"Meleti" Speech and Language Development Support System

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Abstract — **Through this study we are presenting a system that intents to support and monitor speech and language development of children with hearing impairment using hearing aids and/or cochlear implants, or children with language delays. The scope is to support children during their daily life. The system is mainly based on a set of applications for Android devices. These applications can be used anywhere the child and the parents are and they include several tasks presented to the child as a game. The main goal is to support sessions being done by the caregivers like reproducing words, sounds, small phrases etc. The system was created based on the four levels targeted during speech and language support sessions (auditory skills, receptive language, expressive language, speech / articulation). The results from system usage are being recorded from a server where specialists can monitor get results and act accordingly in order to improve the child's performance. Initial design and development steps have been completed. The two first levels of the system have been tested on a small group of user with very encouraging results. Furthermore the development of several other modules related to the levels of language development will continue in order to cover all language development levels**.

I. Introduction

Auditory and language development support of hearing impaired persons has been an issue of research over the years [1]. Technology evolution on hearing aids, the introduction of cochlear implants as well as the evolution of modern personal computers (tablets, laptops etc.) has changed the way of helping and training this group of people.

Current amplification methods: hearing aids and cochlear implants enable the child to develop speech and language, and learn to communicate orally. However, amplification alone is insufficient; training is required in order for the brain to receive the auditory information and start using that information [2]-[5]. The child first learns to become aware of the sounds, afterwards to discriminate between the sounds and to recognize and understand the different sounds as words, and finally proceeds to develop more complex abilities, such as comprehending information in a quiet or noisy environment, and from a distance.

Manuscript received July 31, 2013.

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A. Auditory training and needs of children with hearing loss using cochlear implants and or hearing aids

Audiologists are the first clinical specialty involved in the procedure of helping a hearing impaired child or adult (using cochlear implant or hearing aid) to start listening. An integral part of the audiologist's duties is to verify that the child is receiving benefit from amplification, and that the child has sufficient auditory function. This validation is an ongoing process, which is usually done via aided testing in controlled soundproof room, and with formal and informal questionnaires. Audiological test sessions are often subject to the child's age, mood, attention span, and communication level. Thus, the information that is obtained in one session may be very limited.

B. Language training of children with hearing loss using cochlear implants and or hearing aids

Speech therapists are the second group of specialists involved in the procedure of auditory and language training. They are responsible for the language training of this group of people. Speech and language training in infants with a hearing loss is primarily indirect [6]. The speech and language therapist educates the carers/parents on how to stimulate the infant/toddler with efficient language input, and on how to promote communication and social skills through play, technology and everyday interaction [7][8][9].

Babies first learn their language by watching and/or listening to their caregiver's speech, which is typically provided in close proximity to the baby in a simple and repetitive manner. Parents engage in simple speech "turn taking" games; first cooing, and then babbling. They provide a variety of sounds or repeat their babies' sound approximations. Parents are instructed to talk about the names of objects and actions in the babies' environment, tell stories and read books [10]. The caregivers of both hearing children and deaf children are believed to reinforce their children's early attempts for communication, thus encouraging further and more elaborate communication [11]. Latter language developmental milestones (from 1-5 years of age), such as phonology, syntax, semantics, morphology, and pragmatic aspects of language are acquired at around 4-5 years through direct speech and language therapy sessions [12].

Throughout speech and language therapy sessions the following four levels are targeted: a) auditory skills, b) receptive language, c) expressive language, and d) speech production/articulation. In general these sessions will take place at an average of 2-3 hours per week, while the rest of the work is being done at home by the child's parents.

