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NASAL AIRFLOW MEASUREMENT IN NORMAL SUBJECTS BY USING ARABIC WORD PHONETICS

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ABSTRACT

Arabic letters' phonetics can be divided, from the point of view of nasal airflow, into nasal and non-nasal phonemes. Practical measurements have been carried out to define some nasal and non-nasal words. Two sets of words (nasal and non-nasal) have been selected. A special software package to achieve the required measurement is written in Turbo Pascal. In this software, the end-point detection is used to recognize the silence from the sound. This is used to enhance the calculation of airflow during each word.

Measurements have been performed over 50 normal subjects. The results have been processed to define the range of airflow in each word. These ranges are proposed to be the standardization of the method to be used later with the abnormalities. The system used in the measurement is the nasal anemometer. This system is an achievement of a research project financed by the Egyptian Army. The anemometer and the software is an objective (human independent) tool for the diagnosis of nasal airways.

KEY WORDS

Nasal Airflow, Anemometer, Arabic phonemes.

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INTRODUCTION

The respiratory system consists of two main parts: the upper air passages and the lower air passages. The upper air passages are the nose, nasophyaryngeal, pharyngeal, and the laryngeal. Beside their function in respiration these parts also contributes a great deal in speech. During speech, the respiratory system, the mouth, the tongue, the palate, the lips and the teeth turn the sound into phonemes and words. Any defects in one of the previous parts affect the respiration or the speech or both.

Nasal sounds are found in most languages of the world. The most common type of nasals is [m] and [n]. A coupling of the nasal and oropharyngeal resonators produces nasals. The closed oral cavity and the complex sinus structure of the nose are joined together to form cavities to the main passage (pharynx and nasal tract). Generally the greater the size of the nasopharynx opening, the better the nasal quality. By lowering the velum, a passage is opened from pharynx to the nasal cavity allowing air to escape through the nasal cavity. The air is then blocked from escaping through the oral cavity since the lowered soft palate forces air to exit or radiated through the nose. During nasal production, the chamber of the nose must be closed off during oral sounds and open for nasal sounds. Voicing in nasality seldom occurs since the open nasal passage prevents a build up of pressure inside the vocal tract[1].

Nasality is classified by two kinds of cavity conditions, open and closed. Open nasality occurs as the soft palate is relaxed to allow a free passage of air to escape through the nasal tract. Closed nasality occurs when there is a type of blockage or constriction in the nasal passage. A “twang” is a term sometimes used to describe a person with a constriction problem in the vocal tract. This problem causes the velum to be continually lowered when a person is talking. In the opposite condition (the velum being constantly raised) a person is prevented from speaking through the nose, which can be sign of inflammation of the soft palate or pharynx often resulting from cold. Hypernasality can result from abnormal coupling, a condition in people who have an incomplete palatopharyngeal closure. This problem can occur whenever there is a cleft palate and paralysis of the palatal musculature.

In studying the activity of the air passage in the nose and nasophyaryngeal, the physician satisfy only with the visual comparison. Sometimes, there are some physical abnormalities, but it does not affect the air passage and there is no method to justify it. Another problem, which is the choice of the optimum treatment for the air passages defects.

Based on the English articulatory phonetics, a complete study was introduced in a previous research [2]. An electronic system is built to measure the airflow during the word. A study has been carried out to select the Arabic words to be a part of the test[3]. There is a need to standardize the method of testing. The standardization is the measurement of the airflow during the Arabic words in normal subjects. This research describes the method, the measurement, and the result analysis of the normal subjects’ airflow during the Arabic speech.

The Nasal Airflow Sensor

Thermistor is used as a nasal airflow sensor. Thermistors are metallic oxide types of electronic semiconductors that exhibit relatively high negative temperature coefficient of resistance. The general relationship between the resistance of thermistor and its body temperature is given by [4]:

$$R(T)=R_o(T_o)e^{B\left(\frac{1}{T}-\frac{1}{T_o}\right)} \quad (1)$$

Where B is the material constant of the thermistor and T and T_o are absolute temperatures.

