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MODERN SCIENTIFIC RESEARCH: ACHIEVEMENTS, INNOVATIONS AND DEVELOPMENT PROSPECTS

PROCEEDINGS OF XI INTERNATIONAL SCIENTIFIC AND PRACTICAL CONFERENCE APRIL 24-26, 2022

BERLIN 2022

MEDICAL SCIENCES

DETERMINATION OF THE PERSONAL HEARING STANDARD IN THE AUDIOMETER ON A SMARTPHONE

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Introduction. Most often, we begin to worry about our health, only when the problems with it make themselves felt. A person may not always notice hearing loss [1], especially when it is weak. This is due to the fact that our brain is able to compensate to some extent for disorders of the functional systems of the body and signal only when such disorders are easy to notice.

Therefore, constant hearing testing is important for a person to prevent disease and prevent serious consequences. Traditionally, this uses a tonal threshold audiogram [2] - a graphical representation of the thresholds of audibility of tones in decibels to the frequency functions of the stimulating tone. Usually an audiogram [3, p. 10] are registered in medical institutions with the help of special devices - audiographs [4].

Thus, audiometric research is to determine the curve of the threshold of auditory perception depending on the height and intensity of the stimulating sound signal. The results of the hearing study are presented in the form of a graph, on the ordinate axis of which the level of intensity of tones in dB is plotted, and on the abscissa axis - the height of these tones in Hz. Some values of this graph, obtained in

the testing process, determine the curve of the threshold of auditory perception - audiogram [5, p. 33-34].

With the rapid development of smartphone technology, it is possible to conduct audiometric research using mobile applications that allow the user to check the state of hearing. Most of them use tonal threshold audiometry and compare the results with age norms. Let's analyze some of the most popular applications:

- **Hearing Test (E-audiologia).** Tonal audiometry is performed complete with specially configured headphones. The calibration mechanism provides a special correction of the calibration coefficients based on the results obtained with a clinical audiometer, which does not allow calibration without visiting a specialized clinic [6].
- **Hearing Test (Petralex).** The quality of headphones and the mechanisms of their calibration are not taken into account when constructing audiograms [7].
- **Mimi Hearing Test.** The application is calibrated for the following types of headphones: Apple EarPods, Apple AirPods, Apple AirPods Pro, Sennheiser HDA 200 and 300. The accuracy of measurements depends on the quality and type of headphones. Separate calibration mechanisms are not provided [8].

The use of this method of audiometry is accompanied by either insufficient measurement accuracy, or forces the user to turn to a specialized medical institution to calibrate the headphones, or forces to purchase certain models of headphones, which still leaves some measurement error.

Aim of the paper. Solve the problem of inaccuracy of research results related to the use of headphones using the method of calculating the individual norm.

Materials and methods. The developed software application, oriented to work under the Android operating system, implements intelligent information technology, which allows to take into account previous research to fix the individual norm. The individual norm takes into account the peculiarity of determining the threshold of sensitivity depending on the model of the smartphone, headphones and the subjectivity of the user's actions. The block diagram of the technology is shown in Figure 1.

