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RELATIONSHIP BETWEEN PHONETIC CONTEXT

AND VELOPHARYNGEAL INTEGRITY

(TITLE)

BY

BARBARA WESTRICK WHITE

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

MASTERS OF SCIENCE

IN THE GRADUATE SCHOOL, EASTERN ILLINOIS UNIVERSITY
CHARLESTON, ILLINOIS

1974
YEAR

I HEREBY RECOMMEND THIS THESIS BE ACCEPTED AS FULFILLING
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RELATIONSHIP BETWEEN PHONETIC CONTEXT AND VELOPHARYNGEAL INTEGRITY

BY

BARBARA WESTRICK WHITE

B. S., Eastern Illinois University, 1973

ABSTRACT OF A THESIS

Submitted in partial fulfillment of the requirements
for the degree of Master of Science at the Graduate School
of Eastern Illinois University

CHARLESTON, ILLINOIS
1974

The purpose of this investigation was to determine the relationship between volume/velocity requirements for all commonly occurring phonetic contexts of twelve speech sounds. Further, an extended interpretation of Johnston's[1] single vowel data was used to determine the relationship between velopharyngeal integrity and phonetic context. More specifically, three questions were posed:

1. What is the relationship between volume/velocity of airflow, and phonetic context, for each of twelve selected phonemes?
2. What is the interpretation of expected velopharyngeal integrity and phonetic context?
3. Given that Dorn[2] and Griffith and Miner[3] have shown the frequency of occurrence of speech sounds by their phonetic context, what significance will that data show clinically after volume/velocity air cost have been determined for each in terms of planning therapy for subjects lacking velopharyngeal integrity?

PROCEDURE - Airflow values were obtained from each of the ten subjects as they uttered 353 stimuli. These utterances included all of the phonetic contexts in the 1000 most common words of each of the following phonemes: /r/, /ɚ/, /ɝ/, /l/, /s/, /z/, /ʃ/, /tʃ/, /p/, /k/, /f/, and /ŋ/ in a Consonant-Vowel-Consonant (CVC) environment, when stress did not prohibit. The procedures utilized a penumotachograph and Beckman ink writer to assess and record airflow values for each subject on the selected stimuli.

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[1]Johnston, R. G. An attempt to objectify nasality: A new instrumental approach, doctoral dissertation, University of Illinois, Champaign, Ill., 1970

[2]Dorn, John, A Phonetic Context Analysis of General American Consonants and Vowels, unpublished paper, Eastern Illinois University, Charleston, Illinois, August, 1974.

[3]Griffith, J. and Miner, L. E., "A phonetic context approach to articulation therapy." Paper presented at the Illinois Speech and Hearing Association Convention, Arlington Heights, Illinois, 1973.

Each measurement (millimeters of pen deflection) was computed individually to liters per minute, then to milliliters per minute, and finally to milliliters per second. To answer the experimental questions set forth in this study, airflow values were evaluated both within and among the twelve experimental phonemes.

RESULTS AND CONCLUSIONS

1. There did not appear to be any demonstrable relationship between volume/velocity as measured by a pneumotachograph and frequency of occurrence of the twelve selected phonemes.

2. There did not appear to be any demonstrable relationship between volume/velocity as measured by a pneumotachograph and the frequency of occurrence of the experimental phonemes phonetic context.

3. These results suggested that pressure and airflow was not a predictor of how often a phoneme and its context occur in speech.

4. As useful as the data was from Griffith and Miner (1973) and Dorn (1974) on the frequency of occurrence of speech sounds by their phonetic context; there did not appear to be a relationship between their data and the data collected in this study for pressure and airflow values of each.

5. The data indicated that there was considerable within subject variability in terms of pressure/airflow for phonetic context found in the selected phonemes.

6. The data supported Johnston's data (1970) which suggested that the velum, the most critical valve in pressure and airflow requirements, enjoys considerable latitude within the boundaries of competence or integrity.

ACKNOWLEDGEMENTS

I wish to extend sincere gratitude to my husband for his patience, understanding and support. He could always make the situation look positive and challenging, and thus, I could keep smiling.

Sincere appreciation to my parents, who by their actions, instilled the importance of "bettering oneself, so that one can help others." Their continued motivation and positive encouragements have kept my aspirations high, but also attainable.

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CHAPTER I

INTRODUCTION

An increasing concern in speech pathology is centered around the effects of coarticulation upon the assessment of articulatory behaviors. Harris (edited by Wolfe, W. and Goulding, D., 1973) suggested that coarticulation refers to the tendency of the articulators to assume a different position for a particular phone, depending on which phones precede and follow it - a phenomenon that is very common in speech.

One of the most viable concepts to be developed in speech pathology in the last decade is "phonetic context" and its relationship to speech sound production. McDonald (1964) constructed a deep test of articulation using a sensory-motor approach, in which the production of a sound is assessed by having the subject say two words as one compound word. For example, in order to assess the /st/ blend, the subject is instructed to say the words "bus" and "top" as "bustop".

Griffith and Miner (1973) and Dorn (1974) have analyzed the phonetic contexts of each General American phoneme in the 1000 most frequently occurring words on the Thorndike-Lorge (1944) word list. These authors have considered the adjacent sounds of a particular phoneme, syllabic position of a phoneme, syllabic stress in which the phoneme occurs, and frequency of occurrence as relevant parameters of phonetic context analysis. Dorn (1974) presented the advantages of using this system of analysis: (1), it considers the phoneme and its phonetic contexts as a

function of the syllable; (2), it yields phonetic contexts as they occur in the most frequently used words of the English language; (3), it yields frequency of occurrence distributions for the phonetic contexts.

One of the major articulations involved in the production of speech sounds is the velopharyngeal mechanism. Normal velopharyngeal closure (or approximation) for speech involves two components. One is the displacement of the velum posteriorly and superiorly against the posterior pharyngeal wall. The other component involves the movement of the naso-pharyngeal walls (tori tubari and salpingopharyngeal folds) medially and posteriorly against the lateral portion of the velum. Johnston (1970) hypothesized that these movements enable the velar mechanism to perform various degrees of approximation, closure or opening with the pharynx.

Johnston (1970) has shown that the significant variable in the determination of velopharyngeal integrity is the ability of the supraglottal acoustic tube to impound escaping air (pressure and volume) from the subglottal reserve. His data clearly indicates that vocal damping time is an objective measure of velopharyngeal integrity. That is, the vocal folds obey the Myoelastic-Aerodynamic principle of vibration, which state that a transglottal pressure differential must exist across the glottis for phonation to either be initiated or sustained. If the supraglottal area is intact, and there exists velopharyngeal competence and closure, an articulation gesture such as the /p/ phoneme will dam up the escaping phonated air resulting in vocal damping in approximately 200 - 250 milliseconds. The only exception cited by Johnston would be if supraglottal pressure could be valved during this condition. Valving of supraglottal pressure can be accomplished via the velopharyngeal port. Therefore, as predicted, there exists an inverse relationship between velopharyngeal

integrity and vocal damping time. Because vocal damping time currently, can only be measured using a sustained vowel, his data does not provide the relationship between phonetic boundaries found in running speech and their intraoral pressure requirements. This study will attempt to determine that relationship.

Spriestersbach, Darley, and Rouse (1956) stated that velopharyngeal closure appears to be the predominant factor accounting for variation in judged articulation defectiveness. Given that velopharyngeal competency (integrity) is identified as the single most important element in impounding adequate intraoral pressure for normal production of many consonant sounds. (Spriestersbach, Darley, Rouse, 1956), it is not surprising that cleft palate subjects, CPI (congenital palatal insufficiency) subjects, subjects with a repaired cleft of the palate and individuals who exhibit functional nasality (nasal speakers), misarticulate with greatest frequency those sounds that oral breath pressure is highest for normal speakers (Spriestersbach, Powers, Rouse, 1956; McWilliams, 1958, and Spriestersbach and Powers, 1956). These studies confirm that nasality increases as a function of a phoneme's requirement for intraoral pressure increases.

Statement of the Purpose

The purpose of this investigation was to determine the relationship between volume/velocity requirements for all commonly occurring phonetic contexts of twelve speech sounds. Further, an extended interpretation of Johnston's single vowel data will be used to determine the relationship between velopharyngeal integrity and phonetic context.

Questions

Specifically the following questions were asked:

1. What is the relationship between volume/velocity of airflow, and phonetic context, for each of twelve selected phonemes?

2. What is the interpretation of expected velopharyngeal integrity and phonetic context?

3. Given that Dorn (1974) and Griffith and Miner (1973) have shown the frequency of occurrence of speech sounds by their phonetic context, what significance will that data show clinically after volume/velocity air cost have been determined for each in terms of planning therapy for subjects lacking velopharyngeal integrity?

CHAPTER II

REVIEW OF THE RELATED LITERATURE

It has been accepted for many years that phonemes are considered the basic building blocks for speech. However, specific requirements for phonemes, acoustically or motorically, are only ideal or target definitions of that sound when they are analyzed in isolation. Speech is not a series of static phonemes set side by side in a building block fashion, but rather consists of a ballistic and integrated motor act in which speech sound requirements are shared by the requirements of the surrounding sounds. This has been referred to as coarticulation. The study of a phoneme in terms of its boundaries is a study of phonetic context.

Historically, research has been conducted to understand the phonetic (phonemic) requirements of a sound. One of the parameters used in describing a sounds' requirements is the pressure and airflow (volume/velocity) required for making that sound. However, as previously mentioned, speech sounds rarely exist in isolation, resulting in a dichotomous condition and confusion, knowing those requirements will vary as a function of coarticulation.

Recent data (Griffith and Miner, 1973; and Dorn, 1974) has provided insight into the "frequency" of occurrence of phonemes found in General American English and more importantly the contextual "frequency" of occurrence. This critical information now allows the interested researcher to investigate factors that have been shown to be important in

speech production, in terms of units of production which encompass coarticulation. Results of these investigations with normal or abnormal speakers provide invaluable data in the understanding of disordered speech and in the ultimate planning of therapy.

Subjects who lack the ability to impound intraoral breath pressure often have misarticulations directly attributable to that inability. While exhaustive research has been done to determine the exact nature of the cause and effect between loss of ability to impound intraoral breath pressure and misarticulation, disagreement still exists in this area.