In general, thermistor applications can be grouped into one of three different classifications, depending upon the major thermistor characteristics pertinent to the mode of thermistor operation. Application based on the zero-power resistance-temperature characteristics includes temperature measurement, control and compensation. Self-heated thermistor applications depend, primarily, on the current-time characteristic include time delay, surge suppression, and overload protection and sequential switching. Self-heated applications that depend on the voltage-current characteristic of thermistors are grouped as follow [5]:

I. *Variation in dissipation constant: vacuum manometers – anemometers – flow meters – fluid velocity – thermal conductivity analysis – gas detectors – gas chromatography – liquid level – control and alarm.*
II. *Variation in circuit parameters: oscillator regulation – gain or level stabilization – voltage regulators – volume limiters – expanders and compressors – switching device.*
III. *Variation in ambient temperature: temperature control and alarm.*
IV. *Microwave power measurement: as in boiometers.*

As mentioned the anemometer applications depend on the variation of the dissipation constant (factor). This constant appears in the following equation:

$$\frac{dH}{dt}=P=VI=\delta(T-T_o)+C\frac{dT}{dt} \quad (2)$$

Where P is the rate of thermal energy supplied to the thermistor, V and I are the instantaneous thermistor voltage and current, C is the heat capacity of the thermistor, t is the instantaneous time and δ is the "dissipation constant" of the thermistor. It is defined as the ratio, at specified ambient temperature, of a change in power dissipation in a thermistor to the resultant body temperature changes.

Since the term $\delta(T-T_o)$ is the rate at which heat is transferred away from the thermistor, it is seen that the dissipation constant must be dependent upon the thermal conductivity and the relative rate of motion of the medium surrounding the thermistor. The steady state solution of equation (2), which corresponds to a condition of thermal equilibrium (constant temperature, $\frac{dT}{dt}=0$), is obtained from the reduced form:

$$P=\delta\left(T-T_o\right) \tag{3}$$

So:

$$\delta=\frac{P}{\Delta T}=\frac{VI}{\Delta T} \tag{4}$$

Model studies had been carried out on thermistor. These studies have shown the relation between the dissipation constant and velocity of the medium is as follow [6]:

$$\delta=a+b\ln(v) \qquad for \quad T>T_o \tag{5}$$

The actual thermistor characteristics for the used thermistor type RA53 [7] is shown in fig.1.

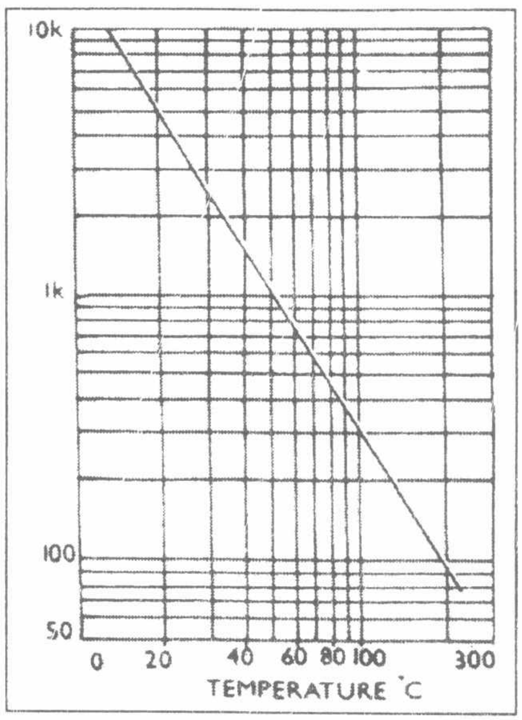

Fig.1. Thermistor Characteristic

Knowing that $P=I^2R$ and $airflow=area\times velocity$, then the relation between the airflow and the thermistor parameters can be obtained as:

$$airflow=area\times\exp\left[\frac{c\exp(2B/T)}{(T-T_o)}-d\right] \qquad for \quad T>T_o \tag{6}$$

Where *c* and ***d*** are the system constants, fig.2 shows this relation for the thermistor used with B = 3250 K.

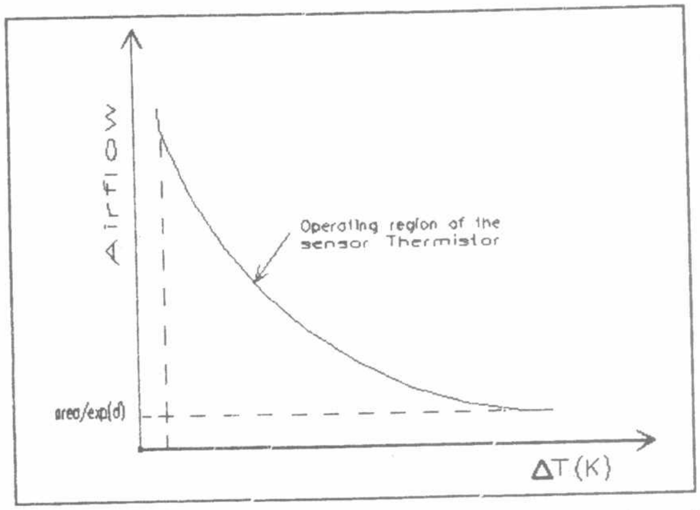

Fig .2. Airflow - temperature relationship over the operating region of the sensor thermistor

