LungSounds@UA interface and multimedia database

Cátia Pinhoa,b; Daniela Oliveiraa; Ana Oliveiraa; João Dinisa,b; Alda Marquesa,*

*aSchool of Health Sciences, University of Aveiro (ESSUA), Portugal
bInstitute of Electronics and Telematics Engineering of Aveiro (IEETA), Portugal

Abstract

The development of graphical user interfaces (GUIs) has been an emergent demand in the area of healthcare technologies. Specifically for respiratory healthcare there is a lack of tools to produce a complete multimedia database, where respiratory sounds and other clinical data are available in a single repository. This is essential for a complete patient’s assessment and management in research/clinical settings. Therefore, this study aimed to develop a usable interface to collect and organise respiratory-related data in a single multimedia database. A GUI, named LungSounds@UA, composed by a multilayer of windows, was developed. The usability of the user-centred interface was assessed in a pilot study and in an evaluation session. The users testified the utility of the application and its great potential for research/clinical settings. However, some drawbacks were identified, such as a certain difficulty to intuitively navigate in the great amount of the available information, which will inform future developments.

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* Corresponding author. Tel.: +351 234 372 462; fax: +351 234 401 597.
E-mail address: amarques@ua.pt.
1. Introduction

The prevalence of respiratory diseases increased to the point where they have become the fourth most common cause of death worldwide [1, 2]. Therefore, in the last decade, significant research efforts have been dedicated to improve diagnosis, monitoring and treatment of respiratory diseases [3]. The diagnosis and monitoring of these common diseases is facilitated by pulmonary auscultation [4, 5]. Nevertheless, pulmonary auscultation findings must be interpreted carefully, given its subjectivity, and put into context with other clinical findings [6]. Gross et al [7], performed a first attempt to combine in a single multimedia database respiratory-related data, however, no detailed information about the interface was given and not all relevant respiratory-related data was addressed. In respiratory health care it is crucial to have the auscultation findings along with other relevant clinical parameters, such as: vital signs, spirometry, six minute walk test (6MWT), pain evaluation, imaging report, clinical analyses, chest examination and other signs and symptoms; in a single respiratory repository to facilitate patient’s diagnosis, monitoring and treatment [8]. Thus, there is an urgent need to develop effective and user friendly graphical user interfaces (GUIs), which comprises all necessary respiratory data. This has been a great challenge in the development of computer-based health care environments [9]. Therefore, the aim of this study was to develop an adaptive and usable interface to collect and organise respiratory data in a single multimedia database.

The following sections focus on the overview of the LungSounds@UA interface functionalities and multimedia database and on the results of its usability assessment. Finally a discussion and the main conclusions are presented.

2. Methodology

The graphical user interface named LungSounds@UA was developed within the pilot study of the “Adventitious lung sounds as indicators of severity and recovery of lung pathology and sputum location” project (ref. PTDC/SAU-BEB/101943/2008). The application was developed in Matlab® [10] because of its rapid prototyping characteristics and to simplify the integration of automatic detection algorithms, e.g., Dinis et al. [3].

2.1. Design principles

The focus of a user-centred interface is to provide maximum usability, however, determining the usability consequences of the implemented design decisions is challenging [11]. To overcome this difficulty and consequently increase the usability of the LungSounds@UA interface the general design principles proposed by Sommerville [12] were followed, i.e., user familiarity, user diversity, consistency, recoverability, user guidance and minimal surprise.

2.2. General structure

LungSounds@UA interface, available in English and in Portuguese, is composed by a multilayer of windows, which allows the upload of different multimedia data, such as: respiratory sounds; clinical parameters; clinical analysis; respiratory physiotherapy monitoring data; functional independence measure (FIM); 6MWT; spirometry; pain evaluation; imaging reports, e.g., computed tomography (CT) and chest X-ray (Rx); and conventional auscultation (figure 1). The multilayer of windows was built with five hierarchy levels, i.e., A1; B2; C3; D4; E5 (figure 1).
The user can interact with the different windows, accessing to the complete respiratory patient’s information. The interface structure allows adjustments to the different information requirements of respiratory health care professionals, researches and/or teaching environments. The terms and concepts used in the interface were based on the user familiarity and user diversity principle, i.e., the user profile [13], which included health professionals, researchers and students with knowledge in the context of pulmonology.

Fig. 1. LungSounds@UA interface structure – GUI composed by fourteen windows, with a hierarchy of five levels.

2.3. Overview of LungSounds@UA interface

The user starts by identifying the population that is going to be assessed, i.e., i) subjects with acute or chronic respiratory diseases and ii) smokers without disease or healthy subjects. This selection is available in the first window of the interface (A1) in the menu “Subject clinical label” (figure 2). The available parameters of the LungSounds@UA are dependent of this initial selection, i.e., when the user selects the option “Healthy or smoker” the panel “Respiratory Physiotherapy” is set as invisible, given its inapplicability for this population. Assuming the consistency principle [12], all parameters of the interface related to the respiratory physiotherapy are consequently set as invisible. For subjects with “acute or chronic respiratory disease”, the interface allows the introduction of parameters related to respiratory physiotherapy, as this type of intervention is recognised as an essential practice in the management of respiratory patients [14].

