

## On hardware and software supporting communication and therapies of speech and voice disorders

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*Abstract:* - One of the most important needs of man is to communicate with other people. The more efficiently such a process is fulfilled, the better is its influence on self-esteem, self-acceptance and consequently on the quality of life of a person, its adaptation and functioning in the society. The disorders in this areas can be due to some underdevelopments and/or damages of structures in brain, neural pathways, neural connections and processes that are responsible for the work of vocal organs: respiratory system, larynx, articulation. In this paper we describe some examples of the ways in which the informatics can be applied to support the processes of communication of people with some impairments and/or disabilities.

This includes the high-tech devices for the Augmentative and Alternative Communication (AAC), the Warnke method and the innovative software called Dr Neuronowski. The alternative communication means an application of an alternative system in a conversation. The augmentative communication occurs when a person with a limited ability of speech uses a supplementary systems of communication. The Warnke method is based on the automation of the processing of perceptions in hearing and seeing and motor skills, the automation of the coordination of the brain-hemispheres, and the development and automation of a visual dictionary. The main motivation for Dr Neuronowski software is the observations that an action of human mind is based on the perception of time and the timeous processing of suitable information, which concerns mechanisms of various cognition operations (eye-hand coordination, speech, language, memory, learning of new information, concentration of attention, decision-making etc.).

Since speech is one of the main ways of communication, we also present a description of applications of the laryngograph – an electronic tool that is very helpful in the diagnosis of speech problems and voice impairments as well as in the therapy of them.

We discuss only some selected systems, but a constant progress can be observed in this area and every year some new devices or just computer applications are available that support speech therapies and/or possibilities of communication and make the life of numerous people with various difficulties much easier.

*Key-Words:* - Augmentative and Alternative Communication, Dr Neuronowski, Electroglotography, Laryngograph, Speech Disorder, Voice Disorders, Warnke Method.

### 1 Introduction

We can easily agree that a communication between people is a natural need. It makes the exchange of information possible and allows to learn new values and skills; therefore it is the main tool in education.

Roughly speaking, the term communication means exchange (transfer) of information between two alive beings or groups of them, in which signs and rules of some system (code) have been used. Such a system (code) is usually accepted and understood by the both sides of the communication process. Communication of human being nearly always is in some relation to speech and language.

People may communicate verbally or nonverbally. The nonverbal way requires conscious and unconscious familiarity with many factors such as body language, gestures, physiological symptoms, facial expression etc., while the verbal transfer of information is possible mainly by speech, which can be defined as an innate ability of human being to perform actions of transmitting and receiving information.

Action of transmitting means some way of speaking (coding), and action of receiving is actually a process of decoding (decryption) based on proper hearing, listening and understanding. Therefore a language (code), as the tool of speech,

is a conventionally accepted system of signs and grammatical rules. Those rules allow us to use a set of signs to form greater units such as syllables, words, tags and texts.

Sender, receiver, statement, code (system), contact, way of information transfer and communicational situation are basic elements of the act of communication. These elements complement each other and determine the quality of that act. Their occurrence characterize the proper development and functioning of human being in the biological, intellectual, psychological and social areas. With regard to this statement, disorders in the areas of communication, speech and language could be due to some underdevelopments and/or neuro-anatomical or anatomical damages of structures in brain, neural pathways, connections and processes that are responsible for the work of vocal organs: respiratory system, larynx, articulation. The sources of such disorders quite often can be a subject to some kind of therapies.

## 2 AAC

Communication with other people is one of the most important needs of man. The more efficient it is, the better is its influence on self-esteem, self-acceptance and consequently on the quality of life of a person, its adaptation and functioning in the society. Therefore it is important to improve or/and support it in the case of any impairments in it. This is the main purpose of *Alternative and Augmentative Communication* (AAC) that encompasses the different communication methods that may be used to help people with a wide range of speech and language disabilities.

There are several congenital conditions, such as: cerebral palsy, autism, intellectual disability that can create problems in communication, especially in speaking and writing. Similar effect have the following acquired conditions: amyotrophic lateral sclerosis, traumatic brain injury, aphasia. Such physical disabilities and motor co-ordination problems may create serious obstacles making the production of speech or writing quite difficult or even impossible.

The alternative communication occurs if a person applies an alternative system in a conversation. The augmentative communication takes place when a supplementary systems of communication is being applied by a person with a limited ability of speech. The AAC systems can support the development of speech and/or to complement it [6], [22].

There are unaided and aided AAC systems. In unaided communication no additional equipment is

used and it is based mainly on signing and body language, while the aided communication applies various external tools. This can be just paper and pencil, communication books or boards, but also quite modern devices generating speech (SGDs) or producing written output.

