	6	0	1	2	0	0	0	0	1	1	0
	1	7	1	3	7	0	3	6	0	2	5	0	0	0	1
/s/	1	2	0	0	3	0	0	2	0	0	0	0	2	0	0
	2	0	0	1	3	0	0	2	0	0	0	0	2	0	0
/z/	3	1	1	1	3	0	1	2	0	0	1	2	2	0	0
	2	0	1	0	1	1	1	5	0	0	0	1	4	1	1
/ʃ/	4	4	1	0	0	0	0	5	0	2	2	0	0	0	0
	0	4	0	0	2	0	1	5	0	2	1	0	0	0	0
/ʒ/	7	1	1	0	3	0	0	7	1	2	1	0	0	1	0
	8	3	1	9	1	1	4	1	0	6	2	0	4	1	0
/h/	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
/w/	0	7	0	0	0	0	0	0	0	0	1	0	0	0	0
/ʍ/	0	1	1	0	1	1	0	1	1	0	2	0	1	2	1
/j/	5	1	0	0	3	1	0	0	0	0	0	0	0	1	0
/tʃ/	0	12	0	1	1	0	0	9	0	1	8	0	2	0	0
	0	7	1	4	0	0	0	5	0	0	0	0	0	0	0
/dʒ/	0	5	6	0	0	0	0	9	0	4	0	0	0	0	0
	0	4	4	2	0	1	2	4	0	6	0	1	4	0	1
Σ_e	56	96	25	55	72	10	36	82	4	35	41	4	38	26	5
%	32	54	14	40	53	7	30	67	3	44	51	5	55	38	7

Table 20. Number of Feature Errors by Type. Intrusion, Addition, Substitution, Subtraction, and Omission.

