Euphoni: a system to support speech therapy

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ABSTRACT
Many rehabilitation therapies ask patients to perform many exercises every day. This requirement strongly stresses the patient who often abandons the therapy too early. This is particulary true in speech therapy which usually has an estimated drop out before reaching the treatment goal of 65%, which is a very high number. In this paper we propose *Euphoni*, a system for distance care of voice problems. The system includes a mobile application which allows to establish a voice therapy protocol which is able to help the patient when performing exercises at home. Moreover, we use a gamification approach to encourage the patient to hold on.

ACM Classification Keywords
H.5.2. User Interfaces: Prototyping; J.3. Life and Medical Sciences: Medical information systems

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Serious Games; Mobile Applications; Speech Therapy

INTRODUCTION

Drop-out-from-therapy as well as *poor patients adherence* are well known phenomena which affect many medical treatments, lowering the effectiveness of many therapies. These problems are particularly relevant in rehabilitation treatments, especially when patients are supposed to perform many exercises every day. This is the case of clinical voice therapy, where therapy protocols typically require daily activities and to learn a target voice-production technique.

In voice therapy, patients perceive the treatment exercises as very challenging [17]. Voice treatment has usually an estimated drop out before reaching the treatment goal of 65%, which is a very high number, compared to other programs like, for example, physical exercise and smoking cessation [15].

Patients report a variety of barriers to treatment adherence between voice therapy sessions. Leer and Connor [19] described the reasons for poor patient adherence as:

- poor motivation,
- difficulty in remembering how to reproduce a target voice technique without a clinician assistance,
- difficulty in judging the results and the accuracy of their efforts and
- concerns about appearing unnatural when using the target technique conversation.

The main difficulty is related to remembering to practice and use the target technique throughout the day. Patients report that they are busy, tired, upset and many of them declared that they are not able to perform the exercises in absence of the therapist.

Patients report that the presence of the voice therapist and the quality of their relationship with him (or her) is crucial to avoid drop out. Unfortunately, daily meeting with the therapist is not a possible solution for all patients, so other answers to this problem must be investigated.

Since smartphones are always on the user's pocket, the use of a mobile application can help to continuously assist the patient. More in details, a mobile application can be used in many different ways [18]:

- as a support to remember to practice the exercises using alert messages, calendars, etc., e. g., Liang et al demonstrated that text-based reminders have strong efficacy in improving adherence to health behavior goals [13],
- as a feedback system for practice completion in order to track healthy behaviors (e. g. the number of exercises done during the week) and
- as a tutorial to help patients producing the target technique independently providing them videos, recordings, or portions of therapy practice between therapy sessions.

Mobile health platforms have the potential to extend voice treatment from therapy session to patient's environment, to increase the practise of the treatment, to motivate patients with feedback and gamification elements, and to support patients.

To be effective, direct voice therapy protocols require daily practice and generalization of a target voice production technique between treatment session [19]. Technology has the potential to optimize patients' adherence to health behavior programs, assisting them anytime and anywhere, but speech and language therapists often report that they can't rely to affordable and good applications.

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In this paper, we describe *Euphoni*, a system for distance care of voice problems. The system includes a mobile application which allows to establish a voice therapy protocol which is able to help the patient when performing exercises at home. Moreover, the system allows to record audio and text messages and to send them to the voice therapist.

The system does not replace traditional therapy protocols, but help patients by remembering the therapist's instructions, encouraging communication with therapist even when patients are at home, scoring their progress and giving them sub-goal that can be easily reached.

RELATED WORK

The use of modern technologies in medical practise is quickly increasing to assist both therapists and patients [5, 7, 6, 8, 11, 16]. Kato explores the positive aspects of using existing commercial video games for health improvements or surgical training, and tailor-made game for particular disease group in order to improve recovery and rehabilitation of patients [11]. She defines Re-Mission, a game to help young patients to understand and deal with cancer: game characters represent the drug which destroys cells with cancer. Moreover, the game also provides patients a forum to discuss together.

HelpMe! [5] is a system which supports the rehabilitation process for children affected by CVI (Cerebral Visual Impairment) through the use of two serious games. It also includes a control panel to allow the therapist to adapt the rehabilitative exercises to each particular child and to follow the improvements of the patient. Moreover the system can help doctors to perform a good assessment of a patient and to create a rehabilitation program.

