CONSTRICTION LOCATION AND VOWEL DURATION IN CVC SYLLABLES

By

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IN CVC SYLLABLES

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PREFACE

The relationships of voicing and the place of stop constriction in the initial and final consonants to the vowels' durations in CVC combinations were studied. The CVC syllables were embedded in a carrier phrase which was read by forty college students. The durations of the vowels in the taped samples were determined. There were significant differences in the durations of the vowels which related to voicing of the consonants and the location of the constriction of the two consonants in the CVC combination. However, changing the proximity of the locations of the constrictions in the first and second consonants did not consistently increase the intervening vowel duration.

I wish to express my sincere gratitude to all the individuals who assisted me in this study and encouraged me throughout my education at Oklahoma State University. I would especially like to thank my thesis adviser, Dr. Arthur L. Pentz, Jr., for his continuous guidance in this endeavor.

I also would like to express my sincere appreciation to the other committee members, Dr. A. Lynn Williams and Mr. Gary Beeby, who provided additional advice.

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CHAPTER I

INTRODUCTION

Vowels in the English language provide the listener with critical information during communicative interaction (House and Fairbanks, 1953; Peterson and Lehiste, 1960; House, 1961; and Lehiste, 1970). The listener most often uses the formant characteristics of vowels to determine which vowel was spoken.

Each vowel is unique because of its distinct formant energy configuration. Regions of energy are determined by the shape, size and length of the vocal tract. The articulators vary the length, size, and shape of the vocal tract chambers. Movement of the tongue in the oral cavity produces the effect of a variable two-chamber Helmholtz resonator (Ladefoged, 1962). The oral cavity acts as an acoustic filter that transmits sounds which are close to its resonant frequencies and damps away those that are not. These concentrated regions of sound energy are referred to as formants. The complex sound can be graphically broken down into its fundamental frequency and its formants using a sound spectograph (Minifie, 1973).

When formant information is not adequate to distinguish between the different vowel sounds, the listener must then use information derived from such perceptual secondary cues as fundamental frequency, duration, and intensity. Of those, vowel duration has been found to convey the most useful information (Peterson et al., 1960; Umeda, 1975; Klatt, 1976; Cooper, Eady, and Muller, 1985; and Crystal and House, 1990). Whenever, vowel duration is altered by a speaker without consideration for the impact of changes on the context of the message, the potential for distorted perception on the part of the listener is present. However, vowel length may be influenced by numerous factors.

In English, there are also inherent durational differences among vowels. Tense vowels tend to be longer than lax vowels because they require more air pressure, greater articulatory precision, and more articulatory force and muscular tension (House, 1961; Daniloff, 1973; and Minifie, 1973). The difference in the vocalic tenseness and duration is evident in the production of the tense vowel /i/ versus the lax vowel /I/. In short, they require a greater number of precise adjustments for their productions.

Voicing, also, influences vowel duration. Vowels are shorter in duration when followed by a voiceless consonant and longer when followed by a voiced consonant (Peterson, et al., 1960). When vowels precede voiced fricatives, /v,ð,z,ʒ/, duration is longest, as in "five" versus "fife" (Peterson et al., 1960). The word-final, voiced fricative /v/ in "five" lengthens the preceding vowel while the voiceless fricative /f/ in "fife" decreases (shortens) the length of the preceding vowel.

Vowel duration can also be associated with the information load that a word carries in a message (Umeda, 1975). In English, words that are less important and occur frequently are emphasized less. In the phrase, "The big dog", the function word carries less stress than the adjective or the noun. These duration cues help the listener successfully interpret the message.

Syntactic patterns of the speaker impact final-syllable-vowels (Klatt, 1975). Oller (1973) reported that lengthening of the final syllable occurs in word final (e.g., honey), phrase final (e.g., "Never mind"), and utterance final positions (e.g., "Take out the trash.").

Linguistic stress and word or syllable emphasis are additional sources of vowel lengthening and influence the meaning of a phrase or sentence. For instance, the word, "interest", can be a noun or a verb depending on where the emphasis is placed. The lengthening of the vowel in a syllable or word is perceived as a perceptual acoustic cue for stress (Klatt, 1976).

The emotional state of the speaker can also affect the length of a vowel. A speaker increases his/her rate of speech when excited and, thus, shortens the vowel sound. If a speaker is hesitant or uncertain, the vowels will be increased in length (Williams & Stevens, 1972).