	AGE																								
	3					4					5					6					7				
	$N_i = 177$					$N_i = 137$					$N_i = 122$					$N_i = 80$					$N_i =$ [illegible]				
PHONEMES	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
m	0 0	0 0	0 0	0 1	0 0	0 2	0 1	0 0	0 1	0 2	0 1	0 0	0 0	0 0	0 0	0 0	0 1	0 0	0 2	0 0	0 0	2 1	0 0	0 0	0 0
n	0 0	1 0	2 0	0 0	0 0	0 1	0 0	2 1	0 2	0 0	0 0	2 0	0 2	0 1	0 0	0 0	0 0	0 0	1 1	0 0	0 0	0 0	0 0	0 0	0 0
ŋ	– 0	– 0	– 2	– 0	– 0	– 2	– 0	– 2	– 3	– 0	– 0	– 0	– 0	– 0	– 0	– 0	– 0	– 0	– 2	– 0	– 0	– 0	– 2	– 1	– 0
p	0 0	0 0	0 0	0 2	0 0	0 0	0 0	0 0	0 0	0 0	1 1	0 0	0 0	0 0	0 1	0 0	0 0	0 0	2 0	0 0	0 0	0 0	0 0	1 0	0 0
b	0 0	0 1	0 0	0 1	0 0	0 0	0 0	0 0	0 1	0 0	1 1	0 0	0 0	0 0	0 0	0 2	0 0	0 0	0 1	0 0	0 0	1 1	0 0	1 1	0 0
t	0 0	0 2	0 2	0 0	0 0	0 0	0 0	3 3	0 0	0 0	0 0	0 0	1 1	1 1	0 0	0 0	0 1	0 0	2 0	0 0	0 0	0 0	0 0	0 0	0 0
d	0 0	0 0	0 1	0 1	0 1	0 0	0 0	1 2	0 1	0 0	0 0	0 1	1 1	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 1	0 0
k	2 0	0 0	1 0	0 0	0 0	1 0	0 0	0 0	0 0	0 0	0 0	0 0	0 2	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
g	0 0	0 0	0 0	0 1	0 1	0 0	1 1	0 2	0 1	0 0	0 0	0 0	0 0	0 1	0 1	0 0	0 0	2 2	0 0	0 0	0 0	0 0	0 0	1 1	0 0
r	1 0	0 0	3 0	1 0	0 0	4	1	2 4	 1	 1	0 0	0 0	0 3	0 0	0 0	0 0	0 0	3 1	0 0	0 0	0 0	0 0	3 3	0 0	0 0
l	4 3	0 0	2 3	0 0	0 0	4 3	0 0	2 3	0 0	0 0	0 1	0 0	1 1	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
f	0 0	0 0	0 1	1 1	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	1 0	0 1	0 0	0 0	0 0	1 1	0 0	0 0	0 1	0 1	1 1	0 0	0 0
v	5 3	0 0	0 0	2 1	0 1	0 0	1 0	0 0	1 2	0 0	3 0	0 0	0 0	0 0	1 1	1 0	0 0	0 1	0 0	0 1	1 0	0 0	1 1	1 1	0 0
θ	1 1	1 1	0 0	1 1	0 0	2 1	0 1	2 1	0 1	0 0	1 2	2 0	1 1	0 0	0 0	0 0	0 0	1 0	1 0	0 0	1 0	1 0	0 0	0 0	5 0
ð	3 1	0 1	1 1	0 1	3 5	4 1	0 2	2 1	1 2	3 4	1 3	0 1	1 1	1 0	0 4	0 1	0 1	0 0	0 0	0 5	1 0	0 0	0 0	1 0	0 1
s	0 0	1 1	1 1	1 0	0 0	0 0	0 0	3 3	0 1	0 0	0 0	0 0	1 2	1 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	2 2	0 0	0 0	0 0
z	0 0	1 2	2 0	1 0	1 1	0 0	1 0	2 1	1 0	0 1	0 1	0 0	2 0	1 0	0 5	0 0	0 0	0 0	1 0	0 1	0 4	2 0	0 1	0 1	0 0
ʃ	5 2	1 0	1 0	2 2	0 0	0 0	0 0	0 2	0 0	0 0	2 2	0 0	0 0	2 3	1 1	2 2	0 0	0 0	2 1	0 0	0 0	0 0	0 0	0 0	0 0
ʒ	4 5	1 1	3 3	1 2	0 1	0 5	0 2	3 2	0 1	0 1	3 4	0 0	1 0	3 1	1 0	2 4	0 0	0 2	1 2	0 0	0 4	0 0	1 1	0 0	0 0
h	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –
w	1 –	0 –	4 –	2 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	1 –	0 –	0 –	0 –	0 –	0 –	0 –
ʍ	1 –	0 –	0 –	1 –	0 –	1 –	0 –	0 –	0 –	1 –	1 –	0 –	0 –	0 –	1 –	0 –	0 –	0 –	2 –	0 –	1 –	1 –	0 –	1 –	1 –
j	5 –	0 –	0 –	1 –	0 –	1 –	0 –	3 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	1 –	0 –
tʃ	0 0	0 0	3 2	3 3	6 3	0 0	1 0	0 4	0 0	0 0	0 0	0 0	2 0	2 1	5 4	0 0	1 0	2 0	1 0	5 0	0 0	0 0	2 0	0 0	0 0
dʒ	0 2	0 0	5 0	2 0	4 6	0 1	0 1	0 0	0 0	0 1	0 0	0 0	2 4	3 2	4 0	0 1	0 1	4 4	0 0	0 1	0 0	0 0	0 4	0 0	0 1
Σ_e	49	15	44	36	33	33	13	56	21	14	29	6	32	25	30	15	5	24	23	13	9	13	18	14	10
%	28	8	25	2	19	24	9	41	15	10	24	5	26	20	25	19	6	30	29	16	13	26	26	20	14

1 - Intrusion
2 - Addition
3 - Substitution
4 - Subtraction
5 - Omission

APPENDIX F

Table 19. Total Proportion of Feature Errors per Child in Rank Order

Subject	Proportion of Total Errors
Three-year-old	.30
Four-year-old	.23
Five-year-old	.21
Six-year-old	.14
Seven-year-old	.12