Title page

RIBS@UA: Interface to collect and store respiratory data, a preliminary study

Authors' information (name, affiliation, email address):

1st Author:
Name: Cátia Manuela Rodrigues Pinho[1,2]
e-mail: catiap@ua.pt

2nd Author:
Name: Ana Luísa Araújo Oliveira[1]
e-mail: alao@ua.pt

3rd Author:
Name: Daniela Santos Oliveira[1]
e-mail: danielaoliveira@ua.pt

4th Author:
Name: João Pedro Campos Dinis[1,2]
e-mail: joao.dinis@ua.pt

5th Author (**corresponding author**):
Name: Alda Sofia Pires de Dias Marques[1,3]
e-mail: amarques@ua.pt

City/Zip/country: Aveiro, 3810-193, Portugal
Address: School of Health Sciences
Agras do Crasto - Campus Universitário de Santiago - Edifício 30
3810-193 Aveiro, Portugal
Department: School of Health Sciences, University of Aveiro (ESSUA)

Affiliation:

[1] School of Health Sciences, University of Aveiro (ESSUA), Agras do Crasto - Campus Universitário de Santiago - Edifício 30, 3810-193 Aveiro, Portugal.

[2] Institute of Electronics and Telematics Engineering of Aveiro (IEETA), University of Aveiro, Campus Universitário de Santiago, 3810-193 Aveiro, Portugal.

[3] Unidade de Investigação e Formação sobre Adultos e Idosos (UNIFAI), Porto, Portugal.

Abstract

Objectives: The development of effective graphical user interfaces (GUIs) has been an emergent demand in healthcare technologies, for assessing, managing and storing patients' clinical data. Nevertheless, specifically for respiratory care there is a lack of tools to produce a multimedia database, where the main respiratory clinical data can be available in a single repository. Therefore, this study reports on the development of a usable application to collect, organise and store respiratory-related data in a single multimedia database.

Methods: A GUI, named RIBS@UA, organised in a multilayer of windows was developed in MATLAB and evaluated. The evaluation consisted of usability inspection (by two respiratory health professionals and two system designers during the development of the prototype) and usability testing (by seven physiotherapists).

Results: The users reported on the utility of the new application and its potential to be used in clinical/research settings. It was also stated that RIBS@UA facilitates diagnosis/assessment and contributes to the implementation of standardised interventions and treatment procedures. Nevertheless, some drawbacks were identified and suggestions were given to improve the content of specific features in the physiotherapy sessions window.

Conclusions: RIBS@UA interface is an innovative application to collect, store and organise the main respiratory-related data, in a single multimedia database. Nevertheless, further improvements are still recommended before the final implementation of RIBS@UA.

Keywords: Respiratory evaluation; respiratory sounds; respiratory clinical parameters; graphical user interface (GUI); multimedia database.

1 Introduction

Respiratory diseases are currently the fourth most common cause of mortality worldwide [1, 2] and a leading cause of morbidity [3].

Respiratory physiotherapy is recognised as essential in the assessment, monitoring and treatment of both acute and chronic respiratory diseases [4, 5]. Physiotherapists' practice relies on collecting and interpreting large amounts of information, such as clinical parameters (e.g., vital signs, spirometry, sub-maximal exercise tests results between others) and auscultation findings (e.g., auscultation clinical notes or/and computerised analysis of respiratory audio files), to understand how each patient's clinical condition progresses over time. Additionally imaging techniques, which are the gold standard to assess the pathophysiology of respiratory diseases, i.e., computed tomography (CT) [6, 7], chest X-ray and magnetic resonance imaging (MRI) also provide relevant information to diagnose and monitor patients with respiratory conditions. Currently, most of these data are collected and recorded using written record sheets or different software applications for each type of clinical data (e.g., lung function data can be recorded and stored in the spirometer). Improved multimedia databases have also been developed to store specific respiratory-related data, enabling comparisons between similar data (e.g., the reference multimedia database of high-resolution computed tomography for interstitial lung diseases, used to carry out research on computerised image-based diagnosis aid [8]). However, despite these technologies' great potential, different respiratory-related data are still collected in distinct repositories. This prevents data combination, leads to dispersion and loss of relevant clinical information, and may ultimately affect the management of patients with respiratory diseases [9].

Therefore, the development of an interface to collect, organise and store patients' information in a single multimedia database, is essential to help planning and conducting effective respira-

tory physiotherapy interventions [10, 11]. However, there has been resistance from respiratory professionals to the use of graphical user interfaces (GUIs) in research/clinical practice due to difficulties interacting with complex technologies and poor data presentation (e.g., lack of reports with graphical and textual summaries) [12-15]. Overcoming these challenges is crucial to guarantee health professionals adherence to these new technologies.

Although few studies have developed GUIs integrating respiratory relevant data [10, 16], they had not taken into consideration all necessary data for a comprehensive assessment of patients. Furthermore, even though these GUIs have been tested in clinical environments, they failed to be implemented in the clinical practice as they were not intuitive enough and easy to use by health professionals. The amount and complexity of respiratory clinical data (necessary for a complete evaluation of patients with respiratory conditions) leads to the need of conducting preliminary studies with prototypes before clinical tests are applied. The conduction of such tests are widely recommended in the literature (i.e., development of applications based on prototyping and iterative usability testing [17, 18]). Prototype testing [18] allow health professionals to establish contact with the interface in a preliminary stage and therefore, their suggestions can be easily implemented and re-tested contributing for enhancing the final version of the developed system. This iterative development can be seen as the step that is missing in other studies to allow respiratory interfaces to be successfully implemented in the clinical practice.

Thus, this study reports on the development and evaluation of an adaptive and usable interface prototype to collect and organise respiratory-related data in a single multimedia database, suitable for respiratory health professionals, namely respiratory physiotherapists.

2 Methods

The GUI named RIBS@UA (Respiratory information and breath/adventitious sounds, University

of Aveiro) was developed in the scope of a clinical study "Adventitious lung sounds as indicators of severity and recovery of lung pathology and sputum location" (PTDC/SAU-BEB/101943/2008). RIBS@UA was informed by the literature and by a preliminary interface developed and tested in a pilot study [16]. The application RIBS@UA was developed in MATLAB [19] because of its rapid prototyping characteristics and to simplify the integration of automatic detection algorithms, e.g., Dinis et al. [20] and Oliveira et al. [21].

Two methodologies were followed in the development of this interface: i) the five steps of system development life cycle (planning, analysis, design, implementation and maintenance/support) [18] and ii) the seven steps for prototyping and iterative usability testing (initial system analysis; basic architecture design; prototype design; prototype implementation; prototype testing; evaluation and final implementation) [17]. The re-design and modifications were performed going back to the basic architectural and prototype design.

2.1 Design principles

The focus of a user-centred interface design is to provide maximum usability, which can be defined as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness[1], efficiency[2] and satisfaction[3] in a specified context of use" [22, 23]. Thus, to increase the usability of the developed application, the design principles proposed in the literature were considered, i.e., Nielsen [24], Sommerville [25], Seffah et al. [23] and Blair-Early and Zender [26]. These principles were implemented gradually, in different stages of the interface development [23]. To avoid an excessive detailed description of the implemented principles, only some key examples are provided:

1. Users' actions were guided and resilience to users' errors was added by displaying warn-

1 Effectiveness: "Accuracy and completeness with which users achieve specified goals".

2 Efficiency: "Resources expended in relation to the accuracy and completeness with which users achieve goals".

3 Satisfaction: "Freedom from discomfort and positive attitudes towards the use of the product".

ing messages (e.g., when the introduced parameter did not meet the expected requirements), allowing the confirmation of destructive actions and providing undo facilities (i.e., the ability to restore the system to how it was before the occurrence of the action, figure 7) – *according to the principles: "prevent errors" and "good error messages"* [24]*; "recoverability" and "user guidance"* [25]. The displayed messages were developed taking into account the "design factors in message wording" [25].