Measurement of Airflow

Measurements of intraoral air pressure and rate of oral and nasal airflow are of great value in assessing the efficiency of the velopharyngeal valve, during either speech or non-speech tasks (Bzoch, 1971). The pneumotachograph yields information concerning the measurement of oral or nasal pressure and airflow. Fleisch (1960) and Counihan (edited by Bzoch, 1971) described this instrument in the following manner:

> The pneumotachograph measures airflow on the theory that the volume of air passing through a straight tube is proportional to the difference in pressure between two points in that tube. Pneumotachograph tubes contain a fine wire screen that provides a slight resistance to flow. Pressure differences across this screen are transmitted by means of connecting tubes to a sensitive pressure transducer which, in turn, provides an electrical output that is proportional to the applied pressures. These voltages, when appropriately amplified, may be delivered to graphic recording systems that allow a permanent record of the data.

Results of Airflow Investigations

Counihan (edited by Bzoch, 1971) suggested that analysis of intraoral pressure and oral airflow during speech contributes to an understanding of normal speech physiology and provides a basis for explaining major features

of the misarticulation of speakers with cleft of the palate, CPI individuals, individuals with repaired clefts of the palate, and individuals who exhibit functional nasality. Comparisons between normals and nasal speakers lead to the conclusion that classes of phonemes associated with increased oral pressure and airflow requirements are those that present the greatest difficulty for these subjects. Spriestersbach and Powers (1959) have suggested that there is a relationship between the ability to impound intraoral breath pressure and the ability to close off the nasopharynx. Also, Pitzer and Morris (1966) have further contended that the sounds that do not have high intraoral breath pressure requirements are misarticulated less often by nasal speakers. Thus, it appears that articulatory proficiency is associated with "near normal" velopharyngeal functions (Morris and Smith, 1962).

Unanimity of opinion does not exist as to the relationship between articulation defectiveness and intraoral pressure requirements. Morris (1971) suggested that the duration over which pressure for a consonant must be sustained may be of more significance than the required peak pressure. In describing duration, Morris was referring to one of the distinctive features of sound. However, once supraglottal pressure is equal to subglottal pressure, there is no "peak pressure."*

Velopharyngeal Integrity. Although the degree of velopharyngeal integrity required for "normal" speech sound articulation has not yet sufficiently been answered, the gestures of this mechanism have been investigated. Daniloff and Moll (1968) hypothesized that the velopharyngeal mechanism has three basic gestures: open, closed and neutral. They found that the velopharyngeal mechanism can coarticulate over as many as

*Personal conference with Johnston

three neutral phones. In running speech, the velopharyngeal mechanism, at least for neutral phonemes (vowels), performs almost a casual gesture, that is, preparing for closure as many as three neutral phones preceding a de-nasal sound, and opening as many as three neutral phones preceding a nasal sound.

Johnston (1970) found contradictory results concerning the velopharyngeal mechanism possessing three basic gestures. He found that the velar mechanism performs various degrees of approximation or closure/opening with the pharynx (velopharyngeal integrity). This approximation of the velum with the pharynx may account for the extent of intraoral breath pressure and airflow that is yielded.

Airflow. Spriestersbach and Powers (1959) suggested that without intraoral breath pressure consonants cannot be articulated. If there exists nasal emission of oral pressure, then emission may distort the auditory perception of the "pressure" consonants being articulated. Results of several studies of normal speakers in which pressure and airflow measures have been employed indicate that oral air pressure and airflow vary for consonants as a function of voicing, manner of formation, position of the consonant in a syllable, vowel context, and effort expended in the production of the sound or sounds. Thus, the effects of phonetic context, voicing, and manner of formation needs further investigation.

Phonetic Context. Phonetic context has been defined by Griffith and Miner (1973) as "the totality of phonetic conditions that effect the productions of a given speech sound". In analyzing phonetic contexts, the phoneme is described in relation to the vowel position, and the function of the phoneme as a single or blend. Spriestersbach and Powers (1959) have presented the most consistent findings concerning nasal variation with phonetic factors.

They suggested that the degree of nasal voice quality perceived is not simply a function of coarticulation with a nasal sound, but dependent on the particular vowel sound produced. However, observations of velopharyngeal closure on a single sound does not indicate how the individual uses his palate in other phonetic contexts, thus, words in consonant-vowel-consonant environments may be more predictive in measuring velopharyngeal integrity. Further, House and Fairbanks (1953) have demonstrated that the acoustic characteristics of vowels depend upon the consonant context in which they occur, and the physiological characteristics of vowels, including velopharyngeal closure, also vary with phonetic context.

In terms of intraoral air pressure requirements, Black (1950) reported that vowel context has no differential effect upon oral air pressure developed during consonant production. Recent research by Emanuel (1965), and Isshiki and Ringel (1964) suggested, however, that vowel context is important.

In terms of air pressure requirements and phonetic context, Arkebauer, Hixon, and Hardy (1967) noted that air pressure requirements varied according to phonetic contexts, especially for those consonants in the prevocalic position. Counihan (edited by Bzoch, 1971) stated that although some inconsistency is evident in findings, there exists ample evidence that variations in oral air pressure and airflow occur as a result of consonant position in a syllable. Many investigators (Black, 1950; Emanuel, 1965; Subtelny, Worth, and Sakuda, 1966; and Arkebauer, Hixon, and Hardy, 1967) reported greater oral air pressure and airflow for consonants in the prevocalic position than in the postvocalic position. Isshiki and Ringel (1964) added that airflow and pressure differences between prevocalic and

postvocalic environments vary for individual consonants. Discrepant findings still exist between prevocalic and postvocalic contexts. Morris (1971) stated that more research is needed concerning the requirements for velopharyngeal competence (integrity) and consonant/vowel production. Consistent findings regarding the extent of the relationship between velopharyngeal integrity and phonetic context required for normal speech has not been demonstrated.

Voicing. There is considerable evidence that greater oral airflow and intraoral pressures occur for voiceless consonants than their voiced cognates (Isshiki and Ringel, 1964; Van Hattum and Worth, 1967; and Subtelny, Worth, and Sakuda, 1966). Arkebauer, Hixon, and Hardy (1967) and Isshiki and Ringel (1964) suggested that these differences in pressure and flow may be attached to the increased glottal resistance that occurs with voicing. Resistance provided by the vocal folds during voicing results in a pressure loss across the glottis, causing decreased pressure within, and flow through, the vocal tract. Johnston (1970) however, suggested that the vocal folds obey the Myoelastic-Aerodynamics principle of vibration. Therefore, to achieve voicelessness in stops, greater intraoral (supraglottal) pressure must be generated to dampen the vocal fold vibration. This can be accomplished by increasing the duration of the articulation gesture for the voiceless cognate, keeping all other place and manner requirements consistent for a cognate pair.

Manner of Formation. Oral pressures and flow rate not only vary according to phonetic context and voicing; it also varies according to manner of formation of consonants. Arkebauer, Hixon, and Hardy (1967) and Isshiki and Ringel (1964) suggested that plosive consonants, for example, are associated with greater intraoral pressure and flow rates than fricatives.

Issihiki and Ringel (1964) and Subtelny, Worth, and Sakuda (1966) and Van Hattum and Worth (1967) suggested that there may be an interaction between voicing and manner of formation. They report that, while peak intraoral pressures for voiceless plosives exceed those for fricatives, voiced fricatives evidence greater peak pressures than voiced plosives.

Current research suggests that there are varying conditions of pressure and airflow for speech sound production. Assuming a normal speech mechanism, the relationship between requirements for a speech sound element vary as a function of coarticulation. A clear understanding of the relationship between phonetic context and pressure and airflow requirements for each context remains an open and desirable research question. If there exists a discernable and measurable relationship on these two parameters, then the data provided by Griffith, Miner, and Dorn concerning the "frequency" of occurrence of phonetic boundaries will have immeasurable utility in planning a therapeutic program for individuals who possess the loss of ability to meet these pressure and airflow requirements for normal speech production.

CHAPTER III

PROCEDURES

To describe the relationship between volume/velocity requirements and the phonetic contexts for twelve speech sounds, the following procedures were used. Ten subjects were selected to participate in this study on the basis of their age, hearing acuity, articulation proficiency, velopharyngeal adequacy, and competence in reading nonsense words written in phonetics. In order to measure the greatest airflow requirements for a particular utterance, a normal functioning velopharyngeal mechanism was necessary.

Selection of Subjects

College students who completed a Phonetics course and were majors in speech pathology were eligible to participate in this study. The ten subjects used in this study were between the ages of twenty and thirty-three years old. Each subject was required to exhibit normal hearing. The hearing thresholds for all subjects were not greater than 30 dB for either ear, for any of the following frequencies: 500; 1000; 2000; and 4000 Hz. Any subject who was found to exhibit any articulation error was excluded from this study. Articulation proficiency was assessed by having the subject produce the identical 353 stimulus words (Appendix A) that were presented on the articulation task. This articulation task included all the phonetic contexts (Miner and Griffith, 1973) of each of the following phonemes: /r/, /ɝ/, /ə/, /l/, /s/, /z/, /ʃ/, /tʃ/, /p/, /k/, /f/, and

/ŋ/ in a consonant-vowel-consonant (CVC) utterance when stress did not prohibit. The subjects were considered to have velopharyngeal adequacy by exhibiting no history of velopharyngeal incompetence or articulatory errors on the articulation task related to velopharyngeal inadequacy as determined by the author, a graduate speech and language clinician. Each subject was presented with the identical 353 stimuli (Appendix A) articulation task. A training session took place prior to the testing situation, in which each subject practiced the correct production of the stimuli.

Methodology for the Selection Test Items

Eight Most Frequently Misarticulated Phonemes: The phonemes sampled for this design included the eight most frequently misarticulated phonemes according to Griffith and Miner (1973). According to their findings, the following list of the eight speech sounds are most often misarticulated: /r/, /ɝ/, /ə/, /l/, /s/, /z/, /ʃ/, /tʃ/.

Manner of Formation. Each category according to "manner of formation" was represented by at least one phoneme. "Manner of formation" refers to the type of sound, that is, the acoustic nature of the sound, whether fricative, plosive, nasal, glide, semivowel, or affricate.

