Modern Tools in Patient-Centred Speech Therapy for Romanian Language

Mirela Danubianu
"Stefan cel Mare" University, 13 Universitatii, 720229 Suceava, Romania
mdanub@eed.usv.ro

Iolanda Tobolcea
"Alexandru Ioan Cuza" University of Iasi, 3 Toma Cozma, 700554, Iaşi, Romania
itobolcea@yahoo.com

Abstract

The most common way to communicate with those around us is speech. Suffering from a speech disorder can have negative social effects: from leaving the individuals with low confidence and moral to problems with social interaction and the ability to live independently like adults. The speech therapy intervention is a complex process having particular objectives such as: discovery and identification of speech disorder and directing the therapy to correction, recovery, compensation, adaptation and social integration of patients. Computer-based Speech Therapy systems are a real help for therapists by creating a special learning environment. The Romanian language is a phonetic one, with special linguistic particularities. This paper aims to present a few computer-based speech therapy systems developed for the treatment of various speech disorders specific to Romanian language.

Keywords: speech disorder, personalised speech therapy, computer-based speech therapy systems, Romanian language.

1. Introduction

Speech is one of the ways we communicate with those around us but in the same time, it is an effective manner to assess the normal growth and development of a person, or to identify potential problems.

Speech disorders address several situations in which an individual has problems to create or to form the sounds needed to communicate. These are easy to recognise because the speech may be difficult to understand, articulation may be unclear, or the fluency may be affected. The common speech disorders are: articulation disorders, disfluency, and voice disorders.

Articulation disorders are the most common types of communication disorders occurring in children under the age of 12, but in most cases they can be corrected if the speech therapy is started at an early stage in the children's development.

Speech therapists must design different ways to treat speech disorder according to the type and severity of impairment. A large variety of treatment techniques may be used for treating affected children, adolescents or adults.

Last years, a particular attention was given to the possibility of using the Information and Communication Technology (ICT) in the process of speech therapy. Research has demonstrated that the combination between the therapist's experience and the facilities provided by information systems has led to an increased efficiency of the treatment.

This paper aims to make a survey of the projects involving computer-based speech therapy for Romanian language which allow building a patient-centred therapy schema.

2. Speech Disorders: Characteristics, Implications and Therapy

Speech and language impairments refer to various problems manifested in communication and associated areas such as oral motor functions (Brice, 2001). From simple problems such as sound substitution to the difficulty of understanding or using the language, these are disorders which, by their nature, do not endanger the life of an individual, but are likely to negatively impact his/her life. Some causes of these problems are: drug abuse, physical impairments, neurological disorders, brain injury or mental retardation. Referring strictly to speech disorders, according to the National Dissemination Centre for Children with Disabilities, they are defined as "difficulties in producing speech sounds, or problems related to the voice quality, and they might be characterised by an interruption in the flow or rhythm of speech, such as stuttering, which is called disfluency, or by the problems with the way sounds are formed, called articulation or phonological disorders" (NICHCY). Also troubles might be related to the quality of the voice or to its volume. Sometimes there may be many combined problems. As such, people with speech problems have difficulty in using some speech sounds, and this can be a symptom of a delay. These individuals may pronounce "lac" instead of "rac" or they may find it difficult to use other sounds like "c" or "g." Listeners may understand with difficulty what a person with a speech disorder is trying to say (Danubianu, Tobolcea, & Pentiuc, 2009). All individuals' communication problems can affect in a negative way their social interaction and their ability to function independently as an adult, and can isolate them from their environment. There are some speech or language patterns, the so called "baby talk", which are part of a normal development, but if they do not correct in time, they can become problems likely to cause learning difficulties. If children have neurological or physiological problems such as muscular or hearing disorders or developmental delays, this could often affect their acquisition of speech, language and related skills. Therefore, it is very important to find the proper moment for intervention (NICHCY). The specific objectives of speech therapy intervention are the "detection, complex assessment and identification of language and speech disorders of preschool and early school children, and targeting speech therapy to correction, recovery, compensation, adaptation and social integration. This latter goal involves the application of a personalised therapy on every child or group of children with similar characteristics, therapy adjusted according to their disease severity, and directed towards eliminating the causes that generated the speech impairment" (Danubianu, Pentiuc, & Socaciu, 2009).

Complex examination provides data regarding social, cognitive and affective parameters, and points out potential general development problems, and articulation or pronunciation problems.

Considering the complexity of the possible disorders involved, there is a need for varied therapeutic methods, ranging from synthesis and analysis, to the global therapeutic specific methods and techniques. As a result, in order for the therapist to be able to choose the best technique for a specific case, (s)he needs to have a very good knowledge of all these methods. Irrespective of the methods used, the therapy stages have to be carried out in a specific order, based on the psychosomatic structure of each child.