In the window A1 (lung sounds recorder) it is possible to record respiratory sounds in the seven most relevant locations (trachea, anterior left and right, lateral left and right and posterior left and right areas of the chest) for short-term acquisition of respiratory sounds [15]. The recordings can be performed using a digital stethoscope, sequentially positioned in the seven locations or using a multi-channel system [16]. In this window the user can also define the duration of each sound recording and the number of repetitions for each selected location (figure 2).
Recoverability features [12] were introduced in A1 to provide some resilience to user errors and allow recovering from unexpected situations, e.g., unexpected noise during a recording. It was therefore, added the ability to stop the recording and repeat the current or previous recordings.

To ensure that all the recordings were acquired during the session, a report is available in the button “Report” (figure 2). This report is also displayed as a warning message when the window A1 is about to be closed, having the undo possibility available, which follows the principles of recoverability and user guidance [12].

The information processing across the different resources is facilitated by an audio sound played after the sound recording, in addition to the displayed window (with the information regarding the current state of the recording) (figure 2). This procedure focus the user attention to the end of the recording, minimising the information access cost [17].

In the window B1 (upload parameters) different clinical parameters can be introduced, namely vital signs, oxygen saturation and dyspnoea evaluation. Dyspnoea is quantified by the subject through the Modified Borg Scale (MBS) [18] and the Medical Research Council (MRC) dyspnoea scale [19]. These clinical parameters are essential in the monitoring of respiratory conditions, helping the health professional to understand how the subject’s clinical condition is progressing over time [20]. Depending on the evaluation requirements of the subject, i.e., healthy or with a respiratory condition, several other information can be introduced/accessed through the following windows such as: other clinical parameters (windows: C1, D1, E1, D2, E2); FIM...
Regarding subjects who need respiratory physiotherapy it is possible to introduce in the window D2 other information routinely evaluated during the respiratory physiotherapy session, such as functional activities, chest examination (palpation, inspection and percussion) and other signs and symptoms (e.g., cough, sputum, dyspnoea, pain and fatigue). This physical assessment represents a simple way to evaluate, monitor and follow the patient’s progression [24]. Furthermore, during the treatments, the physiotherapist can register, in E2, parameters for monitoring the session, specifically during incentive spirometry [25], active cycle of breathing techniques (ACBT) [26] and endurance training (e.g., treadmill and stationary cycle ergometer) [27].

To ensure that comparable actions would have similar effects the principle of minimal surprise [12] was addressed, e.g., when any window is about to be closed, a warning message, with three available options, is displayed: i) Cancel; ii) Save; iii) Not save.

2.4. LungSounds@UA multimedia database

All data is stored at LungSounds@UA multimedia database. The database is structured to provide an easy access to all multimedia data (audio, image and text files). The files can be distinguished through the subject code and session number (which contains the acquisition date). In the audio files, the location of the respiratory sounds acquisition is added (figure 3). Furthermore, data can also be filtered according to specific parameters (e.g., subject’s respiratory condition). The hierarchical organisation of the data in the multimedia database also improves the subsequent statistical data analysis.

2.5. Usability assessment

LungSounds@UA interface was developed and iteratively assessed (through an informal evaluation) during the design process, identifying the problems that users (two respiratory researchers) had when interacting with the interface. A final version of the interface was then tested and informally assessed in a pilot study. These informal and flexible evaluation procedures allows to more quickly acquire experience with the new developed interface [28]. The pilot study was conducted by the two respiratory researchers (familiar
with the interface) in six patients with lower respiratory tract infection (225 recordings acquired in the seven chest locations).

LungSounds@UA interface was also submitted to a formal evaluation session composed by four health professionals (physiotherapists) without any prior knowledge of the interface and its general structure. They were asked to entry respiratory clinical parameters and record respiratory sounds from a pre-structured case study and report their opinions about the usability of the interface through a focus group interview. A focus group interview is commonly used to create knowledge about new products, processes and procedures [29]. Themes were selected following a semi-structured discussion guide, as recommended by Morgan [30] and included user’s perception about the greatest advantages, overall ease of use, navigation, layout/screen organisation, terms/concepts, disadvantages and suggestions for improvement. These used coding categories have been pre-established and recommended to evaluate clinical information systems [31].

The focus group interview was audio-recorded, transcribed and analysed via thematic analysis of latent data at three levels: articulated, attributional and emergent. This method: i) identifies, analyses and reports patterns and ii) organises and describes data in rich detail [32]. The focus-group interview was held one day after the evaluation session. The meeting lasted for 107 minutes and it was chaired by one of the researchers to facilitate discussions.