CLASSIFICATION OF SOUND
Manner of Formation

PLOSIVES	FRICATIVES	NASAL	GLIDE	SEMIVOWEL	AFFRICATE
p	f	ŋ	r	l	tʃ
k	s		ə		
	z		ɝ		
	ʃ				

Certain phonetic environments influence articulatory behavior of the velum, that is, they influence the strength and duration of velopharyngeal

closure-opening (velopharyngeal integrity). Given that subjects with known palatal problems have less velopharyngeal integrity, Spriestersbach, Rouse and Darley (1956) have found that defective consonant articulation in this population is related to manner of formation rather than place of articulation. "Manner of Formation" was selected as a co-consideration along with the eight most frequently misarticulated phonemes as part of the selected phonemes for the investigation.

Phonetic Context of the First 1000 Most Frequently Occurring Words

Articulation requirements vary with changes in sound combinations (phonetic environment). Griffith and Miner (1973) identified and classified words in terms of Phonetic Contexts. These words were selected from the Thorndike-Lorge word list (1944) of the 1000 most frequently occurring English words for 1st and 2nd graders. Griffith and Miner (1973) and Dorn (1974) rank ordered the phonetic contexts for each phoneme according to frequency of occurrence.

The following phonetic contexts for each phoneme were presented according to Griffith and Miner's eight most frequently misarticulated phonemes plus four phonemes selected for manner of formation.

PHONEME	NUMBER OF PHONETIC CONTEXT'S
/r/	46
/ə/	23
/ɝ/	19
/l/	50
/s/	54
/z/	21
/ʃ/	17
/tʃ/	18

PHONEME	PHONETIC CONTEXTS
/k/	43
/f/	28
/ŋ/	5
TOTAL	353

All Contexts

All of the phonetic contexts that exist within the first 1000 most frequently occurring words were represented for each of the 12 selected phonemes. The nonsense words under examination combined the consonant phoneme (C_E) in all vowel combinations (V_A 1-14) that occur in the 1000 most frequently occurring words, and were paired with a controlled consonant (C_K).

For purposes of this study the nonsense words were controlled by using primarily "Consonant-Vowel-Consonant" environments (CVC), except where stress and semivowels occurred. The consonant-vowel-consonant combination accounts for approximately 80% of the stimuli. The following environments are representative of the nonsense words used in this study.

SYMBOL	TRANSLATION
$*C_E\ V_A\ C_K$	Consonant (experimental consonant phoneme) + Vowel (vowel or diphthong represents all contexts) + Consonant (constant phoneme: /t/)
$V_K\ *C_E\ V_A\ C_K$	Vowel (constant vowel: /o/) + Consonant (experimental consonant phoneme) + Vowel (vowel or diphthong represents all contexts) + Consonant (constant consonant: /t/)
$C_K\ V_A\ *C_E$	Consonant (constant consonant: /t/) + Vowel (vowel or diphthong represents all contexts) + Consonant (experimental consonant phoneme)

SYMBOL	TRANSLATION
V_K $*C_E$ V_A C	Vowel (constant vowel: /o/) + Consonant (experimental consonant phoneme) + Vowel (vowel or diphthong represents all contexts) + Consonant (constant consonant: /t/)
$*C_E$ $*V_E$	Consonant (experimental consonant phoneme) + Vowel (experimental semivowel)
$*V_E$ $*C_E$	Vowel (experimental semivowel) + Consonant (experimental consonant phoneme)

Exceptions:

1 $*C_E$	When the phoneme under examination was part of a consonant cluster, then the phoneme that preceded or followed the experimental phoneme varied, (ie: fl, fr)
2 $*V_K$	When there were certain stresses and when examining blends in which the consonant could not be controlled.

An example of the "Consonant-Vowel-Consonant" variations occurring with the experimental phoneme /f/ is displayed as follows:

C_K = /t/
$*C_E$ = /f/
V_A = vowel or diphthong represents all contexts that occur within the most frequently occurring words
$*V_K$ = /o/

WORD	PHONETIC CONTEXT	TRANSLATION
fIt	/fI/ initial accented	$*C_E$ V_A C_K
fɔt	/fɔ/	$*C_E$ V_A C_K
fɑt	/fɑ/	$*C_E$ V_A C_K
faIt	/faI/	$*C_E$ V_A C_K
fɛt	/fɛ/	$*C_E$ V_A C_K
fet	/fe/	$*C_E$ V_A C_K

WORD	PHONETIC CONTEXT	TRANSLATION
fæt	/fæ/	$*C_E\ V_A\ C_K$
fot	/f o/	$*C_E\ V_A\ C_K$
fit	/fi/	$*C_E\ V_A\ C_K$
fUt	/fU/	$*C_E\ V_A\ C_K$
fut	/fu/	$*C_E\ V_A\ C_K$
faʊt	/faʊ/	$*C_E\ V_A\ C_K$
ofə t	/fə / initial unaccented	$*V_K\ *C_E\ V_A\ C_K$
ofot	/fo /	$*V_K\ *C_E\ V_A\ C_K$
ofə t	/fə /	$*V_K\ *C_E\ V_A\ C_K$
otæ f	/æ f/ final accented	$*C_K\ V_A\ *C_E$

Instrument: Fleisch Type "O" Pneumotachograph

To assess airflow values for each subject on selected speech tasks, the pneumotachograph with an Electro model EF filtered D.C. power supply was used. An appropriate sized mask was fitted on each subject and each signal was amplified with a signal recorded on a Beckman ink-writing recorder. One millimeter of pen deflection was equivalent to approximately .65 liters per minute of airflow. The amount of airflow could be roughly determined by measuring the height of the ink trace in millimeters above the base line and multiplying that value by .65. However, the calibration of the Beckman ink writer and the Pneumotachograph indicated, a non-linear relation between pen deflection and volume/velocity. Therefore each measurement (millimeters of pen deflection) was computed individually for Liters per Minute Values. For each millimeter of pen deflection a milliliter value was determined. This value was then converted to liters per minute, then to milliliters per minute, and finally to milliliters per second.

CHAPTER 4

RESULTS AND DISCUSSION

Airflow values were obtained from each of the ten subjects as they uttered 353 stimuli. These utterances included all of the phonetic contexts in the 1000 most common words of each of the following phonemes: /r/, /ɚ/, /ɝ/, /l/, /s/, /z/, /ʃ/, /tʃ/, /p/, /k/, /f/, and /ŋ/ in a Consonant-Vowel-Consonant (CVC) environment, when stress did not prohibit. The procedures utilized a pneumotachograph and Beckman ink writer to assess and record airflow values for each subject on the selected stimuli. Each measurement (millimeters of pen deflection) was computed individually to liters per minute, then to milliliters per minute, and finally to milliliters per second. To answer the experimental questions set forth in this study, airflow values were evaluated both within and among the twelve experimental phonemes.

Table 1 revealed the results of the among phoneme evaluation. Mean airflow values were computed for all of the utterances for all subjects for each of the twelve experimental phonemes. These values were then rank ordered from most to least recorded airflow. These rank ordered values represented a sample of each context in which the phoneme was found in the 1000 most "frequently" occurring words produced by each of the ten subjects. For example, the "ɚ" phoneme (Table 15) revealed 19 possible phonetic contexts (utterances) each of which was produced once by each subject. All of these values were used in determining the mean airflow value and the eventual rank ordering for the twelve experimental phonemes.

In addition, Table 1 reported the frequency of occurrence of each experimental phoneme in the 1000 most frequently occurring words and their rank order from most to least occurrence.

The question as to whether a correlation existed between the mean airflow values of a phoneme and its frequency of occurrence in speech was determined by computing a Spearman Rank Order correlation. Table 1 demonstrated that correlation coefficient to be r=0.03; the author concluded that for the twelve phonemes investigated, there was no positive (+) or negative (-) correlation between the mean airflow requirements for a phoneme and its frequency of occurrence in speech. Stated another way, if airflow values were an essential articulatory ingredient "features" of normal speech production, then the data in Table 1 indicated that it was not a factor in the determination of the frequency of occurrence of that phoneme. Data by Griffith and Miner (1973) and Dorn (1974) clearly showed that speech sounds do have a wide range of values in terms of their frequency of occurrence. However, airflow requirements for a phoneme, even when all phonetic contexts were accounted for, apparently was not a factor in determining frequency.

Table 1 also revealed that manner of production was not associated with airflow requirements for a sound. This evidence called into question previous research (Isshiki and Ringel, 1964; Arkebauer, Hixon, and Hardy, 1967) which suggested differing airflow costs for differing manner of production. However, this study did support Johnston (1970), who predicted that voiceless productions required more intraoral breath pressure than voiced productions. This would also confirm the opinion of (Subtelny, Worth, and Sakuda, 1966) that voiceless sounds were judged to be more defective than voiced sounds in populations which possess the

inability to impound or sustain high intraoral breath pressures.

Table 2 provided a Spearman Rank Order correlation matrix of the ten subjects rank ordering of the airflow requirements for each phonetic context of the /r/ phoneme. Table 3 was an identical matrix for the /p/ phoneme. The author determined that before an in-depth analysis of the within phoneme conditions could be made an estimate of subject performance reliability had to be determined. These two tables compared the rank orderings in terms of airflow values to determine if the subjects performed in a like or unlike fashion for a glide and for a stop plosive. The matrix provided in Table 2 suggested that there was virtually no reliable performance criteria for the glide /r/. Table 3 denoted that subject reliability increased with a plosive (/p/) versus a glide (/r/), but again did not reach a high level of agreement. The result of this low agreement implied that as airflow increased for subject A as a function of phonetic context, it neither increased nor decreased in a like fashion for the remaining subjects. Two obvious conclusions were generated with this apparent lack of subject agreement: first, there was extreme acceptable pressure/airflow variability in speech production within subjects; second, there was, in fact, a relationship between phonetic context and pressure/airflow requirements, but that experimental error prevented the demonstration of that relationship.

