

VOWEL DURATION AND FUNDAMENTAL FREQUENCY

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Apart from other factors, fundamental frequency and intensity of voice have been considered to be affecting the vowel duration. However, studies regarding these relationships are scanty. The present study was conducted to note the durations of /i/ and /u/ in a VCV syllable /idu/. 10 male and 10 female adults were asked to read these 3 sentences at normal pitch and also at two other pitch levels (higher and lower than normal pitch) keeping the loudness constant. The durations of /i/ and /u/ were measured using the High Resolution Signal Analyzer in all the 3 sentences under all 3 conditions. It was found that the duration was significantly low at normal pitch than at other levels. Further, durations of these vowels in the utterances of these 3 sentences by cases with voice disorders (pitch disorders) were measured. It was found that the durations were significantly longer in these cases when compared with the normals.

The vowels have been compared to the day and the consonants to the night. The consonants have been considered as pearls in the string of vowels, perhaps due to the Superior perception of the vowels in normal speech. Vowels play a very important role at different levels in a language *i.e.*, Semantic, Syntactic and Paralinguistic or prosodic.

According to Fairbanks (1960) the acoustic basis of voice quality depends primarily on vowels. The vowel duration has been found to vary the meaning of the word and also as a prosodic feature in a language.

O'Shughnessy (1981) states "that vowel duration varies directly with tongue height, nasality, voicing position of the syllable within the word, number of syllables within the word and manner of articulation of the ensuing consonants". Black (1949) reported that "the duration of vowels in reading varied directly with the opening of the vowel".

Sweetings (1980) found that "the vowel duration increases with the age of the speaker".

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Klatt (1976) lists the following as factors influencing the duration of vowel.

Extralinguistics : Psychological and physical states (Williams and Stevens 1972), speaking rate (Huggins, 1964 : Goldman-Eisler, 1968), discourse level, position within a paragraph (Lehiste, 1975), semantic-emphasis and semantic novelty (Coker *et al.*, 1973), syntactic : phrase structure lengthening (Martin, 1975; Klatt, 1973), word level : word final lengthening (Lehiste, 1972. Oiler; 1973) phonetic inherent, phonological duration for a segment (Peterson and Lehiste, 1960), effect of linguistic stress (Premanter and Treveno, 1936), effect of post-vocalic consonant (House and Fairbanks ; 1953), segmental interactions for *eg* : consonant cluster (Klatt, 1973). physiological incompressibility (Klatt, 1973). According to Wang (1981) the vowel duration varies with the fundamental frequency also.

Lyberg (1981) has reported a strong relationship between duration and the fundamental frequency change. Lee (1978) is of the opinion that the intrinsic duration of a vowel in a tone language is conditioned by the tone that the vowel carries. On the other hand, Nooteboom (1972), Cooper (1976), Lindbloom *et al.* (1976) and Lehiste (1976) have observed the duration to be independent of the fundamental frequency. Thus, there are reports of studies either confirming or rejecting the relationship between fundamental frequency and vowel duration.

Method

Part I: It was decided to have the fundamental frequency as the independent variable and to measure the effect of fundamental frequency on vowel length. For this purpose 3 Kannada sentences were constructed with VCV syllable in the initial position. They were :

/ idu papu / / idu koti/ /idu kempu banna/

20 subjects (10 males and 10 females) age ranging from 18 years to 45 years, were used for this study. Each subject was requested to read all the three sentences at normal pitch, at comfortable loudness level. The subject was then asked to read the same sentences using a high pitched voice and then a low pitched voice, at comfortable loudness level. Thus all the subjects were made to utter the 3 sentences at three different pitch levels. However, the order in which they used normal, high and low were randomized, *i.e.*, some subjects used high pitch first, then normal and then low pitch. All the utterances were recorded using a spool tape recorder (crown) at the speed of 7½ inches/sec Thus for each subject 9 sentences (3 at normal pitch, 3 at high pitch and 3 at low pitch) were recorded. All the recordings were done in a sound treated room.

For the purpose of measurement of vowel duration as decided previously, only the syllable /idu/ occurring in the initial position of each of the sentence was used. The syllable /idu/ was isolated from the sentence using the signal gate facility available in the spectrograph [(VII) Voice Identification Inc. 700 series]. This sample was fed to the High Resolution Signal Analyser (Type 2033). Using the time display mode the duration of vowels /i/ and /u/ in the syllable /idu/ in all the 9 sentences were measured. Thus the vowel duration of /i/ and /u/ at normal, high and low pitches as produced by each subject were obtained. Further the mean fundamental frequency of voice in the word /idu/ using Pitch Analyzer (PM 100 Voice Identification Inc.) was measured. Thus the mean fundamental frequency and the duration of Vowels /i/ and /u/ occurring in the word /idu/ of each sentence were obtained for all the subjects. Table I and II show the results obtained for males and females respectively.