2. The interpretation of some objective clinical parameters was displayed, e.g., body mass index <60 - *Underweight - severe thinness*; Heart rate = 55 - *Normal range* (section 2.3, figure 6) – *following the principles: "active user involvement"* [23]*; and "feedback"* [24, 26].
3. The navigation across the interface was facilitated by a map of the application and the possibility to change the subject and session number in all windows (section 2.3, figure 3-10) – *according to the principles of "shortcuts" and "clearly marked exits"* [24]*; "landmarks" and "proximity"* [26].
4. The content of the interface followed the principles of problem oriented medical system (POMR) [27] and Subjective-Objective-Assessment-Plan (SOAP) [28], according to the importance of content, i.e., "the interface serves the content, not the other way around" [26] – *following the principle of "interface is content"* [26].

2.2 General structure

RIBS@UA interface, available in English (EN) and in Portuguese (PT), was built with four hierarchy levels, i.e., 1-[A]; 2-[B]; 3-[C]; 4-[D, E] (e.g., window A1, in the first hierarchy level, allows the access to window B1). The interface is organised in a multilayer of windows with four major components: patient's socio-demographic/clinical information (windows: B1, C1, C2), problems list (window: C3), treatment plan (window: C4) and physiotherapy sessions (window: C5),

figure 1.

(insert figure 1 about here)

The content of the interface consists of patient's general details, medical and social history, and subjective and objective assessment.

The user can interact with several applications/functionalities (e.g., record and analyse respiratory sounds; upload CT reports and parameters of lung function tests) and easily access a comprehensive respiratory patient's information.

2.3 Main functionalities and content description

The user can access RIBS@UA through an initial login and by selecting a predefined study (e.g., e001 - lower respiratory tract infection) or by defining a new one, figure 2. The application comprises different types of users, with different permissions, i.e., i) administrator and heath professional – which have access to all the information available in the interface regarding their patients; and ii) researcher – which do not have access to patients' personal information, but only to clinical parameters, to guarantee confidentiality and data anonymity.

(insert figure 2 about here)

RIBS@UA is composed by six main windows: socio-demographic data (B1), subjective (C1) and objective (C2) assessment, problems list (C3), treatment plan (C4) and physiotherapy sessions (C5).

2.3.1 Socio-demographic data

The socio-demographic window (B1, figure 3) gathers information about patient's date of birth, gender, nationality, birthplace and diagnosis. In the database, a numeric code is given to each patient. This functionality is crucial to guarantee patients' anonymity and data protection [29]. The data introduced in the database are also associated with the date of the patient's

assessment, e.g., session number, which enables to compare data along a treatment period.

(insert figure 3 about here)

2.3.2 Subjective assessment

In the subjective assessment window (C1) the user can introduce patient's main problems and limitations, according to the guidelines [30], figure 4. The presence and behaviour (e.g., duration and severity) of significant respiratory symptoms [31] are also recorded in this window. The accuracy of the symptoms behaviour assessment is further improved with the use of different scales [31], e.g., the presence of cough (C1a) can be evaluated through the cough symptom score [32] and dyspnoea with the Modified Medical Research Council scale [33] and the Modified Borg scale (C1b) [34].

(insert figure 4 about here)

Pain is evaluated (C1c) using body chart and Visual Analogue scale (VAS). The body-chart allows the assessment of number, location, extension and hierarchy of pain. The visual Analogue Scale is a self-report instrument extensively used to quantify pain [35]. The user can identify the pain area by drawing in the body chart. The undo functionalities such as clean last selection or all selections are also available, figure 5.

(insert figure 5 about here)

Other information such as comorbidities (D1), medication (D2) and functional independent measures (D3) [36] can also be accessed through the subjective assessment window (C1), as they are known to affect lung function.

2.3.3 Objective assessment

Objective assessment (C2) is based on patient's examination, together with the use of quantitative tests [37]. Anthropometric data and vital signs, can be registered in this window, helping

the user to understand how patient's clinical condition progresses over time [38]. Furthermore, the user has access to a wide range of objective assessment methodologies used for standard evaluation, namely conventional and digital auscultation [39], lung function tests (e.g., spirometry) [40], tests for exercise prescription (e.g., cardiopulmonary exercise testing) [41], clinical analyses (e.g., biochemistry and arterial blood gas) [42] and medical imaging reports (e.g., chest radiography) [43], figure 6.

(insert figure 6 about here)

2.3.3.1 Auscultation

Auscultatory findings can be collected/assessed through the windows: *Respiratory sound recorder* (E1), *Auscultation findings* (E2) and *Respiratory sound toolkit* (E3). Respiratory sounds are acquired according to the short-term acquisition guidelines proposed by the computerised respiratory sound analysis (CORSA) project [44]. Health professionals' interpretation of the respiratory sounds heard can be recorded in window E2. In the *Respiratory sound toolkit* window, three main options are available: i) automatic analysis of respiratory sounds (i.e., wheezes, crackles and respiratory phases); ii) manual annotation of sounds to create a gold standard (e.g., by respiratory experts) and iii) manual annotation testing (e.g., inexperience users or undergraduate students).

In the *Respiratory sound recorder* (E1) it is possible to select the location (in the upper body chart, figure 7a), the duration of the recording and the number of repetitions for each location. It is also allowed to stop recording and repeat the current or previous recordings, to recover from unexpected situations, e.g., noise during the recording.

(insert figure 7 about here)

To ensure that all respiratory parameters were recorded during the session, a report list is displayed when the window E1 is about to be closed, having the undo possibility available. The

recording process can be followed in the window *Recording info*, automatically displayed when the record starts. In this window, the acquired audio signal is also displayed, figure 7b. The y-axis label of the graph is highlighted if the signal amplitude saturates (>100%, figure 7b), informing the user that the recording should be repeated. Furthermore, to facilitate the information processing by the user across the different resources, an audio sound is played after the recording in addition to the displayed text information. This procedure focuses the user attention to the end of the recording, minimising the user information access cost [45].

2.3.3.2 Lung function tests

The interface also allows to record spirometry (E5), plethysmography (E6) and respiratory muscles strength (E7) data. In E5 the user can register the spirometry parameters, e.g., forced expiratory volume in 1 second (FEV_1), and select the position adopted by the patient during the test, according to the recommended spirometry standardisation procedures [46]. In E6 the user can collect respiratory parameters taken from body plethysmograph [47]. From these measures, other key parameters such as specific resistance (sRaw) and specific conductance (sGaw) can be calculated, figure 8. Finally, in E7, the user can register values of maximum inspiratory and expiratory pressures and interpret them according to the guidelines [48].

(insert figure 8 about here)

2.3.3.3 Tests for exercise prescription

Multiple tests for exercise prescription can be accessed in RIBS@UA, ranging from laboratory tests performed in a more controlled environment, e.g., cardiopulmonary exercise testing (CPET) [41], to more simple tests, easily performed in the clinical practice such as field test, e.g., *six minute walk test (6MWT)* [49]. The window E10 allows the user to select the exercise testing protocol which better adjusts the patient and enables the recording of crucial parameters (e.g., work rate and oxygen uptake) according to the guidelines [41], figure 9.

(insert figure 9 about here)

The window E11 allows the user to record the 6MWT according to the guidelines [49], and displays the results (total distance achieved, predicted distance and the percentage achieved) using the reference equations for the 6MWT [50, 51]. In the following windows, it is possible to record the *incremental shuttle walk test (ISWT)* (E12), *ten meter walk test (10MWT)* (E13) and *timed up and go test (TUG)* (E14), according to the guidelines [52].

2.3.3.4 Clinical analysis

Clinical analysis data can also be recorded, which facilitates the diagnostic and monitoring of patients during treatment [10, 11], i.e., haemogram values (E16) - haemoglobin and leukocyte; biochemistry and arterial blood gas values (E17) and C-reactive protein. Furthermore, users can also upload existing reports of the clinical analysis.

2.3.3.5 Medical imaging reports/scans

Imaging techniques are currently the gold standard to assess pathology and pathophysiology of respiratory diseases, namely CT [6, 7]. Other imaging techniques are available in C2, e.g., Chest X-ray (E19) and MRI (E21). The respiratory parameters available in the imaging windows (e.g., pulmonary consolidation and pulmonary collapse) were defined by a panel of radiology experts (radiologists and radiology technicians), and allow the characterisation and exact location of the principal disease as well as other clinical associated complications. Moreover, it is possible to compare imaging findings with other parameters, such as respiratory sounds, to confirm the diagnosis and/or assess patient's response to treatment.