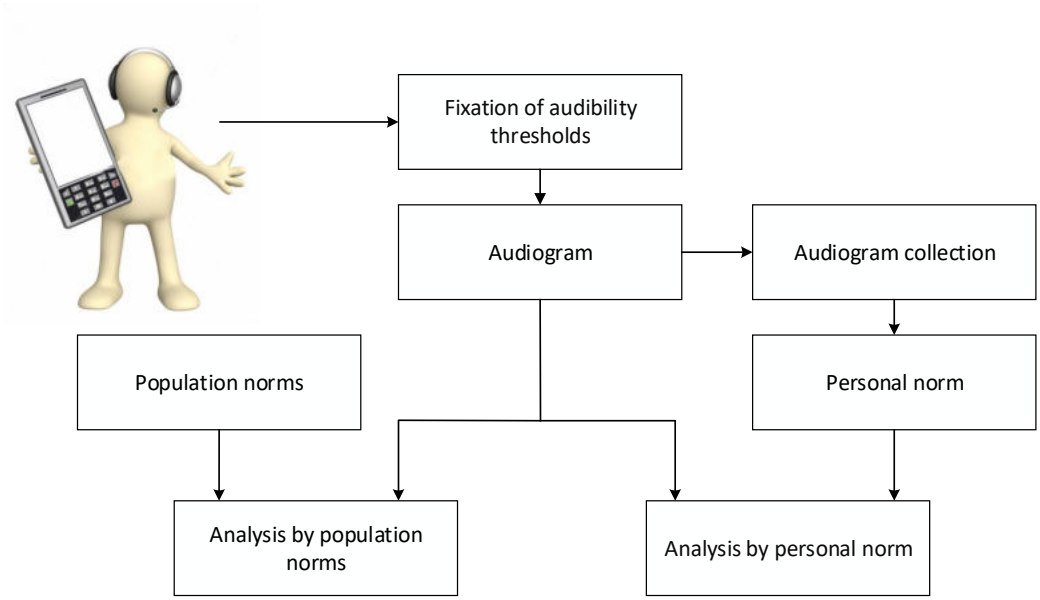

Fig. 1. Block diagram of information technology

Fixation of audibility thresholds and audiogram formation.

The software application makes a request to the Android hardware and receives a response regarding the availability of connecting headphones and setting the volume control to the maximum position. A positive answer allows you to start the testing procedure. Prior to testing, the user has the opportunity to give permission to recalculate the median.

The application launches an audio signal with frequencies from 250 to 8000 Hz with a discrete signal growth of 5 dB in the range from -20 to 100 dB. The sound is fed alternately first to the left, then to the right of the speakers of the headphones. The user stops the amplitude increase at the threshold he heard. The obtained results are entered into the database and a collection of user audiograms is formed.

Analysis by population norm

Population norm is a set of data generated during research [9] to determine the threshold of sensitivity in healthy people of different ages. Figure 2 shows the results of studies [10] of sensitivity thresholds grouped by age.

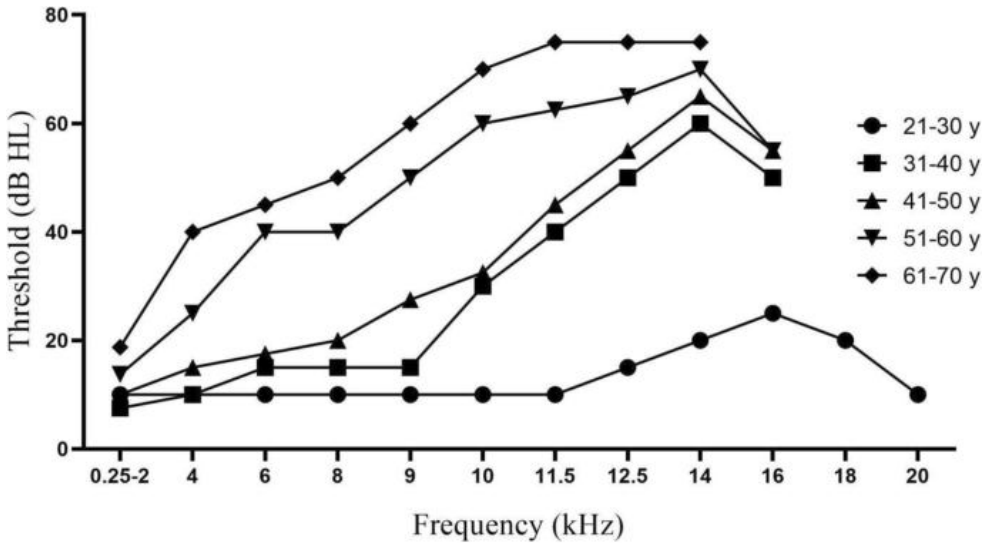

Fig. 2. Population audibility thresholds grouped by age [10]

After each test, the resulting audiogram is analyzed by a software application. In comparison with population norms, the deviation of the audiogram from the norms by 10-15 dB at each frequency is taken into account separately. In the presence of deviations the user's attention to the revealed anomaly of hearing sharpens.

Figure 3 shows the result of the analysis according to the population norm of the user, who, according to age, is classified as category 31-40 years.

