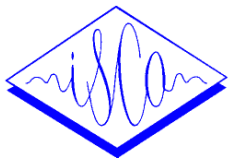

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A DIAGNOSTIC AND REHABILITATION AID WORKSTATION FOR SPEECH AND VOICE PATHOLOGIES[1]

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ABSTRACT

We describe a workstation for diagnostic aid and rehabilitation in speech and voice pathologies. It is the adaptation of speech research experimental devices for a medical application. The workstation consists of a PC computer, equipped with acoustic and aerodynamic sensors. Different programs are designed for each clinical investigation procedure under Microsoft WINDOWS operating system. This apparatus allows to set the objective state of normal and pathological speech production, and for the evaluation of functional results of surgical, pharmacological, logopedic and prosthetic treatments of voice and speech disorders.

1 - INTRODUCTION

MDs have always asked physicists for objective methods to evaluate the differents states of pathological disorders. This objectivation is late in speech domain [1] because of many difficulties. The first multi parameter recording systems appeared at the beginning of the 80s [2], but they are not easy to use for clinical applications and not very powerful [3].

We applied the work station concept to the fields of voice and speech pathologies by designing an apparatus which combines several investigation techniques usually only found in research laboratories. The advantages of such a system are numerous. First, it operates and displays data in a coherent manner which allows the user to gather a large amount of data on a given subject in a very short period of time without having to use a variety of instruments, each with its own operating and data presentation techniques. In addition, it is much less expensive than the series of individual devices it replaces.

The EVA (for Evaluation Vocale Assistée) work station consists of a IBM PC-compatible computer, equipped with acoustic and aerodynamic sensors and measurement circuits. The instrument control panel as well as the collected data and the results of calculations are controlled by computer systems, through programs specifically designed, in the WINDOWS environment, for each clinical investigation procedure.

2 - HARDWARE CONFIGURATION

2-1- Sensors

The speech signal is captured by a microphone calibrated to 120 dB at a distance of 30 cm, and another microphone located in the oral airflow sensor. The vibrations of the larynx are recorded by an electroglottograph.

The transducers which measure the airflow rate from the mouth and nostrils are grid pneumotachographs with a wide range, a small dead volume, and good linearity properties [4]. Their measurement capabilities cover six scales ranging from 0.2 to 10 liters per second. They have been specifically developed for airflow measurement during speech [5]. Intra-oral and sub-glottal pressures can also be measured on six scales ranging from 5 to 200 hecto Pascal.

2-2 Measurement devices

Following the necessity to measure the instantaneous frequency of the vibrations of the larynx, period by period [6], we have developed a highly accurate pitch meter using either the speech signal acquired via microphone or the electroglottographic signal. It operates in real-time and had four measurement scales covering the 250 to 2000 Hz range.

A sound-level meter measures, with an only one 100-dB detection range, the logarithm of the RMS value of the speech signal. Its integration time constant can be set at 10 ms or 50 ms . The bandwidth ranges from 20 Hz to 20 kHz, and A-damping is also available for the phonetogram.. It is calibrated for two types of microphones. A second sound-level meter with a bandwidth between 2 and 3 kHz can be used to measure the amplitude of the "singing formant" of the singing voice.

All parameters : speech and electroglottograph signals, pitch, overal and singing formant intensitys,oral and nasal airflows, intra oral and subglottic pressures, are recorded simultaneously on-line through an A.D

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acquisition add on card, and then stored in memory before being processed.

3 - CLINICAL INVESTIGATION PROGRAMS

3-1 Voice evaluation

The voice evaluation program is designed to give an objective evaluation of dysphonia and to aid in the acoustic follow-up of voice pathologies. The vocal signal, intensity (dB), Fo (Hz), and buccal airflow rate (cc/s) are recorded during the production of the vowel "a" held for several seconds. For each parameter, the following calculations are made for each one-second segment: mean, standard deviation, coefficient of variation, Fo jitter, and intensity shimmer. An average spectrum, from which a numerical index of harmonic prominence is calculated. The values obtained for the 3 parameters are represented as histograms and two-dimensional scatter plots. (figure 2)

3-2 Pneumophonic evaluation

3-2-1 Maximal phonation time

This program was designed to evaluate laryngeal efficiency (pneumophonatory quotient). It records the same parameters as above during the production of the vowel "a" held until loss of voice. The following calculations are made: duration (ms), mean intensity (dB), mean Fo (Hz), and exhaled air volume (liters).