In addition there are physiologic factors which must also be considered. The number of articulatory adjustments and movements required to assume the posture for a sound before the target is made is assumed to influence the length of the vowel. When a word is produced, the articulators move from a neutral position to the approach gesture, assume the posture for the phoneme, produce the target and then return to the neutral position which becomes the approach gesture for the next phoneme in the string.

Consonants with similar places of production such as /k/ and /g/ are produced with the velopharyngeal port closed, the tongue slides posteriorly and the dorsum of the tongue pushes up against the velum constricting the airflow. When the tongue drops, the airway opens and the released air pressure creates a noise burst. In a context such as [kʌk], each of the articulators are required to make minimal changes since each phoneme has the same place of constriction, and there is a neutral vowel between. It is assumed that in this context the shortest vowel duration will occur.

As the point of constriction is moved ahead slightly, an increase in the length of the vowel is assumed to occur as in the production of the /k/ and /t/ in the CVC environment, [kʌt]. The /k/ is produced with the velopharyngeal port closed and with the dorsum of the tongue contacting the velum. The /t/ is produced with the tip of the tongue raised to constrict the airflow at the alveolar ridge. The tongue is required to make intricate segmented movements during the production of [kʌt].

Consonants which require the most shift in the articulators, such as [kʌp], should have the greatest influence on the duration of the vowel. The constriction for /p/ is formed bilabially with the assistance of the mandible and lips. The mandible assumes the articulatory posture of the intervening vowel and opens slightly. Thus, the slow movement of the lips and mandible in assuming the posture for the following bilabial would probably further increase the length of the vowel.

Norton (1986) examined vowel length in CVC syllable contexts where the constriction for the consonants moved from anterior to posterior placement. Norton (1986) found that a syllable which required the articulators to travel a minimal distance, as in [pʌp], to be significantly shorter in vowel duration, than [pʌt] or [pʌk] which required more moderate changes. It has been reported that more articulatory effort is required to produce a CVC syllable in which the consonants vary than a syllable in which the consonants remain the same (Lehiste, 1970). According to Norton's theory of the [pʌt] and [kʌt] durations, the syllable [pʌk] which required maximal shift in the point of constriction should have the longest vowel duration. That, however, was not the case.

Norton found vowel length was longest when the vowels produced were between a bilabial and a lingual-alveolar stops. That investigator proposed that both the place of production and the amount of adjustments needed to make the constriction relate to vowel duration. Further inspection of the CVC combinations revealed the presence of certain coarticulatory activities along with the anticipated adjustment complexities.

Coarticulation appeared to influence vowel length when non-contradictory movements occurred in the CVC productions. Contradictory movements are articulatory gestures that must be produced serially and the gestures may not be overlapped (coarticulated) (Daniloff, 1973). While non-contradictory movements are articulatory gestures that may be overlapped (coarticulated) without interfering with the production of the previous phoneme.

In the production of [pʌp], the lips and mandible may begin to move toward the target position for the final consonant without distorting the vowel /ʌ/. In [pʌk], the lingual-velar actions may be coarticulated with the bilabial and vowel movements allowing a faster execution of the two consonants and resulting in a shorter vowel length (Norton, 1986).

The phoneme /ʌ/ is produced in the posterior portion of the vocal tract with the body of the tongue in a neutral posture permitting the tongue body to raise and form a constriction at the velum for /k/ without distorting the vowel. The production of [pʌk] results in a slight increase in the vowel length.

The bilabial and lingual-alveolar consonants in [pʌt] are difficult to coarticulate. The distance of articulatory travel and the number of contradictory, articulatory gestures and adjustments appeared to result in a longer vowel duration. For [pʌt], the tongue moves from a neutral position to a constricting posture requiring flattening of the tongue blade and lifting of the tongue tip to the alveolar ridge. The contradictory and specified tongue positions for /ʌ/ and /t/ do not allow the tongue to coarticulate the two phonemes.

In Henke's (1966) theory of anticipatory coarticulation, it was proposed that when a nonspecified position for that gesture occurs, the system looks ahead to the next specified position, and the articulators move toward it. The articulators will coarticulate as long as the required articulatory movements are noncontradictory.

