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Usability Study of the CICERONE App for Telemonitoring COPD Patients

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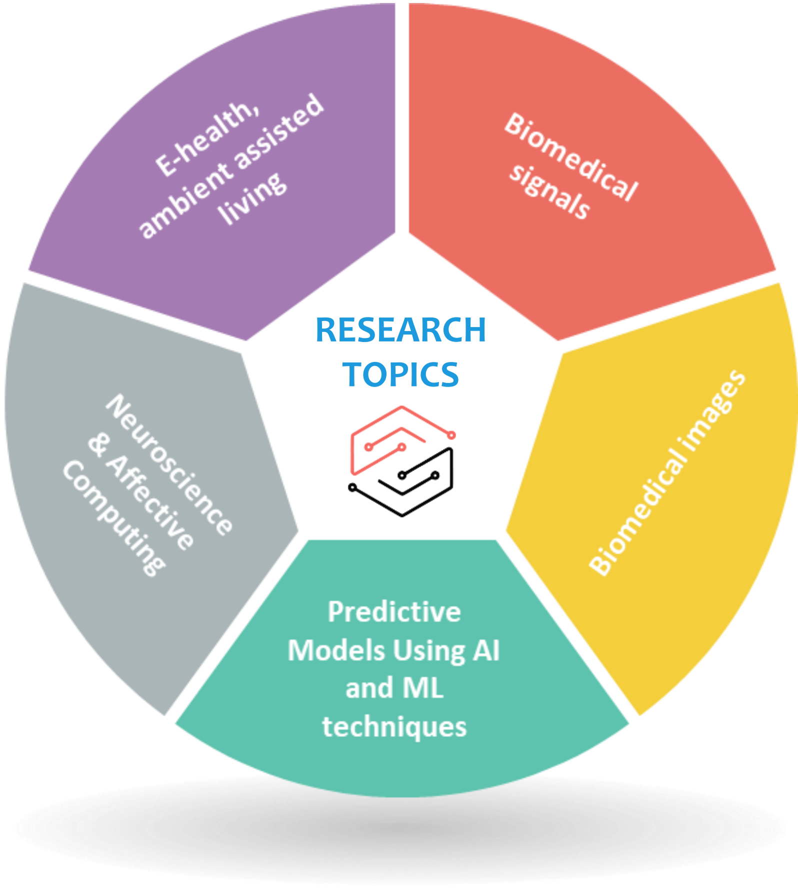
About the Presenter

Patricia Camacho Magriñán is currently a Ph.D. student at the University of Cádiz and a member of the **Bioengineering, Automatic and Robotics Research Group (ATARI).** Her research focuses on the **exploration of physiological parameters and the application of artificial intelligence (AI) techniques to predict COPD exacerbations through personalized predictive models** that aim to balance clinical insight with statistical accuracy.

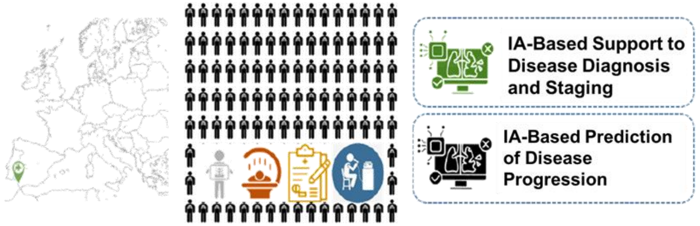
She holds a Bachelor's degree in **Industrial Design and Product Development Engineering,** as well as a Master's degree in **Manufacturing Engineering.** Her interdisciplinary background supports her work at the intersection of healthcare technology, data analysis, and engineering innovation.

About ATARI



Ongoing Projects

PEOPLE



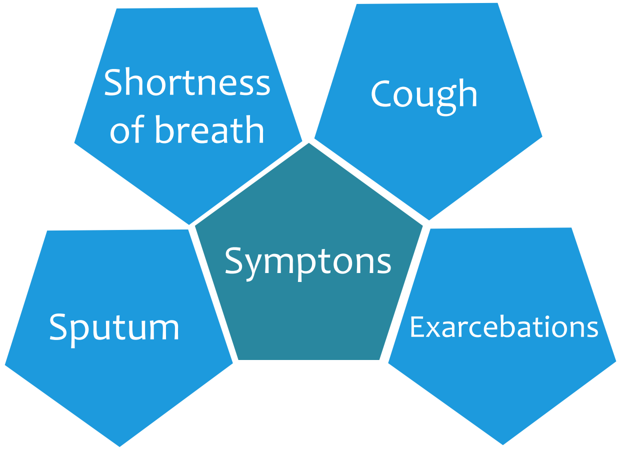
Clinical decision support system for diagnosis, classification and outcomes prediction of patients with engineered-stone silicosis

PID2021-126810OB-I00. Artificial intelligence, smart sensors and new physiological and environmental predictors for better management of COPD [**CICERONE**].