The first explanation (subject variability) disagreed with both research information and clinical impression. These research information and clinical impressions suggested that the distinctive features of a sound and resulting coarticulations follow some lawful and demonstratable relationship between an acceptable acoustic production and pressure airflow requirements for that production. Several studies have demonstrated

that in static isolation productions of consonants and vowels (Spriestersbach and Sherman, 1968) that there existed the clinical impression of a continuum of pressure and airflow requirements. These observations, however, tend to rely on idealized articulations of phonemes, often referred to as "target" articulation. This view of speech production was most clearly presented in the concept of distinctive features (Jacobson, Fant, Halle; edited by Handley and Thurman, 1962). Coarticulation data can be said to be exclusive of the distinctive feature concept (Moll and Daniloff, 1968). Coarticulation data suggested that in terms of place of production, there appeared to be considerable latitude in the production of many speech sounds. Also, depending upon the rate of production, certain phonemes may be said to have variable durational requirements (Johnston, 1970; Morris and Smith, 1962). It may be that the interaction of the parameters of place, manner and duration, which are all affected by coarticulation, resulted in inconsistent pressure/airflow requirements for speech as a function of phonetic context. Each speaker in producing speech manipulates the articulators in terms of their size and the distances that they need to traverse during ballistic speech. The results, therefore, were predictably different values in the resulting pressure and airflow values. While this study did not provide test-retest data on any one of the ten subjects, that data might have also indicated a lack of agreement when a single subject is asked to repeat the identical experimental task.

Experimental error had several possible sources of contamination which would result in the lack of subject agreement on the experimental tasks. First, it was imperative that the subjects produce an acoustically acceptable desired utterance (See Appendix A). During the collection of the data, the

author and two additional listeners monitored the subjects accuracy on their production of the stimuli. Any production by a subject that was acoustically determined as unacceptable was repeated until an acceptable performance was recorded. The subject wore a face mask which may have hindered the monitors in the "normal" perceptual process. Second, one size face mask was used for all ten subjects. Depending upon size and contours of each subject's face the possibility of "leakage" remains. Third, it was possible that the pneumotachograph and/or the ink writing device may be subject to mechanical or electrical error. In the conversion of energy forms from the pneumotachograph to the ink writer, an internal gain or loss of energy may have occurred; thus, the airflow values may have been incorrectly recorded. Finally, in determining the value used for each utterance the peak value was used as the representation score for the utterance. Figure I demonstrates a typical ink tracing for a CVC utterance. The value recorded was that value represented by point A on the figure I. It is possible that the peak value was not a fair representation for the total air cost for that utterance. That is, it may be technically more accurate to measure the entire air cost for the duration of the utterance. (Point B on figure I.) The purpose of this study, however, was concerned with peak values in normal subjects and their production as they might relate to subjects who may not possess the ability to impound intraoral breath pressure. The difference between measurements of peak values and total air costs appears to be an experimental question that needs to be resolved in future studies of this type.

It may be necessary for experimenters to consider the role of intensity in the measurements of pressure and airflow. However, subglottal air requirements for speech did not vary as a function of intensity, but rather

as a function of the mode of vibration of the vocal folds (Zemlin, 1968). Further, peak supraglottal pressure, once equivalent to subglottal pressure, cannot increase (Johnston, 1970).

Tables 4 through 15 analyzed each experimental phoneme according to phonetic contexts. Mean values for each context were recorded and rank ordered and compared with the context rank ordering by their frequency of occurrence in speech. The tables also provided position and stress information for each context. Since Tables 2 and 3 have indicated extremely low within subject reliability, the results of these tables must be interpreted with extreme caution.

Inspection of Tables 4 through 15 revealed that in no instance does the data indicate significant positive or negative correlation between the rank orderings. Pearson Product Moment Correlation Coefficients were not computed for each table for it appeared that there was essentially a zero correlation between pressure and airflow for the phonetic context of the sound and their frequency of occurrence of that sound. Manner of production, position of the syllable and phonetic environments showed no consistent relationship between subjects performance (pressure/airflow) on an utterance and the frequency of occurrence of that utterance. More specifically, no consistency was revealed regardless of whether the experimental phoneme was a plosive, fricative, affricate, nasal, glide or semivowel, and regardless of whether that phoneme occupied the initial or final position of a syllable and regardless of its phonetic environment. Within a phoneme class, Tables 4 through 15 indicated extreme subject variability. The data further suggested that clinically one cannot predict the phonetic environment that consistently has higher or lower airflow costs for speakers. Moreover, there was certainly no observable relationship between air cost

for a prescribed phonetic environment and the frequency of occurrence for that environment as a function of all other environments in which that phoneme may be found. With respect to the data which described the phonetic context in terms of its position in a syllable and its stress, no statistical analysis could be performed. Observation indicated that for the phonemes: /p/, /tʃ/, /ʃ/, /k/, /ŋ/, /s/, /l/, /f/, /r/, and /ɝ/ that there was an increase in airflow requirements when the syllable was stressed. For the remaining experimental phonemes: /z/ and /ɚ/ this pattern was not maintained. For the /z/ phoneme the presence of syllabic stress did not appear to increase with airflow requirements. For the /ɚ/ phoneme there was no accented syllable. This data clearly indicated that the importance of intraoral breath pressure may not be a significant requirement for articulation but may be critical in the production of stress. Distinctive feature analysis again found some limitation in defining the speech act when the concept of stress is included. Tables 4 through 15 demonstrated that stress was an important variable in providing information concerning speech production and it is correlated with intraoral pressure/airflow. Morris and Smith (1962) suggested the importance of syllabic duration as a factor in the perception of and measurement of speech. The data provided by this study does not distinguish between the duration of a syllable and the perception of stress. However, given that Johnston (1970) demonstrated the reciprocal effects in the vocal tract, a logical conclusion was that as speakers increase the duration of an initial plosive consonant of a CVC syllable, intraoral air pressure will continue to build. This would result in increased supraglottal pressure/airflow and the resulting perception of stress.

One of the major purposes of this research was to possibly uncover pressure and airflow requirements as a function of phonetic context with the eventual application of this information in the planning of speech therapy. Unfortunately, with the exception of stress, few conclusions could be drawn that could have strong clinical significance. The data from this study revealed, for example, the lack of relationship between the frequency of occurrence of a phoneme and the pressure and airflow requirements; the lack of correlation between the subjects performance on the experimental task; and, the lack of agreement between frequency of occurrence of the phonetic contexts of a phoneme and the pressure and airflow requirements. Collectively, this information indicated to the author that the pressure and airflow requirements for speech production has enormous variability and lacked predictability.

The reader confronted with this variability can nevertheless, use the data presented in Tables 1 and Tables 4 through 15 as a guide in the planning of appropriate therapy for individuals who lack velopharyngeal integrity. For example, if a speech therapist wishes to work on the /k/ phoneme (Table 7) in therapy, the information provided for the /k/ phoneme and its phonetic contexts may be useful. Initially in therapy, the clinician may wish to select the five phonemes which rank lowest in terms of pressure/airflow, and proceed in a reverse manner through the rank orderings of the phonetic contexts. Behavior modification and learning theory would support this procedure (Winitz; 1969) as well as the concept of progressive approximation. (Van Riper, 1963; pg. 263.) In addition, the clinician may wish to choose five contexts that rank low on the list but which have high frequency of occurrence, this procedure would be useful to obtain carryover. Another procedure might be to have the client produce several samples of each

phonetic context for a phoneme. These samples would then be rated by listener judges for each production, and then compared with those results with the data in the tables for that phoneme. An individual rank ordering of the clients productions can be used as another variable for determining an overall plan for therapy.

CHAPTER 5

SUMMARY AND CONCLUSIONS

The purpose of this investigation was to determine the relationship between volume/velocity requirements for all commonly occurring phonetic contexts of twelve speech sounds. Further, an extended interpretation of Johnston's single vowel data was used to determine the relationship between velopharyngeal integrity and phonetic context. More specifically the questions of interest were: 1) What is the relationship between volume/velocity of airflow, and phonetic context, for each of twelve selected phonemes? 2) What is the interpretation of expected velopharyngeal integrity and phonetic context? 3) Given that Dorn (1974) and Griffith and Miner (1973) have shown the frequency of occurrence of speech sounds by their phonetic context, what significance will that data show clinically after volume/velocity air cost have been determined for each in terms of planning therapy for subjects lacking velopharyngeal integrity?

The author must conclude that the results of this investigation are disappointing and resulted in more questions rather than solutions. There did not appear to be any demonstratable relationship between volume/velocity as measured by a pneumotachograph and, A) the frequency of occurrence of the twelve selected phonemes, or B) the frequency of occurrence of the phonemes phonetic context. These results suggested that pressure and airflow was not a predictor in a lawful fashion which predicts how often a phoneme and its context occur in speech. The data also indicated that there

was considerable within subject variability in terms of pressure/airflow for phonetic context found in speech. Further, the data supported the data of Johnston (1970) which suggested that the velum, the most critical valve in pressure/airflow requirements, enjoys considerable latitude within the boundaries of competence or integrity. If this were not true, listeners would not hear so-called "functional" nasality related to regionalization typically found in speakers in North Chicago. Finally, as useful as the data was from Griffith and Miner (1973) and Dorn (1974) on the frequency of occurrence of speech sounds by their phonetic context; there did not appear to be a relationship between their data and the data collected in this study for pressure and airflow values of each.

Given the limitations of this study as provided in Chapter 6, the reader may still derive clinical importance in planning therapy for children and adults who demonstrate the lack of ability to generate adequate velopharyngeal integrity. The information with regard to stress has direct clinical application.

CHAPTER 6

LIMITATIONS AND RECOMMENDATIONS

Several studies (Johnston, 1970; Moll; edited by Spriestersbach and Sherman, 1968) including the present study have concluded that measurements of pressure and airflow are not an objective correlate of speech production. This was the major limitation of this study. Speculation can focus upon a simple lack of agreement between speech sound production and its air cost. A second source of experimental limitation can be attributed to the state of the art in measuring pressure and airflow. Instruments such as a pneumotachograph simply may not be measuring what they perport to measure. Finally, limitations in the collection of data may have resulted in examiner error. Specifically, the size of the face mask and the seal created by a desirable fit needs constant attention.

The author recommends that further studies on the air pressure or airflow of any group of speech utterances consider more than the "peak pressure" generated, but extend the measurement to the total air costs for an utterance. Prosidic elements of speech such as pitch, intensity and duration also need to be systematically investigated. Also, while there may exist considerable latitude for the normal speaker, investigation with abnormal speakers may show more consistency.