2.3.4 Problems list

Once a thorough assessment has been completed, the findings can be analysed to identify relevant structural or functional problems [31]. In the window *Problems list* (C3) the user has

the possibility to select, from a predefined list, possible problems presented or identified by the patient. This list includes some of the most common problems related to respiratory diseases such as excess of bronchial secretions [53] or increase of airway resistance [31]. Furthermore, the user can add more specific problems according to the evaluation.

2.3.5 Treatment plan

Once the user has identified patient's problems, he/she can design a suitable treatment plan. The window *Treatment plan* (C4) enables the user to record long-term objectives, the initial treatment plan and the treatment plan per session, progress notes and the discharge summary. The discharge summary should summarise patient's progression, instruction for home programmes and other relevant information that could help the patient in future treatments [31].

2.3.6 Physiotherapy sessions

For patients who are prescribed with respiratory physiotherapy treatments, the window C5 comprises the recording of relevant parameters to monitor each physiotherapy technique applied, i.e., incentive spirometry [54], active cycle of breathing techniques (ACBT) [31] and endurance training [52], such as vital signs, oxygen saturation and dyspnoea through the Modified Borg scale (MBS), figure 10.

(insert figure 10 about here)

2.4 Multimedia database

All data registered in the interface is stored in the RIBS@UA multimedia database in a file system with four main formats: i) excel files (which compiles the text information generated by the interface); ii) wave files (respiratory audio sounds recorded with the interface); iii) image

files (i.e., body-chart figures recorded in the pain assessment window); and iv) pdf files, which can be attached in each window of the interface (these extra files should provide additional information, not covered in the application), figure 11. Each file is automatically named according with the following information:

i) excel files: [study]_[patient]_[session].xlsx;

ii) wave files: [study]_[patient]_[session]_[location of the recording] [repetition of recording] _ [type of acquisition, i.e., single or multi-channel] .wav;

iii) image files: [study]_[patient]_[session].png;

iv) pdf files: [study]_[patient]_[session]_[window] [number of file].pdf.

(insert figure 11 about here)

These approaches allow an easy access to all multimedia data, i.e., text, audio and image files. Therefore, data can be compiled and filtered according to specific parameters (e.g., patient's respiratory condition – related with the study being conducted) and statistical analysis is facilitated. Specifically for research purposes, scripts were developed to build databases combining data recorded in the interface. These databases were built in a matrix format to be easily exported to different software used in statistical analysis (e.g., SPSS, MATLAB or Excel).

2.5 Usability evaluation

The usability of the RIBS@UA interface was assessed following two different methodologies: **inspection** and **testing** [17]. Usability inspection was performed in four review meetings with the designers of the interface and respiratory experts (researchers and health professionals). Usability testing was conducted with a representative target user population, assessed in a focus group interview.

The usability **inspection** was held throughout the design process of the prototype (during four

months), by conducting meetings once a month. This systematic inspection of the interface was carried out using: i) pluralistic walkthroughs, i.e., review meetings where respiratory experts and designers went through specific scenarios and discussed usability issues that they felt could be raised during the interaction with the interface [17]; and ii) a set of heuristics [17, 24]. The heuristic violations were assessed through a severity rating scale: (0) not a usability problem; (1) cosmetic problem only; (2) minor usability problem; (3) major usability problem; and (4) usability catastrophe [17]. These two methods have been previously used in the literature to detect interface usability problems [17, 24].

The usability problems, which emerged from the usability inspection, were solved and the solutions implemented in the interface prototype, prior to the usability testing.

The usability **testing** of RIBS@UA prototype was conducted in three evaluation sessions (86±10 minutes) on two consecutive days at the University of Aveiro, Portugal. The testing room was prepared according to Kushniruk and Patel [17] recommendations. The evaluation sessions were conducted with seven physiotherapists (2 sessions with 2 and 1 session with 3 physiotherapists). Prior to the evaluation session, all participants gave their informed consents, answered a background questionnaire about their expertise and usage of informatics systems [17] and enrolled in an instruction-based training session [55, 56], for approximately 20 minutes. Participants also received training manuals containing a hierarchical diagram of the general structure and windows of the interface.

In the evaluation session, each participant received a pre-structured case study. The case study followed the usual practice workflow employed by respiratory healthcare professionals and consisted in a case of a patient with lower respiratory tract infection who consulted a respiratory physician in a hospital emergency department. In the hospital, the patient performed clinical evaluation tests, such as clinical analyses and a CT scan, then the physician prescribed the patient with home medication and respiratory physiotherapy. In the first session of respiratory

physiotherapy, the physiotherapist performed a subjective (e.g., anamneses, presence of symptoms and its behaviour) and objective (e.g., spirometry, auscultation, respiratory muscle strength assessment) evaluation and then executed some respiratory techniques such as incentive spirometry and the ACBT. Auscultation and verification of vital signs was performed after each technique.

The pre-structured case study was read aloud by one of the researchers, and then enough time was given to participants to read by themselves and clarify any doubts. Afterwards, participants were instructed to enter the data from the case study in the RIBS@UA prototype. The two researchers remained at the evaluation sessions to guide participants through the interface and clarify any questions.

After the evaluation sessions, a focus group interview was conducted with all participants. A semi-structured discussion guide was used, as recommended by Morgan [57] and included the following nine topics: user's perception about the overall ease of use, usefulness, navigation, layout/screen organisation, design and used terms, contents, advantages, disadvantages and suggestions for improvement. The meeting lasted for 85 minutes and was chaired by one researcher, blinded to the interface evaluation, to facilitate the discussion without inducing bias. The focus group interview was audio and video recorded, transcribed and analysed via thematic analysis of latent data at three levels: articulated, attributional and emergent.

3 Results

3.1 Usability inspection

The usability issues identified in the *pluralistic walkthroughs* (from the discussions between the designers and respiratory experts) lead to the need of conducting several improvements, such as: i) to insert new tests and parameters that can be performed in patients' respiratory

assessment, e.g., insertion of "Timed up and go test" (figure 6, section 2.3); and ii) re-organisation of contents to facilitate the workflow of health professionals, i.e., guided by the principles of problem oriented medical system (POMR) [27] and Subjective-Objective-Assessment-Plan (SOAP) [28]. In the review meetings, the usability *heuristics* proposed by Kushniruk and Patel [17] were also assessed and rated. A compilation of the *heuristic* results are presented in the table I.

(insert table 1 about here)

3.2 Usability testing

3.2.1 Socio-demographics and general characterisation of the sample

Seven female physiotherapists (24.3±1.0 years old) participated. Three participants were employed as full-time researchers (42.9%), three were recent graduated physiotherapists (42.9%) and one was a part-time employee in clinical practice (14.3%). Data on participants' usage of informatics systems are presented in table II. Most participants reported the usage of informatics systems in their professional (71.5%) and leisure (57.1%) activities. When inquired about the existence of software to insert and store clinical data in their workplace, 57.2% of participants answered that they did not have access to such software, although 57.1% considered having enough competencies to use it efficiently. Finally, 71.4% classified their general performance in the usage of informatics systems as being good.

(insert table2 about here)

3.2.2 Focus group interview

Nine major categories were assessed as previously described.

Overall ease of use: all participants considered that in general the interface was intuitive, easy

and pleasant to use. While interacting with the interface, participants reported feelings of enjoyment and compliance, however, some confusion in the medication category was reported. Participants did not understand why patients had to be treated with different medications in the hospital and home and one participant even referred that this organisation "was confusing" and that one could not understand what the patient was taking in the hospital and at home, in terms of their medication.

Usefulness: the participants emphasised the great value of the interface to guide health professionals, namely physiotherapists, through patient's evaluation and to collect, organise and store clinical data in clinical/research settings. The interviewed group also concluded that to implement the interface in the clinical practice some improvements should be addressed, namely in the help menu and in the interface user manual to facilitate their interaction with the interface.

Navigation: all participants found the interface easy to navigate (e.g., highlighting the existence of the navigation bars on the top right and lateral left columns of the windows). Nevertheless, finding the correct places to register home and hospital medication was a difficult task for four participants, which considered this item incorrectly localised.

