Toward safer pregnancies: Usability evaluation of a prototype application for monitoring and controlling hypertensive disorders in pregnancy

Hacia embarazos más seguros: evaluación de la usabilidad de un prototipo de aplicación para el monitoreo y control de trastornos hipertensivos en el embarazo

Em direção a gestações mais seguras: avaliação da usabilidade de um protótipo de aplicativo para monitoramento e controle de distúrbios hipertensivos na gravidez"

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Received: September 10th, 2023
Accepted: November 30th, 2023
Available: December 30th, 2023

How to cite this article:
M.I. Nielsen Pimentel, V. Villarreal Contreras, L.E. Muñoz Arracera, J.A. González Gómez, D. Dominguez Perez, "Toward safer pregnancies: Usability evaluation of a prototype application for monitoring and controlling hypertensive disorders in pregnancy," *Revista Ingeniería Solidaria,* vol. 19, no. 3, 2023.
doi: https://doi.org/10.16925/2357-6014.2023.03.10

Research article. https://doi.org/10.16925/2357-6014.2023.03.10

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Abstract

Introduction: Hypertensive disorders in pregnancy pose global health challenges. Maternal mortality rates in Panama due to preeclampsia and eclampsia have increased. A mobile application is introduced to monitor and control these disorders.

Problem: Hypertensive disorders in pregnancy pose a risk to maternal health. Panama's healthcare initiatives have shown progress, but there are still gaps in maternal care. Novel technologies may help address these gaps.

Objective: The goal is to evaluate a prototype mobile app for managing hypertensive disorders in pregnancy. Research focuses on usability, including navigation, design-task correlation, acceptability, and user perspectives.

Methodology: The Design Science Research Methodology (DSRM) guides the study through problem identification, motivation, and software artifact development. The evaluation involves 32 participants engaging in tasks and standardized questionnaires, including the System Usability Scale (SUS) and User Experience Questionnaire (UEQ). Tasks assess the app's usability, while questionnaires provide comprehensive insights into user experiences.

Results: Users generally have positive interactions and favorable perceptions. However, there are challenges with task completion, particularly with interface intuitiveness.

Conclusion: The app for monitoring hypertensive disorders has shown positive user experiences and usability. However, there are challenges and user feedback that need to be addressed for refinement and effectiveness in supporting maternal health during pregnancy.

Limitations: The study focuses only on the prototype evaluation phase and may need further iterations to address challenges. The participant pool's limitations may impact generalizability. Ongoing improvements are crucial to meet evolving user needs and technological advancements.

Originality: This article contributes originality by presenting a novel mobile application prototype for managing hypertensive disorders in pregnancy. The use of DSRM for development and comprehensive usability assessments with standardized tools adds to the originality, providing valuable insights for future advancements in maternal healthcare technology.

Keywords: Hypertensive disorders in pregnancy, Mobile health application, Usability evaluation, Design Science Research Methodology (DSRM), System Usability Scale (SUS), User Experience Questionnaire (UEQ).

Resumen

Introducción: Los trastornos hipertensivos en el embarazo plantean desafíos globales para la salud. Las tasas de mortalidad materna en Panamá debido a la preeclampsia y la eclampsia han aumentado. Se introduce una aplicación móvil para monitorear y controlar estos trastornos.

Problema: Los trastornos hipertensivos en el embarazo representan un riesgo para la salud materna. Las iniciativas de salud en Panamá han mostrado progresos, pero aún existen brechas en la atención materna. Las tecnologías novedosas pueden ayudar a abordar estas brechas.

Objetivo: El objetivo es evaluar un prototipo de aplicación móvil para gestionar los trastornos hipertensivos en el embarazo. La investigación se centra en la usabilidad, incluyendo la navegación, la correlación entre diseño y tarea, la aceptabilidad y las perspectivas de los usuarios.

Metodología: La Metodología de Investigación en Ciencias del Diseño (DSRM, por sus siglas en inglés) guía el estudio a través de la identificación del problema, la motivación y el desarrollo del artefacto de software. La evaluación incluye a 32 participantes que realizan tareas y completan cuestionarios estandarizados, incluyendo la Escala de Usabilidad del Sistema (SUS) y el Cuestionario de Experiencia del Usuario (UEQ). Las tareas evalúan la usabilidad de la aplicación, mientras que los cuestionarios proporcionan perspectivas exhaustivas sobre las experiencias de los usuarios.

Resultados: En general, los usuarios tienen interacciones positivas y percepciones favorables. Sin embargo, existen desafíos con la finalización de tareas, especialmente con la intuición de la interfaz.

Conclusión: La aplicación para el monitoreo de trastornos hipertensivos ha demostrado experiencias de usuario positivas y usabilidad. Sin embargo, existen desafíos y comentarios de los usuarios que deben abordarse para su refinamiento y eficacia en el apoyo a la salud materna durante el embarazo.

Limitaciones: El estudio se centra solo en la fase de evaluación del prototipo y puede necesitar iteraciones adicionales para abordar los desafíos. Las limitaciones del grupo de participantes pueden afectar la generalización. Mejoras continuas son cruciales para satisfacer las cambiantes necesidades de los usuarios y los avances tecnológicos.

Palabras clave: Trastornos hipertensivos en el embarazo, Aplicación móvil en salud, Evaluación de usabilidad, Metodología de Investigación en Ciencias del Diseño (DSRM), Escala de Usabilidad de Sistemas (SUS), Cuestionario de Experiencia del Usuario (UEQ).

Resumo

Introdução: Os distúrbios hipertensivos na gravidez representam desafios globais para a saúde. As taxas de mortalidade materna no Panamá devido à pré-eclâmpsia e à eclâmpsia aumentaram. Um aplicativo móvel é introduzido para monitorar e controlar esses distúrbios.

Problema: Os distúrbios hipertensivos na gravidez representam um risco à saúde materna. As iniciativas de saúde no Panamá mostraram progressos, mas ainda existem lacunas nos cuidados maternos. Novas tecnologias podem ajudar a colmatar estas lacunas.

Objetivo: O objetivo é avaliar um protótipo de aplicativo móvel para manejo de distúrbios hipertensivos na gravidez. A pesquisa se concentra na usabilidade, incluindo navegação, correlação entre tarefas de design, aceitabilidade e perspectivas do usuário.

Metodologia: A Metodologia de Pesquisa em Ciência de Design (DSRM) orienta o estudo por meio da identificação de problemas, motivação e desenvolvimento de artefatos de software. A avaliação conta com 32 participantes realizando tarefas e preenchendo questionários padronizados, incluindo a Escala de Usabilidade do Sistema (SUS) e o Questionário de Experiência do Usuário (UEQ). As tarefas avaliam a usabilidade do aplicativo, enquanto os questionários fornecem insights abrangentes sobre as experiências do usuário.

Resultados: Em geral, os usuários apresentam interações positivas e percepções favoráveis. No entanto, existem desafios na conclusão de tarefas, especialmente na intuitividade da interface.

Conclusão: O aplicativo para monitoramento de transtornos hipertensivos demonstrou experiências de uso e usabilidade positivas. No entanto, existem desafios e feedback dos utilizadores que devem ser abordados para o seu refinamento e eficácia no apoio à saúde materna durante a gravidez.

Limitações: O estudo concentra-se apenas na fase de avaliação do protótipo e pode necessitar de iterações adicionais para enfrentar os desafios. As limitações do grupo participante podem afetar a generalização. Melhorias contínuas são cruciais para atender às novas necessidades dos usuários e aos avanços tecnológicos.

Palavras-chave: Distúrbios hipertensivos na gravidez, Aplicativo móvel de saúde, Avaliação de usabilidade, Metodologia de Pesquisa em Design Sciences (DSRM), Escala de Usabilidade de Sistemas (SUS), Questionário de Experiência do Usuário (UEQ).

1. INTRODUCTION

According to the World Health Organization (WHO), hypertensive disorders in pregnancy can be characterized in three groups: gestational hypertension, chronic hypertension, and preeclampsia [1]. The occurrence of Hypertensive Disorders in Pregnancy (HDP) has increased globally, from 16.30 million to 18.08 million during the period from 1990 to 2019, representing a total increase of 10.92% [2]. According to [3] and [4], these disorders are a common complication that affects approximately 5% to 10% of pregnant women worldwide, and in some cases, they can become potentially serious.

In Panama, the implementation of government initiatives such as the National Strategic Plan for the Reduction of Maternal and Perinatal Morbidity and Mortality 2015-2020 and the implementation of the Opportunities Network has generated partial results that reflect a decrease of almost 30% in maternal deaths between 2012 and 2017, according to data from UNICEF Panama [5]. However, the percentage of maternal deaths due to disorders such as preeclampsia and eclampsia in 2020 has increased by 7.5% and 11.3% respectively, in contrast to 2015, according to figures extracted from the report on maternal deaths by the National Institute of Statistics and Census (INEC) (Figure 1).

