JOURNAL OF MEDICAL INFORMATICS & TECHNOLOGIES Vol.6/2003, ISSN 1642-6037

mpaired hearing system,
communication development rehabilitation,
oral ability

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DIAGNOSIS AND IMPROVEMENT OF ORAL DEVELOPMENT OF POLISH CHILDREN WITH IMPAIRED HEARING SYSTEM

The experimental research presented in this paper concerning the evaluation and the development of oral ability of Polish children with impaired hearing system. The aim of the research was the assessment, evaluation of positive changes in the level of oral development. The research have been conducted with the use of two computer attachments: Laryngograph Processor PCLX and Nosality, connected to a PC computer. The obtained results and following practical conclusions can serve as guidelines in clinical and logopedical applications in voice rehabilitation and communication development of groups of non-hearing children whose native language is not necessarily Polish.

1. INTRODUCTION

The basic task facing a child with impaired hearing system is to learn the ability of oral language communication in order to communicate better with the hearing environment. Early revalidation activities, ensuring the child's contact with oral speech in its critical period, namely in the first years of its life, seem to be the most fundamental. If hearing problems appear before 6-8 years of the child's life, then language abilities which are not properly strengthened, will decline (ex. [5]). At present, activities aiming at the development of a language system which enables a non-hearing child to communicate with the hearing population are largely aided by quickly developing computer technology. Its use in diagnosis and rehabilitation of the voice of a child who has problems with achieving proper phonic speech substance covers both computer software and specialized equipment (ex. [6]). This development is being stimulated by significant didactic-educational results that have been obtained. The computer is used comprehensively in this field, enabling the withdrawal of development disorders, the development of intellectual abilities, the assistance of individualistic development and the acquaintance with a new learning and rehabilitation tool. The experimental research presented in this paper concerning the evaluation and the development of oral ability of Polish children with impaired hearing system have been conducted with the use of two computer attachments: Laryngograph Processor PCLX and Nosality, connected to a PC computer. This kind of computer research is the first and unique. It fully considers the specific character of the Polish language, including very difficult dental phones, digraphs and prosodic features of speech, mainly the flow of the melodic waveform, which largely

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influences the understanding of speech in Slavonic languages. Hence, the research results can be applied to not only diagnosis and rehabilitation of children with oral problems, for whom the verbal language is often not a natural language (ex. [2])i.e. those children who cannot hear, but also for those, who have cleft palates or other defects. They can also help teach Polish to foreign students.

2. AIM OF THE RESEARCH

The aim of the research was the assessment, evaluation and positive changes in the level of oral development of Polish children with impaired reception hearing system attending forms 1-6 of special elementary schools (aged 7-13), also younger children (6 year-olds) and older (14-15 years). Individual cases concerned transmission deafness. The research was based on the possibilities of applying multimedia computer technology to the evaluation of speech event through the use of a computer-operated research post in the diagnosis and rehabilitation of children's voices. The post was based on two PC computer attachments: Laryngograph and Nosality (ex. [1]) which monitored the work of the voice, route as a speaking-breathing organ.

The following research problems have been stated:

1. What is the oral level of Polish children with impaired hearing systems and which representative criteria should be adopted?
2. What is the sound expression level in the examined groups of children?
3. What difficulties in the oral development do children with impaired hearing system face, what characterizes their voice and speech?
4. In what way and to what extent can computer technology help with the oral development of non-hearing children?
5. Which factors influence the effectiveness of computer-aided work on the voice quality of a child with impaired hearing system?
6. Which basic features of the Polish language make its proper articulation, including oral expression, difficult to achieve, and how to exercise them?

3. MATERIAL AND METHODS OF RESEARCH

3.1. CHARACTERISTICS OF THE COMPUTER-OPERATED RESEARCH POST

Computer-operated research post was made by joining the two earlier mentioned computer attachments to the computer. The first of them, Laryngograph, was based on electroglottography. Two electrodes are placed on both sides of the throat at the larynx level. The electrical impendence between them is the function of their mutual location, which is changed during larynx vibrations. It is smaller when vocal folds are close than when they are separated. The voltage on the speaker's neck is about 20mW (at the frequency of 1 MHz). The upper frequency limit is ca 5 kHz. In the case of a typical male voice the signal-to-noise ratio is ca 40 dB. In the case of small children and babies the relative noise is bigger, although satisfactory results can be obtained even for newborn babies. The computer screen shows vibrations of vocal folds and the basic frequency of this process.