The therapy starts with the psychological processes involved (cognitive, psychometric and affective-emotional), and it is built on stages, moments and concrete objectives, materialised in specific therapeutic techniques. The techniques take the form of exercises and procedures carried out by the child in order to reach the final goal: the completion of a correct speech act (Danubianu, Pentiuc, & Socaciu, 2009)**.**

The main issues in speech therapy are shown in Figure 1.

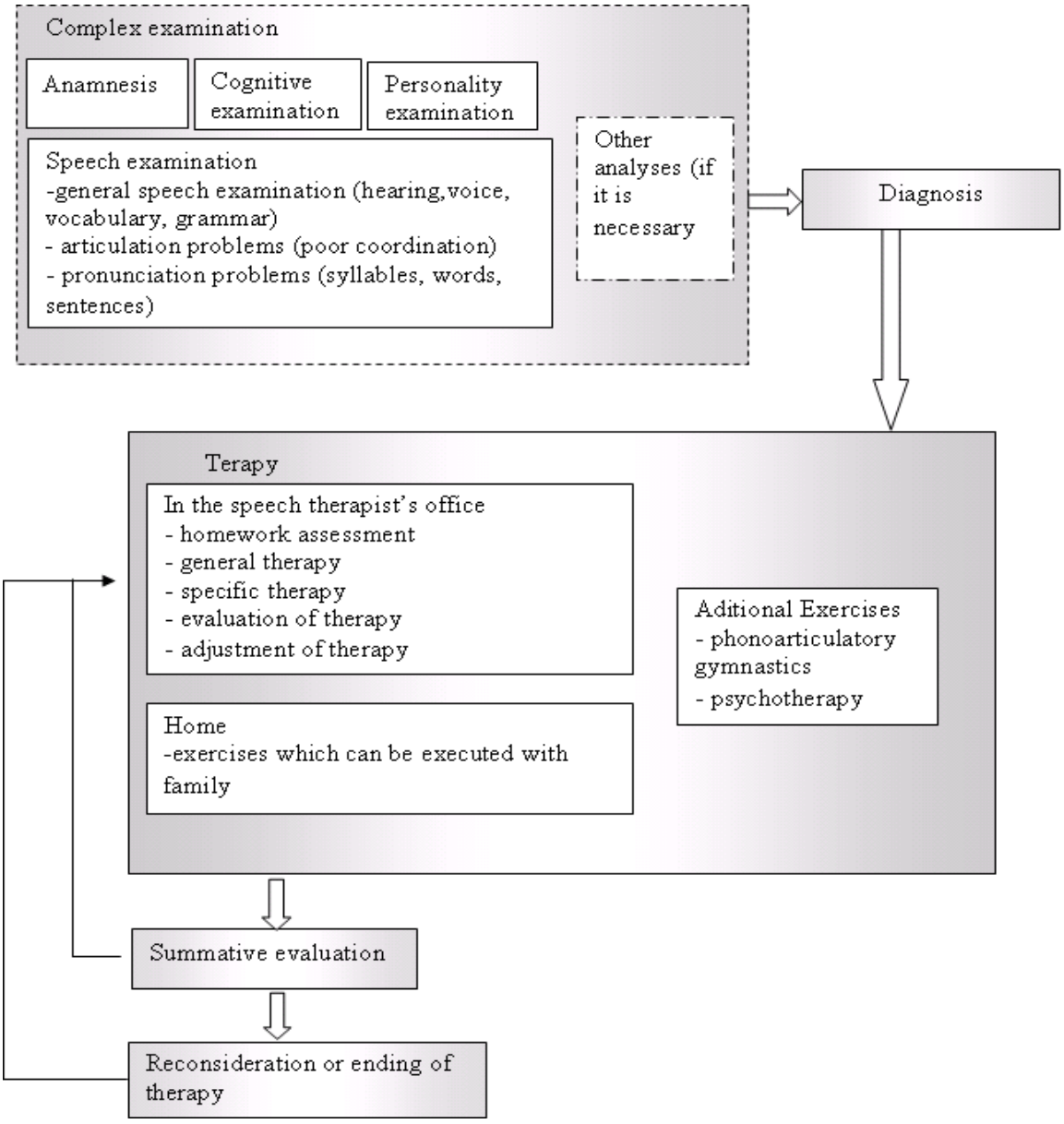

Figure 1. Key issues in speech therapy

3. How Useful is the Information and Communication Technology in Speech Therapy?

Because both research and practice have shown that a significant number of people are affected by such disorders, over the last years, efforts have been made in order to design efficient therapy programs, with the aid of the information technology.

The Information and Communication Technology (ICT) can help children whose physical conditions make communication difficult and, as such, can be employed as a real clinical tool in speech therapy. Therefore, the speech therapist can combine the clinical competences (s)he masters with available technical methods and procedures, and thus manage to help their patients, obtaining assessment, treatment and constant feedback in a more flexible and modern manner.