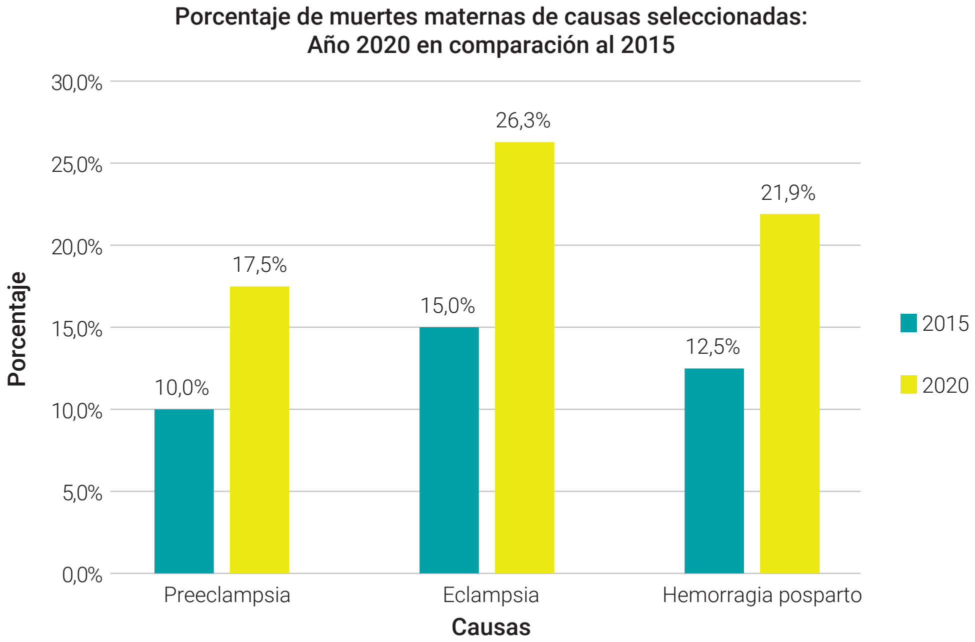

Figure 1. Percentage of maternal deaths from selected causes: year 2020 compared to 2015.
Source: National Institute of Statistics and Census of Panama - INIEC.

The World Health Organization (WHO) has established several areas of interest and focus for the implementation of mobile technology in health (mHealth) such as surveillance, monitoring, education, training, remote communication and collaboration between doctors and patients, which enable an improvement in the availability of medical services in geographical areas of a country or region. Highlighting the role of mobile technology in supporting 'patient behavior change' in areas such as adherence to treatments, promoting physical activity and avoiding neglect of habits that are harmful to health.

Mobile technologies have been incorporated into people's daily routines due to the extension of healthcare systems [6], enabling the emergence of mobile applications supported by software components distributed in the cloud [7], [8]. In this context, technological solutions in the area of digital health must adjust to the new requirements imposed by emerging technologies, such as mobile computing, big data and information analysis through artificial intelligence, among others, with the aim of accelerating the detection, evaluation and reaction, both proactive and preventive, of diseases that affect the population with efficiency and effectiveness [9]. Therefore, current systems must evolve to complex software architectures that allow scalability, openness, reuse, and interoperability, ensuring adequate levels of security and privacy of user and patient information.

In Panama, current methods of screening and monitoring for HDP may be limited by access to health care resources and services, as well as the complexity and cost of traditional monitoring systems for pregnant women. Early detection and management of these disorders are critical to attenuating the rates of illness and death in mothers and fetuses. For this reason, it is intended to create a platform that allows for the monitoring and control of HDP.

2. Related Work

In 2018, big data approaches were implemented in healthcare to improve healthcare excellence. The authors of [10] proposed a Big Data architecture for handling large volumes of data. The architecture includes a data layer with microservices, a batch analysis layer, and a visualization layer. Organizing data into ontologies and using Machine Learning libraries for creating predictive models is emphasized. Overall, the architecture seeks to improve the reliability of healthcare systems through accurate alerts and predictions about patients' health.

Researchers in [11] present a cloud-based structure focused on big data, with the purpose of ensuring intelligent management of pregnancy and the health of mothers. The architecture is structured in layers and uses distributed services such as ElasticSearch, Hadoop, and MongoDB to handle the information. In addition, communication is established in the cloud through a firewall and a load balancer, and it relies on RESTful API technologies to structure inputs and ensure the order of transactions in the application.

Sarhaddi et al. [12] developed a structure for continuous monitoring of exercise, stress, and rest during gestation and beyond. The system uses mood data and patient-specific information to provide a complete understanding of their conditions. The design has four levels: perception, gateway, cloud, and application. The first level uses sensors to obtain physiological data on the mother's well-being. The cloud-based layer analyzes the data and provides processed results to the application layer, where it is presented to users and allows for secure communication between researchers and pregnant women.

Veena et al. [13] developed a system for the timely supervision of a pregnant women's health status using wireless sensors. The architecture is cloud-based and uses sensor networks, mobile devices, and instant communication through cellular networks. AI techniques are incorporated to anticipate possible risks by generating a comprehensive perspective of the gestation period and its status.

Moreira et al. [8] proposed a novel machine-learning model to anticipate HELLP syndrome during pregnancy. The model is used as a cloud-based deduction instrument via a mobile app to monitor patients' symptoms. Microservices distributed in the cloud are used to circulate information necessary for predicting HELLP syndrome. In [14], different models were tested to identify whether women were at higher risk of preeclampsia or not, using information from medical appointments. Remote and constant monitoring of blood pressure through mobile apps may provide an opportunity to implement these models more broadly in identifying women who need further follow-up during pregnancy.

Roca et al. [15] propose a chatbot architecture that uses microservices for scalability, HL7 FHIR for standard data exchange [16], and AIML [17] for standard conversation modeling. Kumar et al. [18] focus on adaptability and customization for pregnancy management, while Bjelica's proposal [19] uses a hexagonal structure for growth and maintenance simplification. Both approaches aim to improve maternal health through technology and various components.

Pealing et al. [4] discuss self-monitoring of blood pressure during hypertensive pregnancy and its acceptance by both pregnant women and their physicians. The authors of [20] evaluated the implementation of this concept in different maternity units in England during the COVID-19 pandemic and found that self-monitoring was helpful in reducing the need for additional in-person contacts and giving women more control and information about their own blood pressure. In another study [21], the platform created for telemonitoring was beneficial in the early identification of new cases of preeclampsia

Understanding user strengths, limitations, and motivations is crucial for effective user experience design. Hypertensive disorders during pregnancy are a leading cause of mortality for mothers and newborns worldwide. Monitoring blood pressure variables is imperative, and a mobile app that allows for the autonomous and remote collection of blood pressure data can help extend health services to pregnant women in need.

3. MATERIALS AND METHODS

This article presents the proof of concept of a mobile application for the monitoring and control of hypertensive disorders in pregnancy. For the methodology of the development of this study, the DSRM process proposed by [22] is shown in Figure 2. DSRM encompasses the software development process from the stages of identification and definition of the problem to the deployment of the application, which includes a process of design and development of software artifacts.

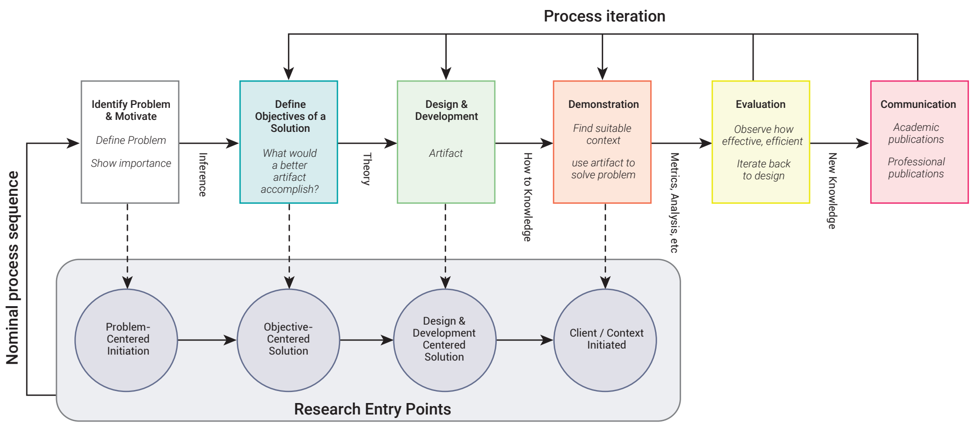

Figure 2. DSRM - Design Science Research Methodology.
Source: Peffers et al., 2007 [22]

This methodology identifies the elements that will be understood during the development of this article. As shown in the figure, the methodology suggests six steps to follow, which are described below.

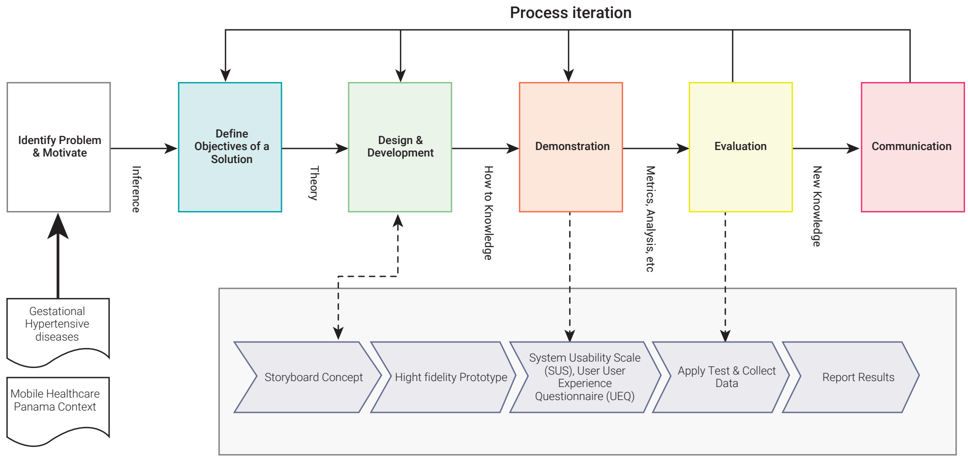

Figure 3. DSRM – Adaptation of the methodology for the study.
Source: Own work - based on Peffers et al., 2007 [22]

3.1. Phase 1: Identification of the problem and motivation:

Early detection of conditions such as preeclampsia and eclampsia, as well as prevention of HELLP syndrome, can mean the difference between life and death of the mother and the neonate. This project focuses on the capture of biometric blood pressure data, specifically aimed at pregnant women who have Bluetooth devices for information capture. In addition, it seeks to provide additional information that contributes to education and empowerment in the field of maternal-fetal health. To fully understand our users, we address the following questions in Table 1 to determine actions to be considered during the design of the application:

Table 1. Design Implications to Consider.