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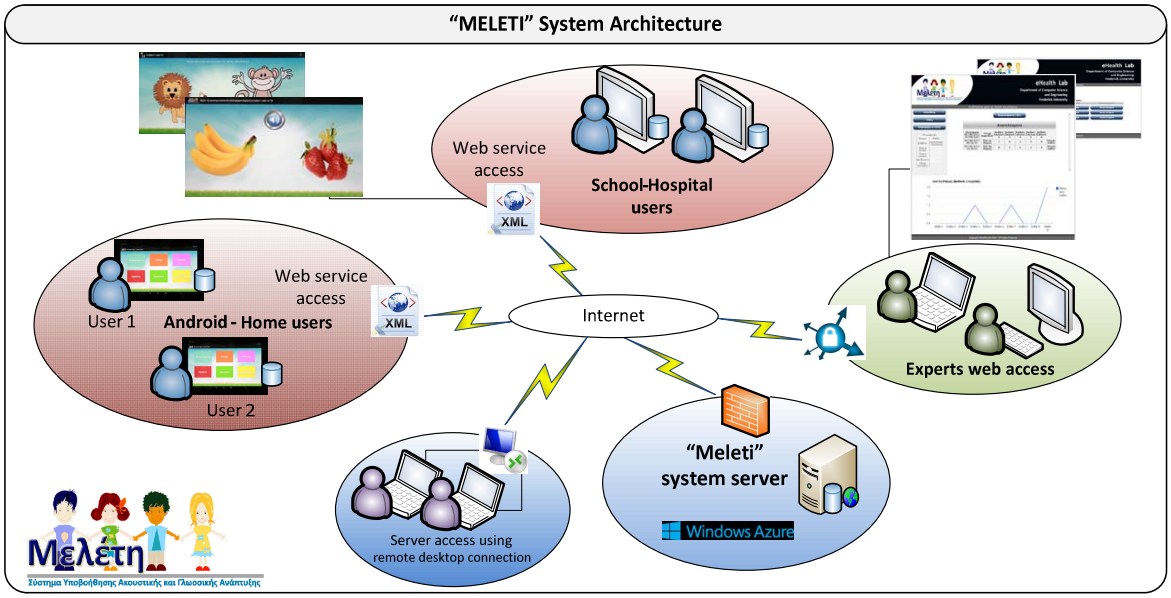

Fig.2. "Meleti" System general architecture

Parents or relatives will have to follow the advice of speech therapists concerning the work that has to be done during these hours. Thus, the need for systems that can help and support language development while at home is obvious, and can be easily achieved using modern technologies.

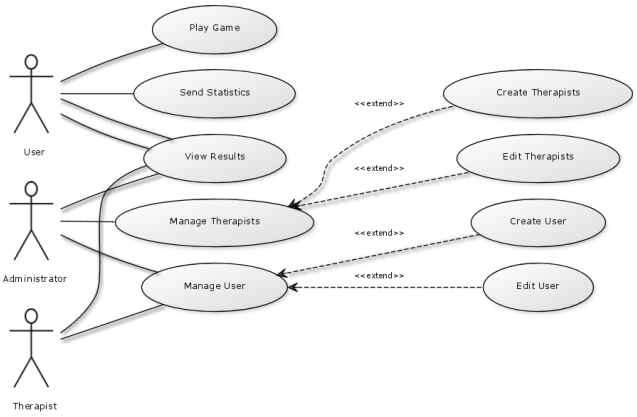

Fig.1. User groups and use case diagram of the system

C. *Similar systems*

Based on research being done by our group, we were not able to find any published work of an integrated system that can support the procedure of auditory and language training of hearing impaired children (especially for Greek speaking children). Related to mobile devices, such as tablets and smartphones, some commercial applications are presented for android devices or ipad, but none of them is based on an integrated system which also records the results of system usage. Cochlear HOPE ® presented online at [13] by Cochlear® has an ipad application which presents words, but no gaming or recording procedure is being supported.

II. METHODOLOGY

Following the above mentioned needs, we have created a system for auditory and language development support called "Meleti". The system will be used to expand the information coming from audiological test sessions as well as support and monitor the language training sessions of children with a hearing impairment.

A. *System general architecture*

In general the system usage can be described using the use case diagram as presented in Fig. 1. The users of the system have been divided into three groups: a) the Administrator which has the full control of the system, b) the therapists which are the audiologists, speech therapists etc. and c) the children-users. The therapists can add and monitor a user (child) and each therapist can monitor only his/her users. The children-users are the actual users of the system and each parent can monitor his/her child's results coming of system usage.