Layout/screen organisation: two major sub-categories have emerged, i.e., organisation of the contents between the windows and within windows. All participants agreed that the information presented was well organised and followed the same lines used by physiotherapists in their clinical practice. This fact reduces the probability of errors occurrence in data insertion and prevents physiotherapists from skipping crucial steps in patient's assessment. The *treatment plan* was the only window that participants suggested to be improved to allow splitting objectives into short and long term.

Design and used terms: The colours used in the interface were found to be pleasant and appealing. Regarding to the language used, most participants stated that the clinical terms were

appropriated to physiotherapist's evaluation. Only two participants reported difficulties in understanding some technical terms due to the great amount and variety of respiratory parameters that can be assessed with the interface.

Contents: all participants agreed that the interface covered the essential tests and procedures to perform a more complete assessment and develop a treatment plan in the respiratory field, than the usual record sheets or software applications for each type of clinical data. However, some treatment objectives, such as "improve quality of life", were considered to be redundant and therefore not necessary. In the physiotherapy sessions window, participants concluded that although the techniques presented were enough to conduct a respiratory physiotherapy session, more techniques could be added.

Advantages: The great scope of respiratory parameters covered by the interface was perceived by participants as: a positive stimulus to perform a full assessment of patients and a contribution to standardise procedures. The possibility to share information between different health professionals following standard procedures was found to be helpful in the clinical practice. The existence of a manual was considered of great importance for users to learn how to navigate in the interface. It was also considered of great value the automatic calculation of some clinical parameters, e.g., distance walked in the ISWT and walking velocity in TUG. Participants also highlighted that this functionality along with the interpretation of the data provided by the interface (e.g., labelling heart rate as normal, lower or above the limits) could save a great amount of time and prevent interpretation errors. Finally, it was concluded that the interface provided relevant information and at the same time preserved the clinical reasoning of health professionals.

Disadvantages: the current absence of a portable hardware containing the graphical interface was considered as being the major disadvantage.

Suggestions: participants suggested having a single list of medication that health professionals

could select in different columns if they were used at the hospital, at home or both. All participants reported the need to improve the content of the physiotherapy session window, adding components of time and number of repetitions per technique. It was also suggested the use of the International Classification of Functioning, Disability and Health (ICF) frameworks to formulate the problems' list and to leave a box for free writing in the objectives of treatment. Many participants also referred the need to incorporate standard guidelines for all procedures covered by the interface in the help system and documentation.

3.2.3 Strengths and limitations

The following list of potential strengths and limitations emerged from the usability test performed.

Strengths:

- collects, organises and stores respiratory clinical data to be used in clinical/research settings in a single multimedia database;
- intuitive, easy to navigate and pleasant to use;
- well organised contents;
- prevents error occurrence in data insertion;
- alerts health professionals when data is missing;
- covers essential tests and procedures to perform patient's respiratory assessment;
- contributes to standardise respiratory evaluation procedures;
- facilitates data interpretation;
- assists health professionals in performing a more complete patient's respiratory evaluation, when compared with the standard record sheets or software applications for each type of clinical data;
- facilitates the information sharing between health professionals.

Limitations:

- the large amount of information presented increases the learning time needed by users to use the application efficiently;
- the help menu does not have information about the tests available in the application (e.g., guidelines, indications and contra-indications);
- the *treatment plan* window does not divide objectives into short and long term;
- the interface does not cover all the available physiotherapy intervention techniques;
- the software used to develop the interface (i.e., MATLAB) implies licensing costs;
- the data is stored in a file system, therefore its combination in a database requires the development of additional MATLAB scripts.

4 Discussion

This study developed and assessed a GUI, RIBS@UA, to be used by health professionals in clinical and research settings. The usability evaluation conducted with the interface prototype highlighted its great potential to perform a full and standardised assessment of respiratory patients.

The RIBS@UA interface allowed adequate collection, storage and organisation of data using a mix methods approach, i.e., qualitative and quantitative, respiratory-related data [52]. The possibility to generate individualised reports, which has been shown to predict patients' compliance [15, 58], also increased the system's value, by providing a detailed explanation of patients' diagnosis and treatment plan. These functionalities may represent major advantages for clinical/research practice as dispersion of information is avoided and clinical reasoning is enhanced [9, 13, 59].

Nevertheless, developing GUIs in healthcare technologies is challenging and therefore following design principles and addressing usability issues is crucial for achieving users' requirements

[17, 24]. In this study, the design principles developed by Nielsen [24], Sommerville [25], Seffah et al. [23] and Blair-Early and Zender [26]) were followed and two different usability approaches were conducted, i.e., inspection (through *pluralistic walkthroughs* and *heuristics*) and testing (through focus group interview) [17].

The *pluralistic usability walkthrough* and *heuristic* evaluation highlighted usability issues and provided new design ideas, which lead to the implementation of improvements prior to the usability testing of the prototype. Nevertheless, the usability inspection should always be complemented with usability testing, described by Nielsen [24] as "the most fundamental usability method", since it provides direct information about how users interact with the system and identifies the specific advantages and problems felt by them [24]. The usability testing was performed with representative target users of the developed application [17], i.e., seven physiotherapists in the research or routine clinical practice. Users reported positive aspects and highlighted the functionalities of RIBS@UA interface in the focus group interview, e.g., emphasised the interface value in guiding health professional through patient's assessment, facilitating data collection, organisation and storage in research or clinical settings. However, some disadvantages were identified and suggestions given which will lead to improvements in the interface. In sum, the implementation of the usability inspection during the design process followed by usability testing in the prototype, showed to be essential to develop a stronger application, which highly meet the users' requirements [17, 24, 60].

5 Limitations and future work

Some limitations need to be acknowledged. Firstly, the evaluation was only performed with physiotherapists and their comments may not be entirely representative of all health professionals. Therefore, further usability testing with other users is recommended, e.g., with physi-

cians and nurses. Nevertheless, the main target users of the developed application are physiotherapists and therefore, it is not believed that this limitation removes the validity of our findings. Secondly, the usability inspection (i.e., *pluralistic usability walkthrough* and *heuristic* evaluation) was not assessed by usability experts. Usability inspection requires experience with the usability guidelines, however, non-experts are also reported as capable of detecting many usability problems by usability inspection [24]. Thus, the inspection performed by the system designers and respiratory experts improved the usability of the developed application prior to the usability testing.

Several improvements are being developed and implemented taking into consideration the usability testing results. These improvements will inform the new versions of the interface, following the systems development based on prototyping and iterative usability testing procedures [17, 18]. To explore the potential of the interface to be used in a teaching environment, usability testing in the educational field (e.g., with physiotherapy students) is being developed.

6 Conclusions

RIBS@UA interface is an innovative application to collect, store and organise the main respiratory-related data, in a single multimedia database. It also allows the associations between different data. Thus, its use may provide a comprehensive assessment of patients in a single or over time assessment, enhancing health professionals' clinical reasoning. Nevertheless, further improvements are still recommended before RIBS@UA final implementation.

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otherapists and moderator for their contributions in the focus group interview.