In speech therapy, computers can help to diagnose a disorder, they can suggest to the therapist a therapeutically schema and also, they can build sets of exercises to be solved in the therapist's office, or when the patients do not benefit from the direct supervision and guidance of a speech therapist (Levitt, 1993).

Used at diverse stages in speech therapy, the Computer Based Speech Therapy (CBST) systems may lead to a new psychological and pedagogic situation. A special learning environment is thus created by means of an innovative, superior method of information retrieval.

Children's interest in the activities used during the therapeutic intervention is cultivated by the rich material resources (such as computers) which provide a more efficient and rapid learning. The computer represents a very useful tool, and, through the systematic introduction of new, rich and high-quality information – which can be reproduced in its natural dynamics and environment – it fuels the child's curiosity and interest in knowledge acquisition, at the same time boosting motivation. As a result, not only does the computer constitute an innovative communication method, but it also contributes to the transmission of emotions, feelings, attitudes, leading to an improved affective life in the child.

Therefore, one may mention some arguments which support the use of ICT in order to improve the speech therapy effectiveness. These are self-assessment tools analysing the errors made and the progress reached, and they allow the patient to hear themselves and judge their progress objectively, because the recording of the verbal samples provide a so called "language immersion" necessary for acquiring a correct pronunciation. CBST systems represent a great support for the therapist in analysing the speech therapy sessions and the feedback received from the patients. They provide the speech therapist with tools for controlling and assessing the effectiveness of the therapeutic strategy initiated, and, if necessary, they contribute to a reconsideration of the strategy. Given their friendly interfaces, these systems create a pleasant, relaxed, and attractive climate, determining a better state of mind. Providing an appropriate feedback stimulates the desire for success, self trust, and the trust in one's own corrective capacities. All these eventually lead to an increased efficiency of therapy.

In conclusion, some of the advantages of using CBST systems are:

1. the possibility to identify aspects, which, by other means, are impossible or extremely difficult to realise, and to separate or recompose phenomena which cannot be perceived by other means;
2. the capacity to playback the content extremely accurately, and to allow immediate playback of the information or as often as necessary;
3. given the original aspects involved, and the aesthetic way in which information is presented, these systems are particularly attractive to children;
4. they always maintain the child in the present day situation.

4. International Projects

At international level there are some programs and systems designed to assist and to improve the speech therapy, most of them for English language. One may consider a few aspects that underlie them. First, therapy sessions appropriate for each speech disorder and adapted for each patient are designed. These are based on real-time audio-visual feedback of the patient's speech. Secondly, speech evaluation is provided by means of the automatic speech recognition on the basis of data collection statistical models during the training phase, and finally, they allow the evaluation of progresses that the patient achieves.

Aphasia Tutor 0: Sights 'n Sounds is a system which allows training the articulation and identification of words through auditory discrimination and repetitions (bungalow software).

Speech Sounds On Cue focuses on independent language practice for individual sounds and complete words (bungalow software).

The *OLP (Ortho-Logo-Paedia)* project (Oster et al., 2002) financed by the EU is started in 2002. It is a complex project, which involves collaboration between the Institute for Language and Speech Processing in Athens and seven other partners from the academic and medical fields. It joins three modules, namely OPTACIA, GRIFOS, and TELEMACHOS, that are able to instruct children suffering from dysarthria (difficulty in articulating words due to a disease of the central nervous system) in an interactive way. It thus proposes an interactive and visual environment adapted to the

subjects' age (games, animations). The audio and video interface with the human subject is the OPTACIA module; the GRIFOS module enables the recognition of pronunciation, while the third module, TELEMACHOS, integrates the computer aided instruction.

STAR (STAR Speech Training) is another interesting project – Speech Training, Assessment, and Remediation (Bunnell, Yarrington, & Polikoff, 2000). It started in 2000, and is still in the development phase. The aim of the members (AI. duPont Hospital for Children and The University of Delaware) is to build a system which at the beginning could recognise phonemes, and later, whole sentences. The research group provides an audio processing voice generation system (Model Talker) as well as a variety of open source applications of the kind.

The Speech Processing Group, and CENTIA Universidad de las Américas, Puebla Cholula, Pue. México have developed the *ICATIANI* device. It relies on sounds and graphics that allow ensuring the practising and exercise of Spanish Mexican pronunciation (Kirshcing, 2003). It offers more lessons that explain the pronunciation of sounds by means of the facial expression, placing particular emphasis on indicating the points of articulation and the lips position. There is also a variety of animated faces; each of these point to the correct vocal pronunciation method, and provide feedback to the work of the child. For example, if the pronunciation of the child matches the one of the system, the child is rewarded with a smile or, conversely, (s)he is warned by a sad face.

