Desenvolvimento de aplicativo para Tuberculose: Um estudo de caso no Brasil com validação da experiência do usuário usando IA

Application development for Tuberculosis: A case study in Brazil with user experience validation using AI

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RESUMO

O uso da Tecnologia da Informação e Comunicação (TIC) é uma ferramenta poderosa em todas as áreas do conhecimento, inclusive na saúde. No setor saúde, há contribuições significativas do uso de novas tecnologias, e a Organização Mundial da Saúde considera o uso de tecnologias digitais uma ação importante na redução da incidência de tuberculose em populações vulneráveis. Este artigo tem como objetivo descrever o processo de desenvolvimento de aplicativo para controle e monitoramento da tuberculose por meio do gerenciamento do seu processo terapêutico. A abordagem metodológica inclui a Metodologia de Pesquisa *Design Science*, abrangendo revisão de literatura, desenvolvimento inicial de protótipo no Brasil e experiência do usuário em Portugal utilizando validação de Inteligência Artificial (IA) com *Eye Tracking*. Os resultados orientam a equipe de pesquisa a melhorar os recursos de monitoramento e acompanhamento de pacientes do aplicativo de tuberculose. Simulações utilizando IA para validação da aplicação demonstraram a possibilidade de simular sua utilização, possibilitando antecipar problemas e melhorar a aplicação.

Palavras-chave: Tuberculose; saúde pública; saúde digital; tecnologia digital; inteligência artificial.

ABSTRACT

The use of Information and Communication Technology (ICT) is a powerful tool in all fields of knowledge, including health. In the health sector, there are significant contributions from using new technologies, and the World Health Organization considers the use of digital technologies an important action in reducing tuberculosis incidence in vulnerable populations. This article aims to describe the process of app development for controlling and monitoring tuberculosis through the management of its therapeutic process. The methodological approach includes Design Science Research Methodology, encompassing literature review, initial prototype development in Brazil, and

user experience in Portugal using Artificial intelligence (IA) validation with Eye Tracking. Results guide the research team to improve the patient monitoring and follow-up features of the tuberculosis app. Simulations using AI to validate the application demonstrated the possibility of simulating its use, making it possible to anticipate problems and improve the application.

Keywords: Tuberculosis; public health; digital health; digital technology; artificial intelligence.

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1 INTRODUCTION

According to the United Nations (UN), tuberculosis (TB) is one of the leading causes of death worldwide. Until the occurrence of the Coronavirus (COVID-19) pandemic, TB was the leading cause of death from a single infectious agent (WHO, 2022). The World Health Organization (WHO), through successful experiences around the world in the use of digital technologies to combat TB, developed a document for the implementation of digital TB solutions (Who, 2017).

The strategic plan from 2021 to 2025 to end TB as a public health issue, launched in 2021 by the Brazilian Ministry of Health, establishes that the cure rate should be greater than 90% and the treatment abandonment rate should be less than 5%. This strategic plan emphasizes the urgency of adopting new strategies according to the Brazilian Ministry of Health (2021), such as: 1) Prevention and comprehensive patient-centered care; 2) Integrated policies and support systems; and 3) Intensification of research and innovation.

Information and Communication Technologies (ICTs) have been used as an important and innovative approach to assist in health. During the COVID-19 pandemic, the use of health mobile applications intensified worldwide to avoid COVID-19 contamination and improve response times to different requests (Netto, Hartz & Magalhães, 2022). Likewise, TB applications were used to for different purposes. A survey conducted by Keutzer et al. (2020) identified 55 mobile phone applications developed specifically for TB, with the following distribution: n=29 (53%) designed for disease guidance; n=8 (15%) designed to monitor patient adherence; n=6 (11%) for dosage treatment adjustment; n=3 (6%) focused on tuberculosis diagnosis; and n=9 (16%) related to other subjects.