Implications	Actions
What are the user's needs?	Effectiveness and Quality in Information Capture
	Visualize Information
	Storing Information
	Understanding the information
Which features are most important to them and why?	Effective and highly accurate information captures are important to define a coherent and correct assessment of the current state in which it is.
	Know the status of your blood pressure, since it is a very high risk factor in pregnancy and the appearance of this constant factor can lead to the termination of pregnancy or even loss of the mother´s life.

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Implications	Actions
What information does the app need to provide so they can interact effortlessly?	Homogeneous and cognitively coherent and constant design. The different states of the application. Processing the information into a normal language, i.e., translating the information for humans, in our case, the pregnant mothers.

Source: Own work

3.2. Phase 2: Study Objectives:

For the development of this evaluation, the following research questions are established:

- Are users able to navigate the app seamlessly and complete experiment tasks?
- Is there a correlation between established design and task accomplishment success?
- How acceptable is the prototype?
- From the respondent's perspective, how does the application perform at the structural, operational, user information, content, and interface intuitiveness levels?

3.3. Phase 3: Design and development:

Using the solution ideas from the previous phase, we model the interaction elements such as the user interface, the services and the software architecture.

3.3.1. Storyboard of concept

In order to contextualize the users, a conceptual storyboard has been developed that addresses the central theme of the application, as illustrated in Figure 4. In the first vignette, a conversation between two friends is depicted, one of them being a carrier of concern due to the complications experienced during pregnancy, attributed to hypertensive problems. The following vignettes describe the reflection of one of the friends on this conversation with Maria, detailing the situation and its implications associated with hypertensive problems. The sequence continues with the protagonist visiting a medical center, where she is suggested to use an application for the continuous monitoring of her biometric variables throughout the day, with the aim of improving medical care. This storyboard provides a coherent visual narrative that establishes the fundamental premise for the conceptualization and development of the application, highlighting the relevance of continuous monitoring of biometric variables in the context of hypertensive problems during pregnancy.

Figure 4. Storyboard Case Study / Hypertension in Pregnancy.
Source: Own work

3.3.2. Prototyping the application

For the prototyping of the application, some software artifacts are developed that allow for the storage and management of the information that will be executed during the proofs of concept and prototype.

3.3.2.1. Microservices Architecture

A microservices-based software architecture is proposed in Figure 5 to enable continuous monitoring and control of hypertensive disorders during pregnancy. The system uses ambulatory biometric sensors to monitor the health [23], [24] of pregnant women and implement information analysis mechanisms powered by artificial intelligence [25], [26]. The architecture aims to bridge the doctor-patient gap by providing a technological solution that facilitates observation, evaluation, and personalized care plan generation, thereby supporting intelligent decision-making in maternal-fetal health [23], [27]–[29].

The microservices architecture provides an alternative solution for the monitoring and control of pregnancy, offering scalability, high availability, failure resistance, flexibility, independence, and autonomy in each device [30]. Additionally, the architecture establishes decentralized information governance or domain, enabling delivery, deployment, and continuous improvement through DevOps [31], and it expands the potential of mobile technologies through the use of cloud resources [32].

The architecture comprises multiple layers that address different aspects of the system. The monitoring layer features microservices that manage biometric data using the database-by-service pattern [33], enabling the development of concept domain microservices. The streaming layer facilitates communication between microservices using event channels managed by microservices that handle notifications and message queues, such as Apache Kafka [34], [35], Flink[36], [37] and Redis [38].

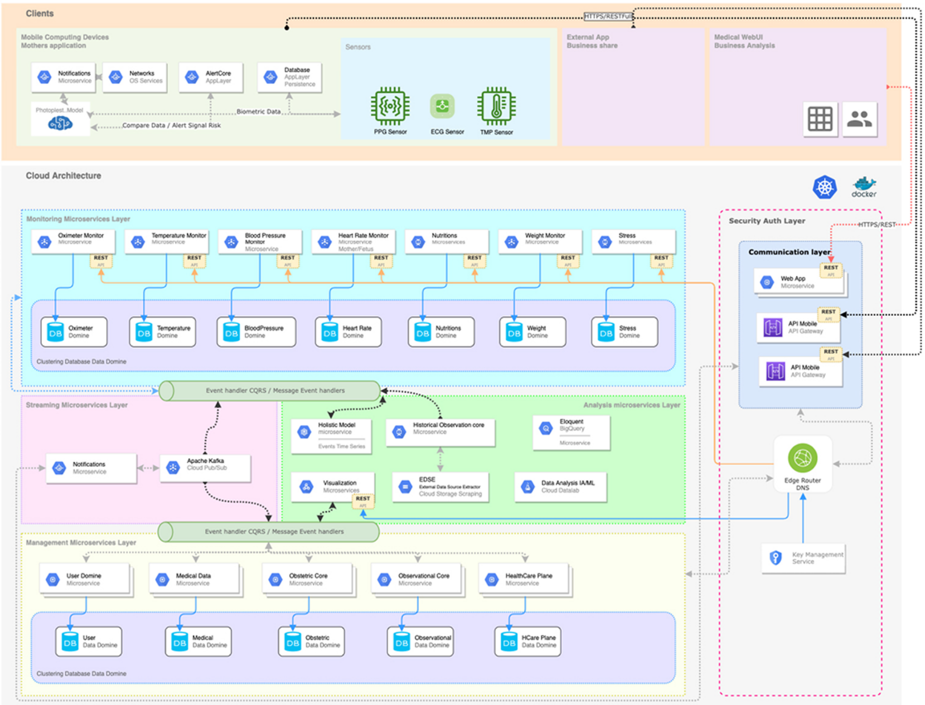

Figure 5. AmIHealth microservices-based architecture.
Source: Own work

The Analytics layer focuses on data analytics, essential for intelligent decision support systems in health [39]–[41]. Microservices in this layer allow for a holistic patient observation based on her clinical history and hereditary family history, using the command query segregation of responsibility pattern (CQRS) and SAGA [33, pp. 110–145], [42]. The Management layer comprises microservices that manage the system by medical staff and patients, providing additional information to the upper layers. The microservices enable the adjustment of subscribed microservices as needed, using the SAGA pattern for communication [42], [43]. The Security layer manages access and communication between authorized clients through API gateways (Web APP API, Mobile API, and Public). The layer logically structures the endpoints for different clients. At the same time, the Edge router filters requests and allows each request to be authenticated through oauth2, ensuring proper control of the flow of information [9], [44]–[47].

3.3.2.2. Mobile App.

The development of the mobile application prototype is divided into two phases. The first phase involves wireframing the Figma application. During this phase, some components that build the user interface are defined, such as color, styles, buttons, flows, and actions.

In the second phase, the development of the application focuses on a minimum viable product as can be seen in Figure 6. For the development of this minimum viable product, we consider features such as the login screen, main menu, information capture screen, measurement history screen, and the results observation screen.

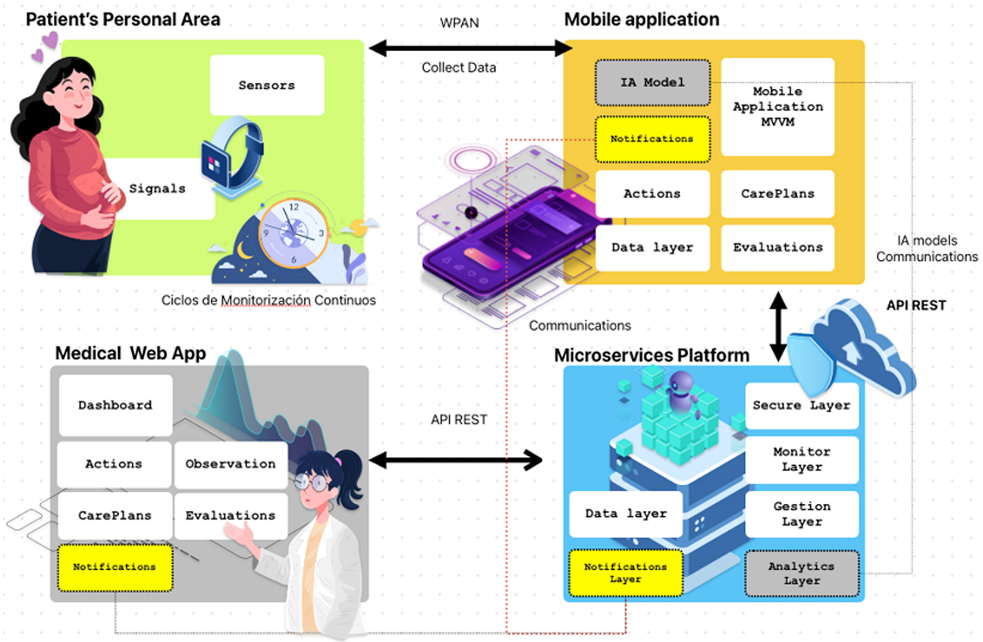

Figure 6. Mobile App functional architecture.
Source: Own work

The prototype of the mobile application for the continuous monitoring of hypertensive disorders in pregnancy was developed for iOS using agile development and the versatility of customization of the user interface [12], [48]–[51] and it also allows for integration with TensorFlow Lite to create applications that use machine learning and neural networks. In Figure 7, you can see some of the user interfaces designed for the application.