5. Achievements for Romanian Speech Therapy

We start from the assumption that the Romanian language is a phonetic language, having its own linguistic peculiarities. This leads to the necessity to develop specific systems which can be used for different speech or language problems therapy.

As a result of the research conducted at the "A.I. Cuza" University of Iasi, and "Stefan cel Mare" University of Suceava, a few projects were developed with the view to assist the speech therapists in their efforts, to determine the most appropriate diagnosis, to design a better therapy, and to track and evaluate the patients' evolution.

Echophone

The construction of the Ecophone has as starting point idea that a clear and correct reception of its own sounds creates to an individual a real image of his pronunciation, and, by the awareness of progress in therapy, he reinforces his will to correct its defects as soon as possible.

The Ecophone is a system which allows achieving the delayed auditory feedback (DAF) (Tobolcea, 2001). It was the first device built to help patients to correct their speech rhythm and fluency. Its architecture is presented in Figure 2.

With the help of the microphone, the patient utters the words in a rhythmical manner, with a view to hear them like an echo. With the help of this device, the patient has the possibility to acknowledge his/ her own articulation, while controlling his/ her own speech and voice. During the occurrence of verbal disfluencies or spasms, spontaneously and following a certain break, the patient with speech disorders regains his/her speech, managing to pronounce the words in a fluent and correct way.

It can be concluded that, with the help of the Echophone, great performances can be achieved in the speech re-education of the patients with speech disorders, by delaying the auditory feedback. Additionally, the Echophone contributes to increasing confidence and courage in the patient, as (s)he acknowledges the progress (s)he made; this encourages the patient to express him/herself correctly and fluently.

Logoped 1.0

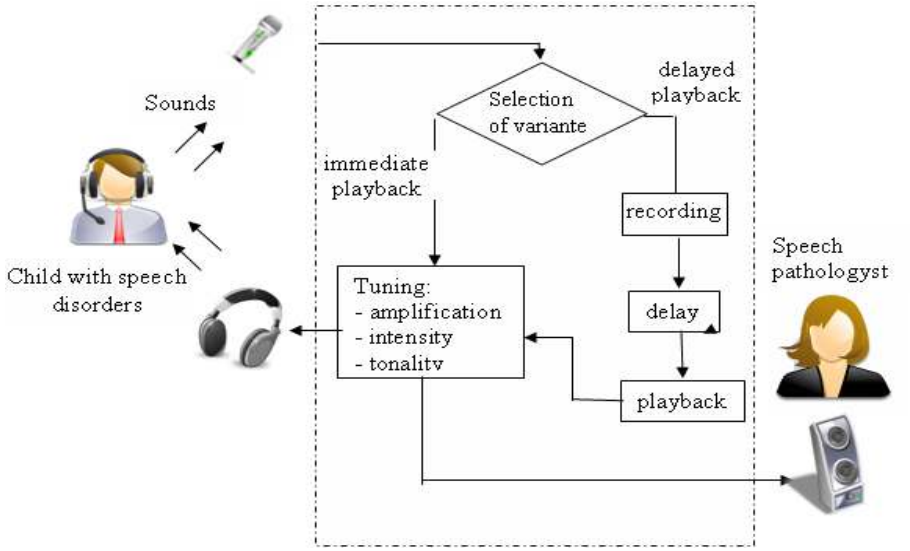

Figure 2. Ecophone architecture (Danubianu, Tobolcea, & Pentiuc, 2009)

The program was designed for the therapy of logoneurosis, while being equally useful for the therapeutic activities used in the treatment of dyslexic-dysgraphic disorders. Logoped 1.0 provides a vast lexical material, which is organised into several sections: exercises involving reading the syllables and the words, sentences reading, followed by phrase and text reading. The colourful design of the words and sentences, the attractive way in which they are displayed on the monitor, and the fact that it allows choosing the exercises level of difficulty render the reading activity much more attractive for the pupil (Tobolcea, 2001). Its functional schema is presented in figure 3.