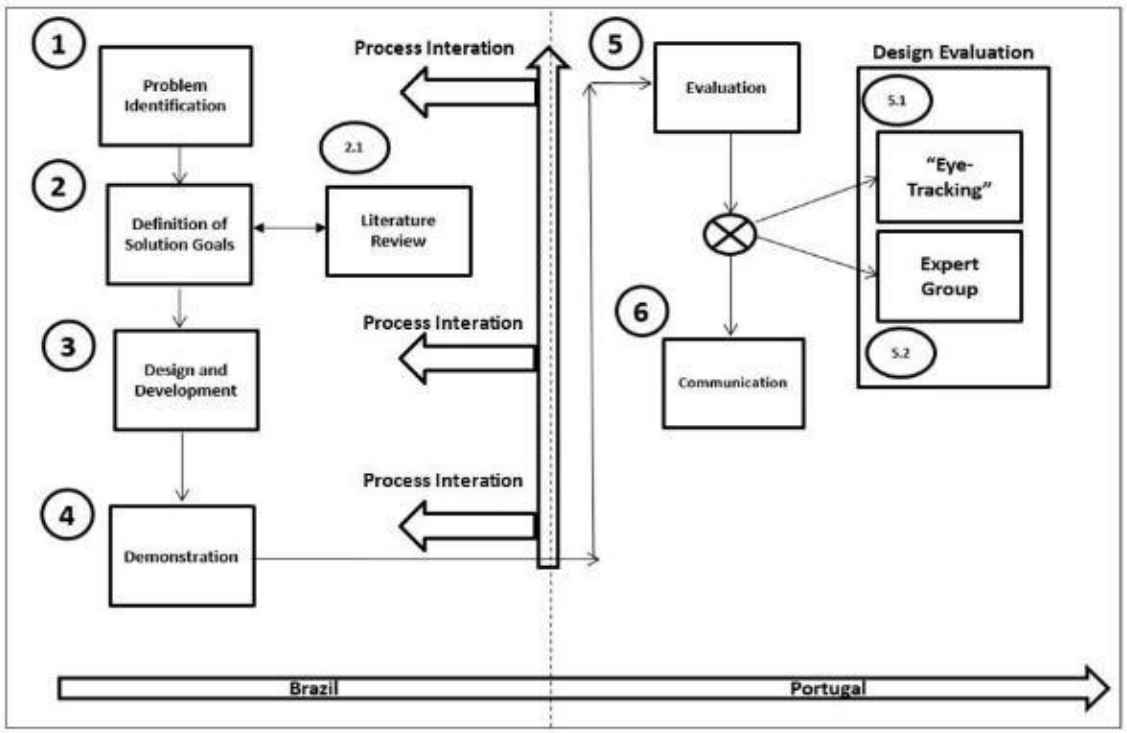
Design Science Research Methodology (DSRM), through its six-step iterative sequence, allows the application prototype to be well-adapted, avoiding unnecessary rework by the development team (Peffers *et al*., 2007). To evaluate the application's design, artificial intelligence was used through eye-tracking, allowing the user experience to be anticipated (Hollander *et al*., 2021). In software evaluation, design is crucial for motivation and engagement, ensuring that end-users feel attracted to using the system (Sutcliffe, 2022). In health profiling, well-designed dashboards enable clearer identification of information, improving the management of healthcare units (Dowding *et al*., 2015).

The aim of this article is to describe the development of an application for tuberculosis for the primary care health system in the Basic Health Unit (BHU) in Brazil, located in the Manguinhos neighborhood, in the north of Rio de Janeiro, place with high rate of TB and low income (O'DWYER et al., 2017). The first stage of research start with a prototype application was adapted from an App used for COVID-19 (Netto *et al*., 2021; Netto *et al*., 2022). The second stage of the project its design validation in Portugal, where initial usability tests were carried out Artificial intelligence (IA) validation with Eye Tracking technology (Hendricks *et al*., 2021) and a design interface evaluation by a group of experts using a heuristic usability assessment (Tripathi *et al*., 2019; Nngroup, 2023).

2 METHODOLOGY

The methodological framework used was the Design Science Research Methodology (DSRM), which combines the development of innovative artifacts with the creation of new knowledge (Johannesson & Perjons, 2021). The main phases of the DSR, as outlined by several authors, typically include: (1) Problem identification; (2) Definition of objectives for the solution; (3) Design and development; (4) Demonstration; (5) Evaluation; and (6) Communication. Each step of the DSRM is described according to the main authors who address the topic (Vom Brocke, Hevner, & Maedche, 2020). The DSRM encompasses both stages of the project. However, it was adapted by the authors of this article to include a literature review to identify the best practices in developing an application for TB. The evaluation phase included steps to assess system usability using eye-tracking and a second stage with a group of experts. Figure 1 summarizes the methodological iterative flow of the research presented in this article.