Norton (1986) proposed that the number of segmented articulatory movements, the intricacy of the adjustments required, and whether the movements could be coarticulated seem to have a strong influence on vowel duration. If there are no opportunities for coarticulation, then shifts in the place of constriction should once again be the dominant factor in vowel length.

The focus of the present study will be on the effect of articulatory movements on vowel duration when the constriction is moved from a posterior to anterior position in CVC combinations that will include lingual-velar, lingual-alveolar and bilabial consonants. It is thought that the syllable [kʌk] will probably be the shortest since the two consonants have the same place of constriction.

The syllable [kʌt] would most likely be of moderate duration since the tip of the tongue, the fastest moving articulator, must travel a moderated distance to the alveolar ridge.

The syllable [kʌp] which contains a lingual-velar and a bilabial consonant would probably have the most influence on vowel duration since the lips and mandible are the slowest moving articulators. The lips and mandible open slightly to produce the /ʌ/ and then must raise to form the constriction for the bilabial.

The purpose of the study is to determine the interactive-effects of articulatory movement and coarticulation upon vowel duration and compare whether the posterior to anterior constriction movements coupled with coarticulatory efforts have an impact upon vowel duration that is similar to the anterior to posterior movements.

CHAPTER II

METHODS

Forty-three normal speaking college students from Oklahoma State University participated in the investigation. The population of this study was composed of 20 male and 23 female volunteers between the ages of 18 and 25 years of age. All subjects were normal adult speakers from the same geographic region who did not have apparent communication problems, hearing loss, or foreign accents. All subjects were screened for normal hearing sensitivity bilaterally for the octave frequencies between 250 and 4000 Hz at 15dB. Individuals were excluded from the study if they failed to respond to the presented signal at one of the frequencies.

The stimulus material was CVC words containing the neutral /ʌ/ vowel. The place of constriction was altered from final to initial position by combining the following consonants /p,b,t,d,k,g/ with the schwa vowel. The target words which were used in this study were: kuk, kut, kup, gug, gud, and gub.

The target words are representative of the following subcategories: 1) the words with maximum relocation of the stop constrictions between the production of the first and final consonant (e.g., kup and gub); 2) the words with moderate relocation of constrictor (e.g., kut and gud); 3) and words with minimal relocation of the stop constriction (e.g., kuk and gug).

The target words were embedded within the same carrier phrase (e.g., "The _____ is over there."). The carrier phrase minimized the effects of word order within the phrase and of the type of word on vowel duration (Klatt, 1975). The sentences were randomized and presented to each subject to reduce the effects of sentence order. The present data were derived from a segment of a larger data set (Norton, 1986).

While seated in an I.A.C. sound treated booth, each subject was given the same recorded instructions. Each subject was given a randomized list of phrases to read and produce in imitation of the speaker. Each phrase contained a CVC sequence. Presentation of the sample was transmitted through sound field speakers located at each side of the sound booth, and the subject's responses were recorded using a Nagra model 4.2 reel-to-reel tape recorder and a Neumann model KM83 microphone. The microphone was placed on a stand approximately twelve centimeters from the speaker's mouth.

Taped responses were directed through a CSL 4300 computerized Sound Spectograph. A broadband spectogram was drawn to electronically measure the duration of the neutral vowel embedded within the target word. The points of onset and of the second formant of the vowel were used to mark beginning and end of the vowel's duration (House, 1961). The length in milliseconds was computed. All vowel durations were compared using a two factor dependent (repeated) measures analysis of variance.

Interjudge reliability was obtained by having one graduate student trained in the use of the Kay Elemetrics Sound Spectograph independently measure the duration of vowels from 23 percent of the samples of the target words. Comparisons of these measures were obtained. The measurements revealed a Pearson r correlation of the two sets of measures of .89.

CHAPTER III

RESULTS

The vowel lengths in the CVC combinations were compared using a two factor repeated measures analysis of variance. The three different consonant combinations in the CVC string (i.e., gug, gud, gub) made up three levels of the first variable. The presence or absence of voicing in the initial consonant in the string (i.e., gug or kuk) constituted two levels of the second variable. (A summary of the analysis is contained in Table 1.)