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List of Figures (with captions)

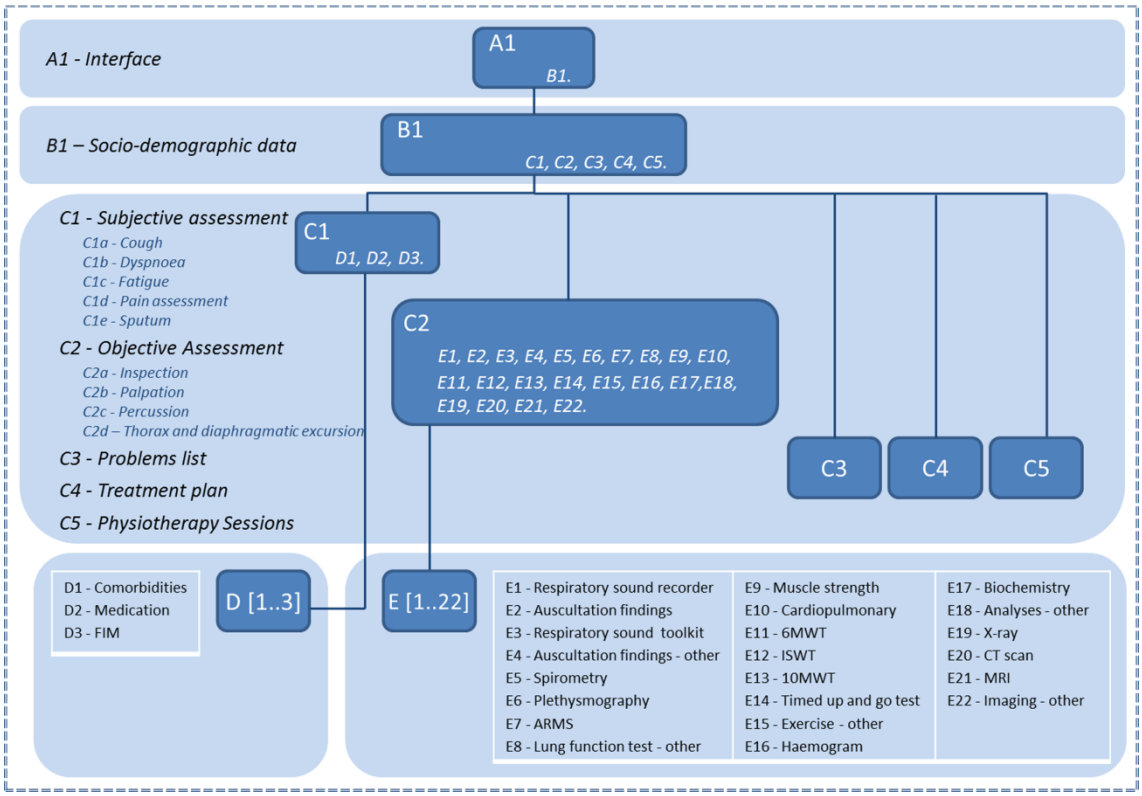

Figure 1. RIBS@UA interface structure – GUI composed by 42 windows, with a hierarchy of 4 levels. *FIM - functional independence measure; ARMS - assessment of respiratory muscle strength; 6MWT - 6 minute walk test; ISWT - incremental shuttle walk test; 10 MWT - 10 meter walk test; X-ray - chest radiography; CT* - computerised tomography; MRI - Magnetic resonance imaging.

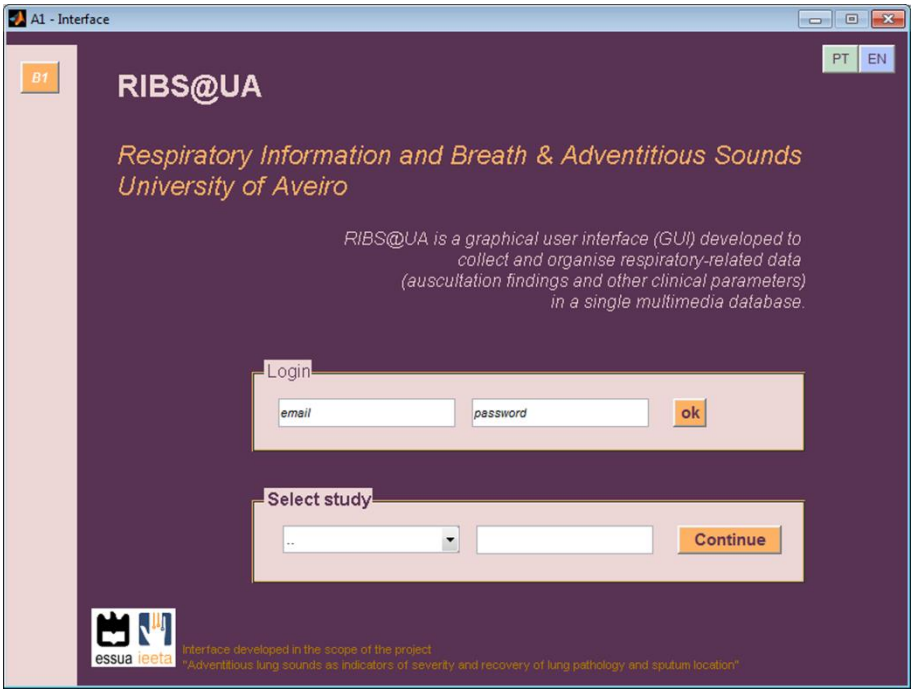

Figure 2. RIBS@UA window A1 – Initial window.

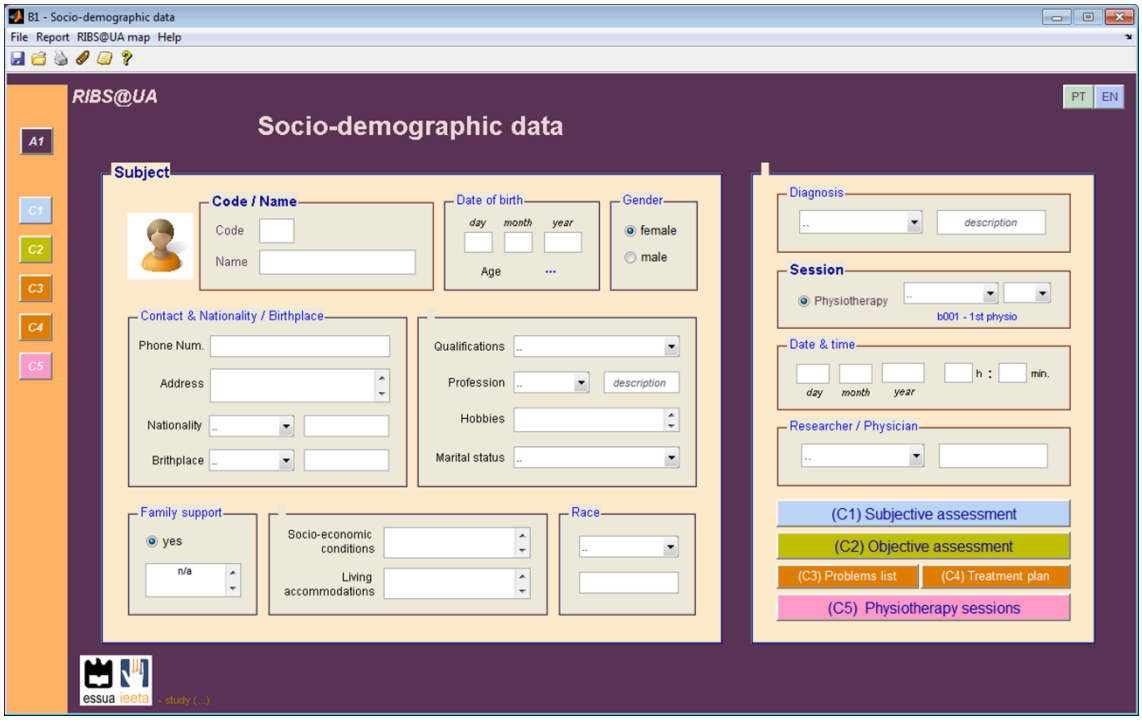

Figure 3. RIBS@UA window B1 – Socio-demographic data.