Figure 1: Methodological Flow



Source: Methodology DSR adapted from (Johannesson, P., Perjons, E., 2021; Vombrocke, J., Hevner, A., Maedche, A., 2020)

Initially, to identify the problem, an analysis of documents from group meetings with health professionals working on the treatment of tuberculosis was carried out. After that, the goals were defined to develop a digital solution, including a literature review to identify the areas of action of TB applications and their results. To better define the objective of the solution, the tuberculosis treatment process flows were identified, obtained from the UBS quality repository, and based on the Business Process Model (BPM) (Turkman *et al.*, 2019). Finally, the application was prototyped

according to the requirements, based on application prototyping (Santos, 2021).

After developing a prototype, an evaluation of the digital application was carried out regarding interface design and system usability. Initially, usability tests were conducted using IA validation with Eye Tracking eye-tracking technology (Hollander *et al.*, 2021; Barreto, 2012; Hendricks *et al.*, 2021), enabling the identification of user feedback through questions clarifying the information on the screen (Alhadreti *et al.*, 2017). This assessment was conducted at LICA – Applied Communication Research Laboratory from the School of Social Sciences and Humanities at NOVA University. This session involved 4 volunteer health professionals from Curry Hospital in Lisbon.

The second part of the validation was carried out with a group of 6 design experts, students from the Master's Degree in Design for Health and Wellbeing from the School of Design and Fine Arts at Polytechnic of Leiria. They conducted a usability assessment in accordance with the Heuristic Assessment (USA, 2023) and Graphical Interface Assessment methodology. Heuristic Assessment consists of a usability system review of a website interface by experts (Nngroup, 2023). The goal of using experts is to support the quality of software development, enabling decisions to improve the system or implement a software version and allocate resources correctly (Tripathi *et al.*, 2019). The evaluation of the graphical interface was conducted according to selected Design Principles analysis (Lidwell *et al.*, 2010). In the end, the team disseminated the research through conferences, seminars and scientific publications (Gregorio *et al.*, 2021).

3 RESULTS AND DISCUSSION

3.1. Problem Identification

To identify the problems, we evaluated the documents from the discussion group of health professionals who work with tuberculosis. The document analysis revealed that the health unit has a monitoring team with the following tasks: (1) identifying and monitoring all TB cases, and (2) filling out a summary spreadsheet with the TB data collected to deliver reports to the Brazilian municipal health department. Furthermore, this team also uses the data to identify alerts of possible cases of treatment abandonment and signs related to the responsible family health team. As they are accounFrame for TB management in the unit, data from different systems are consolidated into a spreadsheet for control purposes. Frame 1 summarizes each sector's main activities, the information collected, and the systems used.

Frame 1. Summary of Sectors, Registration of Information and Health Digital Systems and Activities

Sectors	Registration of Information and Systems	Activities
Care Team	Paper Records	Care for patients at the Fiocruz Health Center, working together with nurses

Monitoring Team	Planilha de controle de Tuberculose	Responsible for monitoring and controlling Tuberculosis at the Basic Unity System.
Monitoring Team	Tuberculosis control spreadsheet	Responsible for monitoring and controlling Tuberculosis at the Basic Unity System.
Laboratory Team	GAL	Responsible for executing and controlling the data from the exams carried out and recording the data in the Management and Laboratory System (GAL).
Surveillance Team	SINAM	Responsible for checking the progress of the services provided and their outcome, recording the data in the National Surveillance System (SINAM), checking the data, and carrying out analysis

Source: Authors (2025).

In Frame 1 is possible to identify that was the main problem for the management of TB: it is used aa spreadsheet by the monitoring team to consolidate disease information. After that task, the information was uploaded or filled in across different Digital Health Systems (E-SUS, SINAM, GAL).

3.2. Definition of Digital Solution Goals

After analyzing the flow of information and documentation from the TB group in the UBS, the main "gap" identified for TB information is the distribution of data across different systems. This results in the need to use auxiliary spreadsheets to visualize, monitor, and calculate tuberculosis indicators. It was identified that the purpose of the application could not be to replace the existing systems, as they are official digital systems from the Brazilian Ministry of Health. However, gaps were identified in the patient management carried out by health professionals. To better identify possible solutions, the research team reviewed existing solutions in the scientific literature to understand what has already been implemented.

