TOPICAL TASKS OF METROLOGY FOR DIAGNOSTICS OF INFANT'S BRAIN PATHOLOGIES

Iuliia Baksheeva, Kseniia Sapozhnikova, Roald Taymanov, Irina Danilova

Abstract: In medicine, a strong necessity exists to develop methods and automatic instruments intended for automatic diagnostics of the state of health. The possibilities of well-known diagnostic methods using voice sounding are limited. An acoustic method of diagnostics is considered that relies on the model intended for measuring expected emotions, which was suggested before. Possibilities of application of the proposed method in diagnostics of the deviations associated with the state of the brain and brain development dynamics of infants as well as improvement of infant's emotional sphere, are shown

Keywords: "smart" healthcare, automatic diagnostics, measurement model, acoustic method, brain development, brain pathology

1. Introduction

One of the most topical tasks of the coming technological revolution (Industry 4.0) is a so-called "smart" healthcare. This term is usually referred to as the healthcare that is characterized by a high percentage of automatic procedures in the technologies of population health observation, disease diagnostics, and their treatment.

The need for automation of the above-mentioned procedures is caused, in the first place, by the necessity to decrease the expected growth of load and improve the work efficiency of medical doctors due to solving of the following actual tasks:

• keeping a performance capability of people older than 65-70 years since the increase in life expectancy and fall of birth rates force to raise retirement ages;

• diagnosing diseases at an earlier stage, including diagnostics during childhood or even babyhood, because in this case, the treatment may be more successful and less expensive.

In the course of the Industry 4.0 era, the high rate of change in demand for goods and services is expected. At the same time, devices and other facilities that are out of action, mainly, will be replaced by new ones instead of their repairing.

Besides, during this period, robots capable to carry out routine operations in the field of manufacturing and services, will be widely applied.

All these features will inevitably lead to rising unemployment rate and toughening the requirements for employees' abilities to react quickly to the necessity for new approaches and products.

As a result, "smart" healthcare will additionally require to solve some qualitatively new tasks such as:

• replacing medical personnel carrying out routine functions with economically efficient robots;

• creating the methods that enable increasing intellect development efficiency, particularly, imaginative thinking in childhood and babyhood;

• revealing non-typical deviations in children development that enables opening opportunities to form his/her outstanding abilities to accomplish socially useful work.

Success in solution of these five tasks, first of all, is determined by an opportunity (ideally, without the participation of medical doctors):

• to use computerized instruments not attracting attention of a patient under observation;

• to obtain information on the deviations of his/her organ functioning quickly and painlessly.

To recognize the value and acceptability of such information regardless of the place where it was obtained, this information should be characterized by a quantitative evaluation with an uncertainty and correspond to a certain standardized scale, in particular, a nominative scale.

In other words, required information should be a result of measurements that, as a rule, are carried out with the help of special "smart" diagnostic instruments.

2. Acoustic method of "smart diagnostics"

It is well-known that human body forms a lot of fields of various quantities that contain information on the state of human health and its deviation from the state accepted as a normal one, which is characteristic for a great number of people tested before.

These fields are caused by interaction of human organism components during the process of their functioning. Sources of "smart diagnostic" infor-

mation that contains indirect data on deviations related to functioning of various organs are heart pulse, electrical and magnetic brain activity, face expression, movements including gestures, voice soundings, etc.

The growth of the number of corresponding publications confirms that specialists gradually realize that investigations in this sphere are promising.

However, the front of studies is unequal. For example, diagnostics of diseases based on heart rate has a centuries-old history in China, but only since recently, computerized cardiographs have been developed in Russia, which can automatically diagnose more than 40 diseases [1].

As for acoustic diagnostics of health [2-9], in spite of a number of revealed features of heart activity, respiration, and blood circulation influencing voice sounding [3, 9], special measuring instruments for such diagnostics are unknown.

The main reason is associated with the fact that there are no convincing arguments for the link between features of voice sounding and the disease being diagnosed.

A disease here is considered as a multiparametric (multidimensional) quantity characterizing certain deviations of human organism functioning from its normal state [5].

However, the acoustic method has very important advantages for "smart diagnostics" since it enables obtaining required information quickly and painlessly, without participation of medical doctors, and not attracting attention of a patient under observation [7] (that is especially important).

Therefore, insufficient effectiveness of diagnostics based on voice in the past should be considered only as an evidence that the methodology of the search should be changed.