The aided AAC can be either low-tech or high-tech. Low-tech tools do not need batteries, electricity nor electronics. In high-tech aided AAC the central part of the educational experience is the application of computers. Interactive software makes the progress in an individual speed possible and provides an immediate information on various aspects of the training. The physical effort necessary in traditional writing can be diminished by the use of special interactive keyboards, various types of mice and software permitting the storage and retrieval of electronic messages. Also, a speech output can be produced in a digitized or synthesized ways. The synthesized way means a use of the prerecorded material; so, the digitized way seems to be more convenient in many situations, because it allows words spelling and creation of various novel messages [13].

There are numerous high-tech AAC systems available that can be used in therapy and in the further part of this section we focus on them. The choice and the adjustment of a proper one is very important and should depend on the type of inefficiency and take into account the diagnosis of all spheres of the development of a person.

For instance the Picture Communication Symbols (PCS) is an advanced software that is very popular in Poland. It is a graphic system that may support communication of people with the mobility disabilities and includes special tools (Boardmaker or Boardmaker with Speaking Dynamically Pro) that allows to generate various PCS symbols, which visualize objects, actions and concepts. New symbols can be added even in the form of colored or black and white photographs, line drawings or written words. Boardmaker with Speaking Dynamically Pro includes voice synthesizer: Real Speak and is assumed to help the advanced users with needs of more advanced alternative communication. It can be used on any computer or tablet (with a touchscreen) transforming it into a speech output device [21].

Another high-tech AAC tools are the Voice Output Communication Aids, which are, in general, light and portable and range from complex computer-based systems to simple single-message devices using recorded speech [11].

The further possibilities may be provided by the usual computers that can be turned to the high-tech

AAC systems by running on them additional software. Also, Android and some other open source operating systems supply real opportunities to develop convenient features and software for smartphones and tablets. Unfortunately, all solutions that require special programming usually can be unreliable and this should be significantly improved, because otherwise a backup is necessary.

On the other hand, there exist keyboards that do not require programming and can be equipped with a Text to Speech converter and used to create speech over a telephone. We also may configure a keyboard and an audio speaker to create a "talking keyboard" that speaks directly the typed text.

It is clear that the high-tech devices may differ in the amount of information that they can store or size, the access methods (through pointers, adapted mice, joysticks, keyboards, switches and scanning), and weight and size (thus their portability can be more or less convenient) [15].

In the near future we should expect significant improvements of the interfaces and reduction of the cognitive and linguistic demands. Brain activity measuring electrodes could have a promising applications. Also speech recognition systems that transcript automatically the dysarthric speech and recognition technologies interpreting body motions would be very desirable. For further related information and references on AAC see [7].

### 3 Warnke method

Several difficulties may occur in the process of education of a child and one of the main obstacles could be the intellectual disability. It may impair the ability to communicate efficiently, slow down the intellectual development and decrease the speed with which the knowledge can be acquired.

The intellectual disability may influence skills such as reading and writing, makes it very difficult to understand a mathematical idea or a reasoning, and decreases knowledge and memory. The fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) of American Psychiatric Association, that was published in 2013 by American Psychiatric Association Publishing, introduces the diagnosis of intellectual disability (intellectual developmental disorder) to replace the DSM-4 diagnosis of mental retardation. The main changes concern the name of the disorder, its impact on a person's functioning, and criteria improvements to allow more comprehensive patient assessment [3]. Let us mention that intellectual disability affects approximately 2-3% of population of which 75-90% have a mild form. The main types of the intellectual disability are usually formed according

to the school-area skill sets, which are mainly reading, writing, and mathematics.

There are two types of intellectual disability in reading. The first one means issues in understanding relationships between letters, sounds, and words; the other concerns problems with reading comprehension and difficulties in grasping the meaning of words, sentences, and paragraphs.

The difficulties in math may be a result of language disabilities, but also of other problems such as visual impairment, difficulties with memorizing and organizing numbers and facts, sequencing, as well as with telling time and with understanding the abstract ideas.

Disability in writing mainly concern physical activity of writing and the mental activity of processing information. The latter means problems in forming letters, words, and written expressions (messy writing, poor accuracy in copying letters and words, spelling problems, poor coherence and organization in writing).

The communicational problems also may result from some disorders in central auditory processing (CAP), which means the perceptual processing of auditory information in the central auditory nervous system (CANS) and the neurobiological activity that underlies that processing and gives rise to electrophysiologic auditory potentials [4]. Such disorders are usually called (Central) Auditory Processing Disorders (APD or CAPD) [2].