Many papers reported evidence to support the efficacy of mobile approaches for a variety of health problems like diabetes [13], smoking cessation maintenance [20], dyslexia [8, 16], etc. [16] integrates dyslexia predictors in a tablet game, to capture children attention to obtain a more accurate measurement. The authors evaluate several existing games for preschoolers to derive a set of guidelines to design an optimal tablet game for 5 years old children. Then, these guidelines are used to develop Diesel-X, a game about a robot dog, Diesel, which has to fight against a gang of criminal cats.

Gaggi et al. [8] developed a set of serious games to identify developmental dyslexia at early stages and immediately start a therapy. These serious games were designed to be accessible from any devices, both tablet using a touch interaction or a PC using a keyboard and a mouse, so the doctor can choose the best interaction method depending on the age and the ability of the child.

Successful mobile applications typically help to maintain adherence using push notifications, SMS, messages to reinforce healthy behaviors, real time feedback and patient self monitoring process. As an example, Fish'n'Steps [14] is a serious game that links the walking activity with the growth and moving activity of a fish in a fish tank. The system uses push notifications to keep attention of the user on the game.

Despite many good results in different clinical treatments, the possibility to use of technology in voice treatment is almost an unexplored land. In [19] Leer and Connor tried to predict patients adherence to treatment measuring three social-cognitive factors: self-efficacy, goal commitment and therapeutic alliance [1], [2]. Moreover, the authors study how much a MP4 video support could influence the same triad of factors. The study demonstrated that adherence to treatment can be predicted by this three social-cognitive factors and that mobile technology can extend treatment to extraclinical settings. This is extremely important because, if we use technology to enhance self-efficacy, goal commitment, and the therapeutic alliance, hypothetically we can reduce rate of dropouts.

Lavaissièri and Melo developed Q-Voz[12], a mobile application for voice therapists which reminds patients on the times for practicing and contains some tutorial for proposed techniques. The application was submitted to seven evaluators that reported that it can be considered an auxiliary tool for voice speech therapy.

PROEL METHOD

Human voice is a sound generated by an elastic system, air and vibrations which resonate into the vocal tract. An euphonic voice production is granted if there is balance of the pneumophonic system. Every alteration of this specific balance creates muscles' rigidity and hypertone, and results in a vocal disfunction called *dysphonia*. At the beginning of a dysfunctional dysphonia there are always rigidity, loss of vocal strength and lack of lubrication.

The *Proprioceptive-Elastic (ProEl)* method [3] is one of the methods used to treat voice alterations. It is a technique used in voice therapy that has been developed since the late 90's in a collaboration between the CFL (Centre of Phoniatrics and Speech Therapy), Santander, Spain and the ORL operational unit of Bufalini Hospital, Cesena, Italy. The basic principles of this method are the sensory "bombarding" of the phonatory apparatus with the aim to make the patient more aware about his/her phonatory structure and body in general, to distend the muscular tension and lubricate the mucosa.

These goals are reached facing different moments of the vocal therapy. In particular:

- *lighting phase*: activation of the learning system mainly using motivational strategies;
- *voice modification*: try to obtain vocal changes in order to give different sensations to the patient;
- *leave a mark*: try to build a new motor pattern by remembering the voice target;
- *compare*: try to focus on the differences between the voice before and after the exercises;
- *automate*: generalize the new vocal production.

Usually the therapy follows specific steps:

- make the patient aware of vocal risk factors and teach him how to control them;

- make the patient more and more conscious about his/her voice production, his/her muscle's tension, breath, posture, tongue and palate: the patient has to become *proprioceptive*;
- make the patient elastic and agile in voice production, eliminating rigidity;
- make the patient's voice projected and resonant in order to preserve the vocal instrument using less energy and obtaining the best result;
- make the patient feel happy when using his/her voice: this is the highest goal of this therapy.

In addition, this method also uses larynx and muscles manipulation in order to eliminate tensions. The strengths of the ProEl method are:

- it is very concrete in many theoretical aspects, allowing the patient to understand better all the problems and the solutions;
- it proposes quick and easy exercises which are powerful;
- it is motivating and inclusive for all kind of patients.

Description of the Exercises

The main keywords in ProEl method are lubrication, elasticity and resonance. The ProEl method proposes many exercises that has been built in order to gain these goals: in the following only exercises that have been implemented in the application are discussed.

As already mentioned, some exercises are really very simple: for example, to lubricate the vocal tract we suggest to increase the amount of drunk water; an exercise which is proposed every day is to drink at least two liters of water per day. This allows the vocal folds to have less friction and to work properly.