In a medical practice, a phenomenological approach is widely used. It stipulates the search of disease indications being characterized by quantities that can be measured or by variation of these quantities (in time and/or space). Fever, cough or running nose, sometimes, weak headache, and weakness are indications according to which a physician usually makes a diagnosis of acute respiratory disease. In essence, the same approach is applied for diagnostics of cerebral spastic infantile paralysis [9].

However, in our opinion, the most prospective is an approach relied on a certain concept concerning a possible "mechanism" of functioning of human body components. This "mechanism" should be reflected in a measurement model linking a measurands with a supposed disease.

Of course, like any model of a complicated phenomenon, such a model should be checked and corrected, if necessary, in the course of diagnostic practice. Nevertheless, it is the way that opens opportunities for economically efficient "smart" diagnostics.

A difficulty with this approach is that the interaction of human organism components, to a great extent, depends on the nervous system, in particular, the brain. However, according to words of the well-known Russian neurophysiologist K. Anokhin, among many hundreds of papers on brain and its functions, "we still lack a satisfactory understanding of mechanism of brain functions" [10].

An acoustic method being suggested by the authors of the present paper relies on the model intended for measuring expected emotions caused by music and other acoustic impacts. This measurement model was proposed and justified before [11-13].

The emotion is defined in the model as a neurophysiological reaction (below, this reaction will be called an emotiogenic one) due to some impact, which causes the transition of a person to a state that enables identifying the emotion character by the sensation or behavior of a person.

The measurement model consists of 3 steps. Its 1st step demonstrating the "mechanism" of the basic (the most ancient) emotion formation is shown in Fig.1.

According to the model, acoustic signal comes to a preselector of sound range oscillations, where a non-informative part of a signal is suppressed. After that, the signal is delayed for a fraction of a second, which corresponds to the time of forming an emotiogenic reaction.

Then, a joint non-linear conversion of the delayed and undelayed signals takes place, as a result of which an intermodulation component spectrum is formed. A selector singles out intermodulation components within the range of infrasound and a lower part of the sound range (IFR).

Their frequencies correspond to the frequencies of brain biorhythms causing emotiogenic reactions. These oscillations synchronize the IFR neurophysiologic reactions that took place before or stimulate them.

Parameters of these oscillations within the IFR and those within the sound range (of a carrier fre-

quency) characterized by the maximum energy are compared with markers of basic emotions stored in a human genetic memory and cause a corresponding basic emotion.

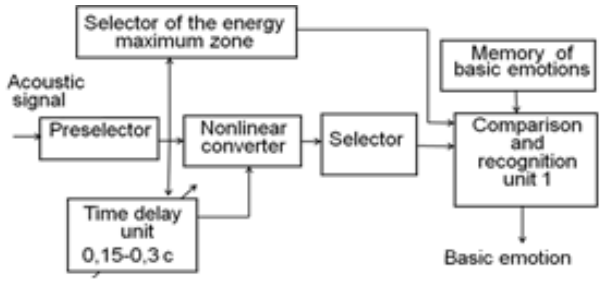

Fig. 1. The 1st step of the measurement model [13]

So, in order to single out emotiogenic reactions from acoustic signals, to carry out its demodulation is necessary. It is reasonable to suppose that emotionally coloured soundings can be formed, if modulation of sounds by the reactions within delta-, theta, and alpha- brain biorhythm zones stimulating basic emotions, takes place. (Such a conclusion can be also drawn from the evolution analysis of emotions transmitted by acoustic signals [12, 13].)

It follows from this statement that the sounding of singer's voice or even sounding of emotionally coloured speech, cry or other infant's vocalizations, contains information on brain activity, at least, within the range of emotiogenic reactions.

Accordingly, to study information on such an activity of the brain, it is sufficient to demodulate voice soundings and analyze the intermodulation component spectrum within the frequency range of brain biorhythms.

The method of acoustic diagnostics can be useful for teaching vocalists, actors, and philologists, since it enables realizing an objective control over an emotion tint of voice.

However, the main advantages of the method, in our opinion, are associated with development and upbringing of children.

The thing is that the activity of emotiogenic reactions characterizes the development of the midbrain (the component of human nervous system that is one of the most ancient and important for the future life of a child).

Therefore, taking into account the accessibility of the acoustic diagnostic method, its application for diagnosing the infant's brain development starting from the moment of his/her birth is of great interest.