TABLE 1

MEAN AIRFLOW VALUES AND RELATIVE FREQUENCY OF OCCURRENCE OF THE TWELVE EXPERIMENTAL CONSONANTS, AND THEIR RANK ORDER CORRELATION COEFFICIENTS

Phoneme	Mean Airflow Values for all Phonetic Contexts of the 12 Phonemes Uttered by the Ten Subjects	Rank Order of the Mean Airflow Values of the 12 Phonemes from Greatest to Least Airflow R_1	Frequency of Occurrence in the 1000 Most Frequently Occurring Words for the 12 Phonemes	Rank Order of the 12 Phonemes by Their Frequency of Occurrence R_2	Voicing/Manner of the 12 Phonemes
p	222.15	1	98	5	V̸; plosive
tʃ	219.77	2	32	11	V̸; affricate
ʃ	210.14	3	40	9	V̸; fricative
k	205.09	4	154	4	V̸; plosive
ŋ	197.23	5	35	10	V; nasal
s	192.71	6	259	2	V̸; fricative
l	191.93	7	191	3	V; semivowel
f	190.98	8	84	7	V̸; fricative
z	173.45	9	51	8	V; fricative
r	166.54	10	269	1	V; glide
ɹ	163.97	11	31	12	V; glide
ə	149.79	12	96	6	V; glide

V = voiced consonant
V̸ = voiceless consonant

TABLE 2

MATRIX OF SPEARMAN RANK ORDER CORRELATION COEFFICIENTS OF THE 10 SUBJECTS FOR RECORDED AIRFLOW ON EACH UTTERANCE OF THE /p/ PHONEME

	2	3	4	5	6	7	8	9	10
1	-0.2	0.37	0.37	0.28	0.29	0.67	0.26	0.11	0.26
2		0.31	0.20	0.33	0.02	0.24	0.42	0.17	0.21
3			0.50	0.20	0.50	0.61	0.35	0.05	0.51
4				0.22	0.18	0.49	0.67	0.09	0.42
5					0.10	0.27	0.29	0.19	0.36
6						0.33	0.14	0.22	0.23
7							0.33	0.08	0.42
8								0.06	0.25
9									0.13

TABLE 3

MATRIX OF SPEARMAN RANK ORDER CORRELATION COEFFICIENTS OF THE 10 SUBJECTS FOR RECORDED AIRFLOW ON EACH UTTERANCE OF THE /r/ PHONEME

	2	3	4	5	6	7	8	9	10
1	0.04	-0.51	-0.17	0.27	0.05	0.17	-0.12	-0.09	-0.02
2		-0.00	0.16	0.10	0.12	0.12	-0.03	0.21	0.14
3			0.05	-0.49	0.00	0.01	0.20	0.36	0.08
4				-0.07	0.18	-0.18	-0.08	0.11	0.05
5					0.29	0.20	-0.29	-0.27	0.16
6						0.34	-0.26	0.09	0.19
7							-0.04	-0.14	0.23
8								0.03	0.24
9									-0.10

TABLE 4

RANK ORDER OF THE MEAN AIRFLOW VALUES AND THE FREQUENCY OF OCCURRENCE FOR ALL OF THE PHONETIC CONTEXTS OF "P" IN CVC AND VCVC UTTERANCES

Utterance	Rank Order of the 33 Utterances by Their Mean Airflow Value for Ten Subjects From Greatest to Least Airflow R_1	Rank Order of the 33 Utterances by Their Frequency of Occurrence in the 1000 Most Frequently Occurring Words R_2	The Frequency in Which the Utterance Occurs in the 1000 Most Frequently Occurring Words	Position and Stress of Each Utterance
p ʌ t	1	28.5	1	I/A
t ɔ It	3	28.5	1	I/A
p ɛ t	3	21	2	I/A
tip	3	14	3	F/A
pIt	5	5.5	5	I/A
taIp	7	28.5	1	F/A
t ʌ p	7	21	2	F/A
tup	7	28.5	1	F/A
t ɛ p	9	28.5	1	F/A
p ɔ t	13	28.5	1	I/A
pot	13	8.5	4	I/A
pit	13	14	3	I/A
pUt	13	14	3	I/A
t ɑ p	13	14	3	F/A
tIp	13	14	3	F/A
tep	13	21	2	F/A
top	17.5	28.5	1	F/A

TABLE 4 -- Continued

Utterance	Rank Order of the 33 Utterances by Their Mean Airflow Value for Ten Subjects From Greatest to Least Airflow R_1	Rank Order of the 33 Utterances by Their Frequency of Occurrence in the 1000 Most Frequently Occurring Words R_2	The Frequency in Which the Utterance Occurs in the 1000 Most Frequently Occurring Words	Position and Stress of Each Utterance
topt	17.5	14	3	Blend-F/A
pʃt	20.5	21	2	I/A
paUt	20.5	21	2	I/A
pæt	20.5	5.5	5	I/A
opet	20.5	5.5	5	I/UA
pet	23	3	6	I/A
pɑt	24	5.5	5	I/A
prot	25.5	1	13	Blend-I/A
tops	25.5	14	3	Blend-F/A
opət	27.5	2	7	I/UA
tæp	27.5	28.5	1	F/A
opit	30	28.5	1	I/UA
plot	30	14	3	Blend-I/A
oprot	30	14	3	Blend-I/UA
otʌp	32	28.5	1	F/UA
opɑt	33	8.5	4	I/UA

TABLE 5

RANK ORDER OF THE MEAN AIRFLOW VALUES AND THE FREQUENCY OF OCCURRENCE FOR ALL OF THE PHONETIC CONTEXTS OF "tʃ " IN CVC AND VCVC UTTERANCES

Utterance	Rank Order of the 17 Utterances by Their Mean Airflow Value for Ten Subjects From Greatest to Least Airflow R_1	Rank Order of the 17 Utterances by Their Frequency of Occurrence in the 1000 Most Frequently Occurring Words R_2	The Frequency in Which the Utterance Occurs in the 1000 Most Frequently Occurring Words	Position and Stress of Each Utterance
tetʃ	1	6.5	2	F/A
titʃ	2	1	5	F/A
t ɑ tʃ	3	12.5	1	F/A
t ʌ tʃ	4.5	3.5	3	F/A
otontʃ	4.5	3.5	3	F/UA
tʃɝ t	6	12.5	1	I/A
t ɝ tʃ	7	12.5	1	F/A
t ʃ it	9	12.5	1	I/A
t ʃ aɪt	9	12.5	1	I/A
tɪtʃ	9	3.5	3	F/A
t ʃɛ t	12.5	6.5	2	I/A
tʃet	12.5	12.5	1	I/A
tʃæ t	12.5	12.5	1	I/A
otortʃ	12.5	12.5	1	F/UA
otʃɑ t	15.5	3.5	3	I/UA

TABLE 5 -- Continued

Utterance	Rank Order of the 17 Utterances by Their Mean Airflow Value for Ten Subjects From Greatest to Least Airflow R_1	Rank Order of the 17 Utterances by Their Frequency of Occurrence in the 1000 Most Frequently Occurring Words R_2	The Frequency in Which the Utterance Occurs in the 1000 Most Frequently Occurring Words	Position and Stress of Each Utterance
ot ʃ ʌ t	15.5	12.5	1	I/UA
t ʃ It	17	12.5	1	I/A

TABLE 6

RANK ORDER OF THE MEAN AIRFLOW VALUES AND THE FREQUENCY OF OCCURRENCE FOR ALL OF THE PHONETIC CONTEXTS OF "ʃ " IN CVC AND VCVC UTTERANCES

Utterance	Rank Order of the 17 Utterances by Their Mean Airflow Value for Ten Subjects From Greatest to Least Airflow R_1	Rank Order of the 17 Utterances by Their Frequency of Occurrence in the 1000 Most Frequently Occurring Words R_2	The Frequency in Which the Utterance Occurs in the 1000 Most Frequently Occurring Words	Position and Stress of Each Utterance
tɛʃ	1	4.5	3	F/A
ʃot	3	3	4	I/A
tʌʃ	3	13.5	1	F/A
otIʃ	3	13.5	1	F/UA
ʃUt	5	4.5	3	I/A
ʃæt	6	13.5	1	I/A
ʃit	8.5	7.5	2	I/A
tIʃ	8.5	2	5	F/A
taʃ	8.5	7.5	2	F/A
tæʃ	8.5	13.5	1	F/A
ʃIt	11.5	13.5	1	I/A
ʃut	11.5	13.5	1	I/A
ʃɛt	13.5	13.5	1	I/A
ʃɑt	13.5	7.5	2	I/A
ʃaUt	15	13.5	1	I/A

TABLE 6 -- Continued

Utterance	Rank Order of the 17 Utterances by Their Mean Airflow Value for Ten Subjects From Greatest to Least Airflow R_1	Rank Order of the 17 Utterances by Their Frequency of Occurrence in the 1000 Most Frequently Occurring R_2	The Frequency in Which the Utterance Occurs in the 1000 Most Frequently Occurring Words	Position and Stress of Each Utterance
ʃet	16	7.5	2	I/A
oʃət	17	1	7	I/UA

TABLE 7

RANK ORDER OF THE MEAN AIRFLOW VALUES AND THE FREQUENCY OF OCCURRENCE FOR ALL OF THE PHONETIC CONTEXTS OF "K" IN CVC AND VCVC UTTERANCES

Utterance	Rank Order of the 43 Utterances by Their Mean Airflow Value for Ten Subjects From Greatest to Least Airflow R_1	Rank Order of the 43 Utterances by Their Frequency of Occurrence in the 1000 Most Frequently Occurring Words R_2	The Frequency in Which the Utterance Occurs in the 1000 Most Frequently Occurring Words	Position and Stress of Each Utterance
kʌt	1.5	2.5	9	I/A
tek	1.5	12	5	F/A
tUk	3.5	17.5	4	F/A
tork	3.5	22	3	Blend-F/A
tIk	5.5	12	5	F/A
toŋk	5.5	17.5	4	Blend-F/A
kUt	7	27.5	2	I/A
kit	9	37	1	I/A
kut	9	37	1	I/A
tokst	9	37	1	Blend-F/A
tosk	11	37	1	Blend-F/A
tæk	12.5	17.5	4	F/A
otokt	12.5	37	1	Blend-F/UA
kɛt	16	27.5	2	I/A