3. Results

The two respiratory researchers, who conducted the pilot study, considered that the interface was easy/enjoyable to use, logic and consistent in its different features, being particularly useful in the context of this research project.

The usability of the interface was also assessed by the results of the focus group interview.

3.1. Focus group interview

The results obtained in the seven pre-established categories (advantages, overall ease of use, navigation, layout/screen organisation, terms/concepts of the interface, disadvantages and suggestions) are presented below.

1. Advantages: all participants agreed that the interface is very useful and has a great potential to be used in the research/clinical setting. The ability to collect respiratory sounds and several other respiratory parameters, and make comparisons between them in a single multimedia database was strongly emphasised by all participants. The benefits of having computerised auscultation data available, which can provide valuable insights in the patient respiratory assessment was also highlighted. The possibility to share information between health professionals following standard procedures was found to be very useful and helpful in the clinical practice. It was also considered of great value the automatic calculation of crucial parameters e.g., body mass index and the distance walked in the 6MWT. Participants also emphasised that this functionality saves a great amount of time to health professionals during their practice.

2. Overall ease of use: participants considered that in general the interface was not intuitive and had a great amount of information not adequately organised. The term most used by the participants to classify their interaction with the interface was “confusion”.

3. Navigation: finding the correct places to register the clinical information was found to be a difficult task for most of the participants, due to the lack of intuitivism in the navigation menu.

4. Layout/screen organisation: two major sub-categories have emerged: i) organisation of the contents within the windows and ii) between windows. The excessive amount of information presented in some
windows was considered a limitation to visualise and select the desired parameters. Regarding the organisation of the contents between windows, some participants found that the repetition of some parameters in different windows was confusing. The majority of the participants referred that the information presented should follow the same lines used by physiotherapist in their patient’s assessment.

5. Terms/concepts of the interface: most participants stated that the medical terms were appropriate to the physiotherapist assessment. Some participants mentioned certain ambiguous language, which caused difficulties in finding the right place to put the clinical information.

6. Disadvantages: the major disadvantage mentioned by the group was the unavailability to generate a paper output of the patient’s assessment.

7. Suggestions: many participants reported the need to improve the navigation menu and reduce the amount of information per window. To create a more intuitive organisation of the contents within and between windows, participants suggested its arrangement by alphabetical order. It was also suggested the use of the Subjective-Objective-Assessment-Plan (SOAP) to organise the information between windows. The introduction of new functionalities also emerged, such as the possibility to generate a paper output of the subject’s assessment and the implementation of a help menu.

4. Discussion

LungSounds@UA allows an efficient introduction of several respiratory parameters and the recording of respiratory sounds with a digital stethoscope or multichannel system, according to Computerised Respiratory Sound Analysis (CORSA) guidelines [15]. This feature overcomes some limitations reported in previous studies such as the difficulty to analyse different clinical information and non-interoperable data repositories [9, 33]. According to our knowledge, there is only a study which have attempt to address this limitation, combining auscultation results and lung function parameters in the same technology [7]. However, LungSounds@UA combines respiratory sounds with the other relevant information used to fully assess and manage respiratory patients.

All data from LungSounds@UA is stored in a single repository, structured to provide an easy and fast access to all audio, image and text data. As indicated in previous studies, it is essential to design a unified multimedia database to be used in the clinical setting for managing a large amount of heterogeneous data [34]. Specifically in respiratory health care, a larger multimedia database is needed for the development of new advanced methods to identify and analyse respiratory sounds [7].

The usability of the LungSounds@UA interface was assessed by two researchers (familiar with this application) and four physiotherapists without any prior knowledge of it. To strengthen the evaluation, and obtain full information about the perceived weaknesses of health professionals (physiotherapists) when using the developed application, it was chosen not to conduct a training-session [12].

As expected, the users without any training-session (usability attribute referred as learnability [12]), reported more difficulties to become fully productive with the system than the ones with prior knowledge (users familiar with the interface). These difficulties were reported in some categories of the focus group, namely overall ease of use, navigation, layout/screen organisation and terms/concepts of the interface. Nevertheless, the users also reported important advantages in the developed application, such as its usefulness and great potential to be used in research/clinical respiratory settings. Therefore, the focus group was essential to evaluate the application and inform improvements/adjustments needed. This is currently being implemented in this GUI and will inform future research.
5. Conclusion and Future work

The design of successful graphical interfaces is one of the main challenges in the area of health care technologies [9]. The LungSounds@UA interface allows the combination of digital pulmonary auscultation data with other clinical parameters. It also organises the information in a single multimedia database, which facilitates the effective respiratory evaluation and correlation with different data. Despite of the drawbacks addressed in the usability assessment of the LungSounds@UA interface, the utility and great potential to be used in research and clinical health care settings was stated.

New developments are being implemented in order to improve the interface usability and meet the users’ requirements.

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