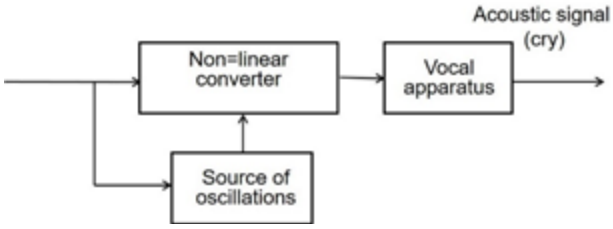

Fig.2. Simplified model of unconscious voice modulation

Although the acoustic method is rather simple, its efficiency, to a significant extent, depends on the results of preliminary investigations.

These results should determine indications characterizing a normal development of the infant's brain according to the present-day concepts.

At this stage, to record cry and other characteristic vocalizations of a statistically significant infant group is necessary. The records should be carried out during many months with the increasing interval between the records. Based on them, after the non-linear conversion of acoustic signals, it is possible to determine (separately for girls and boys) average statistical characteristics of the cry spectrum and their variation in time.

In the future, the results obtained will enable detecting individual deviations inherent in a specific child from the average statistical characteristics and, as a result, diagnosing the feature of infant's development.

At that, both negative deviations, e.g., connected with antenatal troubles or birth traumas, and positive ones giving evidences of certain capabilities may take place.

In the case of diseases revealed, the comparison of a number of the measurement results obtained in some time intervals will allow judging whether an aftereffect of illness occurs.

To confirm that investigations in this field are expedient and promising, cries of babies (girls) 1-2 days old were recorded at one of St. Petersburg maternity hospitals.

In two months, cries of the same infants were recorded once again (see Fig.3).

While processing the data obtained, the level of neurophysiologic reactions was determined by the average values (for a group of infants) of relative power of spectrum components within the zone of brain biorhythms. These average values were calculated after non-linear conversion of the acoustic signals.

The results of the data processing testify that the direction of development of infant's emotional sphere coincides with the direction of its evolution for animals [12, 13].

(The evolutional development of emotions was associated with consecutive growth in neurophysiological activity at higher frequencies.)

For the first days of life the level of neurophysiological reactions within the delta-rhythm zone was significant. It the course of 2 months it decreased a little (from 59.1 % to 57.5 %}. At the same time, the level of reactions within the theta-rhythm frequencies increased from 26.4 % to 28.1 %, whereas within the alpha-rhythm frequencies this value kept near 14.4 %. The power increase within the theta-rhythm zone reflects the process of understanding a surrounding world by an infant and origination of his/her interest to something.

Later on, it is possible to predict the growth of activity within the alpha-rhythm zone.

It is characteristic that the standard deviation of the value of relative power for the same 2 months increased approximately twice: for delta-rhythms from 3.8 % to 8.9 %, for theta-rhythms from 2.9 % to 6,1 %, for alpha-rhythms from 1.6 % to 3.3 %.

The increase in the difference of the level of the brain biorhythm activity demonstrates the development of infant's individual features.

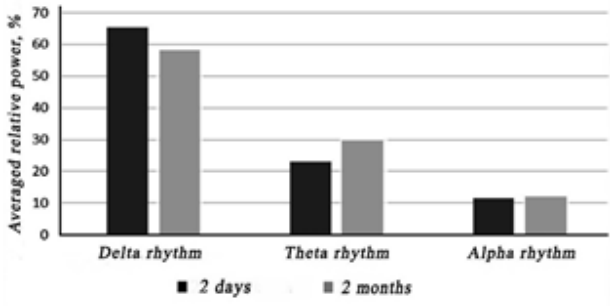

Fig.3. Typical infrasound spectrum singled out (after a non-linear conversion) from an infant's cry (for 2 days and 2 months age)

The possibility to observe the development of infant's emotional sphere using the acoustic method opens new horizons for searching methods of upbringing, which could contribute to improving the emotional sphere.

Such methods include music, games with a child, etc.

The opportunity to keep the result under control, evaluate the result quantitatively, compare it with other results, and reveal the most efficient methods, is important.

3. Conclusions

To analyze neurophysiological activity associated with human emotional sphere, the acoustic method has been proposed.

The method can be applied for both teaching some subjects and diagnosing brain diseases. However, the use of this method for diagnosing brain pathologies and dynamics of infant's brain development seems to be the most efficient.

4. Acknowledgements

In the paper, the materials of investigations supported by the Russian Foundation for Basic Research (RFBR), project "Forming of a measurement model interrelating musical influence and emotions of listeners" (No. 15-04-00565), have been used.

References

[1] **V. M. Uspenskiy.** *Informatsionnaya funktsiya serdtsa. 2-e dopolnennoe izdanie. Pod redaktsiey prof. V.B.Simonenko.* "Planeta", Moskva, 2016.

