Lecture Notes in Mechanical Engineering

Cristina Manchado del Val · Ramón Miralbes Buil · Guillermo Peris Fajarnés · María Moncho Santonja · Caterina Rizzi · Lionel Roucoules *Editors*

Advances on Mechanics, Design Engineering and Manufacturing V

Proceedings of the International Joint Conference on Mechanics, Design Engineering & Advanced Manufacturing, JCM 2024, June 12–14, 2024, Valencia, Spain

Springer

Editors
Cristina Manchado del Val
Departamento de Ingeniería Geográfica y Técnicas de Expresión Gráfica
Universidad de Cantabria
Santander, Cantabria, Spain

Ramón Miralbes Buil
Departamento de Ingeniería de Diseño y Fabricación
Universidad de Zaragoza
Zaragoza, Spain

Guillermo Peris Fajarnés
Departamento de Ingeniería Gráfica, Centro de Investigación en Tecnologías Gráficas
Universitat Politècnica de València
Valencia, Spain

María Moncho Santonja
Departamento de Ingeniería Gráfica, Centro de Investigación en Tecnologías Gráficas
Universitat Politècnica de València
Valencia, Spain

Caterina Rizzi
Department of Management, Information, and Production Engineering
University of Bergamo
Bergamo, Lombardy, Italy

Lionel Roucoules
Département de Conception, Industrialisation, Risque, Décision (CIRD)
Arts et Metiers Institute of Technology
Paris, France

ISSN 2195-4356 ISSN 2195-4364 (electronic)
Lecture Notes in Mechanical Engineering
ISBN 978-3-031-72828-0 ISBN 978-3-031-72829-7 (eBook)
https://doi.org/10.1007/978-3-031-72829-7

© The Editor(s) (if applicable) and The Author(s), under exclusive license to Springer Nature Switzerland AG 2025

This work is subject to copyright. All rights are solely and exclusively licensed by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.
The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.
The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

If disposing of this product, please recycle the paper.

44 A Comparative Analysis of Code-Based Versus Visual Programming Approaches for Extended Reality (XR) and BIM 543
Sara Martínez-González, Francisco-Javier Azcondo-San-Segundo, José-Andrés Díaz-Severiano, and Valentin Gomez-Jauregui

45 Safety Features for HumanTIX: An Augmented Reality Platform to Enhance Human–Robot Collaboration 557
Monica Sileo, Graziano Carriero, Carmela Brancato, Nicolas Calzone, Francesco Pierri, Fabrizio Caccavale, and Rocco Mozzillo

46 Design of Customized Face-Protective Masks for Sport-Related Injuries by Using Reverse Engineering and Computer-Aided Design Tools 573
Xabier Amezua, Gaizka Erkizia, Mikel Jauregi, Mikel Iturrate, Olatz Etxaniz, Xabier Garikano, and Eneko Solaberrieta

47 Digital Tools for Designers: Means for Wearable Prototyping Through Block Programming 581
Marta Siguín, Teresa Blanco, Federico Rossano, and Roberto Casas

48 Digitizing Operations for Enhanced Administrative Efficiency Through Service Design and Frugal Innovation 595
Natalia Carrera, Jesús Navarro, and Teresa Blanco

49 Visual Programming for Minimum Viable Product in a Health Design Project 607
Teresa Blanco, Natalia Carrera, Diego Cajal, Eduardo Gil, and Roberto Casas

50 Comparative Study Between Patient-Specific 3D Corneal Geometric Models Generated from Pentacam, Sirius, and Galilei Topographers 621
José González-Cabrero, Carmelo Gómez-Garcia, Lucas Díaz-Moreno, Jose S. Velázquez, Manuel Paredes, and Francisco Cavas

51 Digitalization of Mental Health Tracking Through a Mobile App to Monitor Anxiety and Depression: A Design Perspective 631
Eva Tausiet, Teresa Blanco, Diego Cajal, Álvaro Marco, Patricia Aznar, and Raquel Bailón

Chapter 49
Visual Programming for Minimum Viable Product in a Health Design Project