3-2-2 Vital capacity

This program can be used to measure the vital capacity and the maximum exhaled air volume over a one-second period, calculated by integrating the air flow rate.

3-3 Phonetogram

3-3-1 Standard Phonetogram

This program evaluates the dynamic vocal area by recording the intensity of the minimal and maximal vocal production (dB) as a function of pitch (Hz) (figure 1). The phonetogram complies with international standards. The scales range from 40 to 120 dB ("A") for intensity, and between G1 (49 Hz) and G6 (1568 Hz) for pitch. For studies on the singing voice, the magnitude of the "singing formant" is calculated from the intensity for frequencies between 2 and 3 kHz

3-3-2 Speech phonetogram

This program indicates a subject's spoken voice range after a long running speech time, with the presentation of the standard phonetogram.

3-4 Acoustic study of the vocal production

3-4-1 Temporal analysis

This program was designed to study voice disorders such as laryngeal dystonia, neurological dysphonia, dysarthias, etc. For the clinician, this means examining the acoustic speech signal patterns and the electroglottograph curve over time. A special program makes it possible to record the microphonic signal for long durations, with a small bandwidth of 1 kHz. This feature can be used to measure total phonation time for long speeches (lasting more than 10 minutes).

3-4-2 Spectral analysis

Spectral variations across time are displayed here in sonogram format. The spectral analysis is done using FFTs with a wide or narrow filter. A display showing spectral sections (frequency-amplitude) can be requested at any point on the sonogram. (figure 4)

3-5 Aerodynamic analysis

3-5-1 Study of the speech production

This program is used to study the correlations between the speech signal and its aerodynamic parameters (buccal airflow rate, nasal airflow rate, intra-oral pressure, and sub-glottal pressure) as a function of the movements of the articulating organs. It is particularly suited to studying labial, lingual, and velar dyskinesia, dysarthria and has specific program for evaluate vocal prothesis.

3-5-2 Velopharyngeal incompetence analysis

This program allows the velar air leakage measurement in running speech for cleft palate or neuro motor disorders. (figure 3)

3-6 Patient file management

A program designed specifically for phoniatric purposes records clinical data, the results of EVA investigations, and digitized voice samples. This data can be stored in a database and saved on tapes. The database fields are user-defined.