The sensor thermistor is connected to one arm of a d. c. bridge circuit and in the opposite arm a compensating thermistor is connected to be used as environment compensating element. The compensating thermistor is a KED103 [7] type. A d. c. bridge amplifier circuit is connected to the d. c. bridge circuit. The simulation of the circuit output depending on the variation of the sensor thermistor is shown in fig.3. This simulation is performed using DESIGN CENTER Ver 6.0.

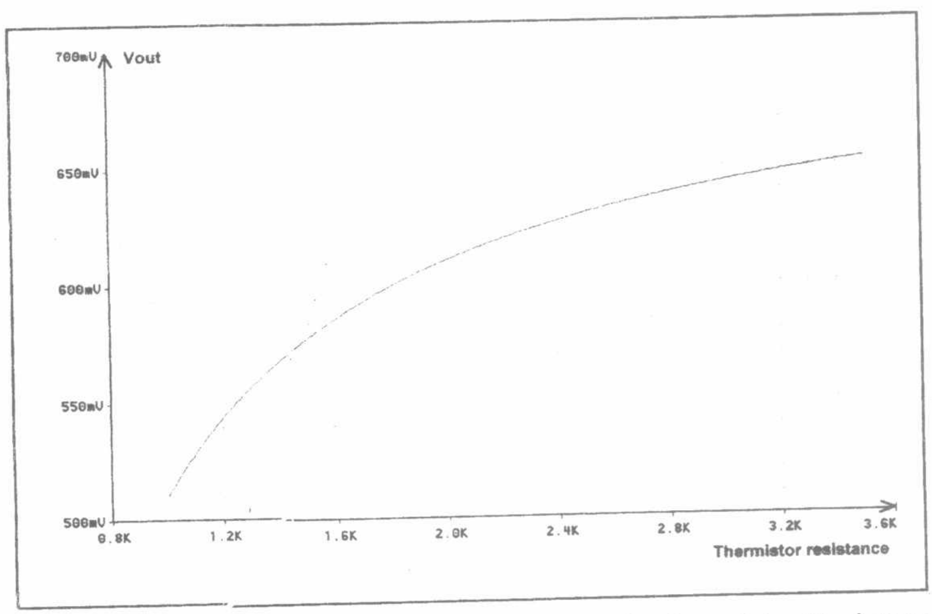

Fig.3. Output Variation of d. c. Amplifier With The thermistor Resistance

THE SYSTEM DESCRIPTION

The system consists of a nasal mask holding the sensor thermistor, signal recovery and signal processing unit (signal conditioning unit), a personal IBM compatible computer) configured with data acquisition card type Das16F) and a special software package written in Turbo Pascal. Fig.4 shows the system setup.

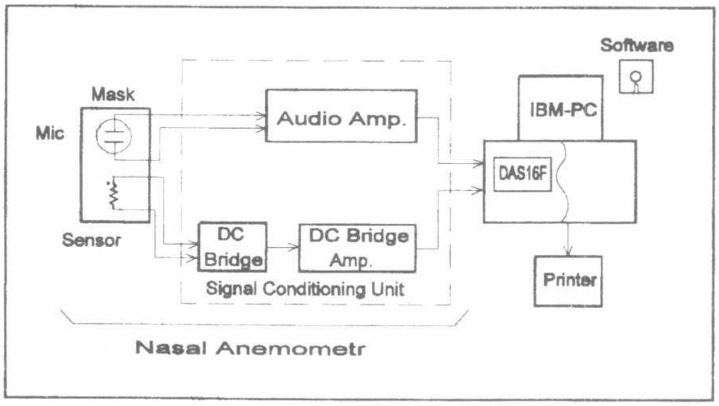

Fig.4. The system setup

The mask has been designed to ensure that the sensor thermistor will always be in the longitudinal path of the nasal airflow, and also will fit both adult and child patients. Next to the sensor a microphone (type EM6) is affixed. The system has two channels the first is the nasal airflow channel which is the dc bridge and the dc bridge amplifier. In parallel to that channel, an audio amplifier channel has been used to record the speech signal. Both the nasal airflow and the speech signals are fed to the data acquisition card DAS16F type placed in one of the free slots of the PC [8].