The measuring result depends not only on vocal folds movements but also on larynx size and vibrating muscles. Thus, the whole phonic structure is evaluated. A separate part of the Laryngograph, namely a microphone, gives the signal which shows changes in the acoustic wave in time (Sp) on the computer screen. These are oscillograms from which, through the analysis of visible changes of vocal wave amplitude in time, its basic acoustic properties, including sound and nasality. However, this way of presentation, does not give full information about proper articulation of nasal phones by the examined person, possible nasality process and its character, as well as the dynamics of air flow through the nose channel, which influences the quality, including the colour of the voice. All these possibilities are offered by the computer attachment called Nosality, which is a part of the research post equipment. An electrode placed on nostrils is its inlet. The waveform generated by this electrode on computer screen shows the dynamics of the air flow through the nose of the examined person, by measuring nostrils vibrations, like an accelerator which measures changes of speed in time, i.e. the acceleration of nostrils movement (lines NxACC). Precise maximum amplitude values can be specified by creating a two-dimensional amplitude-frequency spectrum. PCLX software of the Laryngograph chart has these possibilities. Maximum values, visible on computer screen are called formants. Their frequency and amplitude characterize a phone and are closely related to articulator configuration that has appeared during its creation (ex. [4]). Figure 1 is a deliberately transformed picture for the full analysis of oral efficiency.

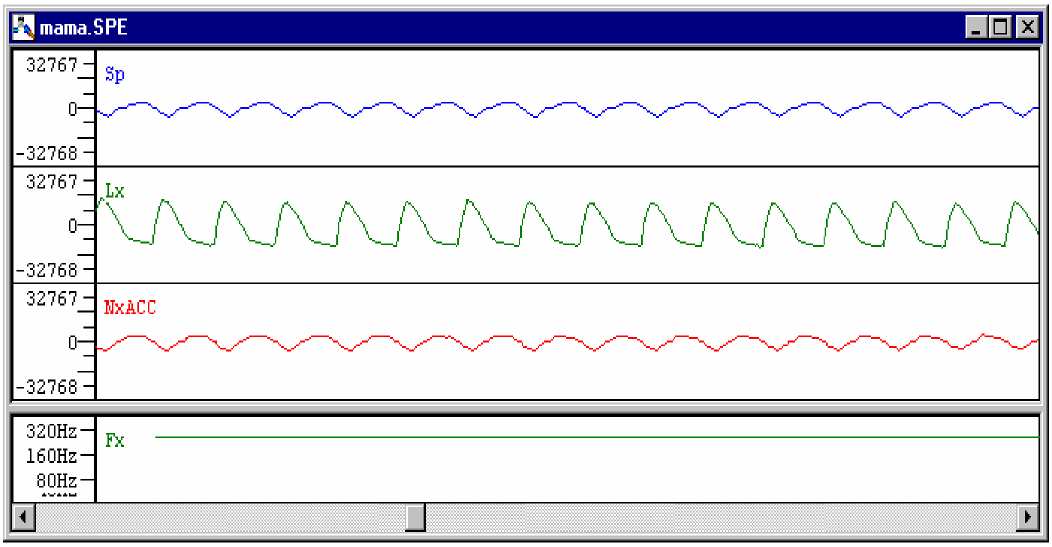

Fig.1 Computer presentation of signal 'mama', enabling the evaluation of child's oral efficiency