3.3. Literature Review

The literature review used in this article was a scoping review aimed at mapping possible gaps in the studied topic and providing an overview of a potentially large and diverse body of literature (CORDEIRO & SOARES, 2019). Articles were selected from relevant databases: Scopus, PubMed, Web of Science, and Scielo, using keywords such as "Tuberculosis in public health," "TB in public health," "App," "Application," "Digital Computing," "Digital Technology," "Mobile," and "Software." The database search was conducted in January 2024, and articles up to five years old were considered. Three independent reviewers specializing in digital health selected articles focusing on digital health technologies and their applications for tuberculosis in public health. The results of these articles are detailed in Frame 2.

Frame 2. Summary of Articles

References	Article title	Digital HealthTechnology	Country	Results
Ali, Ahmed Osman Ahmed, and Martin H. Prins (2019)	Mobile health to improve adherence to tuberculosis treatment in Khartoum state, Sudan	Mobile Health Technology for DOT using (Short Message Service) SMS	Sudan	The results reducing treatment dropout in TB patients using mobile services
Byonanebye et al. (2021)	"Impact of a mobile phone-based interactive voice response software on tuberculosis treatment outcomes in Uganda (CFL-TB): a protocol for a randomized controlled trial"	Mobile health intervention utilizes interactive voice response technology	Uganda	Identified good results in the use of mobile phones for health systems.
Navin et al. (2018)	"A mobile health intervention to support TB eradication program for adherence to treatment and a novel QR code-based technique to monitor patient–DOTS provider interaction	App for Smartphone forDirectly observed treatment (DOT)	India	The use of the App results in better treatment monitoring.
Park, Seup, et al (2021)	"Improving treatment adherence with integrated patient management for TB patients in Morocco"	Mobile Health Technology for Patient management	Morocco	The use of apps was more effective than conventional programs.
Zhang, Mengxian, et al. (2023)	"Digitizing tuberculosis treatment monitoring in Wuhan city, China, 2020-2021: Impact on medication adherence"	Electronic patient Service (E-Pss) Software for clinical Management	China	A higher success was found

Source: Authors (2025).

The studies conducted by various authors identified advantages in using applications for patients with tuberculosis (TB) (Byonanebye *et al.*, 2021; Park *et al.*, 2021; Zhang *et al.*, 2023). Zhang et al. (2023) conducted a study in China between 2020 and 2021, which observed a higher rate of medication adherence among patients who used applications to support their treatment. Park *et al.* (2021), in Morocco, observed improvements in the TB management delivery model through an integrated patient management system with mobile health technology. Byonanebye *et al.* (2021) found improvements in TB treatment outcomes with the use of voice-based mobile applications across five public health units in Uganda. These five selected studies assisted the research team in identifying different types of applications used in various countries.