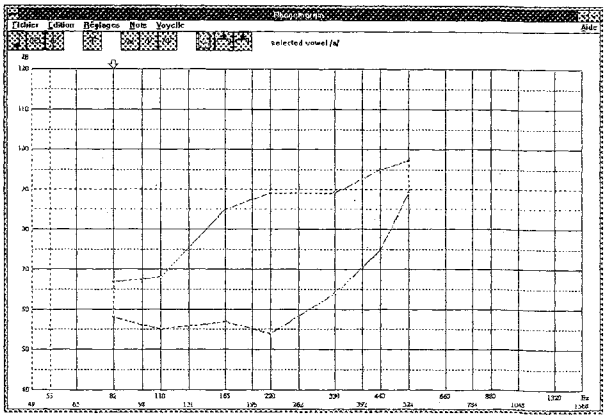

figure 1 : example of phonetogram

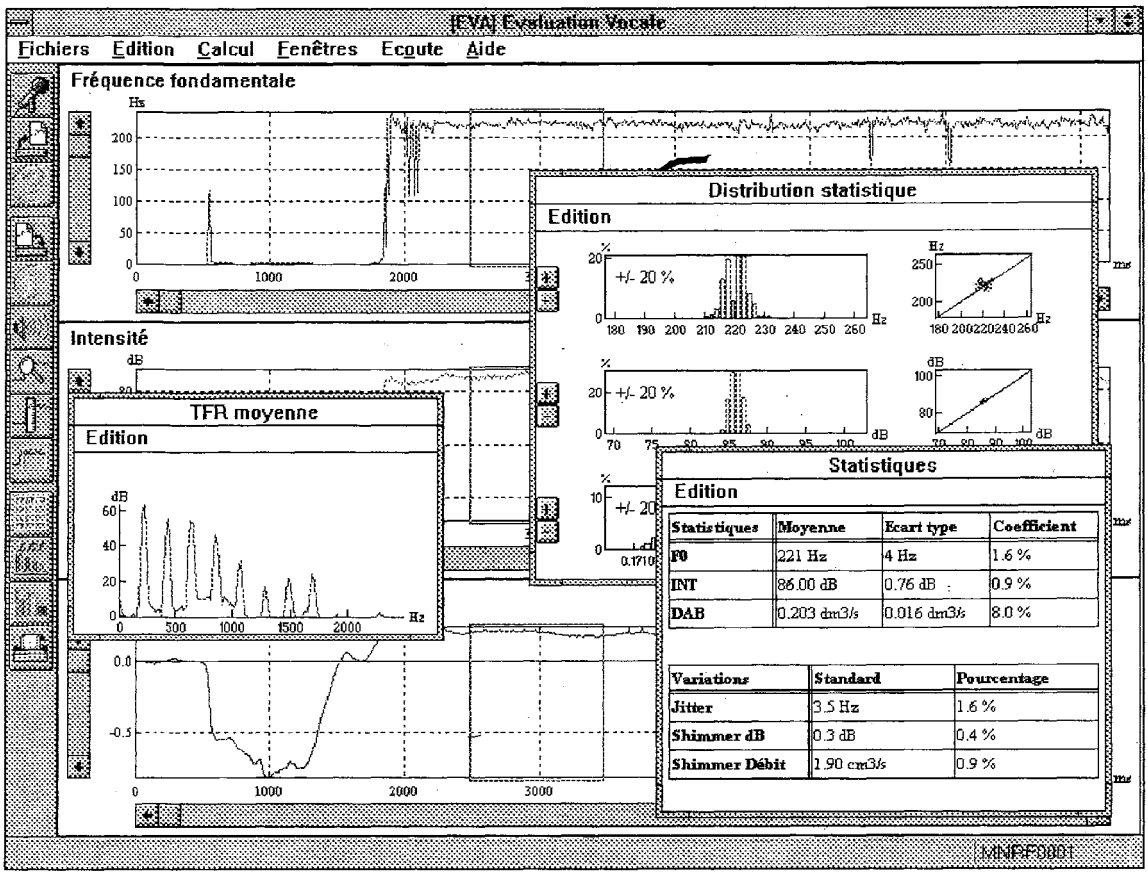

Figure 2 : Voice Evaluation example

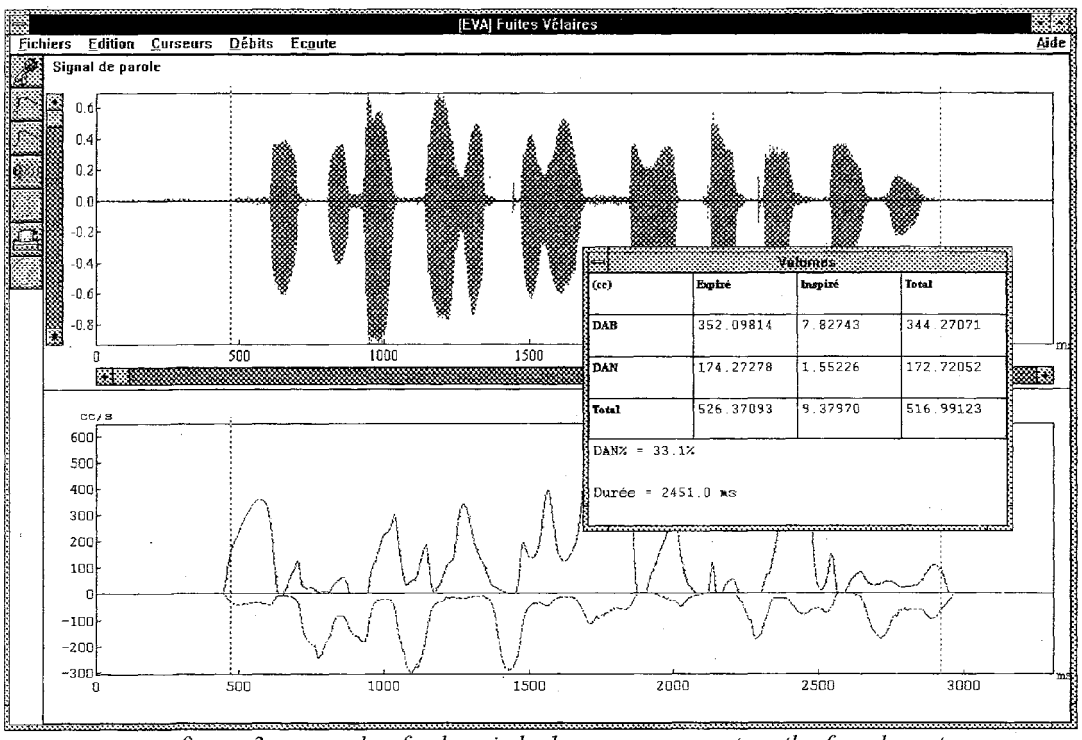

