Experimental Results Obtained in Computer Assisted Auditory-Verbal Education

Ovidiu Grigore. ValentinVelican. Alexandra Craciunoiu.

Abstract**—** The article discusses principles of designing and implementing an educational software application intended for auditory-verbal education of hearing impaired children. Furthermore the paper presents an ActionScript 3.0 based application developed by the authors, discussing and motivating internal architecture choices made during the development process.

Keywords**—** auditory-verbal, e-learning, software design, implementation

I. Introduction

THE ability to perceive sound is a fundamental requirement in the correct development of the human being. Correctly perceiving and understanding sound is the basis of interaction between the world and an individual. From a very early age the process of discovering everything that surrounds us implies correctly assessing and correlating sound and visual stimuli. Therefore, the malfunctioning of the auditory system determines the human to be subject to a complex restructuring process of the acting strategies and of the sensorial and psychic compensation strategies. The sense of orientation and in particular the development of the verbal language and the performing of its functions will be disturbed; the absence of a fluent communication means bringing into danger the active integration of the person in the life's social flow.

A classic methodology of auditory system recovery implies regular visits to specialised cabinets from a very early age, in order to train the child to correlate sound stimuli with images of the emitter. The effectiveness, in this case, could be quite limited as specialised centres are very few and due to distance poorly accessible by some patients. Also in the case of a large number of children needing treatment, the personnel may be overwhelmed and find itself unable to correctly supervise all the recovery exercises performed by the children.

This work was supported by CNCSIS–UEFISCSU, project number 853/2009.

The paper was presented at the **14th WSEAS CSCC Multiconference** in Corfu Island, Greece on July 22-25,2010 having **ID no.646-529**.

O. Grigore is with the Polytechnic University of Bucharest, Department of Applied Electronics and Information Engineering (e-mail: ovidiu.grigore@upb.ro)

V. Velican is with Polytechnic University of Bucharest, Department of Applied Electronics and Information Engineering. (corresponding author, phone: 0040745765137, e-mail: valentin.velican@upb.ro)

A. Craciunoiu was with Polytechnic University of Bucharest, Department of Applied Electronics and Information Engineering. (e-mail: alexandra.craciunoiu@gmail.com)

The computer assisted education or 'e-learning' is nowadays a growing field. Developed to facilitate the learning process, it presumes logic, sequential ways of presenting information in order to make it easier for the students to assimilate knowledge, in a personal, unconstrained and unsynchronized manner. E-learning type computer applications also aim at making the learning process more accessible, by offering internet based solutions that disseminate information in an easier and more rapid way.

Therefore a computer application, designed to improve the auditory education process of young hearing impaired children should offer not only the advantages of the already tested classic methodology but also, additional, e-learning type characteristics.

II. Problem Formulation

The auditory education which prepares the auditory-verbal education was and remains a priority in the recovery methodology panoply, especially for the hearing impaired persons. This is very important for the compensatory process in all shapes of disabilities or developmental disorders as well as in the early education of children without disabilities, thus sustaining the linguistic development and their cognitive processes. In [6] it is underlined the fact that one cause of the lacking of response to word stimulation, besides the auditory deficiency degree, is represented by the inability of freely detecting meaningful verbal material. When trying to rapidly develop the comprehension and verbal language articulation abilities, the stage of practising the skills of auditory acceptance of the nonverbal sounds is in many cases neglected. These lacks are added to the causes determining the low intelligibility of hearing impaired persons' language, decreased scholar performances, and difficult social integration, revealed by the local and foreign literature [7], [8].

The main issue encountered when developing an e-learning type application represents an incorrect development process, where different stages are mixed or skipped. In order to correctly associate a sound with the visual information, the child first has to hear it, listen to it and therefore consciously and actively accept it. Following the established methodology, there are some distinctive stages that the child should run over in order to successfully complete an auditory-verbal education process:

1) Stimulating the attention towards auditory acceptance;

2) Detecting, differentiating, identifying and recognizing the nonverbal sounds in the nature (objects, natural phenomena, animals);
3) Identifying and differentiating, recognizing and reproducing the verbal sounds; comprehension and articulation of the simple and complex verbal structures.
4) Imposing practice of the prosodic traits of language: rhythm, accent and intonation.