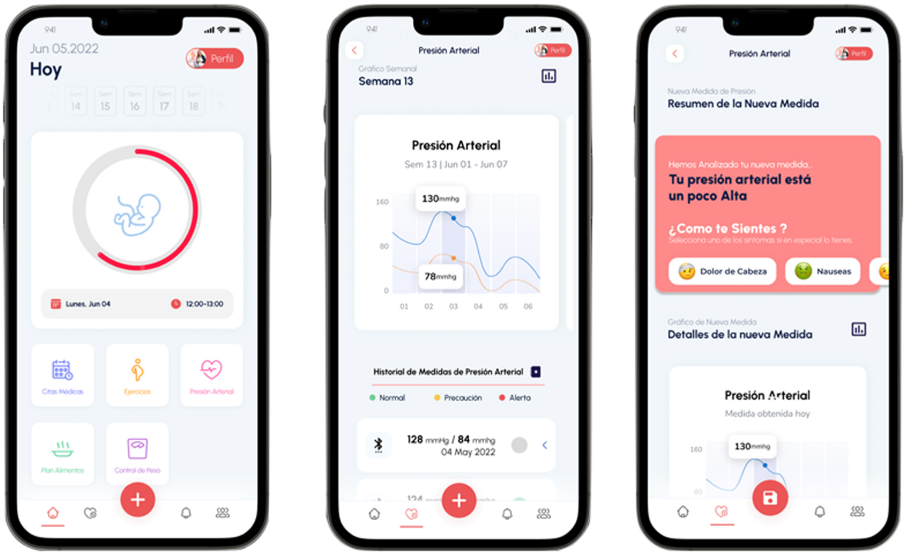

Figure 7. Mobile App prototype Screens.
Source: Own work

Prototype of the user interfaces designed for the mobile application of the proposal.

The mobile application so far includes information on the weeks of pregnancy through which the mother is progressing, the blood pressure management module and the details of the information display, as well as notifications that aim to inform pregnant women about the status of the pressure and obtain feedback from the pregnant woman.

3.3.2.3. Demo.

Once the designs, interface, and application have been completed, the next stage is the distribution of the test using the artifacts described above. The Maze tool is selected, which allows, through one of its integrations, to carry out proofs of concept or prototype based on missions or tasks for this case, which will be described in the next stage.

3.3.2.4. Evaluation.

To evaluate the prototype, the evaluation process has been divided into three stages: first, three tasks are established that the user must accomplish using the prototype (see Table 2).

Table 2. Study Assignments

ID	Task	Description
T1	Identify the section on blood pressure measurements	In this task, the user must be able to locate themselves on the blood pressure screen, go through the main screen, identify the blood pressure section in the menu presented
T2	Add a new blood pressure measurement	In this task, the user must be able to identify the action of adding a new pressure measurement, which consists of alternate flows which will display error notifications and guide the user to compliance
T3	Removing a Blood Pressure Measurement	In this case, the user can move at their convenience through the main blood pressure screen. Once there, the user can choose between weeks 13 and 20 and then identify a blood pressure measurement and remove it

Source: Own work

Second, three questionnaires applied at different times are defined: the first questionnaire is a non-standardized instrument developed for this study. This questionnaire (P) is based on the Nielsen heuristic, which is designed to know how the application is doing from the user's perspective, at the structural level of user information management, the content displayed and the immediate perception of the design (see Table 3). This is evaluated through a Liker scale of 1-5 and is applied after the tasks described above have been completed.

Table 3. P Questionnaire

Code P	Question	Area P	Nielsen's Heuristic	Comparison	Rating Metric
P1	Is the distribution of structural elements in the application (Scrollbar, Navigation Bar, Content Areas, Buttons, etc.) good?	Structure - Layout of the Interface	Flexibility and efficiency of use	Both emphasize efficient arrangement of the interface	1-5
P2	Is the navigation through the application's content easy?	Operation - Levels of Complexity	Match between the system and the real world	Both highlight the importance of understandable concepts	1-5

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Code P	Question	Area P	Nielsen's Heuristic	Comparison	Rating Metric
P3	Are figures, tables, buttons, active zones, and the type of action to be executed easily identifiable?	Operation - Accessibility for Inexperienced Users	Recognition, diagnosis, and recovery from errors	Both aim for accessibility and error recovery	1-5
P4	Are the data that the user is looking for easy to find?	Understanding - Ease of Interpreting Provided Information	Visibility of the system's state	Both focus on providing clear information	1-5
P5	Does the application keep the user informed about tasks in progress?	Integration - Logical Relationship Between Informational Elements	Consistency and standards	Both require logical relationships and coherence	1-5
P6	Is the presentation of content (e.g., font type and size, use of color, arrangement of elements according to their meaning, etc.) good?	Content - Relevance of Presented Content	Aesthetic and minimalist design	Both prioritize relevance and efficient presentation	1-5
P7	"Are the procedures for navigating through the application or performing assigned tasks learned almost immediately?"	Intuition - Natural and Effortless User Experience	Flexibility and efficiency of use	Both aim for a natural and effortless experience	1-5

Source: Own work

The second questionnaire used is the System Usability Scale and was distributed through the Google Form Platform. This instrument has its formula for translating the data into a score from 0 to 100 where ranges of usability acceptance can be located. The data in this heading are numerical values ranging from 1 to 5 and are treated as follows:

- Odd questions, i.e. 1,3,5,7,9 are answered positively, therefore the value of their answer will be translated with the following expression: $val = Rn - 1$ Where Rn is the value of the answer.
- Even questions are considered negative answers and are translated as . $val = 5 - Rn$
- Once the values have been translated, they will have values between 0 and 4 with which the users' appraisals will be given for each question.
- The total questionnaire per participant is then iterated to obtain the range, such that $ValSUS = (\sum_{val}^{n}) * 2.5$.

- The average of the total SUS ratings *(ValSUS)* of the surveys is then obtained to obtain the Average Rating of the application.

The instrument can be interpreted in five ways, either by percentiles, grades, adjectives, acceptance, and NPS promoters and detractors; each of them with its corresponding weightings. In this case, the interpretation by degree of acceptance is used (see Figure 8) where it is established that the mean rating of 68 or higher is acceptable, between 50 and less than 68 is marginal and less than 50 is an unacceptable usability rating.

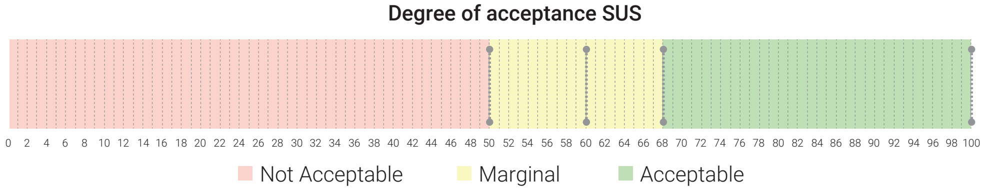

Figure 8. SUS Degree of Acceptance.
Source: Own work– adapted from [52]

The third study questionnaire focuses on User Experience Assessment (UEQ) [53], [54] by using a reference dataset or "benchmark". The UEQ tool contains 26 standardized questions that are evaluated at a positive or negative level regarding an aspect of the user experience and simplifies the analysis of data collected from users evaluating products, focusing on aspects such as ease of use and overall satisfaction. The results are compared to a large dataset spanning more than 21,000 people who participated in 468 studies on everything from enterprise software to social media. Comparison with this benchmark allows us to infer the relative quality of the evaluated product in relation to others of the same type.

4. RESULTS

Once the artifacts described above for this study have been carried out, the methodology described in Figure 9 is applied. The elements of this study were applied to 32 (R1,R2, R3 ... Rn) women in approximately 15 minutes. The first step was to analyze the storyboard to contextualize the participants in the problem. Participants are then instructed to enter the Maze Platform. Once inside, the tasks to be carried out using the prototype of the application are displayed. Through the platform, you will be able to observe the completion rate of tasks and the average time it takes a user to complete them. At the end of the use of the prototype, the SUS and UEQ surveys and a user perception questionnaire are completed.

Once the test is completed, the information collected is placed in the UEQ survey tool and inconsistencies are eliminated. Once the above process has been carried out, a total population of 25 users is obtained for the study, to whom the data analysis is carried out and then the information or findings are reported.

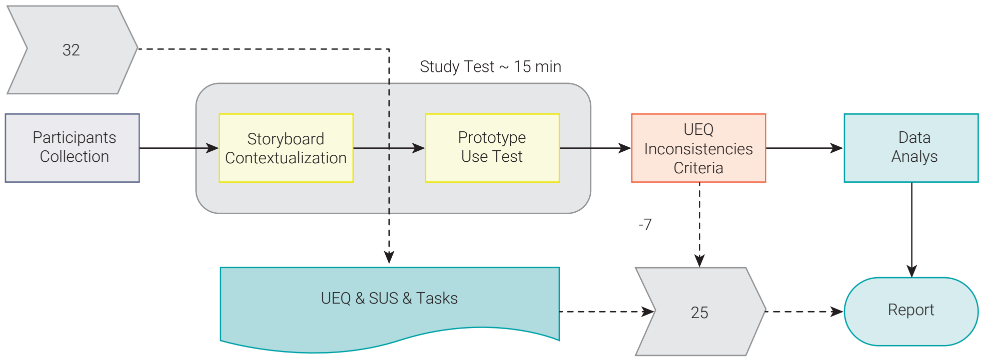

Figure 9. Data collection process.
Source: Own work

4.1. Study Demographics

The survey population corresponds to the following distribution by age range (see Figure 10): 48% of respondents are between 30 and 39 years of age; followed by 36% who correspond to the age group between 20 and 29 years old and finally 16% who are between 40 and 49 years old.