Contents

1. Introduction: COPD: Definition, affected population and symptons

- Chronic Obstructive Pulmonary Disease (**COPD**) is a progressive and heterogeneous lung condition.
- COPD is characterized by persistent respiratory **symptoms**—such as shortness of breath, cough, and sputum production—and recurrent acute exacerbations.
- These symptoms result from structural changes in the airways and alveoli, including bronchitis and emphysema, leading to **chronic airflow limitation**.
- COPD is a major global health issue due to its **high prevalence** and significant contribution to morbidity and mortality.
- It is the **third leading cause** of death worldwide, causing around 3 millions deaths annually (World Health Organization).
- COPD patients are typically older adults who frequently experience both **physical and cognitive limitations**.
  - Reduced mobility, fatigue, shortness of breath during daily activities, and difficulties with memory or attention.



1. Introduction: What is an exacerbation?

- A **key** characteristic of COPD is the occurrence of **exacerbations**:
  - acute episodes of worsening respiratory symptoms.
  - not only impair lung function but also have a significant impact on patients' mental health and can aggravate existing comorbidities.
- Exacerbations contribute to the overall **progression** of the disease, often leading to a rapid functional decline and increased reliance on **healthcare services**.
- They are associated with high rates of **hospital readmission**, and over 20% of patients hospitalized due to exacerbations die within a year of discharge.

- **Early detection and effective management** of these episodes are therefore crucial to:
  1. slowing disease progression
  2. improving patients' quality of life
  3. reducing the substantial economic burden on healthcare systems

- **Home telemonitoring** has emerged as a promising strategy to prevent exacerbations in COPD patients by enabling continuous observation of key physiological parameters and early detection of clinical deterioration.

1. Introduction: Home telemonitoring

- Home telemonitoring has gained attention as a promising strategy to help **prevent COPD exacerbations.**
- In recent years, this approach has advanced significantly with the development of telemedicine systems and **wearable** devices capable of measuring physiological parameters in real time.
- Common strategies include the use of:

  a) Sensors to track:
  - oxygen saturation
  - respiratory rate
  - physical activity
  - sleep quality

  b) Mobile apps for symptom reporting using electronic questionnaires.

- Despite these technological advances, the clinical **impact of home telemonitoring** on reducing COPD exacerbations and hospital admissions remains **unclear**.
  - Potential causes include studies heterogeneity, lack of reliable predictors, low patient adherence, and absence of robust predictive models that integrate health status, lifestyle, and environmental data.
- **Key challenges** include:
  - Identifying clinically relevant predictors
  - Developing validated algorithms
  - Creating patient-centered solutions that are easy to use and encourage long-term engagement.
  - Improve usability to enhance patient adherence, system performance, and clinical outcomes.

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1. Introduction: What is the CICERONE project aiming to achieve??