It is therefore mandatory to follow these theoretical stages in order to correctly build a software application with the intended goal.

III. PROBLEM SOLUTION

A. Approaches in auditory-verbal education

1) It has to be taken into consideration that the interest in an active auditory acceptance is a matter of motivation, and only then, a matter of education. Developing an active attitude towards accepting the environmental sounds, means enhancing the impaired child's chances of a better integration not only in the physical environment but also in the social environment too. Of course this is achieved through the development of the verbal language (as a consequence of the active attitude towards environmental sounds acceptance) and through increasing the informational processing capacity. Therefore a special attention should be granted to auditory acceptance and listening process, for activating this new sensorial channel, for accommodating with this new category of stimuli, the auditory stimulus; for detecting, differentiating, identifying and finding meaning to environmental sounds, including the verbal language which might be firstly perceived as a foreign language, as the literature reveals [1] [2] [3].

An e-learning computer application that respects such considerations should present an appealing interface with abundant games, imagery and sounds, integrating ease of access and interacting with the child up to an emotional level.

2) It is highly important to deliver the stimuli in a sequential manner, progressively increasing the degree of difficulty and constantly monitoring the ability of the child to assimilate a given quantity of information. It is assumed that a correct perception and association of the stimuli with its real correspondent can be done by isolating at first sounds of simple meaning, nonverbal by their nature and only then presenting more complex situations. A computer application should consequently contain a stage of nonverbal training and testing, presenting simple sounds and images of their emitter. Of course, later on, the child should face more complex sounds or should be placed in a situation where it has to carefully listen and then associate sounds with images.

After the understanding of simple sounds (most of them environmental) has been assured, the child can now move to a more challenging level where verbal sounds have to be assimilated. It is important though, to remember that a nonverbal training stage (which includes features that stimulate the attention of the subject) is mandatory in designing a software aiding tool, as an approach too rapidly to developing the verbal language may lead to a lack of the ability to freely categorise the presented material and consequently to a lack of word stimulation. [6].

3) Recognizing and reproducing verbal sounds is the next logic step in the process of auditory-verbal education. At this point the child should be progressively stimulated with verbal structures of increasing difficulty on similar principles as presented on the previous paragraph and monitored on his progress.

4) One last but important factor in correctly developing an e-learning auditory-verbal recuperation application is to impose practice of prosodic treats of language. It should not be forgotten that accent, intonation or rhythm are elements that complete the definition of correctness of a language and therefore a section of the computer program should be dedicated to such type of exercises.

B. Further Ideas to Consider

An important factor to be treated when designing an e-learning application is the accessibility of the software. A client-server architecture or web-page like applications are to be preferred in order to give the opportunity to children in remote places to access an efficient education method. Furthermore an application designed in such a way, should feature the capability of recording the progress data of students, disseminating the results towards specialists for further analysis.

When it comes to the user interface, the application should contain a setup section in order to modify its functionality according to the level achieved by the student. The setup menu should be accessed by the specialists or by a person following closely the specialist's recommendations. The "education" and "testing" interfaces should be designed in an intuitive and in an "as simple as possible" manner. Implementing a hardware interface that replaces the keyboard or mouse or implementing the application on a touch screen system (where possible) should be also taken in consideration as it is important to maximize the concentration of the child towards the stimuli and not to other factors.

The hypothesis from where to begin in developing a completely independent stimulation algorithm is that an association of the auditory stimulus in a certain manner (frequency, length and periodicity) with the image and with the word defining the image, determines on one hand the development of the auditory memory for that auditory pattern and on the other hand the development of the visual memory for the written shape of the word which designates the source of producing the auditory pattern. A truly general plan to develop such an algorithm is not applicable as efficiency is subject to change due to the user's ability to learn; therefore in such cases, an adaptive way is to be preferred to a strictly rigid one. Therefore, an application that implements such an algorithm is supposed at first to screen the subject by extracting features regarding the subject's activity (test results, the rate at which the images were presented, the sounds and images that were presented, etc), correlate them with the subject's ability to learn and in the end adapt al the test parameters in order to obtain better results.