TABLE 7 -- Continued

Utterance	Rank Order of the 43 Utterances by Their Mean Airflow Value for Ten Subjects From Greatest to Least Airflow R_1	Rank Order of the 43 Utterances by Their Frequency of Occurrence in the 1000 Most Frequently Occurring Words R_2	The Frequency in Which the Utterance Occurs in the 1000 Most Frequently Occurring Words	Position and Stress of Each Utterance
ket	16	27.5	2	I/A
kæt	16	4.5	8	I/A
talk	16	37	1	F/A
otIk	16	4.5	8	F/UA
tok	20	22	3	F/A
tik	20	22	3	F/A
tɔk	20	27.5	2	F/A
kIt	24	17.5	4	I/A
oket	24	37	1	I/UA
tʃk	24	37	1	F/A
tolk	24	37	1	Blend-F/A
tokt	24	12	5	Blend-F/A
kɔt	27	6	7	I/A
kɑt	31	12	5	I/A
kalt	31	37	1	I/A
kaUt	31	37	1	I/A
tɑk	31	22	3	F/A
toks	31	27.5	2	Blend-F/A

TABLE 7 -- Continued

Utterance	Rank Order of the 43 Utterances by Their Mean Airflow Value for Ten Subjects From Greatest to Least Airflow R_1	Rank Order of the 43 Utterances by Their Frequency of Occurrence in the 1000 Most Frequently Occurring Words R_2	The Frequency in Which the Utterance Occurs in the 1000 Most Frequently Occurring Words	Position and Stress of Each Utterance
klot	31	1	10	Blend-I/A
kwot	31	7.5	6	Blend-I/A
t ɛ k	35	7.5	6	F/A
kot	37.5	12	5	I/A
ot ʌ k	37.5	27.5	2	F/UA
skwot	37.5	37	1	Blend-I/A
krot	37.5	12	5	Blend-I/A
ok ʌ t	49	2.5	9	I/UA
oklt	41.5	22	3	I/UA
okIt	41.5	37	1	I/UA
skot	43	12	5	Blend-I/A

TABLE 8

RANK ORDER OF THE MEAN AIRFLOW VALUES AND THE FREQUENCY OF OCCURRENCE FOR ALL OF THE PHONETIC CONTEXTS OF "NG" IN CVC AND VCVC UTTERANCES

Utterance	Rank Order of the 5 Utterances by Their Mean Airflow Value for Ten Subjects From Greatest to Least Airflow R_1	Rank Order of the 5 Utterances by Their Frequency of Occurrence in the 1000 Most Frequently Occurring Words R_2	The Frequency in Which the Utterance Occurs in the 1000 Most Frequently Occurring Words	Position and Stress of Each Utterance
tæŋ	1	2	5	F/A
tIŋ	2	1	9	F/A
toŋ	3	3	4	F/A
tʌŋ	4	4.5	3	F/A
otIŋ	5	4.5	3	F/UA

TABLE 9

RANK ORDER OF THE MEAN AIRFLOW VALUES AND THE FREQUENCY OF OCCURRENCE FOR ALL OF THE PHONETIC CONTEXTS OF "S" IN CVC AND VCVC UTTERANCES

Utterance	Rank Order of the 54 Utterances by Their Mean Airflow Value for Ten Subjects From Greatest to Least Airflow R_1	Rank Order of the 54 Utterances by Their Frequency of Utterance in the 1000 Most Frequently Occurring Words R_2	The Frequency in Which the Utterance Occurs in the 1000 Most Frequently Occurring Words	Position and Stress of Each Utterance
tosk	1	45.5	1	Blend-F/A
skwot	2	45.5	1	Blend-I/A
taIs	3	27.5	3	F/A
osə t	5	12	8	I/UA
tas	5	45.5	1	F/A
tɔs	5	27.5	3	F/A
tʌs	7	33.5	2	F/A
splot	8.5	45.5	1	Blend-I/A
sɛt	8.5	1	22	I/A
sɔIt	12	45.5	1	I/A
sut	12	33.5	2	I/A
set	12	18.5	5	I/A
tæs	12	16	6	F/A
tes	12	16	6	F/A
saUt	20.5	33.5	2	I/A
tIs	20.5	7	10	F/A
tɛs	20.5	9	9	F/A

TABLE 9 -- Continued

Utterance	Rank Order of the 54 Utterances by Their Mean Airflow Value for Ten Subjects From Greatest to Least Airflow R_1	Rank Order of the 54 Utterances by Their Frequency of Utterance in the 1000 Most Frequently Occurring Words R_2	The Frequency in Which the Utterance Occurs in the 1000 Most Frequently Occurring Words	Position and Stress of Each Utterance
tis	20.5	27.5	3	F/A
tɔIs	20.5	45.5	1	F/A
stot	20.5	2.5	19	Blend-I/A
skot	20.5	22	4	Blend-I/A
snot	20.5	45.5	1	Blend-I/A
slot	20.5	45.5	1	Blend-I/A
tost	20.5	2.5	19	Blend-F/A
tons	20.5	12	8	Blend-F/A
tokst	20.5	45.5	1	Blend-F/A
tors	27	27.5	3	Blend-F/A
sʌt	30.5	5.5	11	I/A
sIt	30.5	4	12	I/A
taUs	30.5	45.5	1	F/A
tonst	30.5	45.5	1	Blend-F/A
spot	30.5	5.5	11	Blend-I/A
smot	30.5	27.5	3	Blend-I/A
sot	35.5	22	4	I/A

TABLE 9 -- Continued

Utterance	Rank Order of the 54 Utterances by Their Mean Airflow Value for Ten Subjects From Greatest to Least Airflow R_1	Rank Order of the 54 Utterances by Their Frequency of Utterance in the 1000 Most Frequently Occurring Words R_2	The Frequency in Which the Utterance Occurs in the 1000 Most Frequently Occurring Words	Position Stress of Each Utterance
sit	35.5	9	9	I/A
tus	35.5	45.5	1	F/A
otost	35.5	33.5	2	Blend-F/UA
sprot	42	33.5	2	Blend-I/A
sɔt	42	18.5	5	I/A
saIt	42	9	9	I/A
sɝt	42	16	6	I/A
osət	42	27.5	3	I/UA
osot	42	45.5	1	I/UA
tos	42	45.5	1	F/A
otIs	42	12	8	F/UA
otəs	42	22	4	F/UA
toks	49	33.5	2	Blend-F/A
tots	49	22	4	Blend-F/A
tols	49	45.5	1	Blend-F/A
tops	49	45.5	1	Blend-F/A
swot	49	45.5	1	Blend-F/A
osɛt	52.5	45.5	1	I/UA

TABLE 9 -- Continued

Utterance	Rank Order of the 54 Utterances by Their Mean Airflow Value for Ten Subjects From Greatest to Least Airflow R_1	Rank Order of the 54 Utterances by Their Frequency of Utterance in the 1000 Most Frequently Occurring Words R_2	The Frequency in Which the Utterance Occurs in the 1000 Most Frequently Occurring Words	Position and Stress of Each Utterance
otons	52.5	22	4	Blend-F/UA
strot	54	14	7	Blend-I/A

TABLE 10

RANK ORDER OF THE MEAN AIRFLOW VALUES AND THE FREQUENCY OF OCCURRENCE FOR ALL OF THE PHONETIC CONTEXTS OF "L" IN CVC AND VCVC UTTERANCES

Utterance	Rank Order of the 50 Utterances by Their Mean Airflow Value for Ten Subjects From Greatest to Least Airflow R_1	Rank Order of the 50 Utterances by Their Frequency of Occurrence in the 1000 Most Frequently Occurring Words R_2	The Frequency in Which the Utterance Occurs in the 1000 Most Frequently Occurring Words	Position and Stress of Each Utterance
tolp	1	42.5	1	Blend-F/A
tol	2	42.5	1	Blend-F/A
tolk	3.5	42.5	1	Blend-F/A
tolf	3.5	13	5	Blend-F/A
laIt	5	13	5	I/A
lɝt	6.5	42.5	1	I/A
lɔt	6.5	9	7	I/A
lʌt	9.5	30.5	2	I/A
lUt	9.5	42.5	1	I/A
lut	9.5	42.5	1	I/A
tɛl	9.5	10	6	F/A
olIt	13.5	4	10	I/UA
plot	13.5	42.5	1	Blend-I/A
blot	13.5	18	4	Blend-I/A
tols	13.5	42.5	1	Blend-F/A

TABLE 10 -- Continued

Utterance	Rank Order of the 50 Utterances by Their Mean Airflow Value for Ten Subjects From Greatest to Least Airflow R_1	Rank Order of the 50 Utterances by Their Frequency of Occurrence in the 1000 Most Frequently Occurring Words R_2	The Frequency in Which the Utterance Occurs in the 1000 Most Frequently Occurring Words	Position and Stress of Each Utterance
tolt	18	18	4	Blend-F/A
old	18	1	13	Blend-F/A
slot	18	42.5	1	Blend-I/A
tUl	18	42.5	1	F/A
olaIt	18	30.5	2	I/UA
let	21	11	6	I/UA
tall	25	24	3	F/A
tolvz	25	42.5	1	Blend-F/A
tolv	25	42.5	1	Blend-F/A
splot	25	42.5	1	Blend-I/A
flot	25	18	4	Blend-I/A
oglot	25	30.5	2	Blend-I/UA
oblot	25	42.5	1	Blend-I/UA
l ɛ t	30	6.5	9	I/A
ol ə t	30	24	3	I/UA
t æ l	30	24	3	F/A
lIt	36	13	5	I/A
lit	36	18	4	I/A
l æ t	36	24	3	I/A