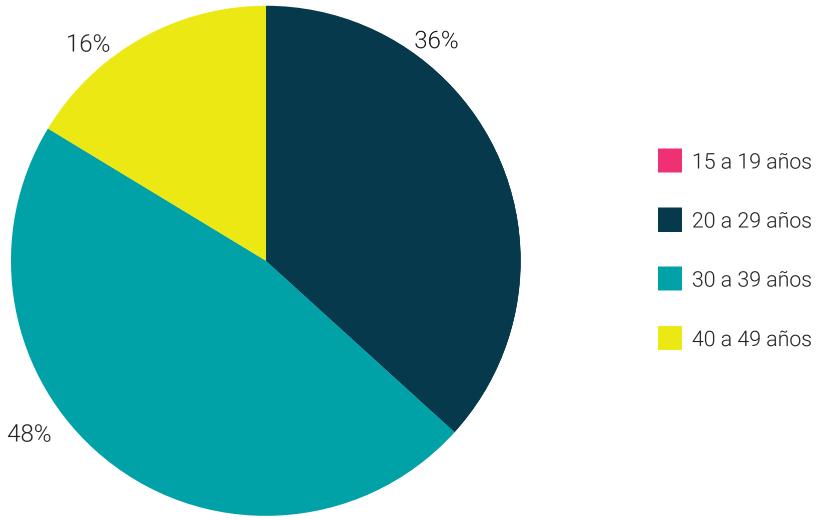

Figure 10. Distribution of the study population.
Source: Own work

4.2. Tasks Completion

The percentage of completion of Tasks 1 and 2 was 100%, which corresponds to the fact that all participants managed to complete the test. However, only 72% of participants were able to complete Task 3, leaving 28% of participants who failed to complete the mission.

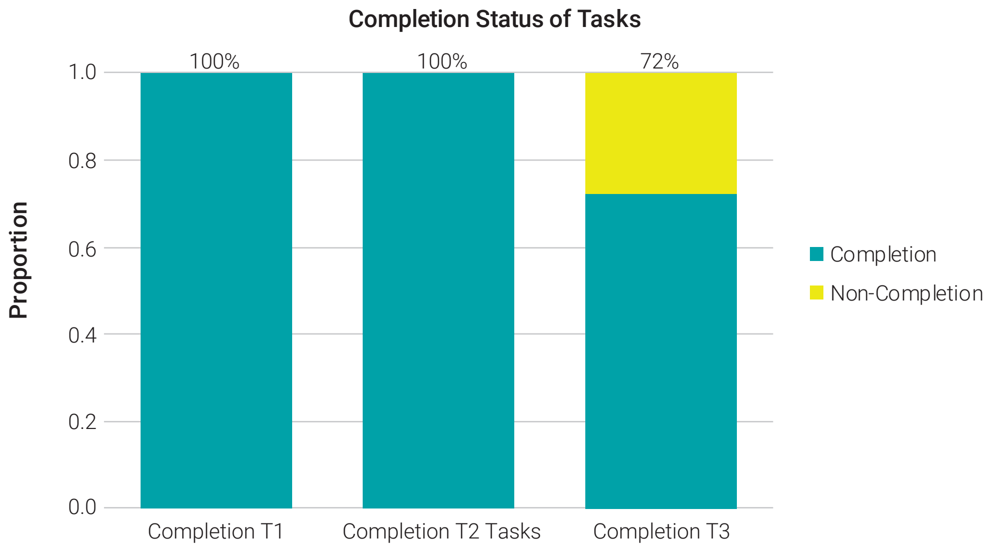

Figure 11. Task Completion Rate.
Source: Own work

The average completion of Task 1 corresponds to an average of 48.56 seconds where we can see that the participant (R8) was the one who performed the task the slowest compared to the group, while the participants (R1, R7 and R30) were the ones who performed it the fastest. It should be noted that this measure corresponds to the average interaction between the screens of the participants see Figure 12.

For Task 2, the average compliance corresponds to the average of 94.86 seconds where we can again observe participant R8 who is the one who performs the task with more time dilation compared to the other users.

On the other hand, the average time of completion of Task 3 corresponds to an average of 61.24 seconds. However, if we add details such as the following graph, we can determine that there were testers who tried to perform the mission but could not fulfill it, such is the case of testers R{3, 4, 7,8,12,19,31}.

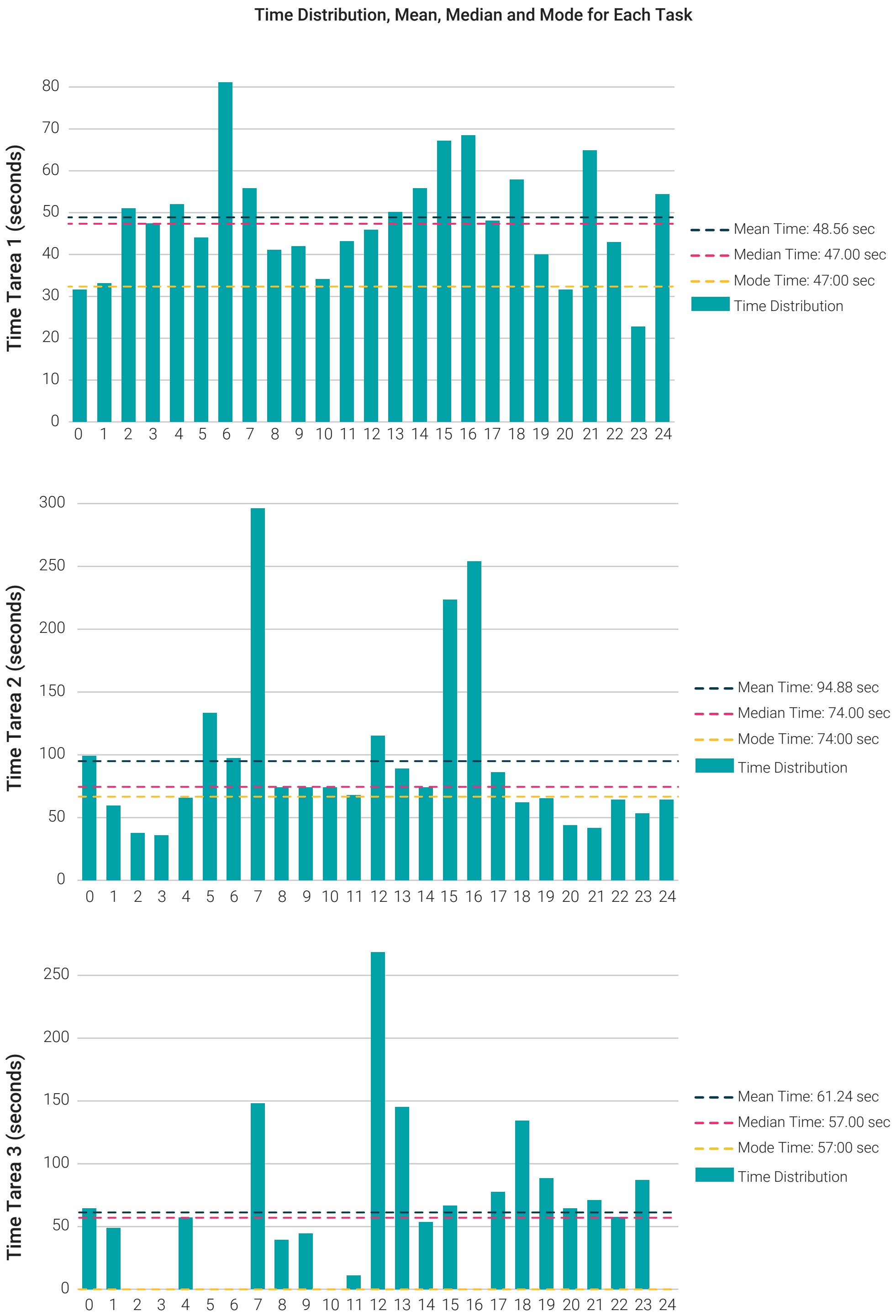

Figure 12. a). Time to Completion T1, b). Time to Completion T2, c). Time to Completion T3.

Source: Own work

4.3. SUS Evaluation, Usability Weightings

In the analysis of the usability of the mobile application for the management of hypertensive disorders in pregnancy, user responses were evaluated using two key metrics: the System Usability Scale (SUS) and usability weights (P1-P7) see Figure 13.

In terms of the SUS, the responses were generally distributed positively, with an average score of 82.3% see Figure 14. The distribution of responses for usability weights also reflected favorable perceptions, with percentages ranging from 72.5% to 100%, indicating substantial acceptance of aspects evaluated, such as efficiency, interface clarity, ease of use, consistency, and overall satisfaction. This analysis provides a detailed view of users' perception of the app's usability, highlighting areas of strength and establishing a basis for recommendations for improvement.