TABLE 1

Analysis of Variance Summary Table

CVC Combinations

Source	Df	F-ratio	p
Initial Consonant Voicing	1	388.577	<.01
Place of Constriction	2	32.256	<.01
Interaction (Consonant voicing and place of constriction)	2	7.497	<.01

The results of that initial analysis revealed there was a significant difference (<.01) among the vowel durations associated with the place of the constriction of the final consonant. The initial consonant was always a lingual-velar stop. The final stop consonant varied from string to string. It was paired with a second lingual-velar in one string (i.e., gug); a lingual-alveolar in a second (i.e., gud); and a bilabial combination in the third (i.e., gub).

There was also a significant difference (<.01) related to whether the consonants in the CVC combinations were voiced or unvoiced. A significant (<.01) interaction (place x voicing) was present. The individual vowel durational means are contained in Table 2.

Followup comparisons across the place of constriction were made. In the three voiced contexts, there were no significant differences among the durations of the vowels in either "gug, gud, or gub" syllables. Also, /kʌk/ and /kʌp/ did not differ significantly from each other. However, the /kʌt/ context had a mean vowel duration which was significantly larger than either /kʌk/ or /kʌp/. Followup comparisons in both the voiced and unvoiced contexts revealed that in all cases, the mean vowel duration in the voiced context was longer than that in its unvoiced context.

TABLE 2

Mean Vowel Durations of CVC Syllables in Milliseconds

Syllable	/gug/	/gud/	/gub/
Msec.	160	166	158
Syllable	/kuk/	/kut/	/kup/
Msec.	106	126	102

CV for voiced/ voiceless contrast (.01, Df 2,86) = 8.48
CV for constriction location (.01, Df 3, 86) = 9.65

CHAPTER IV

DISCUSSION

Vowel durations in the voiced CVC combinations were longer than those in voiceless sequences. In a CVC sequence containing a voiced initial and final stops, the vibration of the vocal folds is essentially continuous through the voiced consonant and the following vowel. Voiced final consonants have a lengthening effect upon the preceding vowel. The present results are consistent with Peterson and Lehiste (1960), House (1961), and Krause (1982).

The difference between the durations of the vowels in the "kup" and "kuk" sequences were significantly shorter than the one in the "kut" sequence. The primary articulator, the dorsum of the tongue, makes only slight adjustments when producing the CVC (kuk) sequence. Very little reposturing or reshaping is necessary for the vowel production after the initial consonant and the subsequent final stop.

The durations of the vowels in the velar/bilabial consonant context (kup) was minimally lengthened. That finding was unexpected because the lingual-velar constriction of the initial consonant is shifted markedly to an anterior point in the vocal tract in order to produce the second stop. The lips, very slow articulators, must be brought together to execute the final stop constriction. However, the finding was consistent with Norton (1986) who also reported that when the constriction is moved from the bilabial to the lingual-velar type, only a small amount of vowel lengthening occurs.

Vowel durations in the velar/lingual-alveolar context (i.e., kut) were found to be the longest in duration. Vowels in these contexts were significantly longer than those contexts requiring minimal or maximal change in the proximity of the two constriction. Again, the findings are consistent with Norton's (1986) findings.

For production of the alveolar stop /t/, there is a build-up of subglottal pressure preceding the release of the stop. The release of the alveolar stop is followed by a little reshaping of the vocal tract. Then the entire tongue must be flattened and reshaped so that it can interrupt the airstream; for a build-up of pressure prior to the burst for the stop.

Two things must occur in this sequence which do not happen in a velar-bilabial sequence. First, the tongue is reshaped and raised in anticipation of closing off the airstream. Second, the stop consonant is not so severely undershot. That is, a vast majority of speakers do build-up the pressure and release the burst as part of the sequence. They did not tend to do that in the velar-bilabial sequences.

The same trend was present in the context where the consonants in the combinations were voiced. The "gub" context contained vowels with the shortest durations. The "gug" sequence contained the vowels with the next longest durations and the "gud" sequence contained the vowels with the longest durations. While all three sequences followed the same durational patterns of these in voiceless CVC context had slightly different durations none of the differences were significant in the voiced contexts.

CHAPTER V

SUMMARY

Forty-three adult subjects produced CVC combinations. Each set of combinations included a lingual-velar stops /k/ or /g/; the vowel /ʌ/; and either a lingual-alveolar, lingual-velar, or a bilabial stop in the final position. The six combinations contained either a voiced or unvoiced initial and final stop.