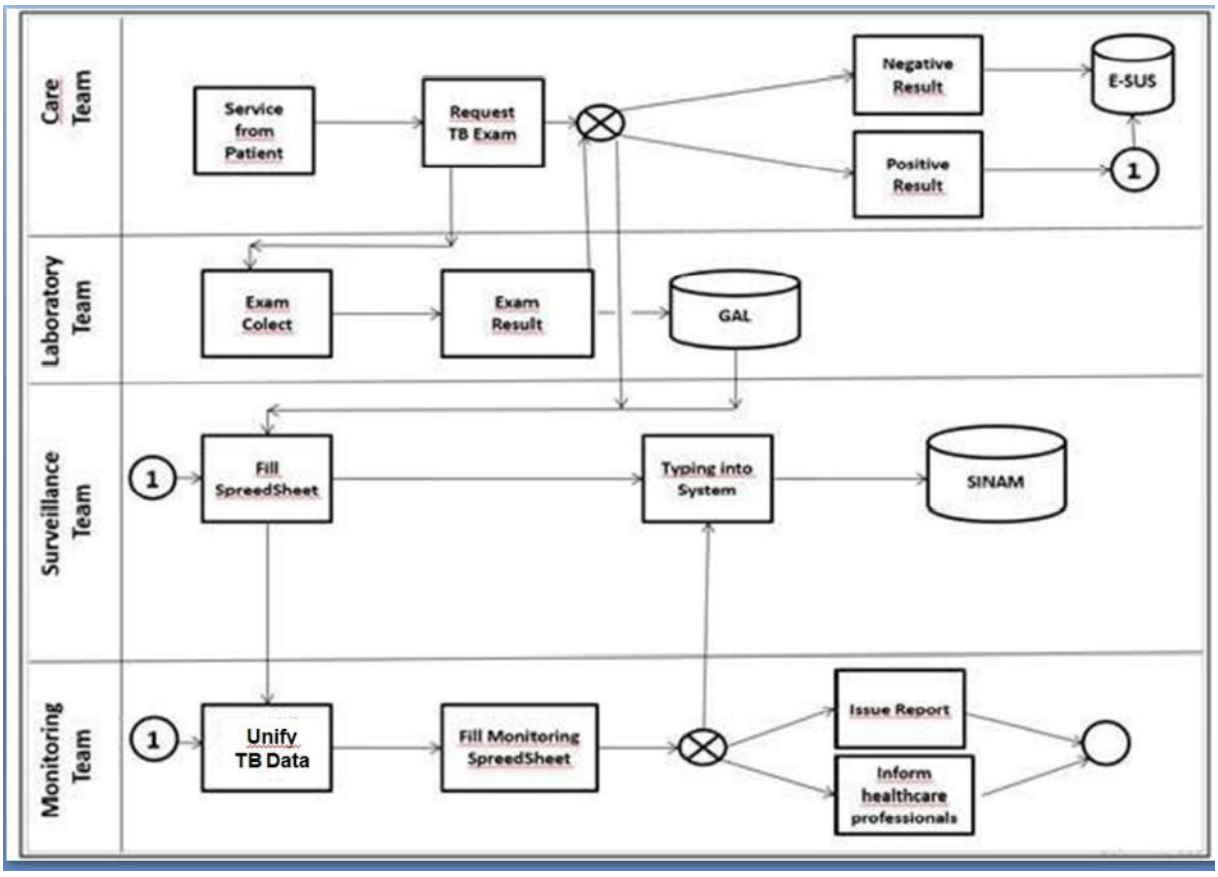
The decision to develop a system will depend on the gaps identified in the analysis of the current Brazilian TB scenario. Since the goal of this project is to enhance the management of TB patients and improve patient monitoring and follow-up, it is aligned with the findings of Zhang et al. (2023). Their study emphasized the urgency of digitalizing TB treatment

information, incorporating digital systems, and using disease indicators to monitor TB in real-time.

3.4 Design and Development

To deepen the analysis of the solution and identify problems, the research team needed to understand the workflow processes related to health professionals dealing with TB. For this purpose, a documentary analysis of the existing work processes was conducted. This flow is available on the Fiocruz/ENSP network website. Analyzing the available flows provided insights into the main activities carried out by each sector and the processes and systems involved. Figure 2 summarizes the available information.

Figure 2 – Flow of tuberculosis monitoring processes



Source: Adapted by the author from the original process flow.

Figure 2 reveals that the TB care team provides specialized health services to patients with TB. The primary activities involve the family health doctor using the E-SUS system to record patient data. In support of care, a technician from the Fiocruz laboratory conducts patient exams and seeks better control over necessary inputs. The laboratory team records results in the Laboratory Environment Manager (GAL) system of the Brazilian Ministry of

Health. Lastly, Epidemiological Surveillance professionals identify TB cases and report them to the Ministry of Health Notification System (SINAM).

By analyzing the activities of each sector, the process flows in Figure 1, and the information available in Frame 2, the research team identified the main problems and gathered ideas for prototyping the demo. Frame 3 summarizes the distinguished contributions.

Frame 3. Summary of contribution to develop the application demo.

Team	Problem	Idea	Prototyping	Prototyping Item
Care Team	Quick identification of patients undergoing TB treatment with their situation.	Identify patients with TB in the Application.	Identify the groups: Active, Cured, Abandonment, and Exit.	1
Monitoring Team and Surveillance Team	They require the data from the Control Sheet to be in the Application.	Insert data from the TB control spreadsheet into the application. Build a graph with Tuberculosis data to visualize the patients' situation in real time.	Dashboard with TB information	2