One last important feature to be mentioned is that the application should contain an as broad as possible database of sounds and pictures, in order to make it more interesting and challenging for the users. Let us once again remember that, by far, the most important factor is to attract the child and not to oblige him to use the program. Also this prevents the possible situation where a child learns to associate a sound with a certain image and not with the subject presented by that image (the sound emitter). Therefore similar images and similar sounds (that present the same type of stimuli) should be used.

C. An Example of Auditory-Verbal Education "E-Learning" Application

Considering all the presented ideas above, the authors developed a simple, e-learning type application, which aims at helping children with affected hearing in associating visual stimuli (in this case pictures of objects, animals or natural phenomena) with sound. The application has been written in ActionScript 3.0 in order to make it accessible remotely, by internet and represents the basis of further development that will be made in this field. Also, it has to be mentioned from the very beginning that the application represents the first stage in the development process of a more complex product, and it does not contain at the moment an adaptive algorithm or a fully automated functioning mode. The education process is presented at a predefined rate, and it's parameters are chosen by a supervisor, from a setup screen.

The entire architecture features two main sections, a "training" section in which the child, supervised by an adult, has to learn new stimuli and a "testing" section in which the child is verified in order to see the achieved level after a period of training. Both these sections are preceded by a setup screen in which the supervisor can choose the parameters of stimulation.

Before going any further it has to be mentioned that the person who supervises the entire process does not have to be trained in auditory recovery methodologies; the supervisor should only help the child by showing him how to use the computer mouse and what he should pay attention to, and intervene only in limited cases (configuring the tests).

In the "learning" section, the interface is as simple as possible with images displayed while associated sounds are being played. The supervisor decides when to start the stimulation, at a click of a button. Also, using the setup screen, the supervisor decides the category of stimuli to be used and the delay between the appearance of the image on the screen and the moment the sound is being started. (Fig.1). The child is only requested to watch and listen as a slideshow of pictures and their associated sounds is being displayed. (Fig.2)