The original hypothesis was that the further removed the places of constriction are for the first and second stops, the longer the duration of the intervening vowel. That is, if two stops had the places of constriction in close proximity, the intervening vowel would be shorter than if the places of constriction were further removed from each other.

First, the present results indicated that when the places of constriction for both consonants were the same, the duration of the intervening vowel was of moderate duration. However, when the proximity of the places of constrictions were at their greatest distance, the duration of the intervening vowel was not at its greatest, but rather at its shortest compared to the others. When the proximity of the constrictions was at midpoint among the three possible combinations, the intervening vowel duration was at its greatest. The trend was consistent regardless of the voicing status of the consonants in the combinations. The proximity of the two constrictions appears to interact with coarticulatory movements to influence the intervening vowel's duration.

Future investigations should address the effect on vowel duration when moving the place of constriction from the middle region of the oral cavity to the anterior and posterior positions. It is not known whether lingual-alveolar stop consonants in the initial position in CVC combinations will have similar findings.

Second, the present results also indicated that voiced stops surrounded longer duration vowels than did unvoiced stops. This information is consistent with House and Fairbanks (1953); House (1961); and Krause (1982).

Based on present and Norton (1986) studies it is apparent that the proximity of the two places of constriction of the stops in a CVC combination are only partially influential in the length of the intervening vowels. Other factors, especially coarticulatory movements, also interact and have a marked influence on vowel durations. Just how much influence each factor has, remains unclear. Later research will need to address the magnitude of differing types of coarticulatory movements on vowel durations.

Third, the present study would indicate that proximity of sequential stops in CVC combinations are only one of a variety of influences which relate to intervening vowel durations. It appears that whether the constriction proximity changes from front to back (e.g., bug) as in the Norton (1986) study or from back to front (e.g., gub) as in the present study, several factors including coarticulation, stop consonant voicing status, and constriction proximity and undershoot the consonant will all influence intervening vowel duration in CVC sequences.

As more data are accumulated on vowel duration, the information can perhaps be used to formulate intervention strategies. Perhaps more appropriate combinations of stop consonants can be used in beginning therapy with a client. The data in the present study suggests that producing lingual-alveolar stops at the end of CVC syllables may provide the client with more time for positioning his/her articulators. The information could also be used to improve the intelligibility of electronic speech devices by applying the shortening and lengthening rules for vowel duration.

The data from the study could be applied to computer programs for aiding the speech intelligibility of clients with hearing impairments or motor impairments. It would be useful in visually cuing the client on the appropriate length of a vowel in differing consonant environments.

As information about the nature and impact of actual vowel length on the vowel's identification and its influences on adjacent word and sentence elements becomes better understood, several factors should become more manageable. First, the value of vowel durational manipulations as potential cues for adjacent sound identification must be considered. For the person with a hearing impairment who lacks the high frequency sensitivity needed to discriminate stops and fricatives, vowel durational cues become an important secondary source of information. Any alteration in normal vowel duration can have devastating effects on the perception of adjacent sounds, especially when the acoustic dimensions of those other elements are not available to the listener.

Also, the person who has motor impairments and lacks the ability to manipulate vowel durational cues, is at a distinct risk in terms of overall speech intelligibility. The message is easily distorted. The speaker who does not coarticulate is also at risk. Coarticulation has a profound effect on the durational patterns needed for added speech signal cues. Without the effects of coarticulation, speech becomes especially difficult to interpret.

In short, the normal nature of vowel durational cues and manipulations must be kept intact. Any time there is disregard for those cues, the message will be distorted. Clinicians and teachers must be cautious and maintain vowel durational cues in their therapy materials and teaching aids. Current electronic devices enable the clinician to manipulate a whole host of speech dimensions. Caution must be taken so that vowel durational dimensions are not manipulated or changed to the point where speech production or perceptual distortion occurs.

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APPENDIX

List of Carrier Sentences

The gug is over there.	The guk is over there.
The gud is over there.	The gut is over there.
The gub is over there.	The gup is over there.
The kug is over there.	The kuk is over there.
The kud is over there.	The kut is over there.
The kub is over there.	The kup is over there.

VITA

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INSTITUTIONAL REVIEW BOARD
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Principal Investigator(s): Arthur Pentz, Elizabeth Blumer

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