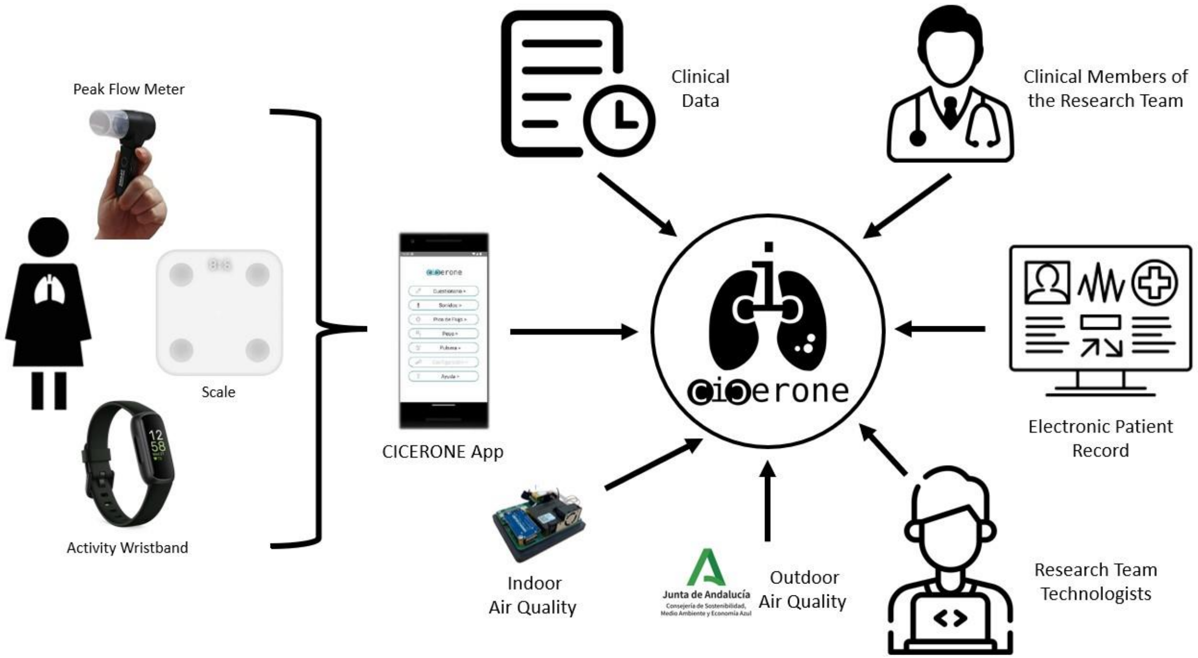
CICERONE proposes a patient-centered approach to improve the early detection and prevention of COPD exacerbations through the use of home telemonitoring technologies.

The ***main objective*** is to identify new physiological and environmental indicators and develop reliable, personalized predictive models supported by AI.

- CICERONE places special **emphasis** on usability and patient engagement, distinguishing itself from traditional telemonitoring systems.
- The project aims to offer a non-invasive and reliable telemonitoring solution that enables early intervention, personalized care, and greater patient autonomy.
- It is designed with an **intuitive and accessible** interface that reduces interaction complexity and integrates naturally into patients' daily routines.
  - This user-centered approach aims to minimize frustration, increase adherence, and ensure that the data collected is accurate and clinically relevant.
- To achieve its goals, CICERONE includes a thorough usability evaluation, using user feedback to improve the system.

2. Methodology: Architecture and Oobjectives of CICERONE

- In **CICERONE**, data is collected from the patient through the mobile app and the indoor air quality device.
- Additionally, external data is used to contextualize the patient's condition, including clinical data, outdoor air quality, research data, and more.



- The goal is to identify new predictors and create an explainable clinical support system powered by AI to predict disease exacerbations.
- The platform gathers **physiological** data (e.g., oxygen saturation, heart rate), respiratory sounds and voice, psychomotor information, weigh, and environmental parameters (e.g., air quality, temperature), as well patient-reported symptoms.
- A **mobile app** has been developed to facilitate data collection and integration with patient sensors.
- The system ensures data security through encryption and complies with GDPR for privacy protection.
- Ethical concerns around data use are addressed in collaboration with ethics committees.
- **Currently**, the platform is being evaluated with COPD patients at the Puerta del Mar University Hospital (PMUH, Cádiz, Spain).

2. Methodology: User-centered development and ethical considerations

- Given the need for both efficiency and usability in managing COPD at home, the ***design*** of the CICERONE system was developed with a strong focus on patient needs.
- The ***mobile application*** was created using an iterative and incremental development model, involving a multidisciplinary team and actively including patients as end users throughout the process.
- To evaluate user satisfaction, the ***System Usability Scale (SUS)*** was used, focusing on two key aspects: usability and capability.
  1. The development began with a ***conceptual design***, which was translated into a mock-up and then into an initial prototype.
  2. This ***prototype*** underwent several cycles of performance testing, usability evaluation, and refinement. Based on user feedback, incremental improvements were made, resulting in an intermediate version of the app, programmed in Java for Android.
  3. This version was again tested to assess its usability and performance.
- Additionally, ***structured interviews*** provided qualitative insights from each participant.
  - Usability was also assessed through quantitative metrics such as task completion time and SUS scores.
  - These results were compared across the initial, intermediate, and final prototypes to ensure continuous improvement and user acceptance.
- The study involved the collaboration of ***31 participants***, recruited by the ***Pulmonology Unit at PMUH***.
- Usability testing was carried out in ***three phases***:
  1. First prototype (P1) →11 participants
  2. Second prototype (P2) → 7 participants
  3. Final version → 13 participants
- The study was ***approved by the Coordinating Committee of Biomedical Research Ethics of Cádiz*** (*CICERONE code: 29.23*).