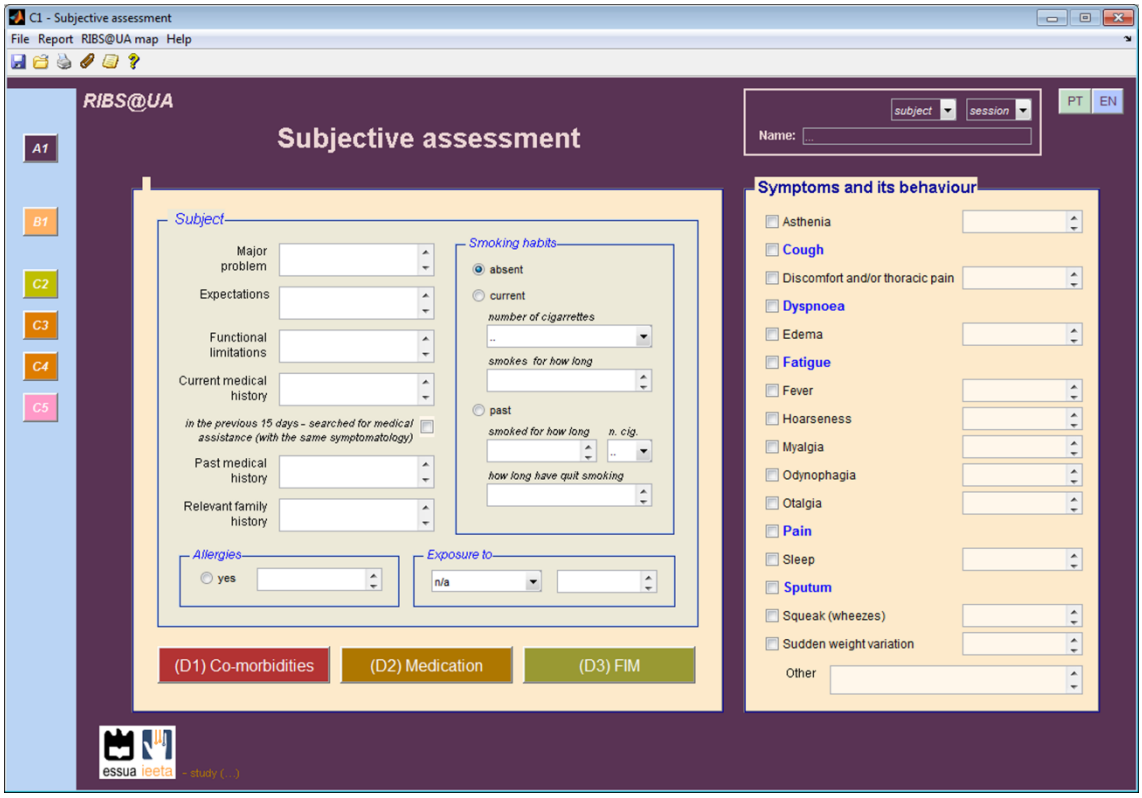

Figure 4: RIBS@UA window C1 - Subjective assessment.

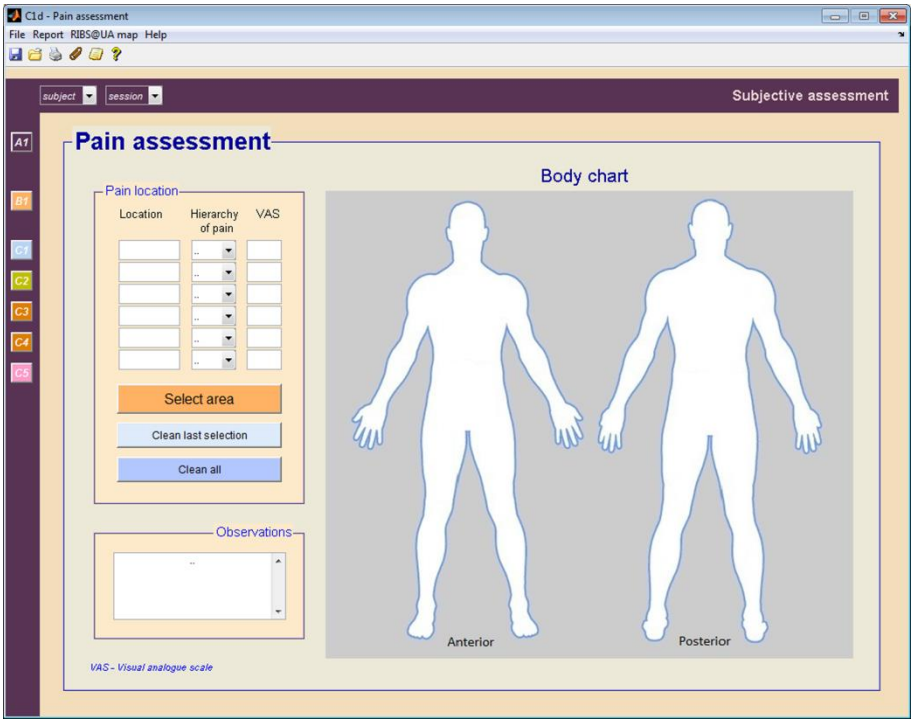

Figure 5. Window C1c – Pain assessment.

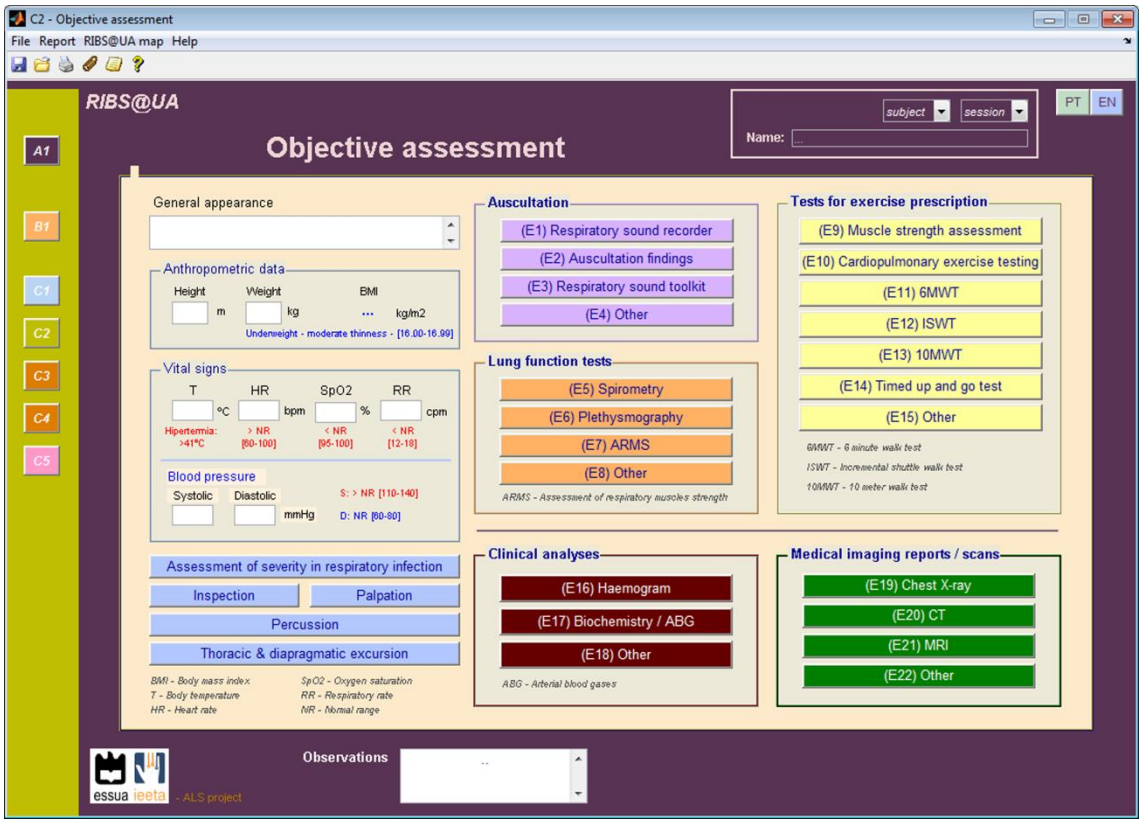

Figure 6. Window C2 - Objective assessment. *CT* - computerised tomography; *MRI* - *Magnetic resonance imaging*.