[2] **A. Chittora, H.A. Patil.** Data collection of infant cries for research and analysis. *Journal of Voice,* 31 (2) (2017), pp. 252.e15-252.e26.

[3] **H. Farsaie Alaie, L. Abou-Abbas, C. Tadj.** Cry-based infant pathology classification using GMMs. *Speech Communication,* 77 (2016), pp. 28-52.

[4] **H. Farsaie Alaie, C. Tadj.** Cry-based classification of healthy and sick infants using adapted boosting mixture learning method for gaussian mixture models. *Modelling and Simulation in Engineering,* 2012, art. no. 983147.

[5] **P. Zanchi, M. Fasolo, et al.** The role of acoustic and contextual features in the recognition of crying causes [Il ruolo delle caratteristiche acustiche e contestuali nel riconoscimento delle cause del pianto]. *Psicologia Clinica dello Sviluppo,* 20 (1) (2016), pp. 103-123.

[6] **M. Hariharan, S. Yaacob, S. A. Awang.** Pathological infant cry analysis using wavelet packet transform and probabilistic neural network. *Expert Systems with Applications,* 38(12), 2011, pp. 15377-15382.

[7] **L. Naranjo, C. J. Pérez, Y. Campos-Ro-**

ca, J. Martín. Addressing voice recording replications for Parkinson's disease detection. Expert *Systems with Applications,* 46 (2016), pp. 286-292.

[8] **T. I. Serganova.** *Kak pobedit detskiy tserebralnyiy paralich.* Meditsina, SPb, 1995.

[9] **S. Orlandi, C. A. Reyes Garcia, A. Bandini, G. Donzelli, C. Manfredi.** Application of pattern recognition techniques to the classification of full-term and preterm infant cry, *Journal of Voice,* 30 (6) (2016), pp. 656-663.

[10] **K. V. Anohin.** Osnovaniya rasshirennoj teorii funkcional'nyh sistem. *IV Mezhdunarodnaya mezhdisciplinarnaya konferenciya «Sovremennye problemy sistemnoj regulyacii fiziologicheskih funkcij», Materialy konferencii,* June 22-29, 2012, Bodrum, Turkey, s. 5-8.

[11] **Y. Baksheeva, O. Bazanova, S. Kostromina, E. Nikolenko, K. Sapozhnikova, R. Taymanov.** Neurophysiological markers of tonalities. *Ninth Triennial Conference of the European Society for the Cognitive Sciences of Music,* Manchester, UK, 17-22 August 2015, pp. 202-203.

[12] **R. Taymanov, K. Sapozhnikova.** Measurement of multiparametric quantities at perception of sensory information by living creatures. *EPJ Web of Conferences* 77, 00016 (2014)

http://dx.doi.org/10.1051/epjconf/20147700016

[13] **R. Taymanov, Iu. Baksheeva, K. Sapozhnikova, A. Chunovkina.** Measurement model as a means for studying the process of emotion origination. *Journal of Physics: Conference Series (JPCS),* 772, art. 012036, 2016. 6p. doi: 10.1088/1742-6596/772/1/012036

Information about the authors:

Iuliia Baksheeva: associate professor (Saint Petersburg State University of Aerospace Instrumentation; Institute of Radio Engineering, Electronics and Communications; Department of Radio-Engineering Systems), author of more than 40 scientific publications and patens. Scientific fields and interests: system analysis and computer simulation, ultrasonic diagnostics, metrological self-check of sensors, "soft" measurements.

E-mail: baksheyeva@rambler.ru

Kseniia Sapozhnikova: deputy head of laboratory (D.I.Mendeleyev Institute for Metrology), member of the International Committee on Measuring Instruments (ICMI), author of about 240 scientific publications and patents. Scientific fields and interests: measurements under harsh environment, metrological self-check of sensors and multichannel measuring systems, measurements of multidimensional quantities in the humanitarian field.

E-mail: k.v.s@vniim.ru

Roald Taymanov: head of laboratory (D.I. Mendeleyev Institute for Metrology), full member of the Metrological Academy, member of the International Committee on Measuring Instruments (ICMI), author of more than 330 scientific publications and patents. Scientific leader of many projects intended for science-based industry. Scientific fields and interests: measurements of non-electric quantities, metrological self-check, measurements of multidimensional quantities in the humanitarian field.

E-mail: taymanov@vniim.ru

Irina Danilova: engineer of category 1 (D.I. Mendeleyev Institute for Metrology), author of about 10 scientific publications. Scientific fields and interests: computer methods of data presenting and processing, metrological self-check.

E-mail: i.m.danilova@vniim.ru