THE MEASUREMENT SCHEME

This research is undertaken in an attempt to quantify the airflow in normal subjects during speech. Based on the Arabic articulatory phonetic the Arabic speech sound can be divided into nasal and oral speech sounds. In nasal speech the majority of the airflow is produced through the nasal passage, while in the oral one the majority of the airflow is produced through the oral ways. Two groups of Arabic words are used; oral group contains the words [4]:

كاكي – سال – ساح – سار – تيس .

While another group contain a nasal sound :

من – قناة – نمور – ميزان – مرمر .

At first, the subject holds the mask over his nose. Then the software will guide him for saying the words through the screen. After saying each word, the signals are acquired. Later on the recorded data will be processed.

DATA ACQUISITION

In either tests oral or nasal, the signal is recorded by the data acquisition card, which is controlled by the written software. The software initializes the Keithley Data Acquisition Das-16F card by defining the base address; the interrupt levels the input channels, and the sampling rate. The sampling rate of the signal acquisition is 300 Hz, since the airflow during speech is less than 30 Hz. The values of the airflow and the speech signals will be recorded in a data file. The heading of the file contains the subject identification, and the date of the test as well as a comment to identify the test part.

THE SIGNAL PROCESSING

One of the software modules is responsible for the signal processing of the post-acquired data. This can be done for either the oral set of words or for the nasal set of words. The user will be asked to enter the data file name. After reading the data, the limits of each word will be determined. These limits are found based on the "end-point detection"[9] of the speech algorithm. The mean of the amount of the airflow of each word is calculated. In a graphic form, the result will be displayed on the screen, including the waveform of the signals. The software provides many options for the user such as: magnification of the waveforms, moving it up and down, and scrolling it left and right. The displayed screen can be printed using different printers' types or saved in HP graphic language file format. For future work, another module of the software is introduced. It provides a quantitative comparison analysis. The algorithm of this analysis is based on the non-parametric statistics (Kendall's tau method) [10].

RESULTS AND DISCUSSION

To define the range of the amount of the airflow in each word of the two sets, the measurement is achieved over fifty normal subjects. Inclusion criteria for individuals sharing this study are:

(i)Ear, nose and throat examination revealed no abnormalities are regards the phono-Articulatory system.
(ii)Arabic speaking, Egyptian from Cairo locality.
(iii)Age ranged between 18 and 40 years old.
(iv)50 male subjects.

The result of the first set in measurements for subject 20 is shown in fig.5. As seen at the graph the mean value of the airflow of each word is presented. While fig.6 shows the result of the second part of the measurement for the same person. The results of the fifty subjects have been collected. From these results, the range of the mean airflow during each word is calculated. Table 1 shows the range of each word. The result of any other subject out of this range means that the subject is abnormal.

The Egyptian army physicians have been faced with a problem in the medical tests during the selection of new personnel for the military colleges. This problem was that the physician could not study the activity of the air passage in the nose and nasopharyngeal. They were satisfied by the visual comparison studies. In some cases, there were some physical abnormalities, but they did not affect the air passage and no method to justify it. This technique will help the choice of the optimum treatment for the nose and nasopharyngeal diseases. The advantages of using this method are noninvasive, easy, accurate and environment independent. This new technique can help the evaluation of the dynamic function of the nose as a part of phono-articulatory system.

CONCLUSIONS

The available method for examining the upper air passages is a subjective method. The device mentioned and the supported software is a new objective method. This system can be used with different schemes of measurements. This research is carried away to measure the mean of the amount of nasal airflow during the Arabic speech for the normal subjects. With the achieved results, the system can be used for distinguishing the abnormal subjects. Our future work is the measurement of the nasal airflow during the normal respiration for the normal subjects.