The initial signal of the laryngograph Lx (the second waveform in figure 1) reflects the work of vocal folds and is the base for determination of basic frequency Fx (waveform in figure 1). Analysis of the signal cycle Lx helps to separate its three phases. The first phase is a quick signal growth, corresponding to the quick closing of the vocal folds. The second phase corresponds to the slightly slower signal fall and is connected with their opening. The third phase, which is a flat waveform, correspond to the state, when the vocal folds are open. Fx frequency is calculated while measuring of each work cycle length in the middle of the Lx signal amplitude value (in practice, the measurement of time intervals between transitions of the signal through that level is made). The sought Fx value is the reverse of Lx signal cycle length. The shape of Lx signal gives information about any abnormality of vocal route work, especially the work of vocal folds. Sp signal (the first waveform in figure 1) which is obtained form the microphone inlet enables a dynamic visualization of signal timing, evaluation of its volume, loudness and exercising dentalised phones, i.g. pairs s – sz, z- rz, which are very often misused and mistaken by children having oral problems, including lisping. The analysis of Fx signal gives information about all parts of a proper signal, which are easily evaluated even by a child. They are: proper dynamic breathing, economical breathing, work of vocal chords, proper articulation, prosodic features, such as: pace. Rhythm, accent or melody, i.e. these elements, which decide about signal expression and, additionally show the level of phone voicing (no voicing – no picture). NxACC signal (third waveform in figure 1) enables to determine proper nasal phones production, including the work of glottis. Such analysis of voice parameters enables to draw many practical diagnostic-therapeutic conclusions.

3.2. PEDAGOGICAL EXPERIMENT METHOD

The 6-month research covered 88 polish children from a special elementary school in Krakow. They had either serious (70-90 dB, 23 % of all) or deep (above 90 dB, 77% of all) reception hearing impairment. The pedagogical experiment method of parallel groups was applied. During research the following research tools were used: a research chart of the child's voice using words and sentences and a questionnaire, interviewing psychologists and teachers. Group equivalence was checked by comparing selected features of children' voices, such as dynamic breathing, work of vocal cords, nasality, voice pitch, articulation and prosodic features. Accompanying variables which could influence voice rehabilitation progress were also taken into consideration when evaluating the equivalence. Those were: pace of learning, operational memory capacity, constant characterizing the process of forgetting, intellect, sight-movement coordination, age, time and level of hearing loss, family conditions, notes at school, way of communication while using oral speech and the way revalidation had taken place. Calculated mean values, variants, mean tests t and variant F and validity coefficients for the variables mentioned above have shown statistically unimportant differences between the groups. Statistic mean calculated for those variables was totally for the experimental group 3.03, for the control one – 2.96. Statistically unimportant differences of the calculated total means pointed at the equivalence of the examined groups in relation to voice quality, too. Pretest, actual, post and distance research tests were also conducted. Language material for rehabilitation exercises held within actual research was chosen on the base of practical, phonetic, audio and communication criteria. The selected material was characteristic for the Polish language mainly in phonetic terms, since it comprised an adequate amount of dentalised or nasal phones as well as diphthongs . Forms of control were connected with the research tools mentioned earlier, child's observation sheet during actual research and computer diagnostic-rehabilitation equipment. Both samples of speech of hearing children of the same age as the examined ones and all the speeches of the non-hearing children covered by the pedagogical experiment were stored in computer memory.

3.3. PROCEDURES OF ACTUAL RESEARCH

Actual research covered voice rehabilitation of children with impaired hearing system form the experimental group. It lasted six months. A multimedia research post was used for that purpose. Meetings with the children took place regularly twice a week and lasted 30 minutes each. The exercises were divided into breathing, phonation, articulation, prosodic, removing nasality, voice complex and self-improvement of the child's pronunciation. The exercises were chosen to suit individual child's voice needs, depending on the earlier diagnosis and were aimed at achieving the proper ortophonic form of speech. Breathing exercises were the most important and they were added to the remaining ones. Computer presentation was selected for each type of the exercises in such a way that it was the most characteristic for the exercises ability, understood by the revalidated child and, at the same time, easy to interpret for the therapist. The efficiency of the assumed therapeutic procedure depended mostly on the language material, selected for the exercises. Those were: logotomes, onomatopoeias, two- and more-syllable words and sentences, including affirmatives, questions and ejaculations, which show speech expressiveness. At the beginning the material contained mostly vowels, successively linked with nasal consonants such as 'm' or 'n'. It helped to obtain and keep proper voice pitch. In the end, 'r', dentalised and nasal labial phones were introduced (ex. [3]). Self-improvement of the child's speech exercises were language entities and used PC Pitch Target computer. Two identical windows were shown on the computer screen. One showed the model speech of a hearing child of the same age as the examined one, the other one showed the real speech of the child with impaired hearing. Computer memory stores the results and notes about the child's behaviour were made in child's observation sheet by the therapist.