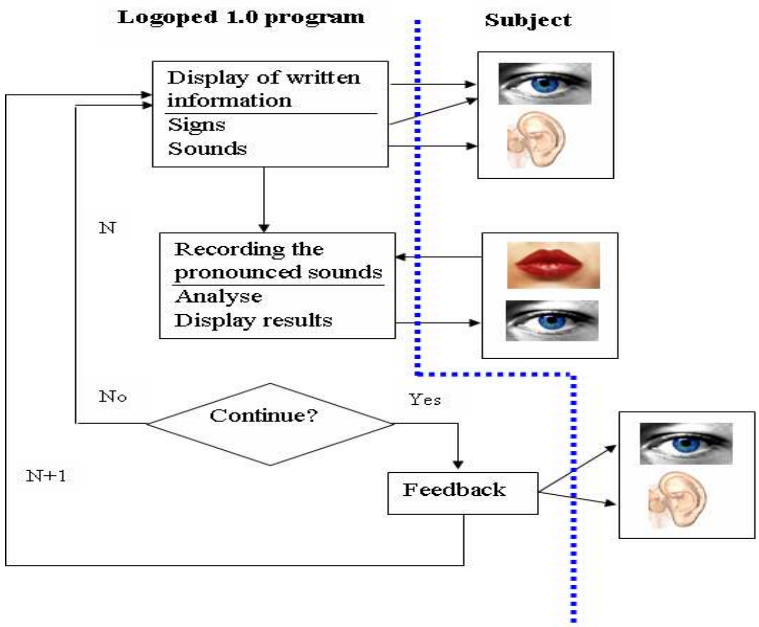

Figure 3. Logoped 1.0 program

Compared to the traditional activity, this program brings some advantages:

- the material included is gradually presented so as to fulfill all the demands of a progressive treatment;
- it stirs much more the interest and dynamism, drawing the pupils towards participation in the therapeutic activity, due to the colored writing, and the rhythm of the reading activity; moreover, the results are displayed on the right side of the screen, which motivates the subjects to outgrow their current performances;
- the performance level set by the computer are reached depending on the physical and mental capacity of each subject;
- an active "subject-computer" relation is created by the appraisals provided by the computer for the subject's performances ;
- the promise of a reward further motivates the subject's performances (Tobolcea, 2001).

Terapers

Information systems which provide real-time feedback in addressing pathological speech impairments have emerged relatively recently in particular given the wide processing power they involve (Chivu, 2007). However, presently, the progress recorded in the field of computer science fosters the development of such a system, which involves a much reduced number of risk factors. The pronunciation of children is also used to complement the existing database of audio materials, and to contribute to improving the performance of the current diagnosis system.

Terapers – the personalised system for the treatment of dyslalia has achieved some specific objectives (Danubianu et al., 2007; Tobolcea, 2002):

- the initial and ongoing therapy assessment of children and the identification of a method for standardising their progress or regress (from the point of view of the physiological and behavioural parameters);
- the rigorous formalisation of an assessment methodology and the creation of a relevant database in this field;
- the design of an expert system used for the individualized treatment of speech disorders that allows for the design of a pronunciation training scheme, personalized according to the type of speech disorder, the child's prior experience, and his/her previous therapy evolution;
- the design of a therapeutic guide that permits to combine the classical methods and the complementary procedures and techniques of the audio-visual system;
- the development of a database which includes the child's data, the exercises used during the therapy, as well as the child's results.

The project's complexity results from the considerable number of research fields it presupposes: artificial intelligence (pattern recognition, learning expert systems), virtual reality, digital signal processing, digital electronic (VLSI), computer architecture, and psychology (assessment procedures and techniques, therapeutic instructions, validation experimental design).

In order to assure an assisted therapy one considers the relationships between six functional blocks: patient, speech therapist, office monitor program, expert system, 3D model and patient monitor program. The information flow of the system is given in Figure 4.

There is a close connection between the child, as a patient, and his speech therapist. All the other modules are designed so as to contribute to the therapeutic action of the teacher. The monitor program allows realising a complex assessment and collecting information about the child; equally, it provides the opportunity to periodically track the child's therapy results. The child is provided instant audio feedback which allows him/her to check the audio recordings history. The home monitor program is designed so as to build a virtual interface between teacher and child in order to allow the patient to continue his therapy at home. This component is designed both for the personal computer, which is placed in the therapist's office, and personal digital assistant (PDA) which is used at home for independent work.

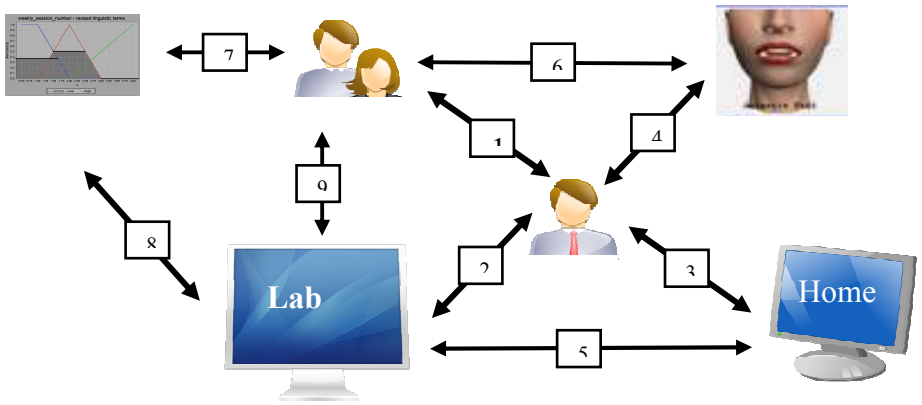

Figure 4. The relationship between the functional blocks of the system

It can provide more attractive exercises, give feedback, and can draw statistics based on the scores obtained by the subject (Cerlinca et al., 2007). The 3D model allows viewing of the correct positioning of the lips, language and teeth for each sound. The child is free to change the transparency of any of the items involved. The monitor program allows transmitting the homework onto the child's PC or PDA. Thus, at a later stage, as the child returns for therapy, an activity report is available.