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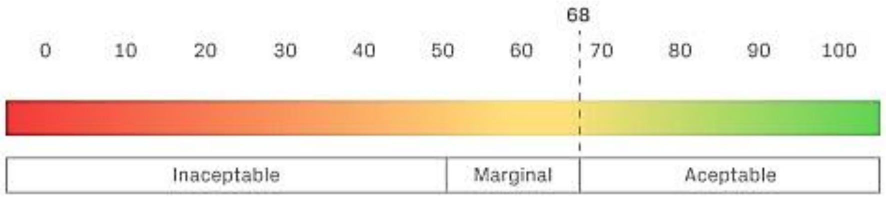
2. Methodology: SUS and evaluation throughout study phases

- The ***System Usability Scale (SUS)*** is a standard, reliable tool used to measure the usability of systems and applications.
- It consists of 10 items rated on a 5-point Likert scale, alternating between positive and negative statements to reduce bias.
- The final score ranges from 0 to 100, with 68 or above indicating acceptable usability.



System Usability Scale (SUS)

- We assessed usability using an **iterative User-Centered Design** (UCD) process involving patients and a multidisciplinary team.
- The development included four stages:
  1. requirements analysis
  2. Design
  3. Implementation
  4. evaluation.
- Three prototypes (P1, P2, and P3) were tested progressively, using SUS scores and user feedback to guide improvements.
- The process ensured that the final application was tailored to the needs of COPD patients, prioritizing both efficiency and ease of use.

2. Methodology: SUS and evaluation throughout study phases

Evaluation of Prototype P1

- The first prototype (P1) was developed using ***Figma*** and simulated an interactive app experience online, without requiring installation.
- Participants could freely navigate through the modules and complete basic tasks.
- At this stage, communication with external devices (peak flow meter and activity bracelet) was not yet included.
- Usability testing was conducted with ***11 participants*** over 50 years old, using the SUS questionnaire distributed via Google Forms.

Evaluation of Prototype P2

- Prototype P2 was developed in **Android Studio** and installed directly on the participants' mobile devices.
- The testing was carried out under supervision, allowing participants to interact with the app in a controlled environment.
- Although device integration was still partial (no peak flow meter), this version allowed deeper interaction with the system.
- **Seven participants** evaluated this prototype, and the SUS questionnaire was completed in person after the session.

Evaluation of Prototype P3

- The final prototype (P3) was tested by **13 COPD patients**, with an average age over 60. The evaluation included:

  a) ***Informed consent*** and collection of medical and lifestyle data
  b) ***Dyspnea assessment*** (mMRC scale)
  c) ***Cognitive screening*** using the MMSE
  d) ***Installation of the app*** and setup of external devices (peak flow meter, activity bracelet, air quality sensor)
  e) ***Guided app*** use and completion of the SUS questionnaire
  f) ***A semi-structured interview*** covering usability, learning experience, satisfaction, and openness to future use

- This final phase provided a comprehensive insight into user experience, combining objective metrics and qualitative feedback to guide future improvements.