Persons with APD usually have normal structure and function of the outer, middle and inner ear, but cannot process the information they hear as other people do, which leads to certain difficulties in sounds recognition and interpretation, especially those composing speech. It seems that a dysfunction in the central nervous system can be a reason of these difficulties.

For further discussion, more information and references on those two mentioned above disorders (i.e., intellectual disability and APD) see [8].

Let us observe that the disorders depicted above are related to the brain functioning. But it has been observed that the human brain has an ability to change (plasticity), which is the biggest in childhood, but also occurs to a significant degree in adulthood. Therefore, if some communicational deficits are related to brain functioning, we can expect that they are changeable by a suitable training, at least to a certain extent.

This observation has motivated Fred Warnke, a communication-expert, to developed a method allowing to identify and train some of the intellectual deficits. It is based on the checking and training of suitable brain functions. Using some

electronic devices, endowed with a suitable software, we can measure to what extent the functions are automated and compare the results obtained against standardized data. In this way we can find out if there are deviations or even clear malfunctions [14].

The method is based on the three steps: automation of the processing of perceptions in hearing and seeing and motor skills; automation of the coordination of the brain-hemispheres; development and automation of a visual dictionary.

The skills of reading, writing and calculating, can be improved by a training using devices called: Brain-Boy Universal Professional, Brain-Boy Universal, Audio-Video-Trainer, and Lateral-Trainer Professional. Special games that can be played on the first two devices improve seven basic functions. Moreover, to coordinate hemispheres and stimulate central processing of perceptions one can use Audio-Video-Trainer and Lateral-Trainer Professional. Better coordination of hemispheres may help in general prevention against dyslexia and dyscalculia.

The main activities in tests and training are special simple games in which some basic, mainly acoustic, patterns in time and space are to be recognized. The efficiency of the method has been proved in a research carried out at the Medical University of Hanover (cf. [8]). The tests have been validated by a large number of qualified experts.

As an example we present below a table from [8] with the results of a training of a 8 years old boy with mild intellectual disabilities and speech disorder problems. It shows the effectiveness of the method in improving and developing the speech abilities. The investigation took place in Department of Special Pedagogy of Pedagogical University of Cracow (Krakow, Poland).

Function	A	B	C	D
1. Visual order threshold	47 ms	24 ms	240 ms	80 ms
2. Auditory order threshold	99 ms	49 ms	550 ms	80 ms
3. Spatial hearing	74 $\mu$ s	42 $\mu$ s	600 $\mu$ s	100 $\mu$ s
4. Pitch discrimination	24 %	8 %	68 %	14 %
5. Auditory – motor coordination	403 ms	322 ms	830 ms	692 ms
6. Choise reaction time	1042 ms	616 ms	1040 ms	488 ms
7. Pattern test recognizing low - high tones	200 ms	90 ms	800 ms	200 ms
8. Pattern test recognizing short - long tones	200 ms	127 ms	500 ms	140 ms

Description of columns:

**A** - Reference value for age 8 years;

**B** - Target value for age 8 years;

**C** - Initial diagnosis values;

**D** - Final assessment values.

#### 4 Dr Neuronowski

The secondary forms of communication are writing and reading skills. Their efficiency depends on the proper control of speech, which means both understanding and producing. The research proves that a serious reason of difficulties in learning reading (consequently in writing and calculating, which implies dyslexia, dyscalculia and dysgraphia) are disorders of central nervous system in the area of perception and data processing concerning hearing, seeing and movement.

A number of computer applications are available that could support therapies of these problems and examples of them are the just discussed Warnke method, but also an innovative system called Dr Neuronowski. In this section we focus on the latter. Its idea is based on the observations that, in view of many years of investigations in neurology and neuro-psychology, we can tell that an action of human mind is based on the perception of time and the timeous processing of suitable information. That specific time dynamics concerns mechanisms of cognition operations such as eye-hand coordination, speech, language, memory, learning of new information, concentration of attention, decision-making and other [16].

The actions of time perception and processing of information in time happen on several levels: a few milliseconds, several dozens milliseconds, several hundred milliseconds, and even few seconds. The speech consists of segments, greater or smaller phonic elements, which have specified time characteristics. We can distinguish three time ranges in the brain activity that are of basic importance for the reception and expression of speech. For example, the phones take several dozen milliseconds (e.g., the production time of plosive phone is around 30 - 40 ms). The several hundred milliseconds level concerns elementary particles of speech, which are syllables and words consisting of one syllable. The level of few seconds is connected with phrases.