The speech therapist analyses the images provided by the 3D model, and is able to correct some of the mistakes made. If activated, the expert system can make suggestions regarding some of the training parameters of the treatment session, such as the frequency, the length or the content (exercises) of the sessions, based on the input variables. Should the teacher notice erroneous conclusions, the inferential route can be checked, and changes can be brought to the knowledge base. By taking the data input from the monitor program, the expert can generate sets of personalised exercises upon request.

The monitor program represents an interface between the speech therapist and the other components, such as the expert system, the database, or the child monitor program. It is at this stage that the speech therapist is able to gather information (both textual and audio) for each child, manage exercises, as well as all the other therapy aspects: children selection, therapy schedule, required statistical reports.

Shown in Figure 5, the architecture of the Terapers system implies the existence of two main connected components: on the one hand, an intelligent system which is installed on the office computer of each speech therapist and, on the other, a mobile system which is used as a virtual friend in the therapy applied to the child (Danubianu et al., 2008). The intelligent system – which represents the fixed component of the system – is installed on each computer from the office of the speech therapist; it is made up of the following parts:

- an information management module for children;
- an expert system, able to produce inferences based on the data given by the assessment module;
- a mouth virtual module which allows the display of all hidden movements that are likely to occur during speech;
- a management module of the exercises uses, which allows creating or modifying the exercises, depending on the various therapy stages, as well as their organization into complex issues.

The mobile device is designed based on two main objectives. First, it is a tool the child relies on in solving the homework given by the speech therapist and, secondly, it transmits to the intelligent system an individualised activity report for each child.

The intelligent system is used by speech therapists for: collecting and analysing the child's specific information (as a result one can obtain automatic special reports); producing phoneme audio recordings and scoring them (for each altered sounds); obtaining the support of an integrated expert system in making decisions; creating and assessing a large vast of exercises for children; transmitting homework onto the child's PC or PDA, and obtaining the activity report (Danubianu et al., 2007).

Figure .5 Architecture of the Terapers system

In order to assist the child's individual training, a mobile device must offer some facilities, such as: presenting the exercises that the child is required to solve; reaching, during the therapy, personalised interaction with the human subject; providing the possibility to assess and stimulate the progress obtained by the human subject by means of the given feedback; allowing to collect audio samples, as well as the exercises solved by the child; and allowing communication with the computer of the speech therapist.

The device provides two important facilities: multimedia facilities (it allows recording, processing and playing audio samples) as well as graphic facilities (it provides a friendly and accessible interface). In Figure 6 is illustrated the main page of the application that is implemented on the mobile device (a), as well as two types of exercises; (b) the child is required to identify whether a sound is present in a word (which is indicated by an image); and (c), the child is required to choose a word from a group of paronyms.

a b c

Figure 6. Three interfaces available on the mobile device

Starting with March 2008, the system has been used to assist the personalised therapy of dyslalia by the specialists from the Regional Speech Therapy Center of Suceava, and it has already proven its viability and efficiency. To demonstrate this fact, we perform an assessment of the system.

For the research we selected 60 children suffering from dyslalia: 30 subjects for the experimental group - which received computer-based therapy - and 30 subjects for the control group. These last 30 subjects underwent classical therapy. The sample of subjects was made up of 8-9 years old children with a normal level of intelligence (they were selected based on the Raven test). In the selection of the children we considered the homogeneity criterion; additionally, the average scores obtained were equivalent for the complex evaluation tests, which was demonstrated by the application of the Anova One Way and Bonferroni tests (Tobolcea and Danubianu, 2010).

Following the logopedic assessment of the investigated subjects, we moved on to the statistic processing of the gathered data, and we analysed the results obtained from the tests administered to the two groups after one year of speech therapy. The conducted analysis was directed both at the overall effectiveness of the speech therapy, and at the importance of strategies for the language development and stimulation, through the use of the computer-assisted Terapers system. It was noticed that the results obtained for the dyslalic subjects (children with pronunciation disorders) from the experimental group improved significantly due to the computer-based therapeutic program, compared to the subjects in the control group (who underwent classical therapy). The mean, the standard deviations and the standard error of the mean obtained for the independent speech variable in dyslalic children (control group and experimental group) are presented in Figure 7.

