Effect of Helium and Sulfur Hexafluoride gas inhalation on voice resonances

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Abstract : **Voice is considered to be a unique biometric property of human being. Unlike other biometric evidences for example fingerprints and retina scans etc., voice can be easily disguised. Present paper talks about how inhalation of Helium and Sulfur Hexafluoride (SF6) gas affects the resonant frequencies of the vocal tract. As Helium gas has low density, voice travels with the higher speed in it than that of the air, shifting resonant formant frequencies upper to the normal range. In SF6 gas, voice travels with lower speed than that of air due to its higher density results in lowering the resonant formant frequencies. Spectrographic analysis is presented with the help of PRAAT software.**

IndexTerms **- Helium, Sulfur Hexafluoride, Formant frequencies, Voice disguise.**

I. Introduction

In the crimes like kidnapping, extortion, betting, ransom calls, threatening calls, bribery criminals use mobile phones as their principle aid of communication and therefore their voice evidence becomes the source to catch them or to identify them. Voice is a unique property that cannot be changed unless you want it to be changed using some disguise strategies. Criminals try to conceal their identity by opting for many easy ways for changing their voice. It becomes very difficult for the investigator to analyze such disguise voices.

There are many ways in which voice can be disguised. Aim of this study is to find out the effect of Helium and Sulfur hexafluoride (SF6) gas inhalation on voice. A paper by AlzbetaRuzickova et al [1] presents voice disguise can be achieved by changing speaking fundamental frequency or by phonatory modifications or modifying resonant characteristics of the voice. Mathur S. et al in their paper studied the amount of variation occurring in fundamental frequency of disguised and normal speech samples of speakers. [2]. Voice disguise can also be achieved by pinching the nostrils or keeping foreign object in vocal tract. [3]. Figueiredo et al [4] talks about how holding a pen between the front teeth can change the voice.

The easier way that most of the speakers use to disguise their voice is placing a handkerchief between their mouth and the microphone. It is considered to be having lesser impact on the resonance characteristics [5]. Imitation of foreign accent also discussed as the strategy to disguise the voice [6]. Whispering and modal effect kind of phonatory modifications can also change the voice. The effect of creaky voice disguise is studied by Hirson Et al. [7]. The paper by Wagner Et al [8] talks about the effectiveness of falsetto as a voice disguise strategy.

The change in the resonating frequencies of musical instruments like trumpet and trombone when filled with air, Helium and Sulfur Hexafluoride is studied by Kyle Forinash and Cory L. Dixon [9]. Our voice also is a musical instrument its frequencies depend on the dimensions of vocal tract [10]. If vocal tract is filled with Helium or SF6 it will also show change in resonating frequencies. The helium gas inhalation produces Donald duck effect is reported in the literature. We can consider the inhalation of these gases is the recent way to disguise the voice.

Spectrographic analysis of the normal voice and helium inhaled voice is done by Christopher D. Wentworth and Mark W. Plano Clark [11]. Helium and oxygen mixture is generally used for deep sea diving. A study of Helium effect on speech is presented in the paper published by James W. Hicks [12]. Helium is a low density gas and the SF6 is comparatively high density gas. The speed of sound in Helium is 972m/s and in Sulfur Hexafluoride is 133m/s [13]. In the present paper we have tried to do the experiments with the inhalation of Helium and SF6 gas and study its effect on the formant frequencies.

II. PRODUCTION OF VOICE

Generation of voice can be understood using a speech production model. In that model vocal folds in the larynx act as an excitation generator and vocal tract acts as a time varying linear system. Vocal folds produce fundamental frequency (f0-pitch) which serves as the input parameter to the vocal tract. This f0 is modified in the vocal tract and according to the length of the vocal tract we get the 1st , 2nd , 3rd, 4th resonances which we call formant frequencies (F1,F2,F3,F4). Formant frequencies depend on the length of the voice box i.e. vocal tract and the medium in the vocal tract. If the medium is changed that is instead of air if we inhale denser or lighter medium than air we can get lower or higher formant frequencies. In denser medium sound travels slowly and reverse of that in the lighter medium. In this study we are using SF6 gas as a denser medium and He gas as a lighter medium and we will study how the medium affects the formant frequencies. The model can be understood using the Fig. 1. The formulae to find out the formant frequencies are as follows.

For first resonance

$$L = \frac{\lambda}{4} ; \lambda = 4L \; ; F1 \; (1st \; formant) = \frac{c}{\lambda} = \frac{c}{4L}$$

For second resonance

$$L = \frac{3\lambda}{4} ; \lambda = 4L/3 \; ; F2 \; (2nd \; formant) = \frac{c}{\lambda} = \frac{3c}{4L}$$

For third resonance

$L = \frac{5\lambda}{4}; \lambda = 4L/5 \; ; F3\ (3rd\ formant) = \frac{c}{\lambda} = \ \frac{5c}{4L}$