4. RESULTS OF THE RESEARCH

During the pretest research oral ability in selected categories for all the subjects with impaired hearing was evaluated. The results of this pretest are shown in table 1.

Tab.1. Percentage results of the pretest analysing oral ability of children with impaired hearing, n = 88

Category	Evaluation		
	Proper	Partially proper	Improper
Breathing	13%	11%	76%
Work of vocal cords	16%	7%	77%
Phonation	24%	3%	73%
Prosodic features	1%	2%	97%
Nasality	Proper	5%	
	Closed	42%	
	Mixed	46%	
	Open	2%	
	No evaluation	5%	
Articulation	(75%, 100%>	5%	
	(50%, 75%>	23%	
	(25%), 50%>	26%	
	(0%, 25%>	41%	
	No evaluation	5%	

As the data in table 1 show, similar results of the pretest evaluation of oral ability were obtained in categories: dynamic breathing, work of vocal cords and phonation. Ca 70% of the children showed abnormalities in these categories. Prosodic features gave the worst results. Only ca 1% of the children showed proper prosodic features of the features. Ca 5% of the children obtained proper results for nasality and articulation. It should be stressed here that only 2% of the children showed open nasality. Mixed or closed nasality appeared in the remaining group at more or less equal proportions (ca 45%). 5% of the children did not make any articulated voice, therefore evaluation there was impossible. The research enabled to draw quality conclusions about the features of non-hearing children's voices, which are referred to later. According to the research procedure of the pedagogical experiment, an experimental and control groups were selected on the base of the preset results. Then, only in the experimental group the specially designed therapeutic procedure was used. The procedure improved the voice route which was treated as a breathing-phonation organ of the rehabilitated children The results of both pretest and posttest which make the evaluation of the effectiveness of activities possible are shown in table 2.

Tab.2. The effectiveness of the diagnostic-therapeutic procedure, testing increases of practice. Experimental group pretest and posttest n = 44

	Increase mean d	Standard deviation S_d	Student's test t	Level of confidence	Number of increases	Test χ^2	Level of confidence p
Total	2,727	2,003	8,93	0,001	26		
Articulation	4,05	2,33	11,40	0,001	20		
Breathing					14	9,624	<0,01
Work of vocal cords					26	30,788	<0,001
Nasality					16	16,56	<0,01
Phonation					26	31,31	<0,001
Prosodic features					17	19,398	<0,01

Statistic research showed that the practice increased in all categories of the children's oral ability and the adopted diagnostic-therapeutic procedure proved to be very successful. The retention of practice in time was specified on the base of distance test results which were made three months after the actual test was conducted. The comparison of post- and distance tests results are shown in table 3.

Tab.3. Posttest (% of the subjects who made progress in relation to the pretest research) and distance test (% of the subjects who suffered regression compared to the posttest research) results. Experimental group n= 44

Research		Posttest	Distance
Breathing		31.8%	7.1%
Work of vocal cords		59.1%	11.5
Phonation		59.1%	34.9%
Nasality		36.4%	12.5%
Articulation		45.5%	35%
Prosodic features	Accent	4.5%	5.9%
	Rhythm	34.1%	

Distance tests showed that a visible regression took place only in two categories of oral ability evaluation, namely in phonation and articulation. The regression was about 35% and meant the comeback of the observed abnormalities from the period before the actual tests. In the remaining categories the drop was relatively small and ranged from 6 to 10%. Such behaviour could result from the fact that those categories which showed regression were typically trainable and habitual. Hence, the children returned to their earlier habits. The remaining categories were more physiological and their therapy, considering difficulties resulting from the specifics of the Polish language, followed the muscular-aerodynamic theory of voice formation. Therefore the changes in those areas lasted longer.

5. CONCLUSIONS

Computer analysis of selected children's speech samples with large or deep impairment of hearing proved that the majority of them show symptoms characteristic for hyperfunctional dysphonia with mixed or closed nasality. Nasality is functional and is caused by the improper work of the soft palate and glottis. The tests showed: improper, mostly collar bone-rib breathing channel, harsh voice, too low or to high, generally with smaller sonority. Also, there appeared: shorter phonation time, disturbed prosodic features and voice tone with nasality features. The tests and following statistic conclusions showed a very high efficiency of the diagnostic-rehabilitation method suggested here. The comparison of all the progresses (number of people who improved) of the experimental and control groups in a general category, i.e. with no improvement, is shown in table 4.