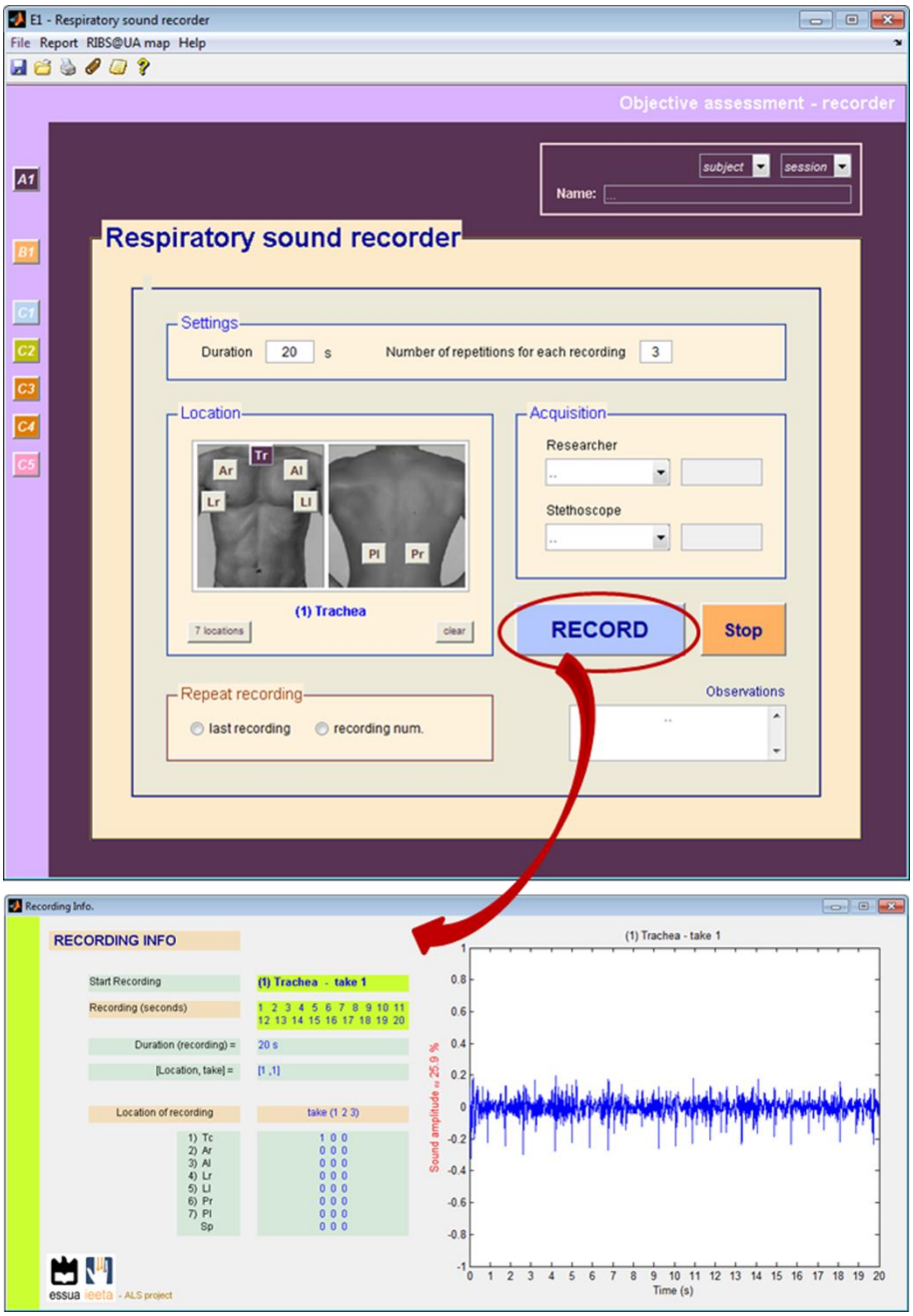

Figure 7. a) *upper figure*: Window E1 – Respiratory sound recorder. b) *lower figure*: Recording info. window displayed during the recording process.

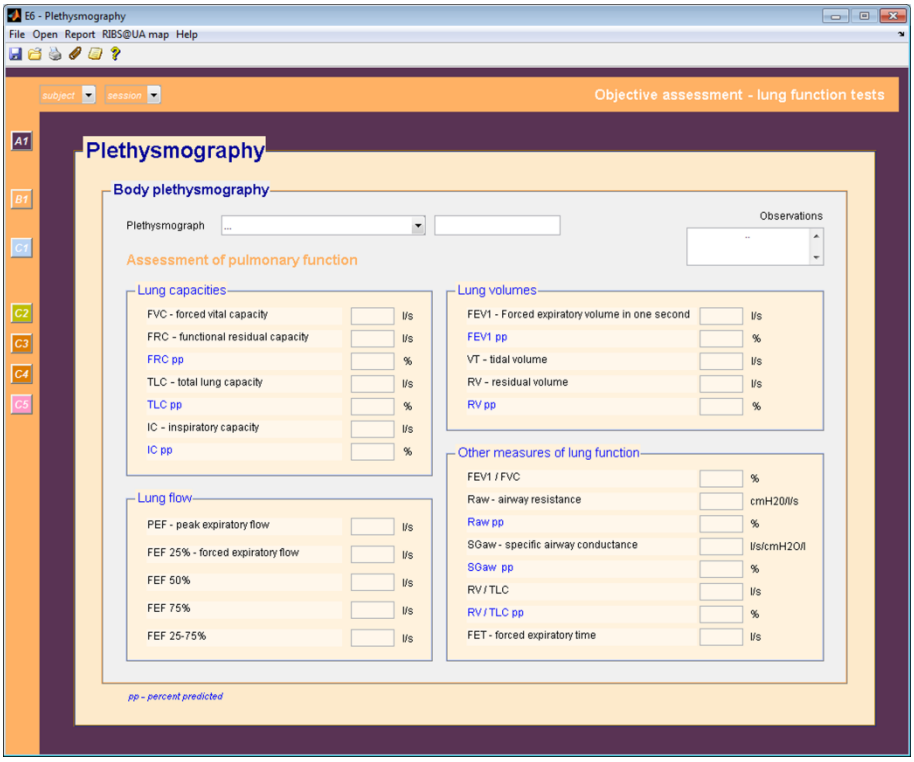

Figure 8: Window E6 – Plethysmography.

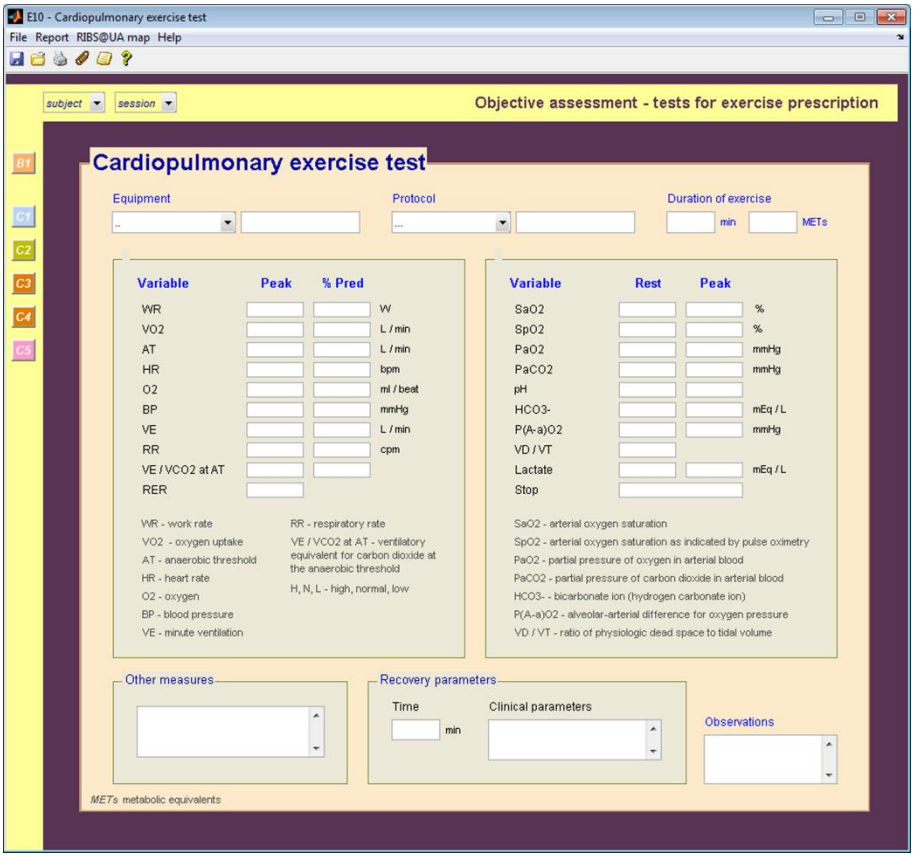

Figure 9. Window E10 – Cardiopulmonary exercise test.