Other exercises have the goal of improving the elasticity, by teaching the "easing Postures", i. e., postures which modify the body balance point to allow a better and easier voice production with less muscles strength. An example is to ask patients to put their hands on their knees, which must be a little bit bent. This position reduces the neck's muscles activity, put the tongue in the right position and allows the voice to flow easier.

In order to make the voice more resonant the ProEl method uses the sensory bombarding with thermal or tactile stimulations in the oral cavity using different kind of tools. For example, an exercise asks patient to put his/her hands on his/her mouth to make him/her aware of his/her vocal vibrations and power.

Exercises described so far are just a few examples of how ProEl method works on dysfunctional dysphonia. Patients are usually very happy and enthusiastic in facing this kind of therapy. The only real problem consists in repeating the exercises at home, between different therapy sessions, which take place twice a week. For this reason, we implemented the *Euphoni* system to support both patients and therapist.

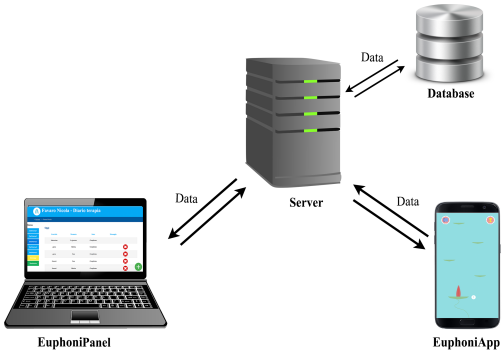

Figure 1. Overall architecture of the system.

THE *EUPHONI* SYSTEM

The system is mainly composed by three components as depicted in Figure 1:

- a mobile application,
- a server and
- a panel for the doctor.

The server is the most important component, it contains the description of the exercises and records data about user performances. Doctors can manage patients through a web interface, i. e., the *EuphoniPanel*: they can personalize the set of exercises for each user, i. e., they can choose among a set of proposed exercises the ones that are suitable for the disease of a particular patient, and check data about user performances.

The mobile application is named *EuphoniApp*: it retrieved the exercises that each patient should do every day and proposed them to the patient. Its main goal is to support patients during therapy in two ways:

- it proposes and explains the exercises that patients are supposed to do during the day,
- it encourages the user to continue the therapy through the use of sub-goals and badges' achievements.

Moreover, it records patient's performances, and sends data to the server.

The first time a patient uses the application he, or she, must log in, and the application retrieves the exercises program decided by the therapist for that particular patient. Practice is organized in five weeks, which contain exercises organized in seven days. Each day may contain many exercises. Some exercises are present every day, i. e. hydration exercise, others can change according to the day and the particular patient. Each exercise must be performed in a precise interval of time, which can be in the morning, in the evening, or during the day.

Since patients are required to practise every day, motivation is an important aspect to consider: the most important goal of *EuphoniApp* is to avoid dropouts. Another important aspect is also to guarantee a correct practise of the therapy, i. e.,