The general architecture of the system is shown in Fig. 2. "Meleti" consists of a central server which is responsible to collect data from the users and display the results to the appropriate group. The server was uploaded on the Windows Azure cloud platform of Microsoft® [14]. We have setup a virtual Windows 2012 server and we are using the Apache Tomcat and MySQL for storing and displaying information. RESTful Web services are being used in order to enable children-users applications to send results to the server.

The children-users can be located either at their home or at the school or clinicians' place. The communication between children's device and the server is done using XML messages whenever Internet access is available. The experts or parents can have access to the system and get the results from their group of children, or their child respectively. The whole procedure of accessing the system has been secured using a security scheme as described in the security scheme section.

B. *Children - Application development*

The applications developed are based on the four levels targeted during speech and language training sessions (auditory skills, receptive language, expressive language, and speech production/articulation).

All these four levels were analyzed, adjusted and included in the applications presented in this paper, in order for the clinicians and the parents to be able to train efficiently and monitor each child's performance. Performance monitoring enables all professionals involved in each child's auditory and language training to adjust and facilitate the user in areas that each child finds challenging.

More specifically, Level 1 includes auditory skills. Based on Erber's hierarchy [15] of Detection, Discrimination, Identification, and Comprehension, the child is aimed to "learn to listen" so that he finally 'listens to learn' [16] .

The development of the auditory system for spoken language involves auditory tasks performed during "auditory training" sessions [17]. Auditory development triggers spoken language, natural speech development, cognitive and social growth. Long before the emergence of language and speech, there are specific auditory skills which can be observed to develop sequentially in the first year or two of a typically hearing child.

Level 2 involves receptive language, which is defined as the understanding of spoken language that includes semantics (vocabulary), morphology (word endings), and syntax (grammatical structure). Since language skills are developmental, the goal is for a child to express his own ideas in a novel form. This is preferable to imitations or repetitions of rote language taught by an adult. Generation of new ideas will only come about when the child has an adequate receptive language bank from which to draw.

Level 3 involves expressive language. This refers to spontaneously generated novel language productions, including vocabulary and narrative skills. A child's spontaneous expressive language relies on his/her underlying knowledge and receptive language base [18]. Finally, Level 4 deals with Speech and Articulation. This refers to the production of speech sounds and how they are made, i.e., clarity of speech articulation. This phase is the last area of speech therapy intervention, no matter what the age of the child may be. Children must acquire all other levels before addressing speech production or articulation.

The android applications were developed using the Eclipse Platform and Android Development tools. They are divided into two types of games, Type 1 and Type 2. Type 1: the goal is the Identification of the correct image based on the sound of the object/animal, e.g., farm animal, musical organs etc., or Identification of the correct image based on the name of the image, e.g., colours, actions, fruits etc.

Type 1 has ten different levels (level 1&2 with 2 images per screen, level 3&4 with 3 images per screen etc.). The results recorded include: Image or sound presented, level and mistakes. These are send to the server using the XML communication scheme. (a typical example of this type is shown in Fig. 3).

Type 2: Repetition of an image name based on what the child listened from the device, (e.g., Colours, Fruits, Actions, etc.). This type consists of ten levels where a different image is presented at each level. The parent or expert that is near the child decides if the pronounciation sounded correct. Recorded results of this type describe if an image name was correctly pronounced or not and how many erroneous attempts existed before the correct answer.

Fig.3. A typical android screen shot from game type 1 displaying five different fruits. The child listens to the name of the fruit and has to choose the correct image.