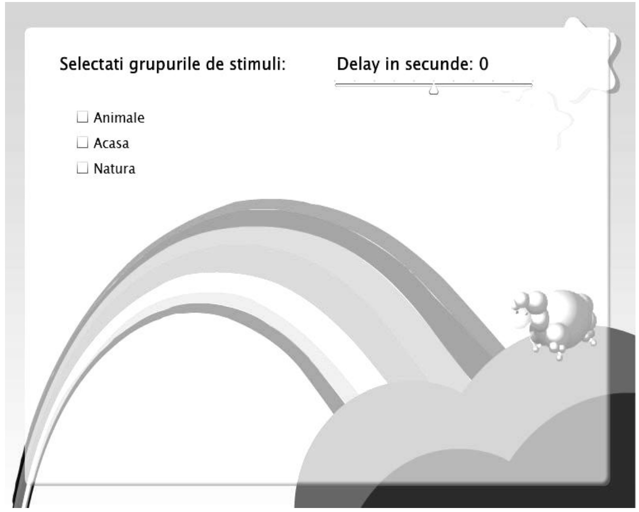

Fig. 1 education stage; setup screen

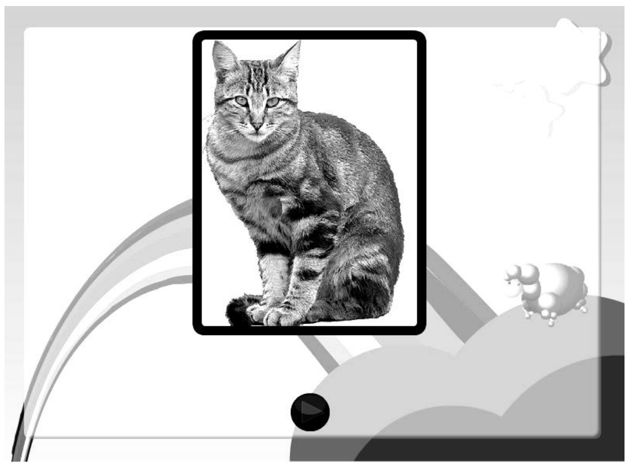

Fig. 2 learning stage

The "testing" is based on a similar interface (images and sounds) but this time, several pictures (2 – 4) are displayed at a time. The child is requested to choose the correct image associated with a sound being played (Fig.3). The setup screen for the tests, presents more options. As can be seen in (Fig.4), the supervisor can choose the category of the stimuli, the number of questions, the delay between sounds and pictures, the number of simultaneous displayed images, etc. The results of the test are being shown at the end using simple bar graph architecture. (Fig.5)

The application can be found at the following web address: *http://ai.pub.ro/education.html*

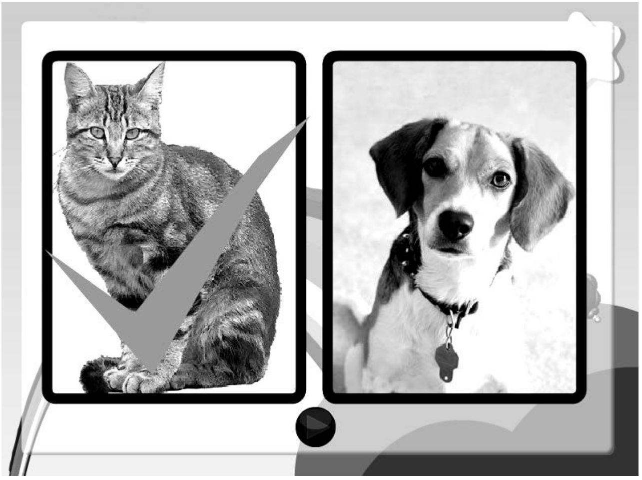

Fig. 3 testing stage

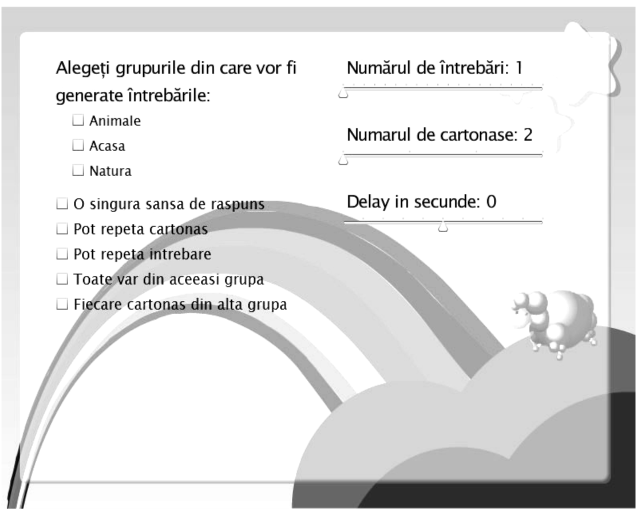

Fig. 4 testing stage; setup screen

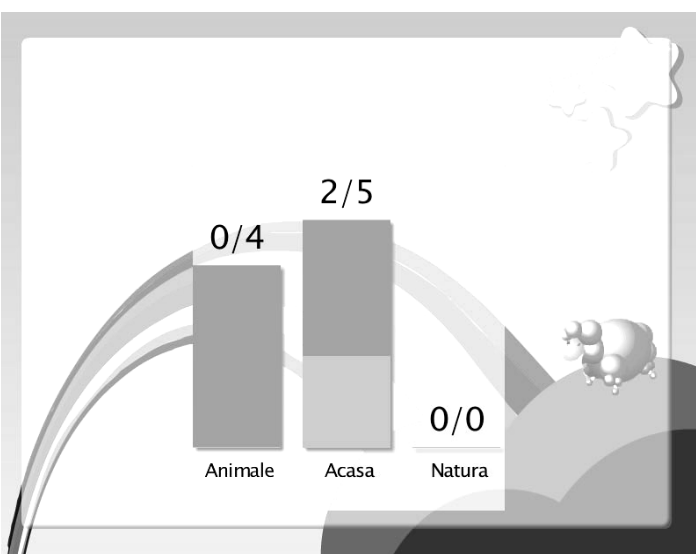

Fig. 5 testing stage; End screen.