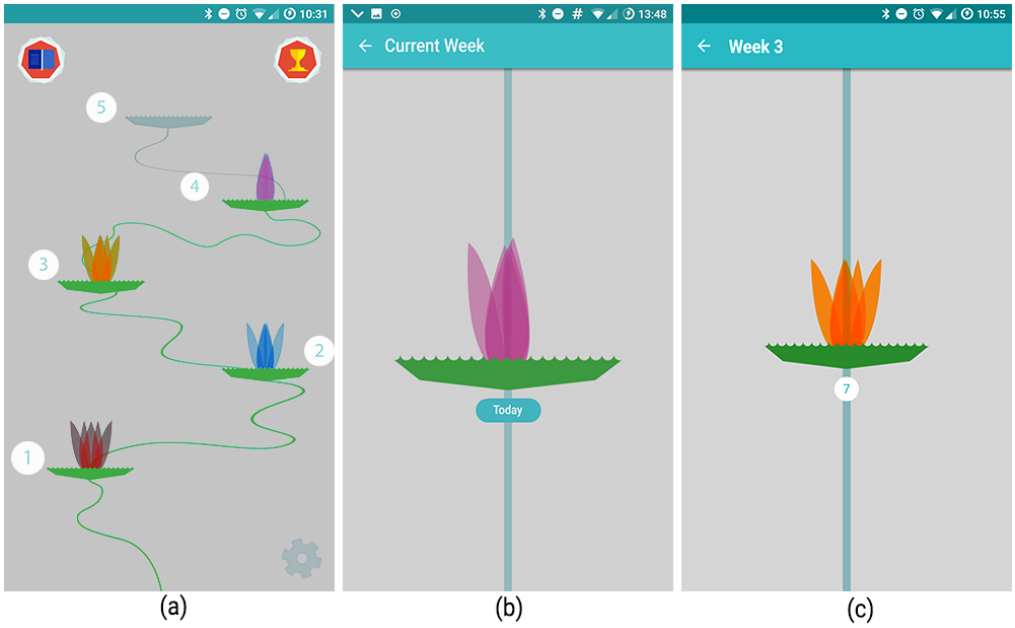

Figure 2. Screenshots of *EuphoniApp* which show the weeks and the days

sometimes it may happen that patients doesn't respect the exercises list or the timetable of the exercises. For this reason, we use the gamification approach, which uses elements of game design in non-game contexts.

The game uses the metaphor of a lotus flower; we made this choice since the shape of this flower recalls the shape of the vocal chords. Figure 2(a) shows the interface after the login: there are five lotus flowers, one for each therapy week, filled with different colors. The flower denoted by number 4 in the figure represents the current week. Future weeks are represented only with a leaf, e. g. leaf with number 5 in the figure.

We keep the graphic simple, to allow all types of patients, different for age and gender, to find the application simple. The patient selects a week by touching the corresponding flower. Figure 2(b) shows the interface for the week: initially the current day, i. e., today, is shown, but the user can scroll up and down to select days after or before, numbered from 1, i.e, Monday, to 7, i. e., Sunday.

The game uses a task/progress/motivation loop [21] in order to increase motivation thus maximizing the number of performed exercises. Every time patient performs an exercise he, or she, can see his/her level of completion through a progress bar, as depicted in Figure 3(a) which shows the interface for a single day. Moreover, completed exercises are marked with a check mark, while expired ones are denoted by a red cross. To engage and motivate the patients, *EuphoniApp* also send them positive feedbacks when they complete an exercise or the whole list of a day.

In the game, the user's goal is to blossom all the five lotus flowers. Upon completion of the entire list of exercises for a day, the flower, that correspond to the current week, opens a few: Figure 2(b) shows the flower after one day that the patient completely follows the therapy, Figure 2(c) is the result of six days of exercises done. To blossom the flower completely the patients have to perform all the exercises all the days of the corresponding week. In Figure 2(a) the patient has done all the exercises all the days in the first week, only for two days in the second week, for six days in the third week and never in the fourth week.

Each exercise is a sub-goal through which the patient can reach the main goal. Before performing an exercise, the patient can watch a tutorial video or read some text instruction (see Figure 3(b)). When the exercise is complete, he, or she, must mark it as completed.

The *EuphoniApp* does not reward the patient after each exercise but only when the patient performs all the exercises of a day. So, to increase patient's engaging and motivation, we added other intermediate goals to the application, i. e. the badges, simple subgoal which has the function to keep the patient focused in the therapy and to encourage him/her with rewarding. Some examples of badges are the following:

- complete all the daily exercises;
- complete all the daily exercises for two consecutive days;
- drink 10 litres of water;
- drink 30 litres of water;
- send the first message to the therapist;
- send five messages to the therapist.

Figure 3(c) shows the panel with badges showed to the patient.

To maximize the support to the patients, *EuphoniApp* provides a communication service between the patient and the speech