Group Statistics

	GRUP	N	Mean	Std. Deviation	Std. Error Mean
independent speech test	control	30	16.6333	1.12903	.20613
	experimental	30	18.0667	.98027	.17897

Figure 7. Results obtained for the mean, the mean standard deviations and the mean standard errors of the independent speech variable in dyslalic subjects (both the control and the experimental group)

The qualitative analysis of the data revealed the main elements contributing to the effectiveness of the computer-based program used in speech therapy: the high interest demonstrated by the subjects, the increased attention children pay to the computer, which facilitates the task of the speech therapist, who no longer has to rely on the classical pencil and paper tools, but simply on the mouse.

Logo-DM

The idea of applying some data mining techniques in order to improve the quality of the logopedic therapy started from the TERAPERS project presented above that is used by the therapists from the Regional Speech Therapy Center of Suceava since March 2008 and allowed collecting a vast amount of data.

These days the key word is “performance” in all areas of life. So, in order to provide a good and performing speech therapy we should be able to answer some questions such as:”what should the final state for a patient be, or what will his/her state be at the end of each stage of therapy, which are the best exercises for each case, and how will they focus their effort to effectively solve these exercises, or how is the family receptivity associated with other family aspects and personal anamnesis” (Danubianu, Pentiuc, & Socaciu, 2009). In addition to this it should be very useful to quicker and correctly establish a diagnosis by considering some features that could group and classify patients in classes labeled with specific impairment names. All this may be obtained by applying data mining techniques on data collected by the TERAPERS system. It could be also very useful to try to enrich the knowledge base of the embedded expert system with some rules built by

data mining algorithms. In order to achieve these goals we proposed the development of the **Logo-DM** system**.** It aims to perform the following tasks:

- to understand and analyze the available data in TERAPERS datasets;
- data preparation (pre-processing) in order to assure a proper data quality for data mining algorithms;
- the use of corresponding data mining methods and algorithms that can be applied in order to find models which can answer to the problems raised in speech disorders therapy;
- interpretation and evaluation of generated models and their validation on new cases;
- enrichment of the knowledge base of the expert system embedded in TERAPERS with new rules obtained as patterns by data mining algorithms.

The useful data mining tasks for speech therapy fall into three categories: classification, clustering, and association rules. Classification places children with different speech impairments in predefined classes, and makes possible to track the characteristics of various groups. To model different classes we use many predictor variables (e.g. personal or familial anamnesis data or related to lifestyle). By clustering we group people with speech disorders on the basis of similarity of different features. This helps therapists to understand their patients. Clustering aims to find subsets of a predetermined segment, with homogeneous behavior towards various methods of therapy that can be effectively targeted by a specific therapy, but it is not based on the previous definition of groups (Danubianu, Tobolcea, & Pentiuc, 2009). Association rules aim to find out relationships between different data which seem to have no semantic dependence. The built patterns might be very useful to determine why a specific therapy program has been successful on a segment of patients with speech disorders, and on the other was ineffective.

The Logo-DM system was designed to help the speech therapists to optimize the personalized therapy of dyslalia. To understand what kind of knowledge we could discover in TERAPERS' dataset to improve speech therapy, we have to describe the collected data.

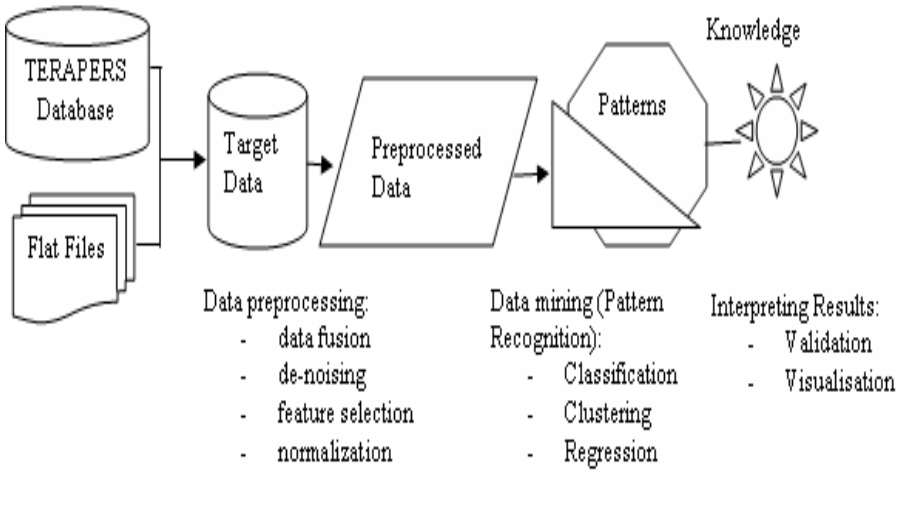

Figure 8. The end-to-end operations in Logo-DM

In order to design the therapy program, as shown in Figure 1, the therapist must perform a complex child examination. This is materialized in records of relevant data relating to personal and family anamnesis that provide information regarding various causes that may negatively influence the normal development of the language. It also contains historical data and data provided by the cognitive and personality examination and last, but not least, it contains a set of tests that show how the children articulate the phonemes in various constructions, allowing to establish a diagnosis. Then, speech therapists design the therapeutically path by establishing: how many sessions of

