PHONATION DURATION AND OPTIMUM FREQUENCY

N. P. NATARAJA*

Optimum frequency is considered to be the frequency at which maximum physio-acoustic economy is achieved. The purpose of this study was to find out the acoustic economy, at optimum frequency, as determined by an objective method of locating optimum frequency. The acoustic economy was measured in terms of the maximum duration for which the subjects could sustain phonation at a particular frequency. The maximum phonation duration at optimum and at frequencies higher and lower than the optimum frequency were measured using a stop-watch. 15 *male and* 15 *female adults were asked to phonate vowel /a/ as long as possible keeping the frequency and intensity constant. The maximum phonation duration at optimum, + 100 Hz, + 200 Hz, + 50 Hz and - 50 Hz from the optimum were determined. The results showed that the maximum phonation duration at optimum frequency was significantly longer than at other frequency levels. Therefore it was considered that there was maximum acoustic economy at optimum frequency, as determined by this method.*

Most of the Voice Therapies are based on the belief that each individual has an optimum pitch and the therapist tries to make the case to use this pitch (Van Riper and Irwin, 1958 ; Greene, 1964 ; Boone, 1971 ; Murphy 1964 ; Berry and Eisenson, 1962).

Finding out optimum pitch is considered as one of the important steps in Voice Therapy.

Several methods of locating optimum pitch have been attempted. These methods have been discussed in detail elsewhere (Nataraja, 1974). All these methods have been discussed under four headings :

1. Methods based on laughing and coughing ;
2. Methods based on total pitch range ;
3. Methods based on loudness swelling ;
4. Methods based on natural frequency of vocal tract :

* Department of Speech Sciences, AIISH, Mysore-6.

Methods 1, 2 and 3 have been considered to be subjective and hence Nataraja (1972) has developed an objective method of locating optimum pitch (frequency). In this method the optimum frequency is determined based on natural frequency of vocal tract, located by stimulating the vocal tract using an external sound source. This method has been found to be useful in providing optimum frequency to various types of dysphonics (Nataraja. 1972 : Shantha, 1973). Geetha P. (1974) after an experimental investigation has concluded that the natural frequency of vocal tract is determined considering the vocal tract as a whole and the natural frequency determined thus docs not coincide with the formant 1 or 2. Further this method of determining optimum frequency has been found to have predictive validity (Nataraja 1972 ; Shantha, 1973 ; Samuel, 1973 ; Gopal, 1980) and this method has been found to be clinically useful (Shantha, 1973 ; Pamel, 1976 ; Nataraja and Veena, 1981).

This method has been validated and can be used with all ages (upto 60 years of age) both in case of males and females ("Nataraja, 1972 ; Shantha, 1973 ; Samuel, 1973 ; Gopal, 1980).

This method of determining optimum frequency has been found to be useful in differential diganosis of dysphonics (Jayaram, 1975). It has also been shown by Nataraja (1972) and Nataraja and Jayaram (1982) that the optimum frequency determined by this technique would provide a specific goal for the therapist, *i.e.*, of achieving the optimum frequency in the cases of Voice Disorder. This method has been considered to be objective as it does not involve the direct participation of subject or the therapist.

It is believed that there will be maximum physio-acoustic economy at optimum pitch (frequency) Murphy, 1964 ; Fisher, 1966 ; Gray and Wise, 1959 ; Fairbanks, 1949). In an attempt to find out the physio-acoustic economy at the optimum frequency, Shashikala (1979) measured maximum phonation duration, mean air flow rate and intensity range at optimum frequency (as determined by natural frequency method) and + 200 Hz, + 100 Hz and $\pm$ 50 Hz from optimum. She has found that there was minimum mean air flow rate, longer maximum phonation duration and maximum intensity range at optimum frequency when compared with other frequencies. Based on this she has concluded that there was maximum physio-acoustic economy at the optimum frequency determined by rinding out natural frequency of vocal tract, as the phonation duration, mean air flow rate and intensity range indirectly give information regarding the efficiency of larynx. Maximum phonation duration refers to the maximum duration **for** which an individual can sustain phonation at a particular frequency and intensity, after a deep inhalation.

Patacek and Sander (1963) seems to be the first to suggest the maximum phonation duration as a diagnostic indicator in case of dysphonias. They have also

suggested the possible relationship between the frequency, intensity and phonation duration. The result of their study has indicated that males could phonate for a longer duration than females at low frequencies and intensities and as the frequency and intensity levels increased the phonation duration in males and females tend to be similar.

According to Van Riper (1954) the normal phonation duration would be around 15 secs, whereas Fairbanks (1949) consider this to vary from 20-25 secs. Luchsinger *et al*. (1965) consider that the phonation duration varies from 20 to 30 secs.

The frequency, the intensity, the vowel being phonated, the general physical condition of the individual and the amount of training seems to affect the phonation duration.

Thus the maximum phonation duration is dependent on the frequency, the intensity and the vowel, within an individual. Therefore it was considered that it would be possible to determine the physio-acoustic conditions at optimum and at other frequencies, when the subject is made to phonate a particular vowel, by varying the frequency of phonation keeping the intensity and other variables constant, as in the earlier study (Shashikala, 1979).

The present experiment was intended to determine the maximum phonation duration at optimum frequency and at other frequencies in the frequency range of the subjects and to validate the findings of earlier study (Shashikala, 1979) with a larger population.

The study included 15 males and 15 females with the age ranging from 17 to 25 years, with no history of Speech or Hearing or other problems which would affect the voice.