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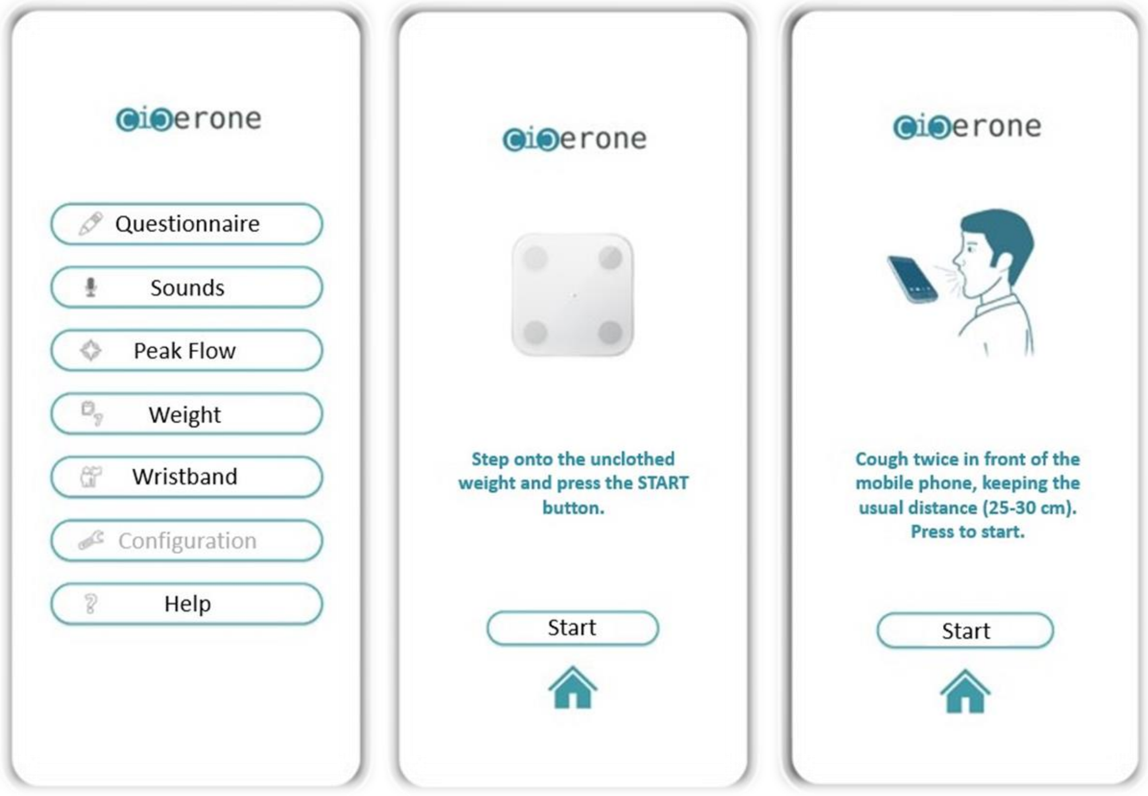
3. Results: Design phase →Prototype and results

- The first prototype of the CICERONE app was created based on initial user requirements.
  - It featured graphic icons, visual indicators, and text-based screens, enabling intuitive interaction through visual elements.
- The design was ***tailored for older adults*** (60+), taking into account potential sensory limitations by using simplified layouts, strong visual cues, and minimizing memory and attention demands.
- The app included ***six core modules***:
  - a) Respiratory symptoms questionnaire and two psychomotor gamified tests
  - b) Cough and voice sound recording
  - c) Peak flow respiratory function assessment
  - d) Weight tracking
  - e) Data reading from a smart bracelet (activity and sleep)
  - f) Help section with video tutorials
- The mock-up was developed in *Figma* and tested with a group of senior users.
- **72.8%** of participants scored above the average usability threshold (SUS > 68), but their feedback highlighted areas for aesthetic and functional improvement to enhance the user experience.



Screenshots from the mock-up.