D. Architecture and Implementation

Choosing the ActionScript (Flash) as the basis on which to build the application presented above is motivated by the need of a guaranteed on-line accessibility. Flash is nowadays the most popular web-based application development platform (more than 98% of the computers with internet access have installed a copy of Flash Player) featuring a high volume of multimedia content, an ease of development and a low resource requirement.

ActionScript is an object oriented programming language used to develop interactive applications with high audio and video content. Obviously, compiling ActionScript source files generates small size bytecode outputs (.swf files) that can be downloaded through a web-browser (or embedded in a web-page) and ran on the Flash Player virtual machine located on the user's personal computer.

The internal architecture of the application is divided in several activities that have to be performed: load external data (pictures and sounds), construct the configuration user interface based on the data stored, fetch and store all the options the user enters and run the algorithm that generates the training and/or the testing. While the test runs, correct and wrong answers are being counted in order to build a results page at the end. (Fig.6)

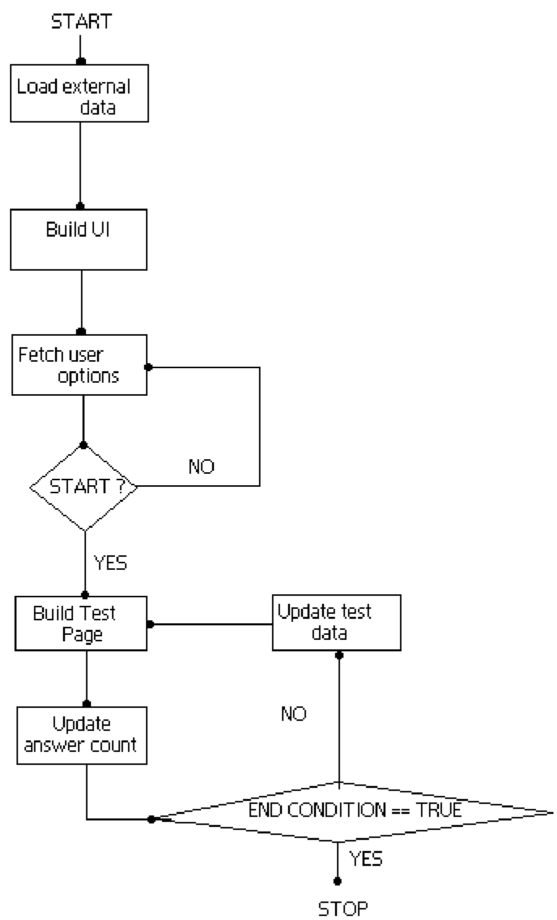

Fig. 6 testing stage, block diagram

The simpler block diagram for the training stage of the application is presented in (Fig.7).

Going a bit further into details, the external information (links to pictures and sound files) is being retrieved by reading an XML index file. In order to enrich the database of stimuli, one should update the XML in addition to copying the new files in the resource folders.

Most of the user interface (UI) is being built at runtime, after reviewing the just stored information. For example, the checkboxes representing the types of stimuli stored, the sliders storing the possible maximum number of questions, etc, all are being generated at runtime.

Fetching user generated events and updating the user interface accordingly is the next step. At this point, some of the controls present on the screen may be updated due to their inter-dependability to the information the user enters.