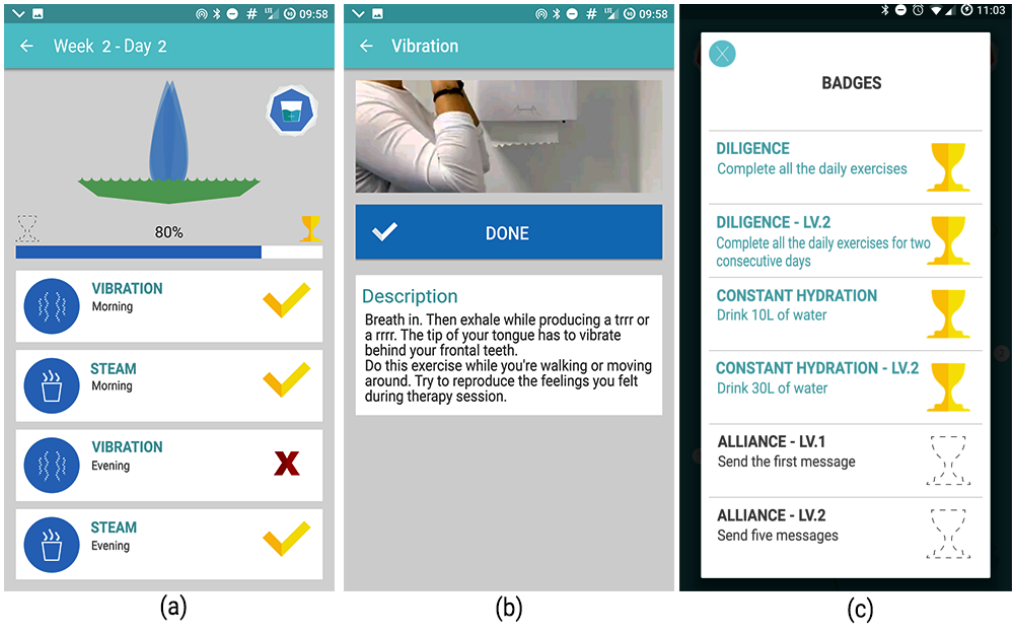

Figure 3. Screenshots of *EuphoniApp* which show: (a) the list of exercises, (b) the details of an exercise and (c) the panel of badges

therapist: the user can record an audio message or digit some text that will be recorded by the server. The therapist can listen to the audio messages and read the text messages using the *EuphoniPanel*.

The system reminds the user to perform the exercises using a push notification system that could be customized according to patient's time preferences.

Implementation Details

EuphoniApp has been developed only for Android operating system, but we are currently working to support all available operating systems, using a framework for cross-platform mobile development [4]. The application has been developed using the Java language with Android SDK 25 and Android Studio. We choose the Android platform rather than other operating systems since, according to Gartner statistics [9], it is the most widespread among users (80,7%). The application is developed for Android 7 (Nougat) but it is retrocompatible until Android 4.1 (Jelly Bean), so the 98,2% of Android devices are supported [10].

The application communicates with the server only when necessary, in order to limit the network usage, i. e. it connects to the server to synchronize exercises when the user log in and to change their state of completion. The communication is made using some Json Web Services which are used to implement the authentication system, the download of the exercises and the upload of exercises' scores and messages of the patients. Parameters, such as user's id, exercise id, exercise status, etc., are sent using POST method.

As already said, the therapy provides two appointments per week during which the therapist can adjust the exercises according to the progress or failure of the patient. The speech therapist uses *EuphoniPanel* to manage all the patients and exercises assigned to them.

EuphoniPanel is a web interface, which shows the patients records. The therapist can read or listen the messages sent by patients, check if a patient has completed the list of exercises or not and eventually change it. It has been developed using standard web technologies, i. e., PHP, HTML, CSS and Javascript, with a particular attention to accessibility.

Both *EuphoniApp* and *EuphoniPanel* communicate with a MySQL database situated at the server side, which collects data about patients and exercises. Personal data about patients are stored separately to preserve their privacy, even in case of malicious access.

CONCLUSION AND FUTURE WORKS

In this paper, we propose *Euphoni*, a system to support speech therapy. This kind of therapy requires patients to perform several exercises every day, so the main goal of the system is to support and encourage the patient to avoid the *drop-out-from-therapy* phenomenon.

The strong points of our system are:

- the use of gamification to involve and encourage the patient;
- the use of a mobile application, *EphoniApp*, since we use a tool commonly available in the patients' pockets and we do not ask patients to buy other devices. Moreover, previous works have demonstrated that the use of modern mobile technologies is very efficient in the treatment of health problems and the use of push notification allows the system to easily remind the patients to perform the exercises,
- the use of the ProEl Method as treatment for dysphonia and

- the availability of video tutorial helps patients to understand the exercises and practise them correctly.

We plan to test our system with a large number of patients divided into two groups, one using our system and the other following the therapy without any additional help or tool. The test will aim at understanding if the system is able to increment the number of performed exercises and therefore the level of adherence to the protocol therapy, and to lower the number of dropouts. At the time of writing, we are currently testing the efficacy and the level of acceptability of our system. A group of 5 patients affected by dysphonia is using the system. The group is composed by 3 females and 2 males, all the patients are aged between 45 and 65 and they have been using the system for 30 days. The initial results are encouraging since they do not report problems in using the application and they are performing the exercises daily.

In the future, we plan to develop the application for all the available operating systems using a framework for cross-platform mobile development, to allow also users with other operating systems to use the application.

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