Teresa Blanco, Natalia Carrera, Diego Cajal, Eduardo Gil, and Roberto Casas

Abstract The presented work is part of a project aimed at designing and developing a digital health ecosystem focused on improving the monitoring and treatment of depression. This ecosystem integrates various physiological indicators with subjective mood and activity records to provide valuable insights for therapeutic interventions. After conducting a comparative analysis of existing software related to health digital ecosystems that integrate data from different sources, several limitations were identified and addressed in our design. This paper presents the first steps in the design of one of the key touchpoints of the overall service: the web interface for healthcare professionals. The design strategy prioritizes real-world testing of functionalities at an early stage through autonomous user testing, before undertaking user experience design. The need to develop fully functional early prototypes led to the use of Low-Code and Visual Programming Language techniques. These techniques minimize the need for textual coding and increase the accessibility of functional programming for teams without extensive programming expertise, as shown in the paper. From a technical standpoint, the Minimum Viable Product (MVP) facilitated data collection from multiple sources, including wearable devices, app-generated data, subjective mood and activity logs, and qualitative diary entries. Open tools from Google were used to collect and store subjective data, a third-party platform

T. Blanco (✉) · N. Carrera · D. Cajal · E. Gil · R. Casas
Aragon Institute of Engineering Research (I3A), University of Zaragoza, 50018 Zaragoza, Spain
e-mail: tblanco@unizar.es

T. Blanco
Departamento de Ingeniería de Diseño y Fabricación, University of Zaragoza, 50018 Zaragoza, Spain

D. Cajal · E. Gil
Centro de Investigación Biomédica en Red en Bioingeniería, Biomateriales y Nanomedicina (CIBER-BBN), 28029 Madrid, Spain

Instituto de Investigación Sanitaria Aragón (IISA), 50009 Zaragoza, Spain

R. Casas
Departamento de Ingeniería Electrónica y Comunicaciones, University of Zaragoza, 50018 Zaragoza, Spain

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2025

C. Manchado del Val et al. (eds.), *Advances on Mechanics, Design Engineering and Manufacturing V*, Lecture Notes in Mechanical Engineering,
https://doi.org/10.1007/978-3-031-72829-7_49

integrated with Google for objective data, and Looker Studio was integrated for visualization and comparison between subjective and objective data. From a collaboration and teamwork perspective, seamless integration of front-end and back-end functionalities was achieved without requiring traditional coding approaches, facilitating multidisciplinary collaboration between designers and developers. From a product perspective, iterative refinement based on co-design and user feedback gathered through evaluations involving healthcare professionals allowed for early validation of the concept's feasibility in a real-world setting and informed decision-making.

Keywords Functionalities assessment · Design-driven development · Design of technological ecosystems · Low code · Health digitization · Multidisciplinarity · Personalized medicine

49.1 Introduction

Approximately 7% of the adult population suffers from Major Depressive Disorder (MDD) in Europe each year. The World Health Organization (WHO) describes depression as a mental disorder characterized by a depressed state, lack of interest and satisfaction, feelings of guilt and low self-esteem, sleep and appetite disturbances, low energy, and concentration [1]. These disorders can become recurrent or chronic, significantly challenging patients' ability to fulfill their responsibilities, thereby limiting their quality of life, or even increasing individuals' cardiovascular morbidity and mortality [2]. Early identification and treatment of depression has been shown to be a cost-effective intervention, which would reduce the associated burden. Traditional diagnosis of depression is based almost exclusively on self-administered scales, questionnaires, or interviews. Diagnosis is challenging because symptoms are assessed retrospectively, thus can be biased by the patient's dysfunctional perception and ability to communicate psychological symptoms, especially in certain populations such as the elderly and children.

Beyond diagnosis, one of the main challenges within the realm of depression lies in effectively monitoring the progression of the disease. This is very important to detect and prevent relapses, as well as to measure treatment efficacy, readjust treatment, and ensure commitment and adherence to therapy [3]. Like many habits, change in a problematic situation usually occurs gradually, progressively, and sometimes imperceptibly; thus, professional follow-up is imperative to monitor that improvements are consistently maintained. However, ensuring adequate follow-up is not straightforward, as it requires more than just providing motivation, and it also involves striking a balance to avoid dependence on the therapist.