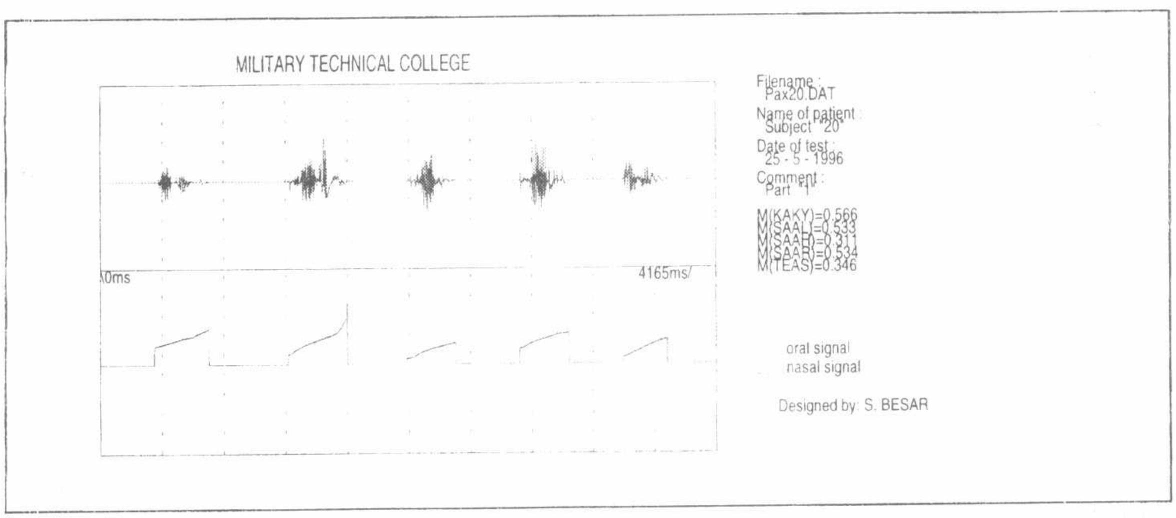

Fig.5. Results of subject 20 for the non-nasal words

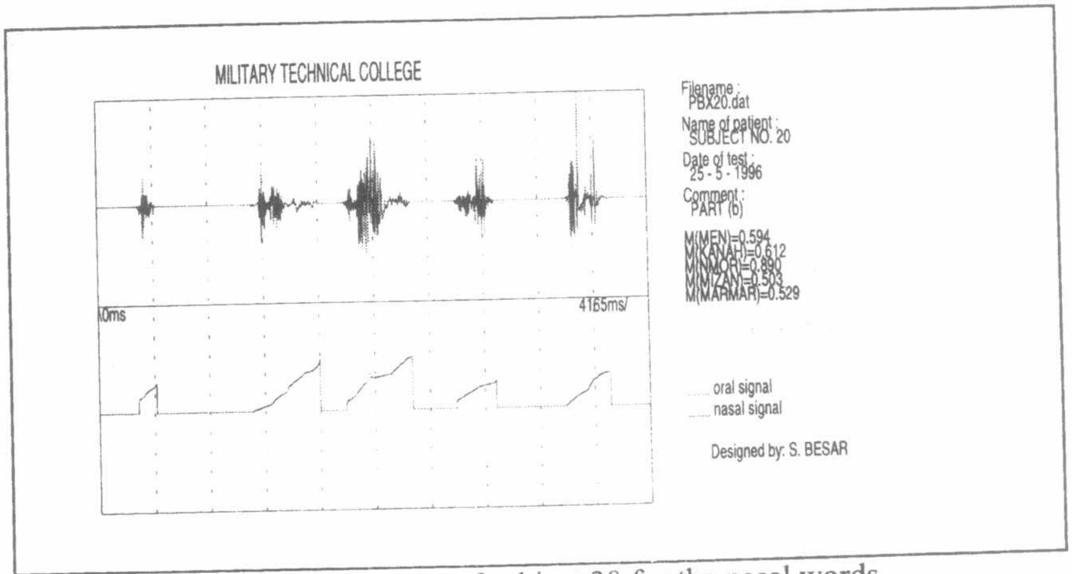

Fig.6. Results of subject 20 for the nasal words

Table 1. The mean of the amount of airflow in the words.

Word	Mean of the amount of Airflow	
	Min.	**Max.**
كاكى	0.253	2.051
سال	0.288	1.981
ساح	0.311	1.611
سار	0.307	1.960
تيس	0.310	1.937
من	0.301	1.914
قناة	0.391	1.783
نمور	0.497	2.215
ميزان	0.288	2.035
مرمر	0.507	2.214

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