C. *Security issues*

Our server is stored on Windows Azure and thus we leverage its inherent security in terms of providing *confidentiality*, *integrity*, and *availability* for patient data. Windows Azure also provides logging capabilities to enable transparent *accountability* and allow customers and their agents track administration of applications. For brevity more information on Windows Azure's security can be found in [19]. Key issues that have been our focus with this work are authentication, authorization, and privacy. Authentication lies on the systems capability to verify the identity of a user. This task was achieved by tying a user name and password to every user (patient) and clinician/therapist. During registration a patient sends his data and password to the sender (see transaction 1 in Fig. 4).

Transaction 1 also includes a Message Digest (MD) and a timestamp (TS). The MD verifies that the entire message has not been altered in transit and the TS guarantees the liveness of the transaction during the registration phase. The entire transaction is encrypted with the public key of our server ensuring the privacy of the patient's data in transit. When the server receives transaction 1 it will verify the uniqueness of the patient's information to avoid duplicates and reply with an Activation Code (AC) (see transaction 2 in Fig. 4). The activation code is important as it prevents an attacker from sending multiple requests to the server without proceeding with the rest of the registration phase. Continuing in transaction 3, the patient sends his user name, AC, and TS to acknowledge the servers response. Lastly the server confirms that the account is active (see transaction 4). To enhance security the passwords of the patients are not stored on the server, but rather a modified hash of the passwords is stored to avoid attacks from rainbow tables, in case security is bridged. Further, simplifying the key management process we require that only the server utilizes asymmetric keys.

The aspect of authorization and privacy was handled by using an adaptation of the Clinical Information Systems Security Policy [20]. Initially the system administrator has permission to add the clinicians and then the clinicians can accept patients and establish a medical record. Each medical record of a patient has an access control list naming the clinicians who may have read/write access to the patient's

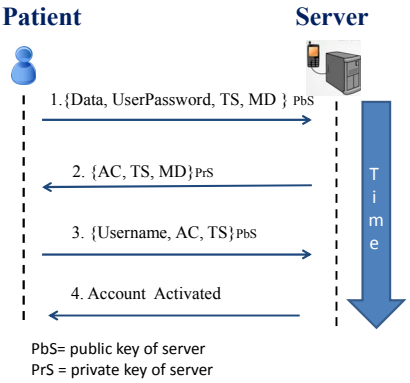

Fig.4. Transactions for Registration into the system

record. Any of the clinicians on the access control list can add other clinicians to the access control list, as long as the patient is also notified so as to obtain the patient's consent. In terms of logging, the name of the clinician, the date, and the time of access/modification of a medical record is recorded. Lastly, a patient has the right to view his record, but not modify it. As far as long term storage, patient information cannot be deleted unless a specific period of time has passed.

III. Results - Conclusions

Implementation of the system has been completed. The system has been demonstrated. All functions were tested, including local testing by a child user, a speech therapist, an audiologist, and the system developers. Any software bugs or functional errors that appeared have been corrected.

Concluding, this functional assessment tool can provide informal information to the audiologists on how the child perceives the sound, and assist the audiologist with monitoring and intervention. This program collects information such as response to Ling sounds, identification and recognition tasks, and minimal pairs, repetition of words and phrases. This information along with the formal assessment done in a booth will allow a) the audiologist to identify specific errors that the child makes regularly and systematically, and address them to enhance audibility and b) the speech therapist to identify any weaknesses on language development progress and act accordingly. For example, mistakes of specific sounds or consonants will help the audiologist to make specific changes to the high frequencies. Also the information collected over time, allows the audiologist to measure progress, and identify problems that arise gradually, or any sudden changes that require immediate attention. It will also provide valuable information and training for children that live in rural areas where supportive and educational services may be limited.

For the time being the system has been given to a small group of 8 children that are using cochlear implants and/or hearing aids. This is the initial testing phase in order to get feedback on usefulness, and correct functionality of the system. The future plans include a) expansion of the number of system application levels, in order to cover the whole procedure of speech and language development, b) Translation of the system to other languages like English, German etc., and c) increasing the number of users in order to prove the impact that this system has.

Acknowledgment

We would like to thank Microsoft ® and especially Microsoft Cyprus for providing us access to the Windows Azure cloud platform.

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