TABLE 10 -- Continued

Utterance	Rank Order of the 50 Utterances by Their Mean Airflow Value for Ten Subjects From Greatest to Least Airflow R_1	Rank Order of the 50 Utterances by Their Frequency of Occurrence in the 1000 Most Frequently Occurring Words R_2	The Frequency in Which the Utterance Occurrs in the 1000 Most Frequently Occurring Words	Position and Stress of Each Utterance
laUt	36	30.5	2	I/A
tɔ l	36	4	10	F/A
tel	36	24	3	F/A
til	36	30.5	2	F/A
otə l	36	6.5	9	F/UA
otɔ l	36	30.5	2	F/UA
tɝ l	41	42.5	1	F/A
lot	42.5	18	4	I/A
tIl	42.5	2	12	F/A
tol	44.5	8	8	F/A
tul	44.5	18	4	F/A
glot	47	30.5	2	Blend-A/A
tɑ l	47	18	4	F/A
tʌ l	47	42.5	1	F/A
tɔ Il	49	30.5	2	F/A
klot	50	4	10	Blend-I/A

TABLE 11

RANK ORDER OF THE MEAN AIRFLOW VALUES AND THE FREQUENCY OF OCCURRENCE FOR ALL OF THE PHONETIC CONTEXTS OF "F" IN CVC AND VCVC UTTERANCES

Utterance	Rank Order of the 23 Utterances by Their Mean Airflow Value for Ten Subjects From Greatest to Least Airflow R_1	Rank Order of the 23 Utterances by Their Frequency of Occurrence in the 1000 Most Frequently Occurring Words R_2	The Frequency in Which the Utterance Occurs in the 1000 Most Frequently Occurring Words	Position and Stress of Each Utterance
tæf	1	20.5	1	F/A
fæt	2	9.5	4	I/A
fIt	4	2	8	I/A
tolf	4	6.5	5	Blend-F/A
toft	4	13	3	Blend-F/A
faUt	6	20.5	1	I/A
fot	7	9.5	4	I/A
fat	8	4.5	6	I/A
otæf	9.5	20.5	1	F/UA
falt	9.5	4.5	6	I/A
fUt	11.5	16	2	I/A
fut	11.5	16	2	I/A
frot	14	1	9	Blend-I/A
fit	14	13	3	I/A
fɔt	14	3	7	I/A
fet	16.5	9.5	4	I/A

TABLE 11 -- Continued

Utterance	Rank Order of the 23 Utterances by Their Mean Airflow Value for Ten Subjects From Greatest to Least Airflow R_1	Rank Order of the 23 Utterances by Their Frequency of Occurrence in the 1000 Most Frequently Occurring Words R_2	The Frequency in Which the Utterance Occurs in the 1000 Most Frequently Occurring Words	Position and Stress of Each Utterance
fjUt	16.5	13	3	Blend-I/A
flot	18.5	9.5	4	Blend-I/A
of∂t	18.5	16	2	I/UA
fΛt	21	20.5	1	I/A
ofot	21	20.5	1	I/UA
ofαt	21	20.5	1	I/UA
fεt	23	6.5	5	I/A

TABLE 12

RANK ORDER OF THE MEAN AIRFLOW VALUES AND THE FREQUENCY OF OCCURRENCE FOR ALL OF THE PHONETIC CONTEXTS OF "Z" IN CVC AND VCVC UTTERANCES

Utterance	Rank Order of the 21 Utterances by Their Mean Airflow Value for Ten Subjects From Greatest to Least Airflow R_1	Rank Order of the 21 Utterances by Their Frequency of Occurrence in the 1000 Most Frequently Occurring Words R_2	The Frequency in Which the Utterance Occurs in the 1000 Most Frequently Occurring Words	Position and Stress of Each Utterance
otomz	1	16.5	1	F/UA
tɛz	2.5	7.5	3	F/A
otaIz	2.5	10	2	F/UA
tolvz	4	16.5	1	Blend-F/A
zIt	6.5	16.5	1	I/A
taIz	6.5	5	4	F/A
tæz	6.5	10	2	F/A
tez	6.5	16.5	1	F/A
zaIt	9	16.5	1	I/A
tuz	10.5	1.5	6	F/A
otez	10.5	16.5	1	F/UA
zʌt	13	16.5	1	I/A
zæt	13	16.5	1	I/A
otIz	13	16.5	1	F/UA
tɔz	15	10	2	F/A
ozə t	16	7.5	3	I/UA

TABLE 12 -- Continued

Utterance	Rank Order of the 21 Utterances by Their Mean Airflow Value for Ten Subjects From Greatest to Least Airflow R_1	Rank Order of the 21 Utterances by Their Frequency of Occurrence in the 1000 Most Frequently Occurring Words R_2	The Frequency in Which the Utterance Occurs in the 1000 Most Frequently Occurring Words	Position and Stress of Each Utterance
toz	18	3	5	F/A
tiz	18	5	4	F/A
tʌz	18	5	4	F/A
tIz	20	1.5	6	F/A
ozIt	21	16.5	1	I/UA

TABLE 13

RANK ORDER OF THE MEAN AIRFLOW VALUES AND THE FREQUENCY OF OCCURRENCE FOR ALL OF THE PHONETIC CONTEXTS OF "R" IN CVC AND VCVC UTTERANCES

Utterance	Rank Order of the 46 Utterances by Their Mean Airflow Value for Ten Subjects From Greatest to Least Airflow R_1	Rank Order of the 46 Utterances by Their Frequency of Occurrence in the 1000 Most Frequently Occurring Words R_2	The Frequency in Which the Utterance Occurs in the 1000 Most Frequently Occurring Words	Position and Stress of Each Utterance
torθ	1	37.5	2	Blend-F/A
krot	2	22	5	Blend-I/A
tork	3	29.5	3	Blend-F/A
strot	5	15	7	Blend-I/A
torn	5	37.5	2	I/A
rɔt	5	44.5	1	Blend-I/A
prot	7.5	3.5	13	Blend-I/A
tord	7.5	12	8	Blend-F/A
tat	9	44.5	1	I/A
tɛr	11	1	24	F/A
drot	11	15	7	Blend-I/A
torm	11	22	5	Blend-F/A
rʌt	14.5	37.5	2	I/A
brot	14.5	9.5	10	Blend-I/A
sprot	14.5	37.5	2	Blend-I/A
tær	14.5	22	5	F/A

TABLE 13 -- Continued

Utterance	Rank Order of the 46 Utterances by Their Mean Airflow Value for Ten Subjects From Greatest to Least Airflow R_1	Rank Order of the 46 Utterances by Their Frequency of Occurrence in the 1000 Most Frequently Occurring Words R_2	The Frequency in Which the Utterance Occurs in the 1000 Most Frequently Occurring Words	Position and Stress of Each Utterance
otrot	18	29.5	3	Blend-I/UA
tort	18	9.5	10	Blend-F/A
trot	18	6	12	Blend-I/A
ralt	21.5	22	5	I/A
frot	21.5	11	9	Blend-I/A
rot	21.5	37.5	2	Blend-I/A
orot	21.5	44.5	1	I/UA
rit	29.5	18.5	6	I/A
ret	29.5	22	5	I/A
rut	29.5	29.5	3	I/A
r&t	29.5	37.5	2	I/A
raUt	29.5	37.5	2	I/A
t > r	29.5	3.5	13	F/A
tIr	29.5	3.5	13	F/A
taIr	29.5	25.5	4	F/A
grot	29.5	7.5	11	Blend-I/A
oprot	29.5	29.5	3	Blend-I/UA

TABLE 13 -- Continued

Utterance	Rank Order of the 46 Utterances by Their Mean Airflow Value for Ten Subjects From Greatest to Least Airflow R_1	Rank Order of the 46 Utterances by Their Frequency of Occurrence in the 1000 Most Frequently Occurring Words R_2	The Frequency in Which the Utterance Occurs in the 1000 Most Frequently Occurring Words	Position and Stress of Each Utterance
tortʃ	29.5	44.5	1	Blend-F/A
tors	29.5	29.5	3	Blend-F/A
rIt	37.5	15	7	I/A
tordʒ	37.5	29.5	3	Blend-F/A
taUr	37.5	37.5	2	F/A
tUr	37.5	18.5	6	F/A
rot	42.5	25.5	4	I/A
orət	42.5	37.5	2	I/UA
orIt	42.5	3.5	13	I/UA
tar	42.5	7.5	11	F/A
tor	42.5	15	7	F/A
odrot	42.5	37.5	2	Blend-I/UA
rɛt	46	15	7	I/A

TABLE 14

RANK ORDER OF THE MEAN AIRFLOW VALUES AND THE FREQUENCY OF OCCURRENCE FOR ALL OF THE PHONETIC CONTEXTS OF "ɹ" IN CVC AND VCVC UTTERANCES

Utterance	Rank Order of the 19 Utterances by Their Mean Airflow Value for Ten Subjects From Greatest to Least Airflow R_1	Rank Order of the 19 Utterances by Their Frequency of Occurrence in the 1000 Most Frequently Occurring Words R_2	The Frequency in Which the Utterance Occurs in the 1000 Most Frequently Occurring Words	Position and Stress of Each Utterance
tɹt	1	13.5	1	F/A
hɹt	2	5.5	2	M/A
fɹt	3.5	13.5	1	M/A
θɹt	3.5	13.5	1	M/A
wɹt	6.5	1.5	4	M/A
tɹt	6.5	5.5	2	M/A
gɹt	6.5	13.5	1	M/A
sɹt	6.5	13.5	1	M/A
bɹt	9	5.5	2	M/A
ɹθ	11	13.5	1	F/A
fɹ	11	13.5	1	F/A
lɹt	11	13.5	1	M/A
pɹ	13.5	5.5	2	F/A
ɹθ	13.5	13.5	1	F/A
tʃɹt	15	13.5	1	M/A
hɹ	16	13.5	1	F/A
wɹ	17	13.5	1	F/A

TABLE 14 -- Continued

Utterance	Rank Order of the 19 Utterances by Their Mean Airflow Value for Ten Subjects From Greatest to Least Airflow R_1	Rank Order of the 19 Utterances by Their Frequency of Occurrence in the 1000 Most Frequently Occurring Words R_2	The Frequency in Which the Utterance Occurs in the 1000 Most Frequently Occurring Words	Position and Stress of Each Utterances
ʃɝ	18	1.5	4	F/A
dʒɝ	19	3	3	F/A

TABLE 15

RANK ORDER OF THE MEAN AIRFLOW VALUES AND THE FREQUENCY OF OCCURRENCE FOR ALL OF THE PHONETIC CONTEXTS OF "ə" IN CVC AND VCVC UTTERANCES