Part II: "In most of the dysphonics, it has been found that the pitch (fundamental frequency) deviates from the optimum pitch (Nataraja and Jayaram, 1975). Therefore it was considered that it will be of interest to note the Vowel duration in dysphonics, who show a deviation fundamental frequency. Therefore Part II in the study was carried out-

The cases who visited AIISH, with the complaint of voice disorder and diagnosed as dysphonics, by qualified Speech Pathologists were considered as subjects for the present purpose. This group was comprised of 17 males and 3 females, age ranging from 15 years to 58 years. Most of the subjects (18 out of 20) were using a higher fundamental frequency than normals. The remaining 2 subjects were using a low pitched voice, only 3 of the subjects had shown pathology of larynx, and others were diagnosed as functional voice disorders.

All the subjects were asked to read the three test sentences, *i.e.*, /idu papu/, /idu koti/, and /idu kempu banna/, and were recorded, using the same procedure as described in Part I. Further the word /idu/ from the three sentences uttered by each was analysed, using the procedure as described in Part I to obtain the duration of vowels /i/ and /u/ (in the word /idu/) and mean fundamental frequency. Table III shows the details of subjects and results obtained.

Results and Discussion

The duration and the fundamental frequency of /i/ and /u/ have been averaged for each subject, as at normal pitch, high pitch and low pitch (fundamental frequencies). The obtained values are shown in Table I for males and in Table II, for females.

TABLE I. The mean fundamental Frequencies f_{in} HZ and durations (in m econds) of vowels /i/ and /u/ for males

Mean F.F.	Normal	High	low	Normal	High	Low
	Pitch (131 Hz)	Pitch (364 Hz)	Pitch (102 Hz)	Pitch (131 Hz)	Pitch (364 Hz)	Pitch (102 Hz)
1	68.8	107.1	116.80	189.8	202.70	260.96
2	93.76	120.14	129.90	216.6	240.28	222.0
3	52.73	63.30	72.30	58.96	73.06	83.60
4	50.36	82.00	73.83	86.10	99.63	101.20
5	105.00	128.13	131.20	214.06	259.00	290.66
6	68.33	90.76	127.76	164.06	172.63	189.83
7	56.26	92.95	134.80	80.90	110.96	137.50
8	58.21	95.83	136.40	100.20	130.40	138.66
9	60.32	85.34	120.20	150.60	170.63	177.20
10	55.45	96.37	125.40	82.40	100.28	130.83
Mean	66.092	96.19	166.25	134.27	155.95	174.24

TABLE II. The mean fundamental frequencies (in Hz) and durations (in m. seconds) of vowels /i/ and /u/ for females

Mean F.F.	Normal	High	Low	Normal	High	Low
	Pitch (248 Hz)	Pitch (385 Hz)	Pitch (213 Hz)	Pitch (248 Hz)	Pitch (385 Hz)	Pitch (213 Hz)
1	68.73	81.43	103.13	85.56	134.36	125.03
2	68.03	104.26	103.53	85.56	130.86	107.40
3	78.13	112.10	110.93	100.40	112.10	127.03
4	67.60	103.13	82.83	91.80	102.36	98.10
5	61.70	112.93	99.23	182.03	214.46	218.00
6	71.33	94.93	88.50	84.36	93.36	100.80
7	49.16	87.13	61.73	84.36	106.26	95.30
8	52.06	76.36	77.50	89.63	95.30	90.80
9	54.66	76.73	70.00	64.03	75.93	83.56
10	65.20	93.56	84.00	74.76	141.23	126.20
Mean	63.66	94.26	88.16	94.27	120.62	117.22

The mean fundamental frequency at normal pitch was 131 Hz for males, which can be considered as normal. The higher fundamental frequency samples showed a mean of 164 Hz and the lower fundamental frequency samples showed 102 Hz as the mean fundamental frequency. Thus there was a significant difference in mean fundamental frequency, the independent variable.

All the male subjects of the study showed distinct increase in the durations of vowel /i/ and /u/ when the fundamental frequency was either increased or decreased

Further the mean duration of vowels /i/ and /u/ of the male group also showed a definite increase with variations in fundamental frequency *i.e.*, at normal fundamental frequency the duration of /i/ was 66-92 m.sec. and at higher and lower frequency it was 96-19 and 116-25 respectively. Similarly the duration of vowel /u/ at normal fundamental frequency was lowest, *i.e.*, 134-27 m.sec and it has increased to 155-95 m.sec. at higher frequency and 174-24 at lower frequency.

The statistical analysis using Wilcoxon matched Pair Signed-ranks Test, confirmed the above observation, *i.e.*, the duration of vowels /i/ and /u/ at high and low frequencies were significantly longer than at the normal fundamental frequency in case of males.

The inspection of Table II showing the mean duration of vowels /i/ and /u/ at normal, higher and lower fundamental frequency in case of females, also showed that all the subjects had longer vowel duration at higher and lower fundamental frequencies when compared to the vowels at normal fundamental frequency.