therapy are needed, and their distribution, what exercises are proper for each patient and for each phase of therapy, and how the original therapeutic program could be corrected to meet the patient evolution. In addition, the report downloaded from the mobile device collects data on the efforts of the child's self-employment. These data refer to the exercises done, to the number of repetitious for each of these exercises, and to the obtained results. The tracking of the child's progress materializes data which indicate the moment of assessing the child and his status at that time. The data stored in the TERAPERS's database together with data from other sources (eg demographic data, medical or psychological research) is the set of raw data that will be the subject of data mining. Figure 8 presents the complete sequence of the operations applied on these data.

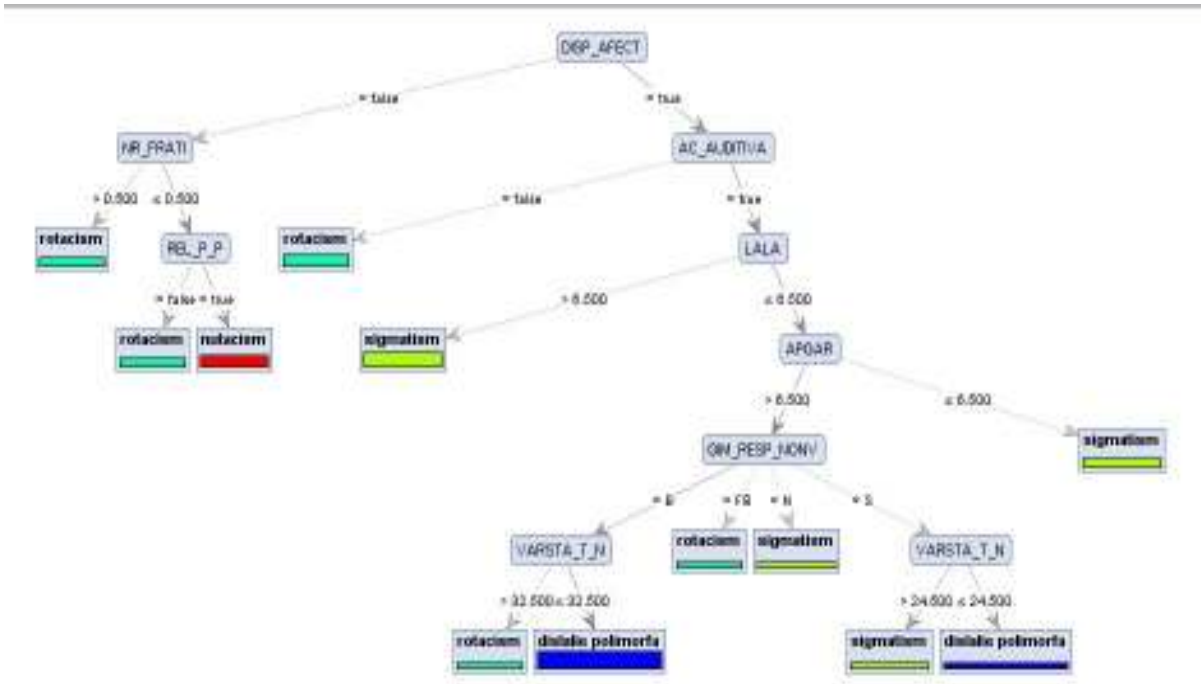

Figure 9. A model that helps the diagnosis prediction

We have already implemented many modules of Logo-DM, such as: data cleaning module, data transformation module, feature extraction module, data clustering module and a classification module for diagnosis prediction. Figure 9 shows the model achieved using a decision tree built on complex examination data that aims to predict the patient's diagnosis.

Currently, we are testing the built models on new cases in order to estimate their quality.

6. Conclusions

The information systems have been assigned a variety of roles: from the mere replacement of the classical teaching materials which were simply drawn with (3D) images displayed on the computer monitor, to the use of the computer as an actual assistant that the speech therapist can rely on; from this perspective, the computer participates to the assessment of an individual's state of health, takes part in the diagnosis establishment, in conceiving an individualised treatment plan, as well as in the follow-up to the treatment.

As a matter of fact, the CBST represents the most complex strategy involving audio-visual techniques. Its great advantage consists in the development of educational and instructive software programs, as well as in the fact that it fosters and increases the didactic activity efficiency.

CBST systems developed at the international level are rather expensive and inadequate for the specific phonetics of the Romanian language. This is the starting point of research that has led to the development of some dedicated systems such as: Ecophone, Logoped 1.0, and Terapers. More

than that, because TERAPERS allowed collecting a consistent set of data, it was possible to design and to start the implementation of the Logo-DM system that aims at helping therapists to optimize the personalized therapy of speech disorders.

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