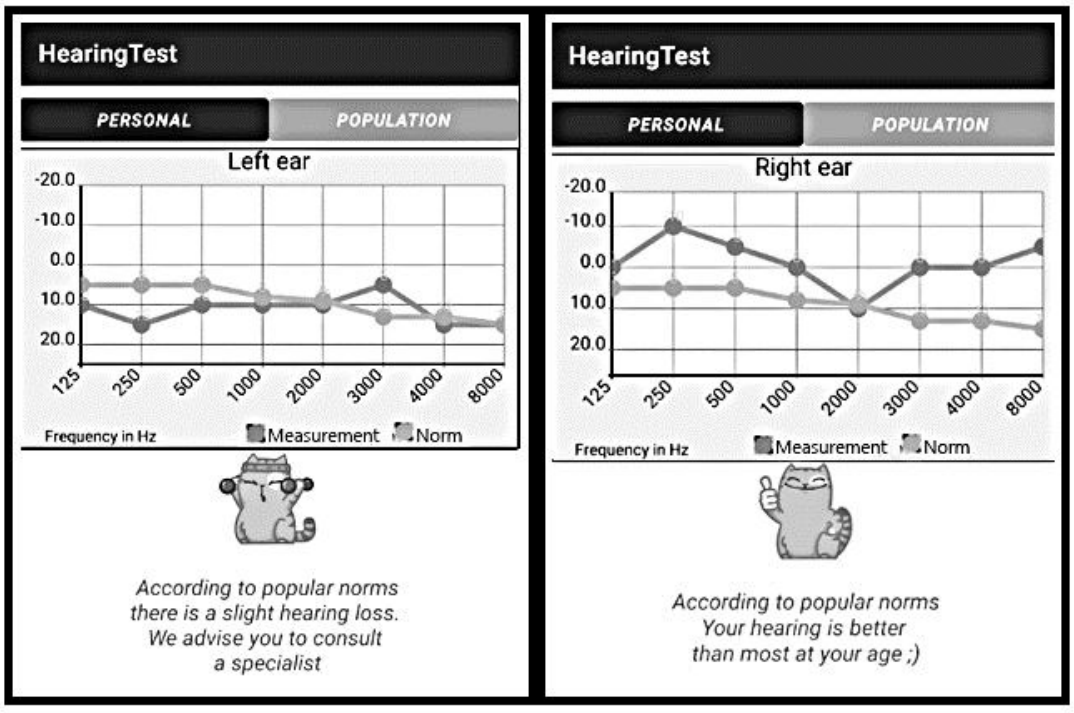

Fig. 3. The working window of the application in the test mode according to the population norm

Analysis by personal norm

The personal norm is calculated as determining the center of the group of values in the distribution of the collection of audiograms - the median (Fig. 4).

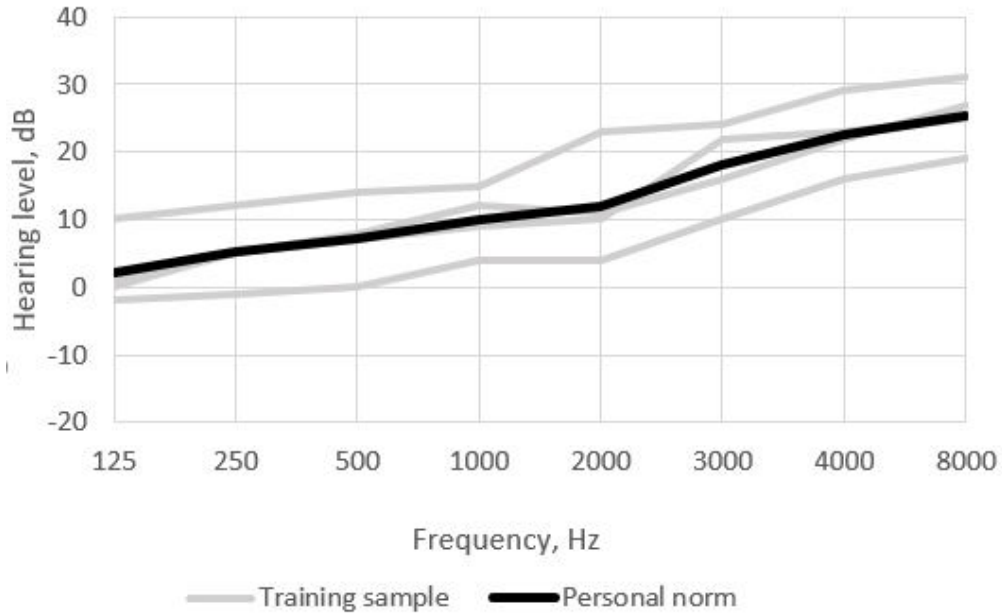

Fig. 4. The idea of building a personal norm on the educational sample of audiograms

The calculation of the median automatically starts when the collection size is at least 3 values and ends when it reaches 5. If desired, the user can allow to list the median for more values in the collection. Each calculation is entered into the database, and the last value of the median is used when analyzing the results of the audiogram.