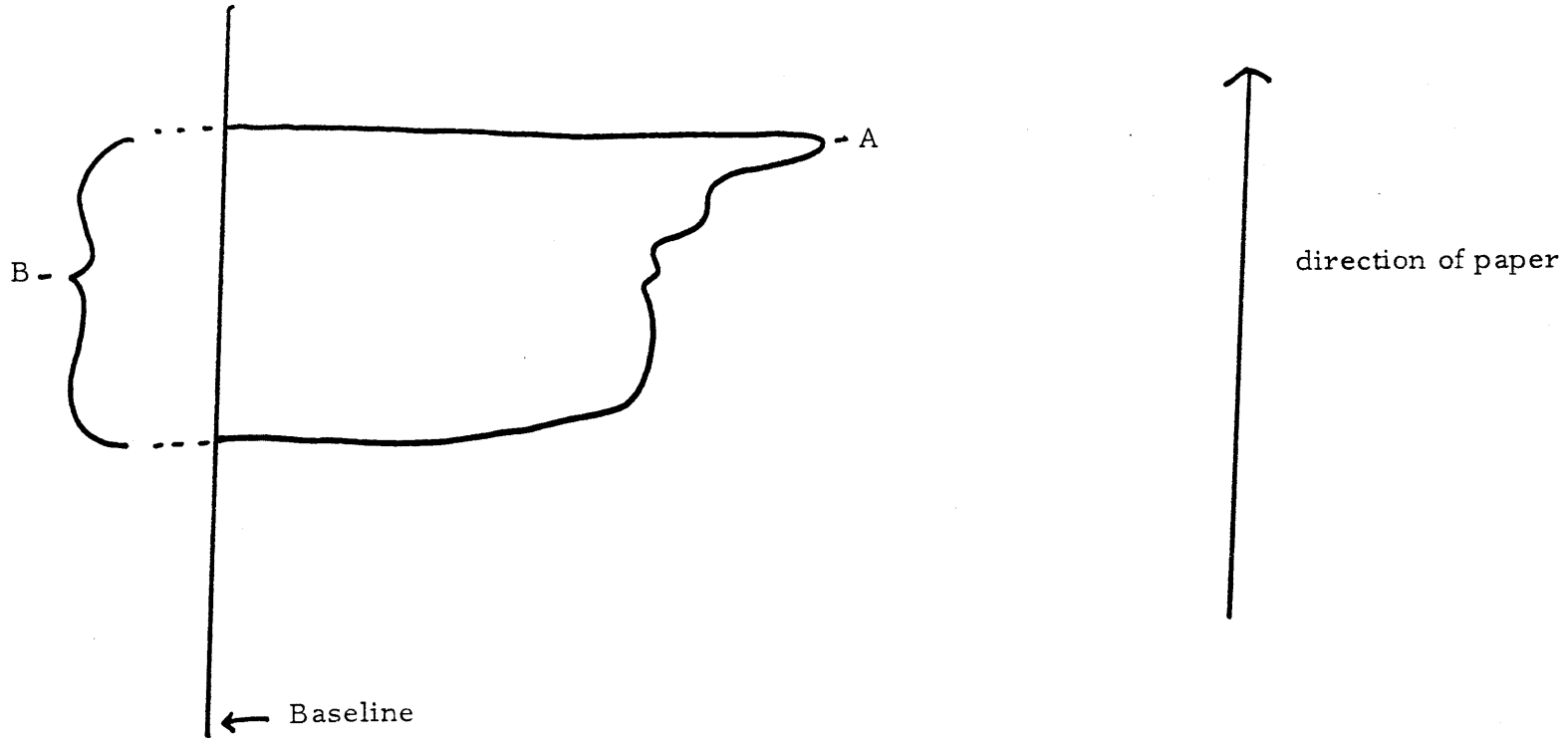
Utterance	Rank Order of the 19 Utterances by Their Mean Airflow Value for Ten Subjects From Greatest to Least Airflow R_1	Rank Order of the 19 Utterances by Their Frequency of Occurrence in the 1000 Most Frequently Occurring Words R_2	The Frequency in Which the Utterance Occurs in the 1000 Most Frequently Occurring Words	Position and Stress of Each Utterance
ofə	1	5.5	5	F/UA
okə	2	18	1	I/UA
ohə	3.5	18	1	I/UA
odə	3.5	4	8	F/UA
odʒə	6	15	2	F/UA
osə	6	11.5	3	F/UA
opə	6	11.5	3	F/UA
otʃə	9	8	4	F/UA
oθə	9	18	1	F/UA
owə	9	15	2	F/UA
omə	11	11.5	3	F/UA
ovə	12.5	3	10	F/UA
olə	12.5	8	4	F/UA
obə	14	5.5	5	F/UA
otə	15	1	16	F/UA
oʒə	17	15	2	F/UA
onə	17	8	4	F/UA

TABLE 15 -- Continued

Utterance	Rank Order of the 19 Utterances by Their Mean Airflow Value for Ten Subjects From Greatest to Least Airflow R_1	Rank Order of the 19 Utterances by Their Frequency of Occurrence in the 1000 Most Frequently Occurring Words R_2	The Frequency in Which the Utterance Occurs in the 1000 Most Frequently Occurring Words	Position and Stress of Each Utterance
ogə	17	11.5	3	F/UA
oβə	19	2	13	F/UA

FIGURE I

TYPICAL BECKMAN INK TRACING OF PRESSURE/AIRFLOW FOR A CONSONANT-VOWEL-CONSONANT UTTERANCE



* POINT A Represents the peak value for the utterance

* POINT B Represents the total air cost for the utterance

APPENDIX A

1.	rlt	27.	grot	53.	ɵɻ
2.	rɛt	28.	brot	54.	hɻ
3.	rit	29.	frot	55.	wɻ
4.	ralt	30.	drot	56.	wɻt
5.	ret	31.	strot	57.	bɻt
6.	rot	32.	krot	58.	tɻt
7.	rut	33.	θrot	59.	hɻt
8.	rætt	34.	sprot	60.	fɻt
9.	raUt	35.	oprot	61.	gɻt
10.	rʌt	36.	otrot	62.	sɻt
11.	rat	37.	odrot	63.	θɻt
12.	rɔt	38.	tort	64.	lɻt
13.	orlt	39.	tord	65.	tʃɻt
14.	orət	40.	torm	66.	otɚ
15.	orot	41.	tork	67.	odɚ
16.	tɛr	42.	tordʒ	68.	ovɚ
17.	tɔr	43.	tors	69.	odɚ
18.	tlr	44.	torθ	70.	ofɚ
19.	tar	45.	torn	71.	obɚ
20.	tor	46.	tortʃ	72.	opɚ
21.	tUr	47.	tɻ	73.	olɚ
22.	tær	48.	ɻθ	74	onɚ
23.	talr	49.	sɻ	75.	otʃɚ
24.	taUr	50.	dʒɻ	76.	omɚ
25.	prot	51.	pɻ	77.	ogɚ
26.	trot	52.	fɻ	78.	osɚ

79. odʒɚ
80. oʒɚ
81. oθɚ
82. olɚ
83. ohɚ
84. owɚ
85. odɚ
86. okɚ
87. ofɚ
88. ovɚt
89. lɛt
90. lɔt
91. let
92. laIt
93. lIt
94. lit
95. lot
96. læt
97. lʌt
99. laUt
100. lUt
101. lut
102. lɝt
103. olɪt
104. olə t
105. olaIt
106. tIl
107. tɔl
108. tol
109. tɛl
110. tul
111. tɑl
112. talI
113. tæl
114. tel
115. til
116. tUl
117. tɔIl
118. tʌl
119. tɝl
120. otəl
121. otɔl
122. klot
123. blot
124. flot
125. glot
126. plot
127. slot
128. splot
129. oglot
130. oblot
131. old
132. tolf
133. tolt
134. tolk
135. tolv
136. tolvz
137. tols
138. tolth
139. tolp
140. sɛt
141. sIt
142. sʌt
143. sit
144. saIt
145. sɝt
146. set
147. sɔt
148. sot
149. sut
150. saUt
151. sɔIt
152. osʌt
153. osɚt
154. osɛt
155. osot
156. tIs
157. tɛs

158. tæ s
159. tes
160. tis
161. talz
162. tɔ s
163. tʌ s
164. taUs
165. tɔ Is
166. tus
167. tos
168. tɑ s
169. otIs
170. otʌ s
171. stot
172. spot
173. strot
174. skot
175. smot
176. sprot
177. splot
178. snot
179. slot
180. swot
181. skwot
182. tost
183. tons
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210. otaIz
211. otIz
212. otez
213. tolvz
214. otomz
215. ʃot
216. ʃUt
217. ʃit
218. ʃet
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222. ʃaUt
223. ʃIt
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226. tIʃ
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229. tæʃ
230. tʌʃ
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237. tʃɑt
238. tʃaIt
239. tʃɝt
240. otʃət
241. otʃʌt
242. titʃ
243. tItʃ
244. tʌtʃ
245. tetʃ
246. tɑtʃ
247. tɜ˞tʃ
248. otontʃ
249. otortʃ
250. pet
251. pIt
252. pæt
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254. pot
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256. pUt
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258. pɝt
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260. pɔIt
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263. opət
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267. tɑp
268. tip
269. tIp
270. tep
271. tʌp
272. tɛp
273. top
274. tup
275. taIp
276. otʌp
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299. tɛk
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305. tɑk
306. tok
307. tɔk
308. taIk
309. tɝk
310. otIk
311. otʌk
312. klot
313. kwot

314. krot
315. skot
316. skwot
317. tokt
318. toŋk
319. tork
320. toks
321. tosk
322. tolk
323. tokst
324. otokt
325. flt
326. fɔt
327. f t
328. faIt
329. fɛt
330. fet
331. fæt
332. fot
333. fit
334. fUt
335. fut
336. fɜt
337. faUt
338. fʌt
339. ofot
340. ofət
341. tæf
342. otæf
343. frot
344. flot
345. fjUt
346. tolf
347. toft
348. tiŋ
349. toŋ
350. tʌŋ
351. tæŋ
352. otIŋ
353. tæ p

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