The results of experimental investigations in the Neuropsychological Laboratory of the Instytut of Experimental Biology of Polish Academy of Sciences confirm the theory that slowness in time perception and in the processing of information can

be responsible for the speech disorders such as aphasia, autyzm, SLI (an abbreviation of Specific Language Impairment) and other [19], [20]. Let us yet mention the research on the efficiency of Dr Neuronowski system resulted in several PhD degrees.

Dr Neuronowski is a software for a tablet that mainly supports classical speech therapy of children and adults with neurodevelopmental and neurodegenerative disorders. However, it can also be helpful for persons without any damage in nervous system and, in such a case, the main purpose is the improvement of the behavioral and brain actions.

The system consists of 10 units, which contain 46 basic games. There are two versions possible: for children and for adults. The basic games are smart, that is they may adjust to the types of disorders and the level of a user; also to the level of a selected unit. This includes in particular a change of parameters of the presentation of stimuli, the number of displayed elements, the speed of presentation and the complexity of a game.

Each of the units is to improve a particular cognition operation such as linguistic functions (e.g., phonemic hearing, sound analysis and synthesis, understanding of speech), visual perception, movement coordination, concentration of attention, logical thinking etc. The names of them are following: initial, introductory unit; patterns of sounds; order of two sounds presented in a sequence; composed sequences; treasures and mazes; verbal games; tales and stories; postponed reactions (only for adults); estimation of a time duration of a stimulus; phonetic hearing and time perception [19], [20].

## 5 Electroglottography method

The voice is one of the main means of communication. Therefore its functioning has a big influence on the efficiency of it. Any of its disorders can make the communication significantly less efficient.

The voice disorders can be of the organic nature (structural and neurogenic), functional (depending on various patterns of muscle tension), or of any combination of the two. For further description of those issues we refer to [10], [23], [24], [25].

The electroglottography method is an instrumental analysis of such disorders, made by the device called electroglottograph (shortly, EGG), sometimes referred to as a laryngograph. Those measurements are performed in non-invasive ways and are based on the electrical impedance measurement between vocal folds during their vibrations in speaking process. Actually no absolute measure of contact

area is obtained, but only a pattern of variation. The obtained results can be followed by practical conclusions, which can serve as guidelines in clinical and logopedic applications of voice rehabilitation. The method can be used in stroboscope synchronization, the study of the singing voice, fundamental frequency tracking of voice and tracking of vocal fold abductory movements.

The technique is quite a new one and it is based on displaying and analyzing EGG signals, providing in this way an intuitive means for quick assessing of vocal fold contact phenomena and their variation over time [5], [12], [17], [18]. It can complement and/or replace the traditional methods of diagnosis of voice disorders such as laryngostroboscopy, fibroscopy, tomography of larynx, and some other of a limited meaning (such as glottography, electromyography, laryngofotokymography) [5], [18].

Laryngograph Processor PCLX possesses three input signal detectors and provides the unique range of analyses of speech and voice. Predefined groups of examples (from simple pitch measurements to complex multi-component analysis) have been set up to help the users. They are [1]:

1. Frequency Fx - pitch range & regularity.
2. Amplitude Ax - loudness range & regularity.
3. Contact Qx - % range & regularity.
4. Loudness + contact + frequency.
5. Pitch & Contact.
6. Frequency Fx & contact Qx - pitch & quality.
7. Aspects of Voice Quality.
8. Frequency Related Measurements.
9. Elapsed Time Measurements.

For example, 23 histograms are determined in the analysis of basic frequency Fx signal, including CFx histogram of the vocal cords work irregularities.

Further computer analysis of speech signal can provide the voice profile of a patient in the form of acoustic parameters such as the average value of basic Fx frequency, its minimum and maximum value, frequency oscillations, standard deviation, the factor of frequency disturbance called Jitter, percentage value of the average occlusion factor Qx, its minimum and maximum value and standard deviation, and the value of voice amplitude disturbance factor (called Shimmer). That material can be analyzed also in various other ways by statistical calculations, parametrical calculations, or graphical processing.

## 4 Conclusion

As we could see on those examples, there are various ways in which informatics can be applied in a support of communication. However all of them have, bigger or smaller, disadvantages. Some of

them need more research on their efficiency, while the other awaits for some improvements of their hardware and software. Anyway, we can observe a constant progress in that area, which makes the life of numerous people much easier. Every year some new computer applications are available that support therapies, possibilities of communication or just life activities of disabled people.

In the near future a significant improvement of the interfaces and a reduction of the cognitive and linguistic demands are expected. Also, some new methods such as brain activity measuring or speech recognition systems indicate new promising directions.

In general, those methods have a solid scientific background. For instance the investigations of the Dr Neuronowski efficiency resulted in several PhD Theses. That software will be systematically modified.

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