Figure 13. a). Distribution of responses by Item SUS , b). Distribution of Responses by Adhoc Item (P)
Source: Own work

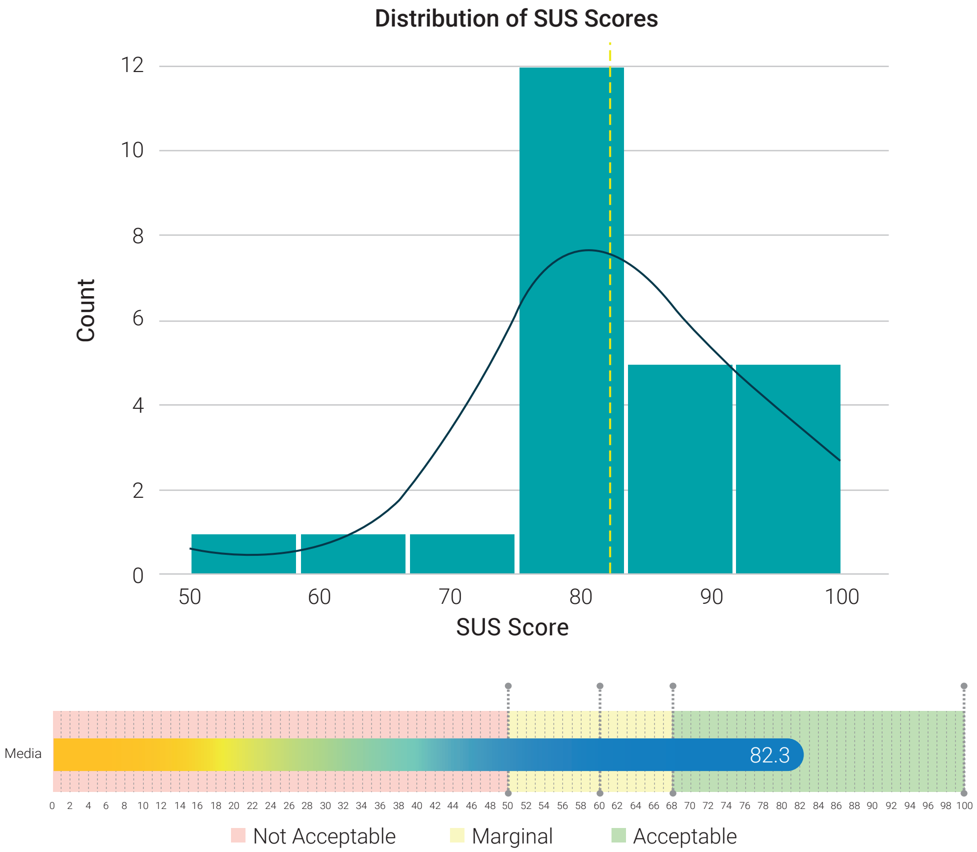

Figure 14. a). Distribution of SUS Score, b). Total SUS Score
Source: Own work

4.4. User Experience Questionnaire

The graphical representation of the distribution of responses from the User Experience Questionnaire (UEQ) provides a detailed view of the users' perceptions of several key aspects of the user experience. Each item evaluated, from attractiveness to innovation, is presented on a scale of 1 to 7, where users indicated their degree of agreement with the proposed statements. Notably, the results reveal that many users experienced high attractiveness, with a score of 16 on the item "Annoying/Enjoyable" see Figure 15. Clarity and ease of learning also received positive evaluations, evidenced by the responses concentrated in categories 4, 5 and 6 in the items related to perspicuity. In addition, the app's innovation and novelty were highlighted, with significant responses in the highest categories for items such as "Dull/Creative" and "Usual/Leading Edge." These results provide a visual and detailed understanding of the user experience, highlighting areas of strength and opportunities for future improvements.

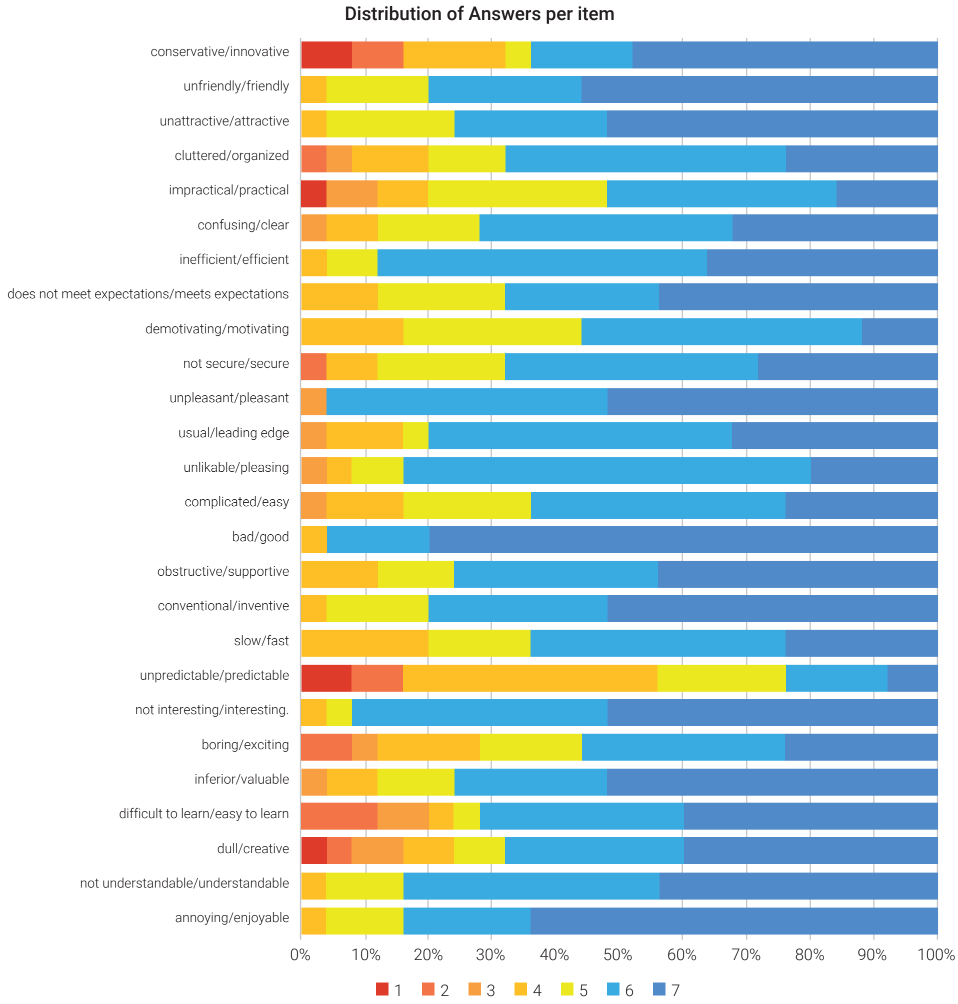

Figure 15. Distribution of responses by Item UEQ
Source: Own work

The results obtained through the User Experience Questionnaire (UEQ) provide a comprehensive assessment of the user experience across several key dimensions. In terms of Attractiveness, Efficiency and Stimulation, the app has demonstrated outstanding performance, with scores that place it within the top 10% of results (see Figure 16), thus highlighting its visual appeal, efficiency in use and ability to generate interest and motivation. The perspicuity and dependability also earned favorable ratings, rated as "Good," indicating that most users experienced a clear understanding of the interface and perceived the app as trustworthy. The novelty dimension, which measures the app's innovation, was also highlighted with an "Excellent" rating, placing the app in the top 10% range in terms of originality and novelty. These results suggest a highly positive user experience in all areas evaluated, supporting the effectiveness and positive acceptance of the mobile application for the management of hypertensive disorders in pregnancy.

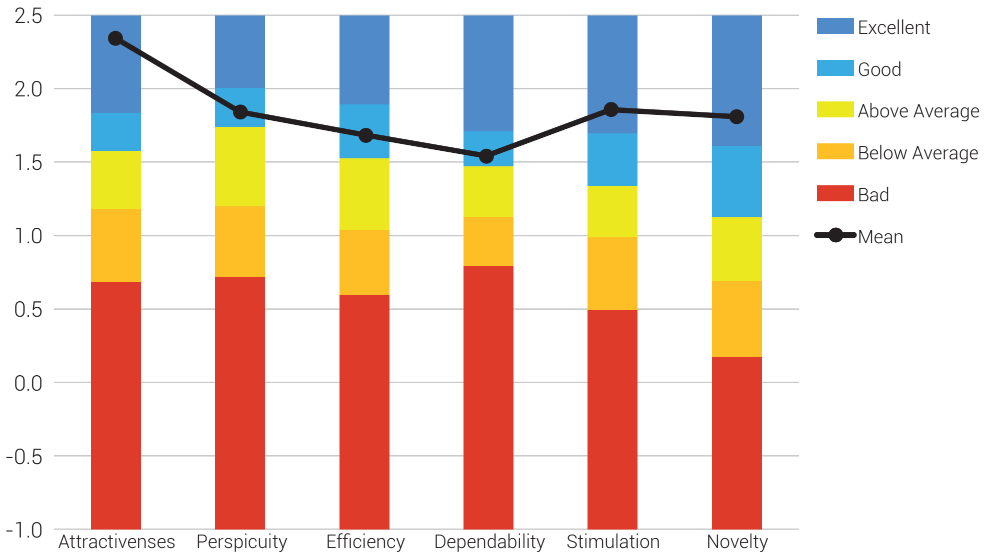

Figure 16. Assessment chart of the UEQ instrument study
Source: Own work

The results of the evaluations suggest that the app has achieved a positive user experience and a strong perception of usability, supporting its effectiveness in the context of the application prototype. However, it is necessary to observe some details related to the fulfillment of the tasks and the results of the questionnaires applied.