For fourth resonance

$L = \frac{7\lambda}{4}; \lambda = 4L/7 \; ; F4\ (4th\ formant) = \frac{c}{\lambda} = \ \frac{7c}{4L}$

c is the speed of sound in air

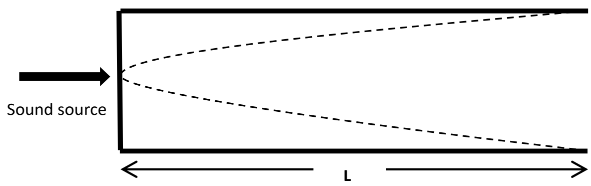
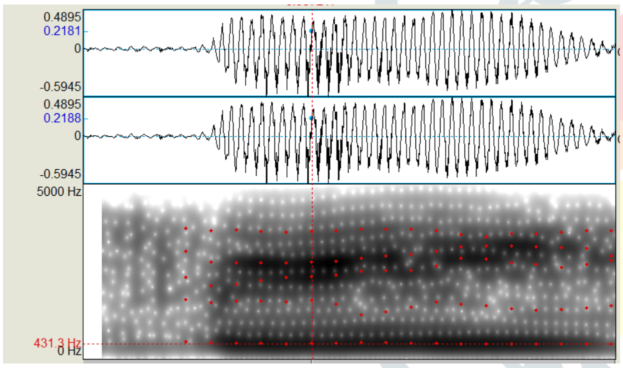


Figure 1. Speech production model explaining how voice is produced

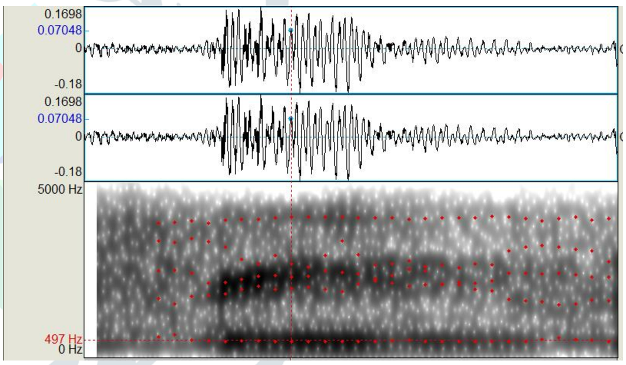
III. EXPERIMENTAL PROCEDURE

To carry out the formulated study five speakers of different sex, different age were selected and voice samples were taken from them in quite laboratory environment. Voice samples in three conditions were recorded in digital voice recorder of make SONY. First is normal condition second is after inhaling Helium gas and third after inhaling SF6 gas. For inhalation of the Helium and SF6 gases, balloons filled with He and SF6 were handed over to the speakers. To record the voice samples in second and third condition speakers were asked to inhale from the balloon and then give the voice samples. Speakers were told to utter six vowels /e/,/i/,/o/,/u/,/ə/ and /a/ in each condition. Those vowels of each scenario were analyzed spectrographically by using PRAAT software. Formant frequencies observed for each vowel in all the three conditions were tabulated and conclusions were drawn from the data gathered from all the five speakers. The effect of helium and SF6 inhalation on the f0 and other formant frequencies is discussed. The observed first formant frequencies in three conditions are tabulated in Table I.

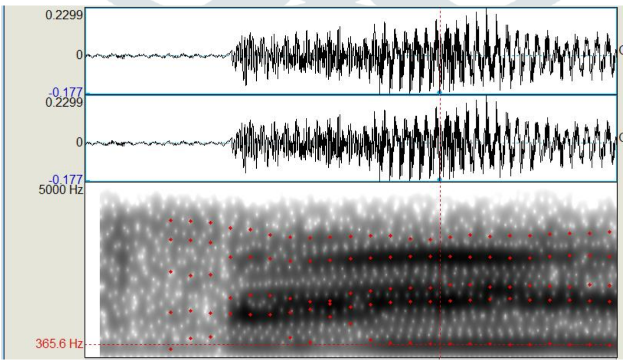
IV. RESULTS AND DISCUSSION



(a)



(b)



(c)

Fig.2 Spectrogram for vowel /i/ (a) in normal condition (b) after inhalation of Helium gas (c) after inhalation of SF6 gas

Table 1 Formant frequencies in Hz for speaker 1

Vowels	In normal condition	In helium gas	In SF6 gas
/e/	441	502	350
/i/	431	497	365
/o/	450	532	380
/a/	620	789	554
/u/	413	484	345
/ə/	585	670	504

From Table 1 it is clear that the formant frequencies do affect due to inhalation of He or SF6 gas. Frequencies shift to the higher side in Helium and towards the lower side in SF6 gas. This is because the density of the medium which is filled in the vocal tract. When the vocal tract is filled with normal air we get the normal formant frequencies, but as we change the medium which has high density or low density formant frequencies shift towards the lower side and higher side respectively. Helium is having low density than air and the speed of sound in it is 972m/s opposite to this SF6 gas has higher density that air the speed of sound in it is 133m/s. Fig. 2 is the spectrograms of the vowel /i/ in normal condition and after inhaling Helium and SF6. Fig. 2 (b) and (c) clearly indicate the shift in formant frequencies towards higher and lower side.

V. Acknowledgment

Author would like to thank the proprietor of Swami Lab Solutions, Tehsil Kankavali, District Sindhudurga, Maharashtra, Mr. Chetan Prabhu for making available the required gases. The experiment is done under the observation of medical specialist.

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