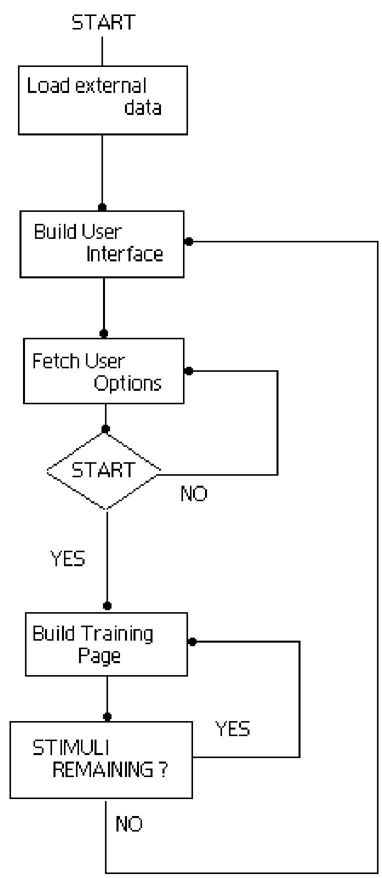

Fig. 7 training stage, block diagram

All the above steps are treated by methods of a base class that is being instanced when the application starts. Data is being stored in private variables of the same class.

Once the test is launched the stored information is being passed to a second class. Its instance is used to generate/refresh test pages, retrieve user's answers and pass these answers to an instance of a third class. The latter has the role of calculating a mark according to the number of correct/wrong answers and display the final result.

Test pages are being loop-generated until all the possible situations are exhausted (remember, these are computed prior to launching the test based on information retrieved form the user interface). A test page is presented in (Fig. 3). While this screen is displayed, a sound is being played. The impaired person has to associate the sound with one of the images on the screen by clicking on the image he considers to be the emitter. Depending on the answer (correct / incorrect) a tick or a cross is being drawn over the selected image.

The training stage of the application is similar in architecture yet simpler as there is no need to calculate arguments to be passed to a test generation algorithm. There is only one instance of a class that treats both the user interface construction and training session. Data about the stored stimuli, as in the previous case, is being retrieved, firstly, at runtime, by reading resource links from an XML file, and stored in the private members of the class.

As said before, the impaired person is trained by being presented screens with images while sounds are being played at the same time. The subject is requested to listen to the sound and watch the screen. The sound is being played in a loop; the supervisor deciding how many times the impaired person should listen to it. Passing to a new image/stimulus is done by clicking the next button bellow the image.

As a general idea that can also conclude this paragraph is that even though the implementation lacks in sophistication, it is still very important to divide the primary tasks and treat them in distinct classes in order to enhance future development of the application.

IV. RESULTS

The above application has been developed as part of CNCSIS project no. 853/2009 due to the fact that research in our country, in this domain, is insufficient [4], [5].

The application was tested in an auditory training center in Bucharest on a small batch of seven children. The subjects were selected on the following criteria:

- Auditory deficiencies of different degrees.
- Some experience using auditory prosthesis.
- Between 4 and 7 years old.

The experiment consisted in a *pre-evaluation stage*, a *training stage* and a *post-evaluation* stage. The first assessed the initial ability of the children to perceive sound stimuli while the latter was meant to mark the improvement of every subject.

The *pre-evaluation* was conducted using all the available stimuli and the "testing" part of the application. Sounds were played only after the images were displayed in order to assure the child's complete attention. Two or three tests (of 5 "questions" each) were realized per child. Those who where unable to use the computer mouse were helped by the supervisor.

After the initial evaluation it was observed that most of the children that were able to correctly relate the sound stimuli with the images had a smaller degree of auditory impairment. Also children were a bit reluctant in taking a decision of their own and looked for the support of their supervisor, probably due to the novel situation they faced.

The training was conducted over a period of three weeks, consisting of two sessions of 15 minutes per week for every child. In this time, most of the features of the computer application were used. It was decided to use as a training mechanism only the "testing" part of the computer application. Correct / incorrect answers were not counted. It was observed, during this period, that children were attending the sessions with pleasure and were highly interested in obtaining good results. Also, from a technical point of view, an increased number of possible answers (for a given sound stimuli) were a bit confusing for the children. Most of the incorrect answers were received for this type of parameterization.

The post-evaluation was a test given to every child in order to observe the improvement. At this point, the chosen sound database was completely ran-through and correct / incorrect answers were counted.