3. Results. Implementation → Mobile app and results

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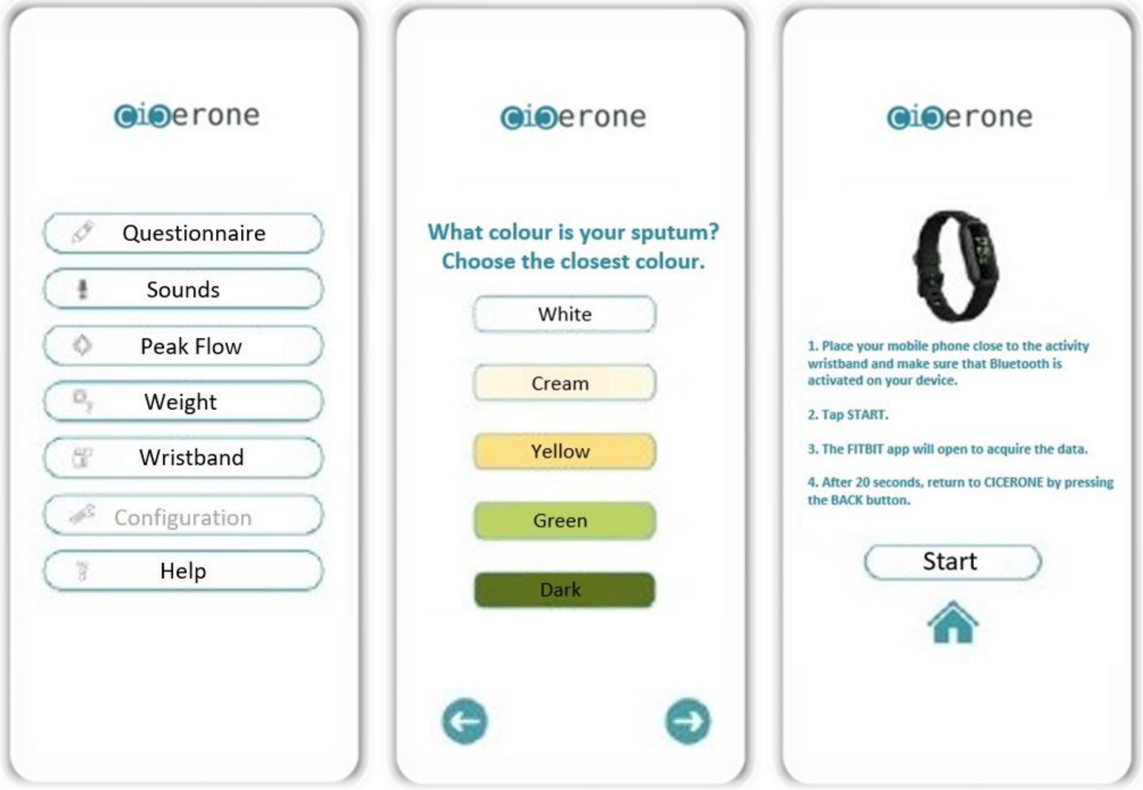
- The first high-fidelity prototype (P2) underwent ***two redesign iterations*** to address the usability issues identified in earlier evaluation. These improvements included:
  - Simplified content and interface design tailored for older adults
  - Improved control navigation for easier use
  - Aesthetic enhancements for better visual clarity
  - Software stability fixes to ensure smooth performance
- As a result, Prototype P3 was developed and tested.
- This final version demonstrated a ***high level of perceived usability***, reflecting the success of the iterative, user-centered design process.



CICERONE Mobile App.