figure 3 : example of velar air leakage measurment on the french sentence "c'est une affaire intéressante, qu'en pensez vous ?"

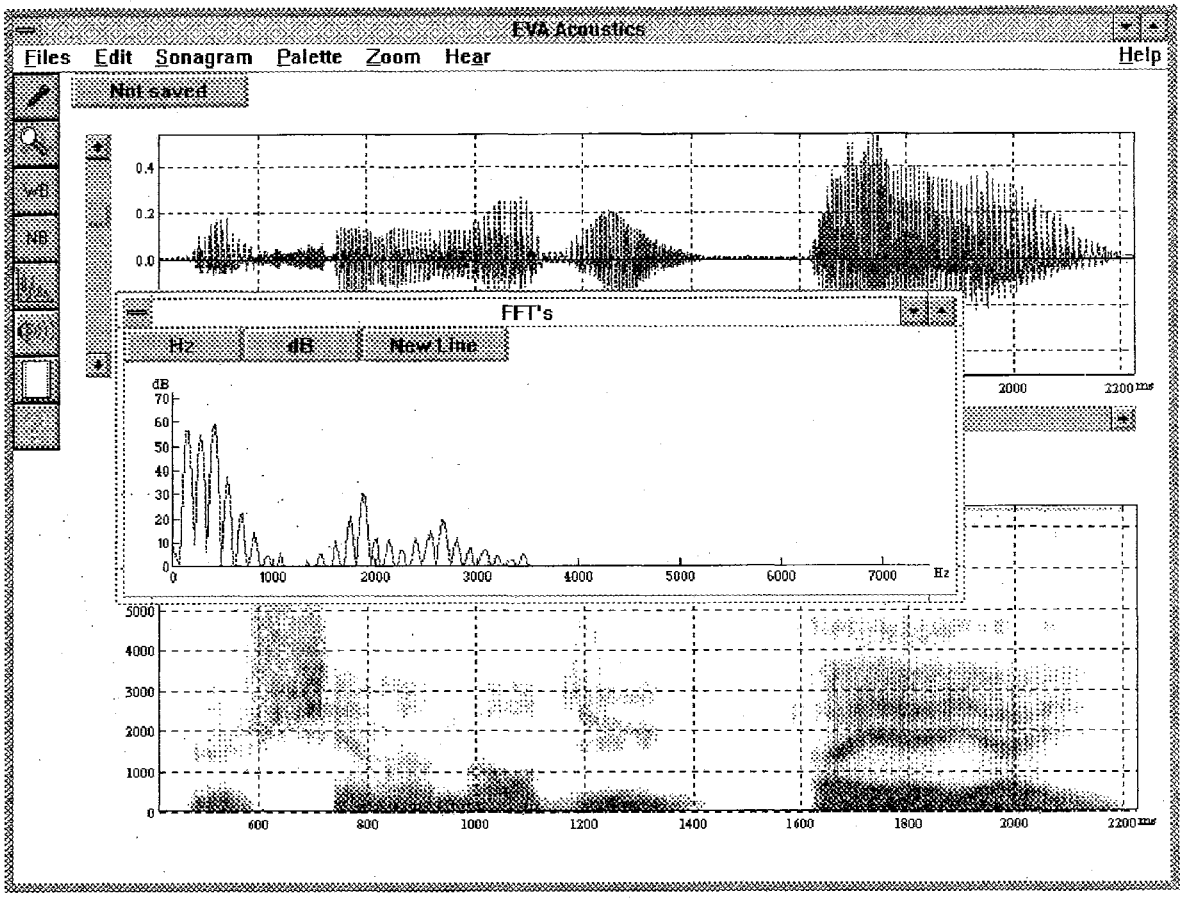

figure 4 : example of acoustical analysis

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