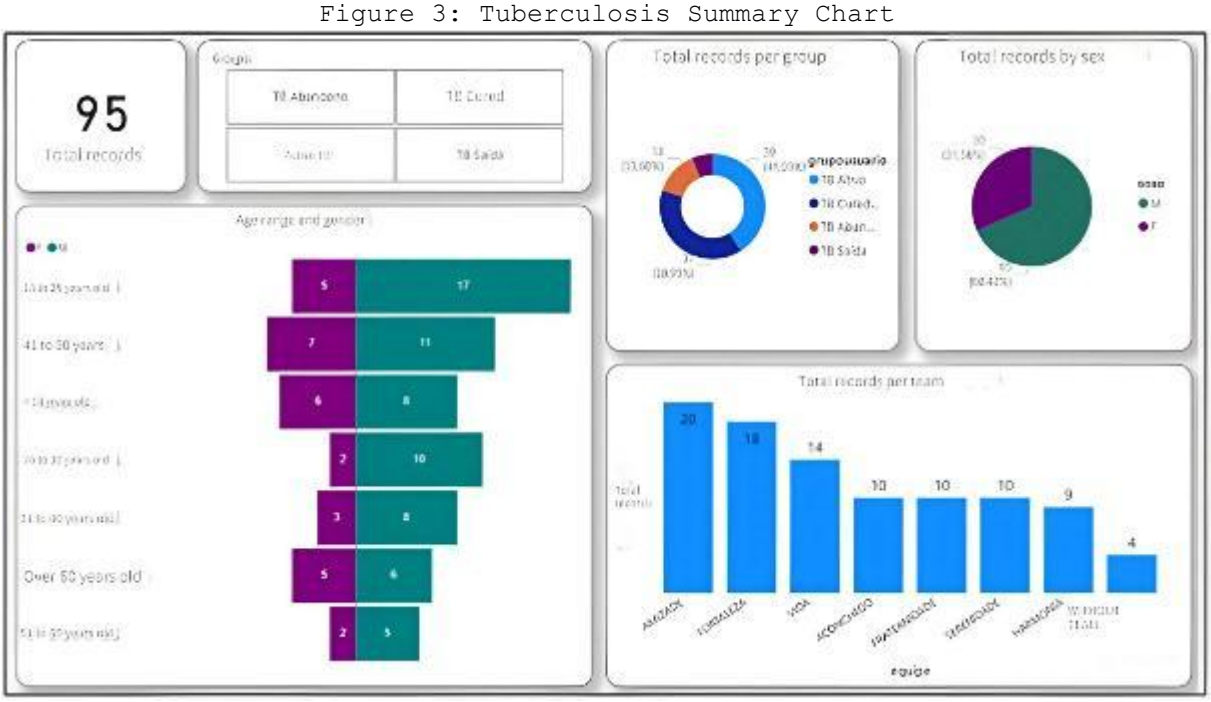
Source: Authors (2025).

In Frame 3, the required systems to implement in the application were identified for each team. The analysis identified control spreadsheets developed by the TB teams, crucial for managing Tuberculosis data, categorizing patients into the following groups: 1. Active (patients undergoing treatment); 2. Cured; 3. Abandoned (patients who abandoned treatment); and 4. Exit (patients who left the clinic's care). The urgency to centralize data from different spreadsheets and systems used by each user was also identified as a critical issue to solve. The following requirements were listed to address the identified problem: 1. Identification of Tuberculosis Patient Groups; 2. Dashboard with a disease summary.

The first requirement identified in Frame 3, Item 1, involves classifying TB patients into groups. These classifications include: Active TB—patients diagnosed with TB undergoing treatment; Cured TB—patients who have recovered from TB; TB Abandonment—patients who have discontinued treatment; and TB Exit—patients transferred to another treatment unit or whose diagnosis has changed. In the VigSaúde application, a column was created for patient classification.

After establishing this field, the simulation demo began using fictitious TB patient data. On the patient screen within the VigSaúde application, TB patient classifications (Active, Cured, Abandonment, and Exit) were incorporated. Each patient was assigned to a specific group, visible in the user group column where an arrow highlights their respective classification.

Figure 3: Tuberculosis Summary Chart



Source: Authors (2025).

3.5 Artifact Demonstration

The prototype of the application was informally demonstrated to the coordination of the TB management unit. During this demonstration, some adjustments were requested by these health professionals regarding the nomenclature used in TB indicators. Overall, the assessment was satisfactory, particularly due to the capability for quick, easy, and real-time visualization of information within the health unit.