The females as a group had used 248 Hz as mean fundamental frequency when they were asked to say the sentences with their normal fundamental frequency. A fundamental frequency of 375 Hz and 213 Hz were used by these subjects while saying the sentences at higher and lower fundamental frequencies. Thus it was evident that the independent variable, *i.e.*, the fundamental frequency had been varied significantly. Further, the mean durations of vowels /i/ and /u/ at normal fundamental frequency showed the lowest value of 63-66 m.sec. and 94-27 m.sec. for /i/ and /u/. A duration of 94-26 m.sec and 120-62 m.sec. at higher fundamental frequency and 88-16 m.sec. and 117-22 m.sec. at lower fundamental frequency were found for /i/ and /u/ respectively. Thus the duration of vowels /i/ and /u/ had increased at high and low fundamental frequencies when compared to the duration of vowels at normal fundamental frequency.

This was further confirmed by statistical analysis, *i.e.*, like male subjects, females also showed longer durations on Vowels /i/ and /u/ at higher and lower fundamental frequencies when compared to vowels at normal fundamental frequency.

It was interesting to note that there was greater increase in duration of vowels /i/ and /u/ at higher fundamental frequency when compared to increase in lower fundamental frequency in the case of females. But in the case of males there was a greater increase in the duration of vowels /i/ and /u/ at lower fundamental frequency than at higher fundamental frequency. Thus it can be concluded that the duration of vowels varies with fundamental frequency. This study confirms the statement of Wang (1981) and Lyberg (1981), that the duration of vowel varies with fundamental frequency and rejects the observation of Nootboom (1972), Cooper (1976), Lindbloom *et al.* (1976) and Lehiste (1976) that duration is independent of fundamental frequency.

Any variation in fundamental frequency from the normal, thus would call for increased duration of vowels, to produce a normal word and sentence. Therefore it was hypothesized that the cases with voice disorders, specifically using abnormal pitch, would show longer durations of vowels than the normals. It will be interesting to speculate that the cases with voice disorders will be spending extra energy while speaking, than normals.

TABLE III. The mean FF and the durations (in milli seconds) of vowels /i/ and /u/ in dysphonics (males)

No.	Sex	Age	Diagnosis	/i/	/u/	F.F. in Hz
1.	M	22	High pitched with hoarse voice	83.20	180.40	350 Hz
2.	M	34	High pitched voice	91.80	130.30	260 Hz
3.	M	58	High pitched voice	84.33	142.10	245 Hz
4.	M	20	High pitched voice	80.53	155.46	240 Hz
5.	M	23	High pitched with hoarse voice	76.03	113.10	220 Hz
6.	M	28	High pitched voice	107.93	114.03	220 Hz
7.	M	18	Puberphonia with pitch breaks	76.40	77.10	280 Hz
8.	M	53	High pitched voice	67.56	89.06	240 Hz
9.	M	16	High pitched voice	85.96	209.36	280 Hz
10.	M	15	High pitched with hoarse voice	89.46	157.16	320 Hz
11.	M	42	High pitched voice with nasality	112.66	193.33	263. Hz
12.	M	21	pitch breaks	97.03	114.80	240 Hz
13.	M	36	Hoarse voice	110.20	207.33	166 Hz
14.	M	32	Hoarseness	82.43	191.00	190 Hz
15.	M	44	Hoarseness voice	143.36	254.33	280 Hz
16.	M	32	V.C. Paralysis	77.33	168.33	150 Hz
17.	M	28	Denalized voice	113.70	208.90	245 Hz
Mean				95.50	164.60	246

TABLE IV. The mean FF and the durations (in milli seconds) of vowels /i/ and /u/ /ot dysphonics (females)

SI. No.	Sex	Age	Diagnosis	/i/	/u/	FF in Hz
1.	F	24	Spastic dysphonia	87.5	184.53	300 Hz
2.	F	19	Hoarse voice	128.93	156	305 Hz
3.	F	32	Hoarse voice	106.73	245.4	318 Hz
Mean				107.72M.S.	195.31 M.s.	307 Hz

The results of Part II of the study showed in Tables III and IV a mean fundamental frequency 246 Hz for males and 307 Hz for females and mean duration of vowels /i/ and /u/ as 95.6 m.sec. and 164.6 m.sec. respectively. The normals at normal fundamental frequency showed a duration of 65.29 m.sec. (mean of males and females) 114.27 m.sec. for /i/ and /u/.

Thus a comparison of duration of vowels /i/ and /u/ as used by normals and dysphonics showed that the dysphonics used a longer /i/ and /u/ in their utterances. Further, statistical analysis to determine the significance of difference between normals (normal fundamental frequency) and dysphonics also confirmed the observation that the dysphonics used a significantly longer vowels than normals. The results of Part II of the experiment also thus confirms the relationship between the fundamental frequency and vowel duration. It also showed that the relationship between fundamental frequency and vowel duration was not linear. The vowel duration was minimum at normal pitch or fundamental frequency and it increased as frequency changed either upwards or downwards from the normal. It is interesting to speculate that it would be further reduced, when optimum frequency is used, than at normal frequency. Thus it is 'economical' to use optimum frequency for speaking. Therefore speech pathologist must provide optimum frequency to the dysphonics in voice therapy where a deviation of frequency is found.

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