Tab.4. The comparison of all the progresses of the experimental and control groups

Group	Experimental	Control
Increase mean d	2,727	0,624
Standard deviation S_d	2,003	0,74
Student test t	6,554	
Level of confidence p	0,001	

The tests of the oral ability of children with large or deep hearing impairment enabled to specify the pathology of changes characteristic fort this group in some selected evaluation categories and gave preliminary possibilities of removing them on the base of mainly voice breathing rehabilitation connected with the release of larynx muscle tonus and the work of soft palate muscles and glottis. The fact that the research was made on a statistically valid group of children gave the possibility to generalize presented conclusions and compare them to clinical tests performed in this subject. The analysis of the efficiency of the diagnostic-therapeutic procedure (data shown in table 3 as posttest results) showed that the therapy aiming at achieving proper dynamic breathing is connected with the work on nasality and prosodic features of speech, while the work of vocal cords is connected with the proper voice pitch. The research gave unique, physiological results. Dynamic breathing, the work of vocal cords, voice pitch, and dynamic breathing with nasality behave according to the rules of mathematical implication, which was confirmed by practical tests on a statistically valid group of children. For example, if dynamic breathing is proper, then the work of vocal cords must be proper, too, whereas improper breathing does not have to cause the improper work of vocal cords. Other statistic conclusions from the tests and shown in table 5 specified the influence of the assumed accompanying variables on the efficiency of the therapeutic process.

Tab.5. The efficiency of the therapeutic process vs accompanying variables (increase of practice in general)

Accompanying variables	Mean value x	Standard deviation S	Pearson's correlation coefficient r	Level of confidence P
Capacity of operation memory	0,447	0,174	0,196	n.i.
Pace of learning	0,537	0,203	0,620	<0,01
Forgetting constant	0,0897	0,214	0,423	<0,01
Motivation	0,705	0,456	0,259	<0,1
Intellect	0,818	0,386	0,406	<0,01
Sight-movement coordination	0,705	0,456	0,434	<0,01
Social environment	0,413	0,212	0,314	<0,05

As the data in table 5 show, a statistically very important influence on the improvement efficiency of voice quality of children with impaired hearing had pace of learning, forgetting constant, intellect and sight-movement coordination. The influence of family environment was smaller but statistically important, motivation was not statistically important. The capacity of operation memory played a statistically unimportant role in the process. It should be stressed here that there was no influence on the therapeutic activities of child's age, the course of previous rehabilitation, earlier preferences of the oral speech in communication process, time and level of hearing loss and notes at school. The contribution of the pace of learning and forgetting constant, characterizing time length a child keeps information in memory was obvious in the discussed progress, since they characterize the child's mental speed, i.e. formal properties of information processing. The lack of such influence form operation memory seems surprising, but it could result form connecting computer work on voice quality to repeated exercises imposed by the researcher. Therefore, the subjects based their improvement strategy not on memory scope but on methods of accelerating the learning curve. The influence of other variables, i.e. intellect seen as a mental power having its own contribution to each learning process, and sight-movement coordination, which is connected to perception, seems to be obvious. Disorders of coordination are usually related to disorders of perception and movement, e.g. during speaking. Teaching correct speech phonic substance using the multimedia research post during the experiment had perception-motor character, so the motor level influenced the level of learning. It can be stated then that if the coordination disorder is deep, then the work on oral efficiency using the computer will not be possible. When interpreting statistical results one should consider justification of the weak influence of social environment on the obtained therapeutic results. The same procedure should be applied to justify and even weaker influence of motivation. It was difficult to contact the children's homes because they attended a boarding-school, and motivation referred only to their general inclination to an effort connected with learning, which was largely disturbed with the non-hearing children. The experimental research tests filled the methodology and application gap in the process of using computer technology for diagnosis and development of oral efficiency of Polish children with impaired hearing system. Their results and conclusions can serve as guidelines in clinical and logopedical applications in voice rehabilitation and communication development of groups of non-hearing children whose native language is not necessarily Polish.

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