3.6 Artifact evaluation

After artifact evaluation, two design evaluations were conducted. The first utilized eye-tracking technology at the School of Social Sciences and Humanities at NOVA University, followed by the second at the School of Design and Fine Arts at Polytechnic of Leiria.

3.6.1 Design Evaluation using IA withEye-Tracking

Initial tests were conducted at LICA – Applied Communication Research Laboratory, where each healthcare professional was presented with the screen. This session aimed to validate the design by assessing whether users looked at the correct screen position containing the requested information. Several tests were performed for each screen of the application. This article briefly describes the validation of the graphical screen to illustrate how the research team gathered feedback. The tests involved asking questions about the displayed information on the screen while using software to track the participant's gaze direction.

The following questions were asked on the graphical screen:

What is the total number of users?

What is the abandonment rate?

What is the age and gender distribution for 18 to 25 years old?

What is the total number of records per healthcare team?

What is the total number of records by gender?

During the tests, the Eye-Tracking software tracked participants' gaze directions, enabling the identification of whether the location of the requested information matched the question being asked. The results indicated a need for clearer graph captions, especially regarding TB rates (e.g., "Question 2: What is the abandonment rate?"). It was observed that participants took longer to direct their gaze to the specific panel where this information was displayed. Figure 4 illustrates an example of an eye-tracking session.

Figure 4: Tuberculosis Summary Chart, IA with Eye Tracking Evaluating

Source: Authors (2025).

3.6.2 Design Evaluation using Expert Group

The design evaluation was conducted by a group of 6 students from the Master's in Design for Health and Wellbeing course. Initially, the application was presented to the students, who then individually validated each screen using ten principles of software usability (NNGROUP, 2023) – Heuristic Evaluation. A summary of suggestions for improving the application emerged, including:

1. System status visibility: Highlight click feedback.
2. Error prevention: Implement character limits in each input field.
3. Correspondence between system and real world: Improve UX Writing to enhance information model recognition versus recall.
4. Clickable VigSaúde App logo: Make the logo clickable from the start.
5. Error handling: Assist users in recognizing, diagnosing, and recovering from errors.
6. Tab information: Hide unnecessary information available in tabs.

Following the evaluations, the students remotely presented their results to the Brazilian development team and discussed each suggested improvement. Subsequently, the software development team in Brazil implemented the corrections recommended by the Portuguese experts. New tests were then conducted by the developers' testing team to ensure all corrections were successfully implemented.

4 CONCLUSION

This article outlines the development of a prototype aimed at enhancing TB control at a Basic Health Unit (BHU) located in a community with a high prevalence of this disease in Brazil and a low cure rate. Throughout the research, a significant reliance on parallel control spreadsheets alongside existing systems (ESUS-AB, SINAN, GAL) was observed. The results indicate that these existing systems alone are insufficient for effective TB control.

Various teams encountered challenges in quickly accessing comprehensive information, necessitating the use of spreadsheets containing additional data not captured by current Ministry of Health systems. Moreover, data fragmentation posed difficulties in identifying patients undergoing treatment and addressing their specific needs. The centralization of data through the VigSaúde application facilitated faster and more effective identification of TB patients, including those who abandoned treatment. The development of this application suggests potential improvements for patient control systems within Brazil's Primary Health Care (SUS).

The collaboration with Portugal fostered new partnerships between universities in Brazil and Portugal, enriching capacity and knowledge in Health Application Design validation. This collaboration also supports the integration of new technologies into health application research and educational institutions in Brazil.

Comparing our findings with those of other authors, we observed that TB applications have a broad scope, benefiting both patients and health professionals. Similar to findings in the literature (BYONANEBYE et al., 2021; PARK et al., 2021), improvements in disease management were evident. Challenges in managing information across multiple official systems without seamless communication were also highlighted (ZHANG et al., 2023); (NETTO et al., 2021), echoing recommendations by the World Health Organization (WHO, 2021) on the use of applications for TB control.

The primary contribution of this research lies in demonstrating the feasibility of developing applications to enhance disease management. Centralizing information through an application and visualizing data via a Dashboard significantly enhances efficiency and information accessibility. The study encountered limitations due to the inability to conduct exhaustive tests or deploy the application for operational use. Future research should focus on refining the application for improved TB monitoring and control.

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