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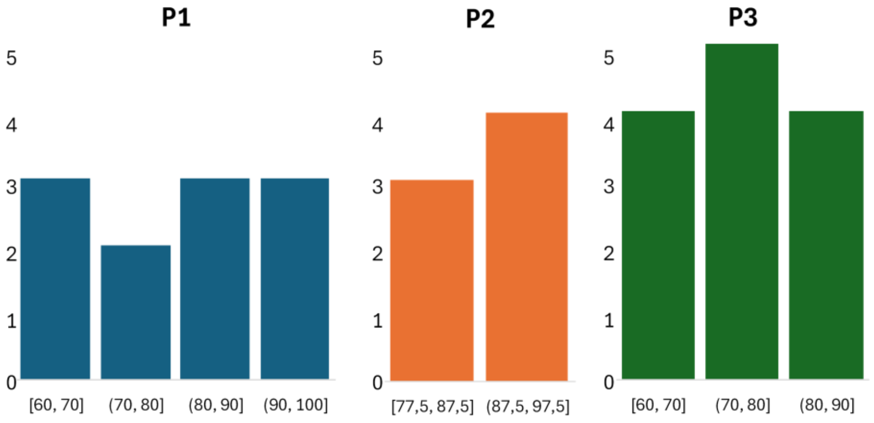
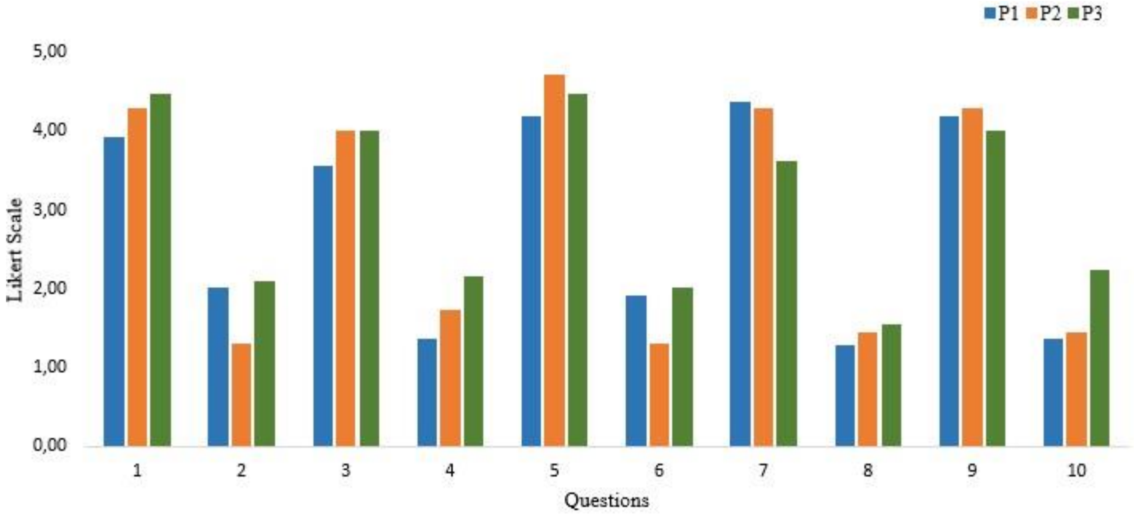
3. Results: Comparative analysis of results across phases

- The figure shows the histogram of the SUS scores for each evaluated prototype (P1, P2, and P3).



- A ***positive evolution*** is observed between versions P1 and P2, with a clear increase in perceived usability following the implementation of improvements.
- In the case of P3, although the average score slightly decreases due to the added complexity of integrating external devices, the scores remain within ***acceptable levels***, with no values falling below 60.
- This confirms that the system ***remains usable*** even in real-world scenarios with higher technical demands.

- The figure presents the **average response** for each of the 10 items in the SUS questionnaire, comparing the three prototypes.



- The results show consistent improvements between P1 and P2 across most items, particularly in aspects related to ease of use and user confidence.
- In prototype P3, while some scores show a slight decline, the overall evaluation ***remains positive***.
- This indicates that despite the increase in complexity, users continued to perceive the application as ***intuitive, accessible, and helpful*** for self-management.

4. Discussion

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- This study describes the design and evaluation of a mobile application for the telemonitoring of COPD patients, based on daily recordings of symptoms, sounds, and physiological parameters.
- A ***user-centered design*** and usability-driven development approach were followed, resulting in three iterative prototypes.
- The usability evaluation, conducted across ***three phases***, showed consistent improvements in user perception. Prototype P2 received the highest SUS scores, highlighting the impact of design refinements. Although P3 introduced real device integration, which added complexity, it still achieved ***high usability scores***, confirming the feasibility of real-world application.
- The platform was ***developed to minimize patient burden***, requiring less than five minutes per day, supporting long-term adherence.
- However, ***older participants faced more challenges***, particularly with device linking and navigation, emphasizing the need for technical support and accessible design for this group.
- Participants' feedback ***confirmed the system's clinical potential***, with some requesting simplified versions and others expressing interest in continued use.
- These findings **validate** the platform's design and guide future improvements in engagement, self-management, and long-term usability.

4. Conclusions and future work

Conclusions

SUS Usability Analisis

Identified significant improvements between development stages, highlighting the effectiveness of iterative design.

User-Centered Approach

Emphasized the importance of involving users throughout the process to improve usability and acceptance.

Future work

- ***Scalability***: Future work will focus on scaling the platform for deployment across diverse clinical contexts.
- ***Technical Challenges***: Ensuring the platform's technical capacity to manage a growing number of patients and devices.
- ***Regulatory and Infrastructure Adaptation***: Adapting to different healthcare regulations, technological infrastructures, and clinical workflows.
- ***Interoperability***: Addressing the integration of electronic health records and compliance with data protection standards (e.g., GDPR, HIPAA).

Thank you very much for your attention

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