An SPL meter with Octave Filter Network (B and K 2033) connectedto motion analyser (B and K 5066). with Tacho Unit were used to determine the fundamental frequency and intensity of voice. A stop-watch was used to determine the phonation duration.

Optimum frequency for each subject was determined using the procedure described by Nataraja (1972) and Shantha (1973).

The subjects were made to sit comfortably on a chair with a distance of 2 feet between the mouth of the subject and the Condens- r Microphone of the SPL meter.

The subject were instructed that they should ta,e a deep inhalation and pho-

nate vowel /a/ at optimum frequency (which they were aware of) as long as possible and they must also try to maintain the same intensity and frequency. They were permitted to see the needle of the SPL meter (to maintain the intensity) and the Tacho Unit (to maintain the frequency). Whenever it was necessary, trials were given. Using the stop-watch the phonation duration was determined. Each subject produced vowel /a/ for 3 times at this frequency with an intensity of 60 dB. Whenever there was a. change of ±5 dB/Hz in intensity or frequency, the stop-watch was stopped and the duration of phonation was determined-.

Using the same procedure phonation durations, 3 times at each level, were determined at the following frequences with an intensity of 60 dB, while the subjects phonated vowel / a / at

1. 50 Hz above optimum ;
2. 100 Hz above optimum ;
3. 200 Hz above optimum :
4. 50 Hz below optimum or lowest frequency level of the frequency range.

The longest phonation out of the 3 phonations was considered as the maximum phonation duration at that particular frequency level.

Thus for all the subjects maximum phonation duration at 5 frequency levels in the frequency range of each subject was determined.

The following table shows the mean maximum phonation duration in secs. for both males and females at different frequencies :

	O.F.	+ 50 Hz	+100 Hz	+200 Hz	— **50 Hz**
Males	22.5	15	13.6	6.5	12.5
Females	16.3	**11.4**	10.2	7.8	10.00

Maximum phonation duration for males varied from 14 secs to 25 secs and 10 secs to 20 secs in case of females at optimum frequency.

Thus the males show ability to phonate for a longer duration than the females. The table shows that the maximum phonation duration for males is higher than in case of females at all frequency levels. This is in support of the findings of Patacek and Sander (1963)

Application of Wilcoxin sign ranked correlation showed that there was significant difference between the optimum frequency and other frequency levels, in terms of maximum phonation duration both in case of males and females. When this significance of difference was considered along with the mean values of maximum phonation duration at optimum frequency and at other frequency levels, it was concluded that the maximum phonation duration at optimum frequency was significantly greater than at other frequencies, both in case of males and females. In other words, it can be stated that there was maximum physio-acoustic economy at optimum frequency in terms of phonation duration when other variables were kept constant. This finding is in support of the findings of Shashikala (1979). Further, it also validates the method of locating optimum frequency based on natural frequency of vocal tract.

It was, also noticed from the table that the phonation duration increased as the fundamental frequency approached the optimum. Thus the optimum frequency, located by this method, meets the criteria of optimum frequency stated by Murphy (1964) according to which " each person in accordance with his unique physical vocal equipment has a pitch level at which the greatest power and best resonance occurs under the conditions of greatest physio-acoustic economy ".

Hence, this method will be useful in providing " appropriate " or " suitable " and " economical" pitch to the cases with voice disorder .

References

Berry, H. F. and Eisenson, J., *Speech Disorders : Principles, Practices of Therapy,* Peter Owen Ltd., London, 1962.

Boone, D., *The Voice and Voice Therapy,* Prentice Hall Inc., Englewood, Cliffs, N.J., 1971

Fisher, H. B., *Improving Voice and Articulation,* Harper and Row, N.Y., 1966.

Fairbanks, G, *Voice and Articulation Drill Book,* 1949.

George, S., "A study of the fundamental frequency of voice and natural frequency of vocal tract on an Indian population of different age ranges," Master's dissertation, University of Mysore, 1973.

Gopal, H. S., " Relationship for locating optimum frequency in the age range of 7 to 25 years," Master's dissertation, University of Mysore, 1980.

Gray, G. W- and Wise, G. H., *The Bases of Speech,* Harper and Row Publishers, London, 1959.

Green, M. C. L., *The Voice and Its Disorders,* Pitman Medical Publishing Co., London, 1964

Luchsinger, R. and Arnold, G. E., *Voice-Speech-Language Clinical Communicology : Its Physiology and Pathology,* Constable and Co. Ltd., 1965.

Murphy, A. T., *Functional Voice Disorders, P*emice Hall Inc., Englewood, Cliffs, N.J., 1964.

Nataraja, N. P., "An objective method of locating optimum pitch," Master's dissertation university of Mysore, 1972.

Nataraja, N. P., Methods of locating optimum pitch, *JAIISH,* Vol. 4, 1974.

Nataraja, N. P. and Veena, N. R., Vocal cord paralysis and its therapy, *Hearing Aid Journal,* Vol. 3, No. 1, 1981.

Patacek p. H. and Sander, E. R-, Maximum duration of phonation, *J.S.H.D.,* Vol. 28, 171-182, 1963.

Shantha, Y. V., "Establishing and validating isochronal tone stimulation technique," Master's dissertation, University of Mysore, 1973.

Shashikala, H. R., "Physio-acoustic economy at optimum frequency." Master's dissertation, University of Mysore, 1979.

Van Riper, C, *Speech Corrections* : *Principles and Methods,* Prentice Hall, New York, 1954.

Van Riper, C. and Irwin, J. V., *Voice and Articulation,* Prentice Hall Inc.. N J., 1958,