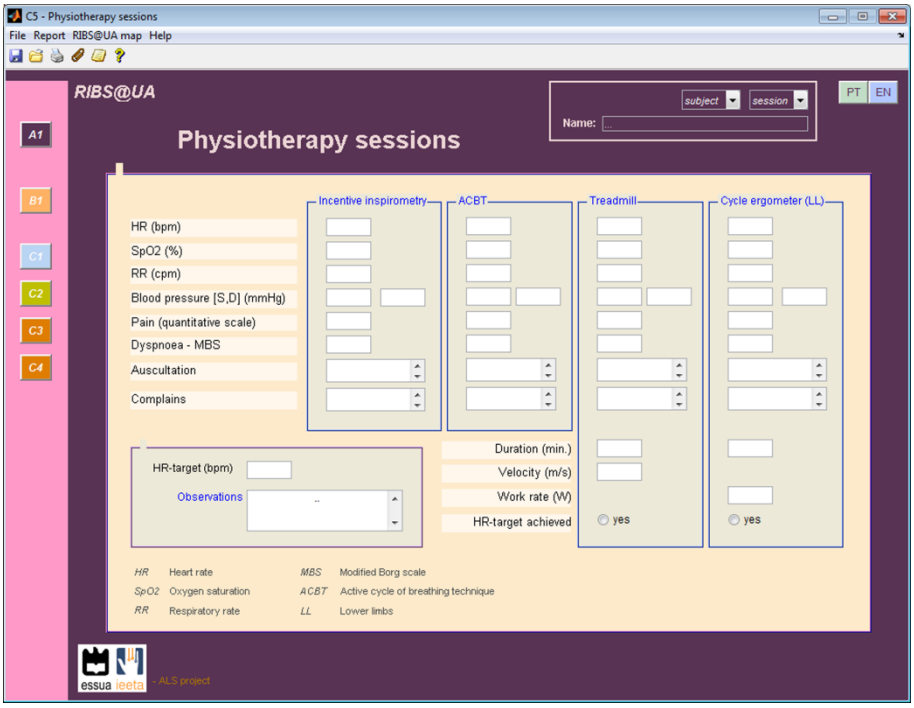

Figure 10. Window C5 – Physiotherapy sessions.

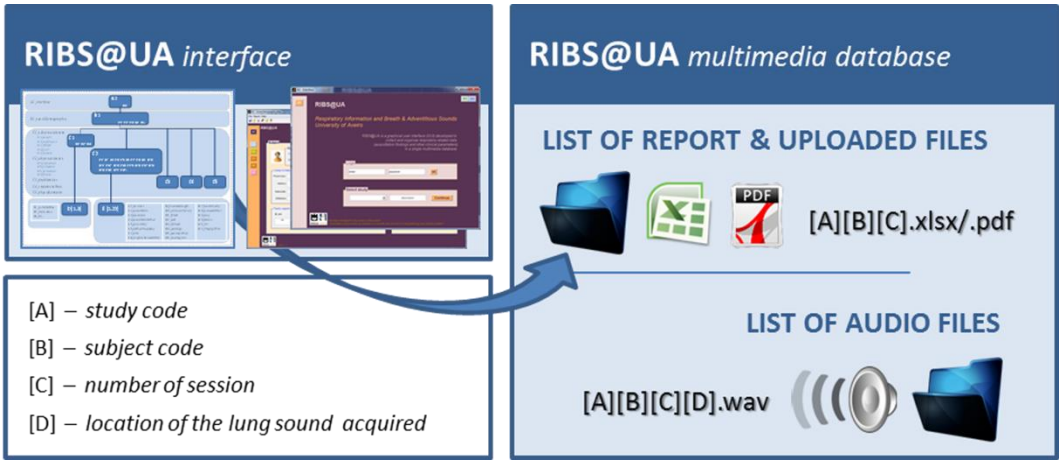

Figure 11. Scheme of RIBS@UA multimedia database.

List of Tables (with captions)

Table I. Assessment and rating of some usability problems highlighted in the *heuristic evaluation.*

Heuristics	*S*	*Rating and description of usability problems*
Visibility of the system status.	2	In some windows, it was difficult to evaluate the current state of the system during and after performing a task, e.g., lack of feedback during the upload of a file and indication if the operation was successfully completed or not.
Match the system to the real World.	0	Not considered a usability problem, e.g., whenever a new terminology (not familiar to the user) was applied, a descriptive label was provided.
User control and freedom.	3	Clearly marked exits were successfully implemented in the application, nevertheless support undo and redo actions were pointed out as a usability problem. Therefore it was suggested to avoid irreversible actions.
Consistency and standards.	0	The layout, display and terminology of information in the windows were correctly addressed.
Error prevention.	2	The system did not always prevent the occurrence of slips (unintentional error) and mistakes (occurring through conscious deliberation). Therefore it was suggested to simplify some windows to avoid misunderstanding of how to carry out basic operations.
Minimize memory load - support recognition rather than recall.	0	Despite the great amount of information addressed in the interface, the organization based on health professionals' workflow was reported as being meaningful.
Flexibility and efficiency of use.	2	The application should allow experienced users to create shortcuts for common operations.
Aesthetic and minimalist design.	1	In some cases there was still a great amount of available options, which could negatively influence the user performance (e.g., figure 6, representing the window C2 - Objective assessment).
Help users recognize, diagnose and recover from errors.	1	Despite the introduction of warning and error messages, design factors in message wording could be improved, e.g., phrased in a more clear and meaningful language (concise, constructive and "polite").
Help and documentation.	2	The documentation can be complemented with bibliography supporting the clinical procedures available in the interface.

S - Severity rating scale: (0) - Not considered a usability problem; (1) - Cosmetic usability problem; (2) - Minor usability problem; (3) - Major usability problem.

Table II – Participants' expertise/usage of informatics systems.

	Strongly disagree (%)	*Disagree (%)*	*Neither (%)*	*Agree (%)*	*Strongly agree (%)*	*n/a (%)*
My professional activity requires the use of informatics systems.	26.6	0	0	42.9	28.6	0
My leisure activities involve the use of informatics systems.	0	0	42.9	57.1	0	0
In my workplace, I have software that allows me to record and store clinical information.	42.9	14.3	14.3	14.3	0	14.3
I consider myself prepared to efficiently use all the features of the software available in my workplace.	0	0	14.3	42.9	14.3	28.6
In general, I believe that my performance in the use of informatics systems is good.	0	0	28.6	57.1	14.3	0

N/a: not applicable.

Summary

Propose: The development of effective graphical user interfaces (GUIs) has been a demand in healthcare technologies, for assessing, managing and storing patients' clinical data. Nevertheless, specifically for respiratory care there is a lack of tools to produce a multimedia database, where the main respiratory clinical data can be available in a single repository. Therefore, this study proposed to develop a usable application to collect, organise and store respiratory-related data in a single multimedia database.

Methods: A GUI, named RIBS@UA, organised in a multilayer of windows was developed and evaluated. The evaluation consisted of usability inspection (by two respiratory health professionals and two system designers during the development of the prototype) and usability testing (by seven physiotherapists). Usability inspection was performed in four review meetings during the design process of the prototype. A systematic inspection of the interface identified usability problems using *pluralistic walkthroughs* and a set of *heuristics*. Usability testing was conducted in three evaluation sessions, assessed in a focus group interview.

Results: The users reported on the utility of the new application and its potential to be used in clinical/research settings. Namely, participants highlighted that RIBS@UA: i) facilitates patients' management; ii) contributes to the implementation of standardised interventions and treatment procedures; and iii) allows comparisons between different respiratory parameters, e.g., imaging findings with respiratory sounds, to confirm the diagnosis and/or assess patient's response to treatment. These advantages led participants to conclude that having RIBS@UA interface in their clinical/research practice would be valuable. Nevertheless, some drawbacks were also identified and suggestions were given to improve the content of the physiotherapy sessions window.

Conclusions: RIBS@UA interface is an innovative application to collect, store and organise all necessary respiratory-related data, in a single multimedia database. It also allows associations

between different data. Thus, a more comprehensive assessment of patients in a single or over time assessment is facilitated, enhancing health professionals' clinical reasoning. Nevertheless, further improvements are still recommended before RIBS@UA final implementation.