The main results and observations are the following:

- Significant improvements were obtained for 5 out of 7 subjects. A sixth subject could have also obtained better results but his audio prosthesis suffered a malfunction during this period. (Table 1)
- Two of the seven children had outstanding results. (Table 1)
- Comparing results (pre-evaluation versus post-evaluation) are given, in Table. 1. More details about the tests are given in Tables 2-7. What can be seen is that better results were obtained in the cases of Type 'A', and Type 'C' stimuli, probably because sounds related to home items were strong (ex: telephone ring, radio – a high frequency signal) or very fade (ex: toy duck,) and were harder to differentiate.
- Children were no longer feeling reluctantly and were no longer looking for support on their decision.
- Towards the end of the experiment, children were able to give answers at a much faster rate, indicating they were getting more familiar with the system.
- A rich database of sounds is important as the final goal of the system is to resemble a real world with many different stimuli. At some point, as mentioned before, children were unable to correctly choose the emitter when more possible answers were presented to him. This indicates a possible accommodation with the images and sounds stored in the database.
- One of the most important results was obtained in stimulating the child's attention and concentration. They were visibly paying more attention than usual and were interested in giving only correct answers.

V. Future Development

A further developed application should limit as much as possible the intervention of the supervisor. Such a feature will permit the impaired persons the possibility of self training and in the cases were a supervisor is needed, the latter is should not necessarily be a specialist.

The application should itself decide the best practices to be conducted in order to successfully train an auditory impaired child. Therefore an adaptive stimulation algorithm should be developed. Using information available from previous experiments and estimating probabilities of the wrongly identified stimuli, the algorithm should auto-modify itself in such a way to emphasize the learning of the wrongly identified stimuli.

Further features should include the possibility of enlarging/modifying the current stored database in an easy manner, giving the administrator of the equipment the opportunity to customize the stimuli.

Not only that a large database is mandatory in order to closely simulate real world but customizing the stimuli database stored should be useful for further emphasizing the learning of wrongly identified stimuli, for a given person.

VI. Conclusion

Integrating some theoretical patterns and some experimental results for psychology and informatics, in order to achieve a new concept with an enhanced degree of appeal and adaptability which will successfully address to different subjects categories (hearing impaired people with development disorders or without such other deficiencies) are the basic goals of an e-learning software application design.

Moreover, a correct organization of code is highly recommended from the very beginning as these kinds of applications often require changes during their testing period in specialised cabinets, all in order to make o more robust and efficient product. Integrating a very elaborate database of stimuli is also important to remember.

During the conducted experiments it was observed that the novelty of learning through a computer program stimulated the young children's attention and improved their ability to correctly identify sounds and use the computer. It is also important to mention that the game like architecture of the application had great appeal and is well suited for children.

APPENDIX

TABLE I
COMPARING RESULTS FOR THE PRE-EVALUATION AND POST-EVALUATION STAGES

No	Subj.	Pre-evaluation	Post-evaluation	Gain
1	N.A.	30	34	+4
2	T.S.	27	29	+2
3	N.Cr.A	25	32	+7
4	T.A.	18	22	+4
5	I.D.*	18	18	0
6	P.M.V.	20	33	+13
7	T.G.	28	22	-6

* The subject's auditory prosthesis suffered a malfunction during this period. The results presented for his final evaluation are those obtained at the initial evaluation stage.

TABLE II
RESULTS FOR THE PRE-EVALUATION STAGE, TYPE 'A' STIMULI

No.	Subj.	Correct	Incorrect
1	N.A.	12	0
2	T.S.	10	2
3	N.Cr.A	6	6
4	T.A.	6	6
5	I.D.*	1	11
6	P.M.V.	3	9
7	T.G.	9	3

* The subject's auditory prosthesis suffered a malfunction during this period. The results presented for his final evaluation are those obtained at the initial evaluation stage.

Type 'A' of stimuli consists of a database of sounds emitted by animals (cat, dog, etc.)

TABLE III
RESULTS FOR THE PRE-EVALUATION STAGE, TYPE 'B' STIMULI

No.	Subj.	Correct	Incorrect
1	N.A.	9	1
2	T.S.	9	1
3	N.Cr.A	10	0
4	T.A.	5	5
5	I.D.*	7	3
6	P.M.V.	8	2
7	T.G.	8	2

* The subject's auditory prosthesis suffered a malfunction during this period. The results presented for his final evaluation are those obtained at the initial evaluation stage.