It should be noted that users have valued the application at a structural and operational level, with respect to the information provided within the application, the content of the application in general terms and intuition where the vast majority agree or totally agree with each of the items of the surveys applied. With the exception of the items that evaluate the ease of use of the components and the resistance to use (SUS 3 ~ 2.72/4 and SUS 8 ~ 3.20/4), the logical relationship between the information elements and the naturalness and effort in the user experience (P4 ~ 3.96/5 and P7 ~ 3.96/5), as well as the efficiency and reliability of the interface to perform tasks quickly and with little effort (UEQ 3 ~ 1.69/ ± 3 and UEQ 4 ~ 1.55/ ± 3) See Figure 17 and Table 4

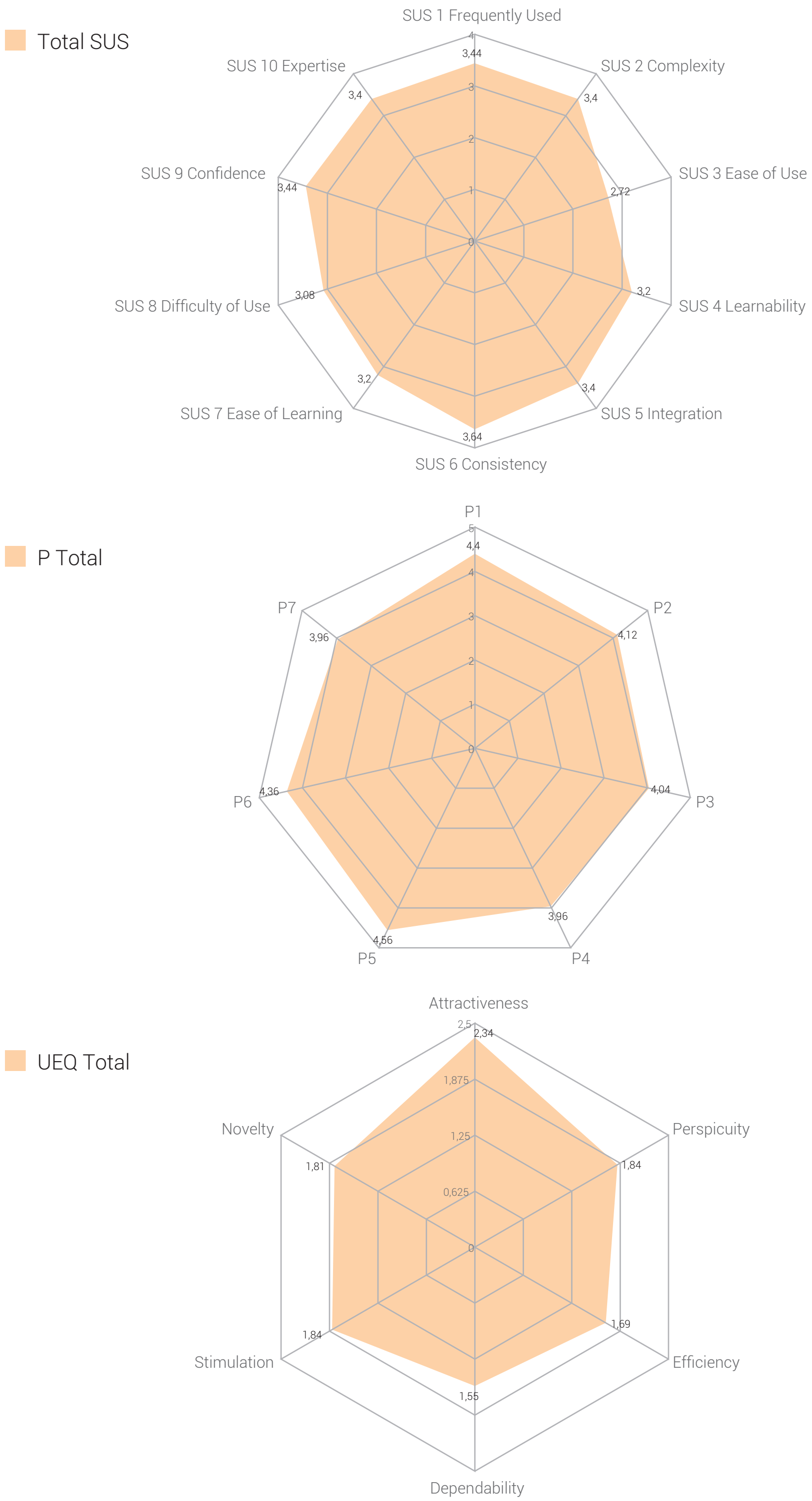

Figure 17. User Experience Radar Chart: SUS, UEQ, and P Scores
Source: Own work

Table 4. User Experience Evaluation Scores: SUS, UEQ, and P Scores

SUS Code	SUS Area	Total SUS
SUS 1	Frequently Used	3.44
SUS 2	Complexity	3.40
SUS 3	Ease of Use	2.72
SUS 4	Learnability	3.20
SUS 5	Integration	3.40
SUS 6	Consistency	3.64
SUS 7	Ease of Learning	3.20
SUS 8	Difficulty of Use	3.08
SUS 9	Confidence	3.44
SUS 10	Expertise	3.40
UEQ Code	**Scale Area**	**UEQ Total**
UEQ 1	Attractiveness	2.34
UEQ 2	Perspicuity	1.84
UEQ 3	Efficiency	1.69
UEQ 4	Dependability	1.55
UEQ 5	Stimulation	1.84
UEQ 6	Novelty	1.81
P Code	**P Area**	**P Total**
P1	Structure - Layout of the Interface	4.40
P2	Operation - Levels of Complexity	4.12
P3	Operation - Accessibility for Inexperienced Users	4.04
P4	Understanding - Ease of Interpreting Provided Information	3.96
P5	Integration - Logical Relationship Between Informational Elements	4.56
P6	Content - Relevance of Presented Content	4.36
P7	Intuition - Natural and Effortless User Experience	3.96

Source: Own work

It is evident from the graphs presented in Figures 11 and 12 that some users found it challenging to perform Task 3. To understand this, in Figure 18, you can observe the user journey. When examining the heat map and mis-clicks of some users through Maze, it appears that users lack clarity on how to perform the delete action.

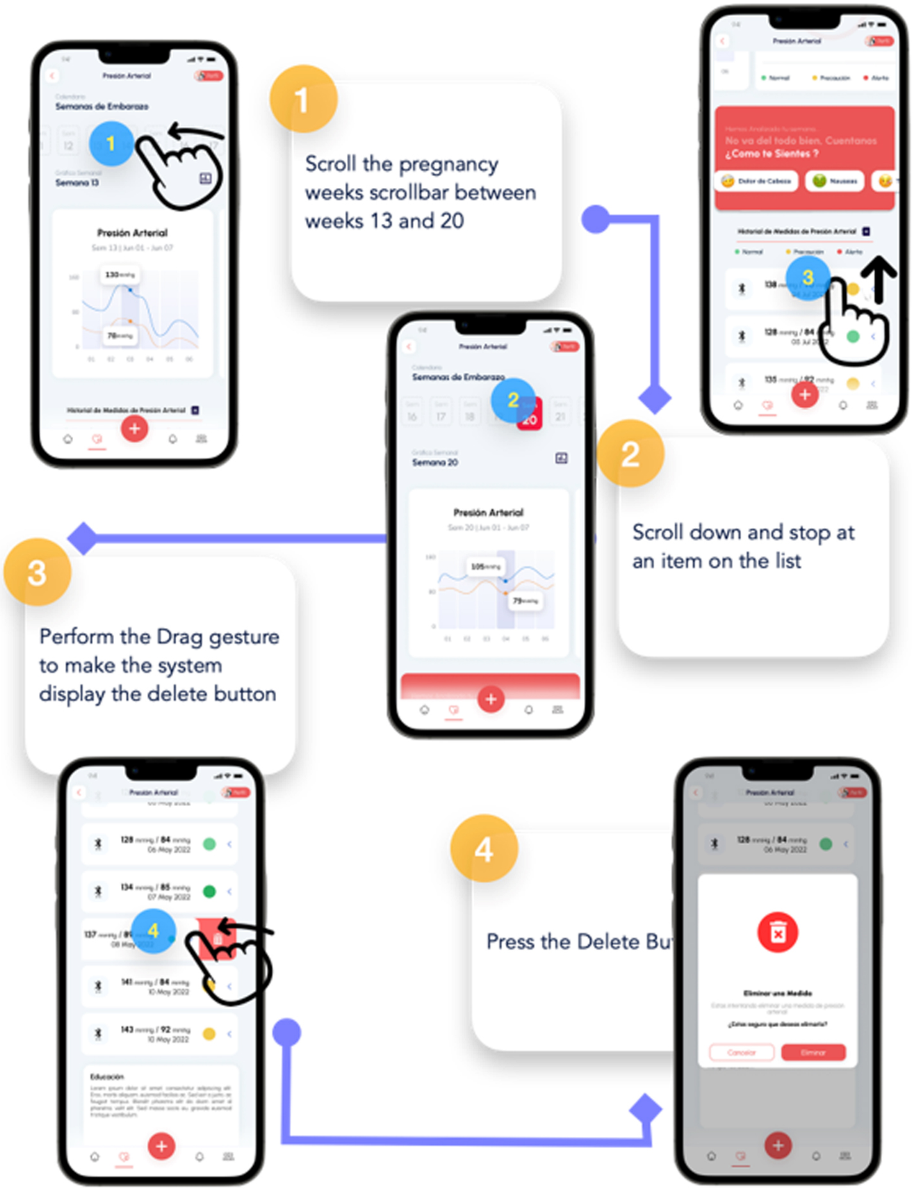

Figure 18. User Journey and Interaction Patterns in Task 3
Source: Own work

To contrast the details of this aspect, the subset of users who failed to complete Task 3 is obtained, obtaining a total of 7 users R{3, 4, 7,8,12,19,31}. The results obtained are evaluated (see Figure 19). To effectively address this situation, the results of the comparative analysis between the two groups, A and B, reveal significant differences in usability perceptions, especially for those users who did not comply with Task 3 (Group B). Below are the most relevant findings in Table 5:

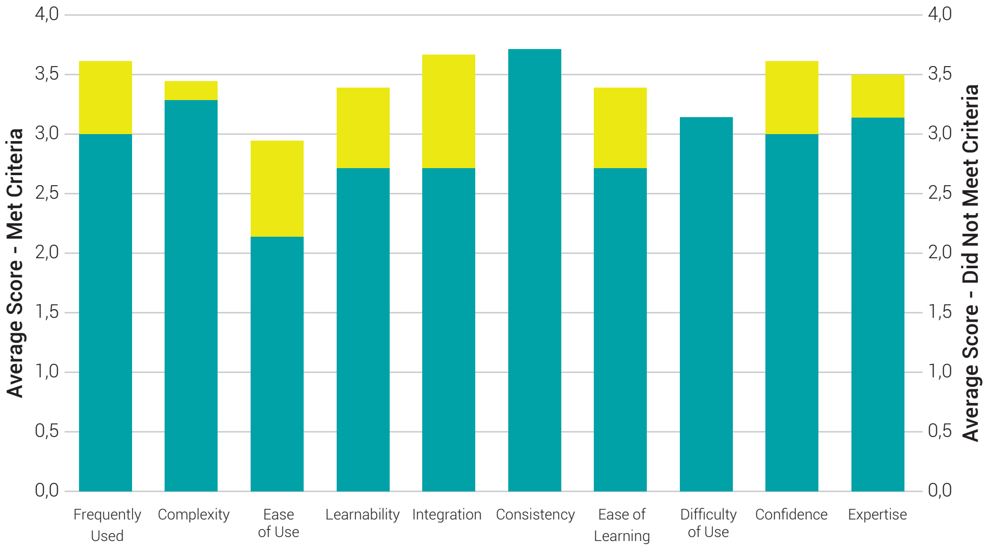

Figure 19. Comparison of SUS Scores between Groups that Met and Did Not Meet Criteria

Source: Own work

Table 5. SUS Evaluation Scores for Groups A and B with Differences and Overall Total

SUS Code	SUS Area	Group A	Group B	Dif	Total SUS
SUS 1	**Frequently Used**	3.611111	3.000000	-0.611111	3.44
SUS 2	**Complexity**	3.444444	3.285714	-0.158730	3.40
SUS 3	**Ease of Use**	2.944444	2.142857	-0.801587	2.72
SUS 4	**Learnability**	3.388889	2.714286	-0.674603	3.20
SUS 5	**Integration**	3.666667	2.714286	-0.952381	3.40
SUS 6	**Consistency**	3.611111	3.714286	0.103175	3.64
SUS 7	**Ease of Learning**	3.388889	2.714286	-0.674603	3.20
SUS 8	**Difficulty of Use**	3.055556	3.142857	0.087301	3.08
SUS 9	**Confidence**	3.611111	3.000000	-0.611111	3.44
SUS 10	**Expertise**	3.500000	3.142857	-0.357143	3.40

Source: Own work

Group B, composed of users who did not meet Task 3, shows a significantly lower score in frequency of use compared to Group A. This suggests that the frequently used functionality may have been less clear or accessible to Group B. The ease-of-use category (SUS 3) reflects a marked discrepancy between the groups, with Group B giving a considerably lower score. This result indicates that users who did not comply with Task 3 experienced greater challenges and negative perceptions regarding ease of use.

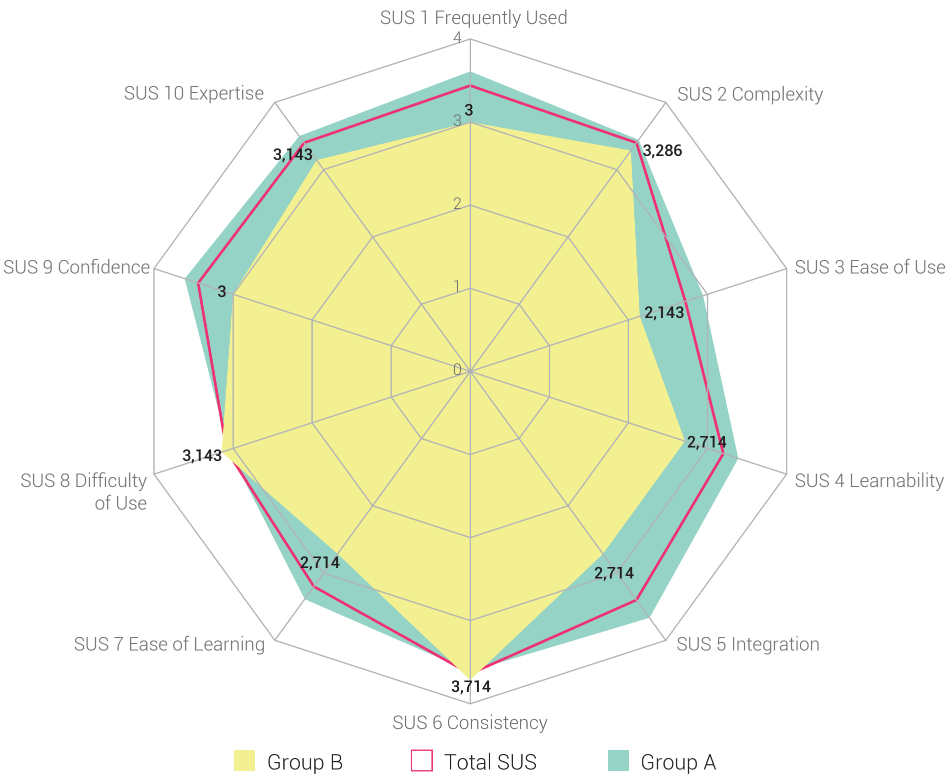

Figure 20. Comparison radar chart of SUS Scores between Groups that Met and Did Not Meet Criteria and Mean Total SUS

Source: Own work

Group B shows a lower perception of learning ability (SUS 4) compared to Group A, suggesting that the interface may have been less intuitive for those who did not complete Task 3. Element integration (SUS 5) also evidences a significant gap, indicating that Group B users experienced difficulties in integrating system components (see Figure 20).

In the context of the Usability Evaluation System (SUS), we focused our attention on the item SUS 3 Score, which evaluates the 'Ease of Use' of our prototype Total SUS (see Figure 20). According to the results table, we observed that the mean score for this area is 2.72, with a standard deviation of 1.24. This indicates that the scores range from 1.48 to 3.96. This interval suggests that, in terms of ease of use, user opinions vary, but on average, the prototype doesn't stand out significantly. To improve the usability experience, it will be crucial to address the specifics that influence these divergent assessments.

5. DISCUSSION AND CONCLUSIONS

The importance of approaching problems from the user's perspective is a fundamental guiding principle in application design. By considering the context in which the user operates and the various tasks they can carry out, a framework is established that goes beyond simple functionality, embracing the user experience. In this sense, the first result of the evaluation of the initial prototype gives us valuable lessons and suggests necessary adjustments to improve user interaction, where they have identified significant design implications that should be considered for modification in a future iteration:

When adding a new pressure media through the interface, it was observed that users tend to quickly go through the onboarding process designed to mitigate potential erroneous measures. It is suggested to explore ways to reduce the number of cards in this section. In addition, in response to the suggestions of the participants, it is proposed to consider the inclusion of options for the manual insertion of information and the implementation of a forum where mothers can share experiences.

A percentage of users failed to complete the task of deleting a record. Analysis of the data suggests that the difficulty experienced is due to the design of the action. We identified the need for additional monitoring to manage blood pressure measurements. We recommend incorporating OS gesture action controls and the possible addition of context menus or long-touch gestures.

Although most of the participants positively valued the amount of information provided, the analysis of the variables SUS 2, SUS 3, P3, and P7 indicates a perception of complexity in the interface. It is suggested to simplify the interface to improve the distribution of items, divide the blood pressure screen into specific chunks, and add search filters.

The comprehensive usability study, which has integrated mission-based assessments, usability-specific analyses, and measurements across the System Usability Scales (SUS) and User Experience (UEQ), yields essential conclusions in response to our predefined research questions:

User Capability and Task Fulfillment: The first prototype's evaluation yielded encouraging results regarding users' ability to navigate the application and complete assigned tasks. Overall, 100% success in the tasks of identifying and aggregating information, and 72% in the task of removing indicate an effective understanding and execution by users.

General Prototype Perception: Despite the challenges identified, users' overall perception of the prototype was positive. Scores above 3 on SUS and good to excellent ratings on UEQ reflect widespread acceptance of the prototype. This result suggests that, generally speaking, the app was well-received by users. However, the areas identified for improvement, especially in user information and interface intuitiveness, indicate the need for specific adjustments to achieve a more effective application.

Valuable Insights for Improvement: Detailed analysis of respondents' responses provided valuable insights, highlighting specific areas for improvement. Suggestions from participants, such as the ability to add measurements manually and the inclusion of a forum to share experiences, highlight the importance of tailoring the app to users' needs and preferences.

Importance of Coherent and Consistent Design: This study highlights the importance of coherent and consistent design, especially when addressing critical or complex tasks in the user interface. The delete task, where users faced difficulties, revealed that the current design of the delete items action may not be intuitive. Participants' recommendations emphasize the need for additional controls to manipulate blood pressure measurements. In addition, the perception of complexity in data presentation highlights the importance of simplifying interfaces to avoid confusion. Final recommendations include implementing intuitive controls and simplifying interfaces to improve the user experience.

This study highlights the importance of coherent and consistent design, especially when tackling critical or complex tasks in the user interface. Recommendations include implementing intuitive controls and simplifying interfaces to improve the user experience.

6. ACKNOWLEDGEMENTS

M. Nielsen is supported by a scholarship from the National Postgraduate Strengthening Program of the National Secretariat of Science, Technology, and Innovation (SENACYT in Spanish) of Panama. V. Villarreal and L. Muñoz are members of the National Research System (SNI in Spanish) of the SENACYT. This research is part of the larger project "ECOSISTEMA DIGITAL Y UBICUO DE SOLUCIONES BASADAS EN TECNOLOGÍA MÓVIL PARA FACILITAR LA GESTIÓN DE DATOS EN ENTORNOS PRIORITARIOS," which is partially financed by contract DDCCT No. 006-2023 received from the National Secretariat of Science, Technology, and Innovation (SENACYT) of Panama

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