Deviations from the median of 5 dB at least 2 frequencies are taken into account when analyzing the results of the audiogram according to the personal norm. A deviation of more than 5 dB at only 1 frequency is considered to be a measurement error. Depending on the deviations towards higher or lower values, the user is notified of hearing impairment or improvement. When replacing the headphones of one model with another, the user is recommended to create a new account of the software application to form a new individual standard, which will take into account the properties of the new speaker system.

Figure 5 shows the result of the analysis according to the personal norm of a user who has previously passed 3 tests at different times.

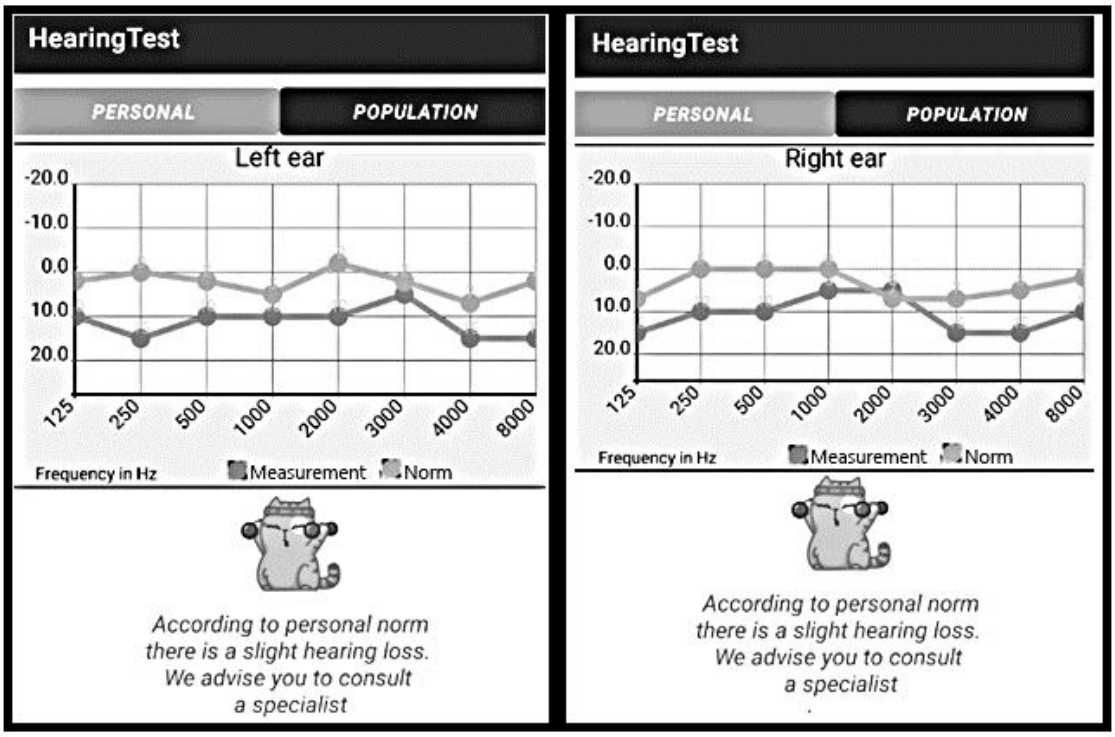

Fig. 5 The working window of the application in the test mode according to the personal norm

Results and discussion. The software application records all studies and allows the user to view a collection of all audiograms, test results on them and assess the dynamics of hearing loss depending on the date of the study. This material can be presented to the doctor as a monitoring of hearing. In addition, it is possible to conduct research on the same smartphone of different users and save the history of these studies.

Conclusions. Preliminary verification of the software application confirmed its operability. The developed algorithm for determining the individual norm allows to reduce the error of the results when conducting audiometry associated with the use of household headphones. Preserving the history of research allows the user to independently assess the dynamics of hearing changes and to acquaint the specialist with the results of audiograms.

The results obtained are not a diagnosis, but only help to monitor the patient's hearing around the clock. It can also be useful for remote monitoring by a doctor.

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