Type 'B' - sounds emitted by different object (door, radio, phone etc.)

TABLE IV
RESULTS FOR THE PRE-EVALUATION STAGE, TYPE 'C' STIMULI

No.	Subj.	Correct	Incorrect
1	N.A.	9	3
2	T.S.	8	4
3	N.Cr.A	9	3
4	T.A.	7	5
5	I.D.*	10	2
6	P.M.V.	9	3
7	T.G.	11	1

* The subject's auditory prosthesis suffered a malfunction during this period. The results presented for his final evaluation are those obtained at the initial evaluation stage.

Type 'C' of stimuli consists of a database of sounds emitted by nature phenomenon (rain, thunder, etc.)

TABLE V
RESULTS FOR THE POST-EVALUATION STAGE,
TYPE 'A' STIMULI

No.	Subj.	Correct	Incorrect
1	N.A.	12	0
2	T.S.	12	0
3	N.Cr.A	12	0
4	T.A.	8	4
5	I.D.*	1	11
6	P.M.V.	12	0
7	T.G.	10	2

* The subject's auditory prosthesis suffered a malfunction during this period. The results presented for his final evaluation are those obtained at the initial evaluation stage.

Type 'A' of stimuli consists of a database of sounds emitted by animals (cat, dog, etc.)

TABLE VII
RESULTS FOR THE POST-EVALUATION STAGE,
TYPE 'B' STIMULI

No.	Subj.	Correct	Incorrect
1	N.A.	10	0
2	T.S.	8	2
3	N.Cr.A	8	2
4	T.A.	5	5
5	I.D.*	7	3
6	P.M.V.	10	0
7	T.G.	6	4

* The subject's auditory prosthesis suffered a malfunction during this period. The results presented for his final evaluation are those obtained at the initial evaluation stage.

Type 'B' - sounds emitted by different object (door, radio, phone etc.)

TABLE VI
RESULTS FOR THE POST-EVALUATION STAGE,
TYPE 'C' STIMULI

No.	Subj.	Correct	Incorrect
1	N.A.	9	3
2	T.S.	8	4
3	N.Cr.A	9	3
4	T.A.	7	5
5	I.D.*	10	2
6	P.M.V.	9	3
7	T.G.	11	1

* The subject's auditory prosthesis suffered a malfunction during this period. The results presented for his final evaluation are those obtained at the initial evaluation stage.

Type 'C' of stimuli consists of a database of sounds emitted by nature phenomenon (rain, thunder, etc.)

REFERENCES

[1] Ling D., Ling A, H., *Aural Habilitation: The foundation of verbal Learning in Hearing- Impaired Children*,Washington D .C., 1978;

[2] Tucker I., Nolan M., *Educational Audiology*, Croam Helm, London, 1986;

[3] Popa M., *Deficienta de auz – repere psihologice si metodologice*. Ed. Dimitrie Cantemir, Tirgu-Mures, 2002;

[4] Mare V., Badau F., Cosmuta T., „Unele tendințe moderne in reabilitarea, recuperarea deficientilor de auz . Sistemul verbo tonal al profesorului P. Guberina din RSF Iugoslavia", in *Probleme de defectologie*, București, 1972;

[5] Mare V., Cosmuta T., „Cinci ani de activitate a Centrului de reabilitare a auzului si limbajului din Cluj.", in *Studia Universitatis Babes-Bolyai, Series Pedagogia*, Psihologia XIX, 1974;

[6] Anca M., *Metode si tehnici de evaluare a copiilor cu CES*, Presa Universitara Clujeana, 2003;

[7] Moors D., Meadow-Orlans K. P., *Educational and Developmental Aspects of Deafnes*, Galludet University Press, Washington D.C.,1993;

[8] Popa M., *Comunicare si personalitate la eficientul de auz*, Editura Pro Humanitate, Bucuresti,2001;