There are several products and services currently on the market that perform functions such as patient tracking or data integration between practices. Classic clinic management software includes products for appointments, storing clinic history, and issuing invoices [4]. The emergence of new technologies has led to the development of

technological ecosystems that offer solutions for measuring patient monitoring data through wearables and medical devices. The most relevant are included in Table 49.1.

For instance, Google Health [5, 14–16] leverages technology and data to improve medical care and public health. Employing artificial intelligence, machine learning, and medical informatics, it seeks to deliver innovative solutions, by interconnecting several tools, including:

- Wearable health trackers for physical activity and health (heart rate, blood oxygen saturation, skin temperature, and sleep, among others), offering personalized tracking and insights.
- Health and activity platform with personalized recommendations and support resources based on wellness data collected from apps and wearable devices.
- Clinically validated self-diagnostic questionnaire to assess mental health symptoms, which provides links to appropriate support resources. It is only available in the United States of America.
- Data-sharing platform for data sharing between health, fitness, and wellness apps, prioritizing user privacy.
- Clinical software that focuses for unifying healthcare data for clinicians, healthcare professionals, integrating medical records, test results, and other relevant information of the patient.

Nonetheless, despite the proliferation of digital ecosystems, several limitations remain unaddressed:

- Fragmented data integration: Existing applications often collect diverse data (physical activity, sleep, eating patterns), but lack the ability to integrate these

Table 49.1 Software for measuring patient monitoring data with wearables and medical devices

Products	Devices	Patient platform	Online consultation	Chat	Reports
Google Health [5]	Wearables	Yes	No	No	Yes
iOS Health [6]	Wearables	Yes	No	No	Yes
Samsung Health [7]	Wearables	Yes	No	No	Yes
Cerner Health [8]	Wearables	Yes	No	No	Yes
Veradigm FollowMyHealth [9]	Wearables	Yes	Yes	No	Yes
Validic [10]	Wearables and other medical devices	Yes	No	No	Yes
Healow Hub [10]	Wearables	Yes	Yes	Yes	Yes
AirStrip ONE [11]	Wearables	Yes	Yes	No	Yes
QardioDirect [12]	Medical devices	Yes	Yes	No	Yes
Welldoc [13]	Wearables	Yes	No	No	Yes

with subjective measures like mood and daily activities. This hinders a holistic view for mental health treatment.
- Limited Individualization: Current solutions may offer insufficient customization to address the individual needs of each patient and therapist. Highly personalized interventions are crucial for major depression, as symptoms presentations and treatment responses can vary considerably among individuals.
- Restricted patient-professional interaction: Many health apps prioritize self-monitoring and self-help, neglecting to facilitate communication and collaboration between patients and healthcare professionals.
- Compartmentalized approach: Many tools focus on isolated aspects of mental health or physical well-being, failing to address the interconnectedness of physiological and psychological factors in a comprehensive manner.

49.1.1 Objectives

This paper presents the initial design stages of a digital mental health ecosystem for major depressive disorder (MDD). We hypothesize that integrating objective physiological data with subjective mood and activity tracking between consultations will yield valuable insights to inform therapeutic, psychological, or psychiatric interventions, potentially allowing to expedite interventions, enhancing treatment value, and strengthening patient-professional connection.

The development of this ecosystem required different service design processes and the development and integration of innovative technologies, including several interfaces for several user profiles. This paper specifically focuses on the design and development of a Minimum Viable Product (MVP) for the web interface of the ecosystem, targeted towards mental health professionals.

Due to the project characteristics, a design approach was defined to prioritize rapid user feedback and codesign through iterative design cycles, aligning with agile methodologies. This approach emphasized functional evaluation over formal considerations during initial development, enabling early user evaluations with a fully functional and autonomous field prototype. Also, in line with the emphasis on technological literacy for designers [17], this proposal seeks to explore the potential of no-code tools within design-driven development (DDD) processes. Notably, the MVP presented was designed and developed entirely by designers.

49.2 Materials and Methods

49.2.1 Low-Code and Visual Programming as Design Tools

The primary goal of a Minimum Viable Product (MVP) lies in presenting the fundamental functionalities for a commercial product. Within the design process, prototyping and evaluation play a crucial role in substantiating or discarding hypotheses, ultimately leading to the creation of a refined product that aligns with user and contextual requirements. For designers lacking development or prototyping skills, particularly those involving complex interactions or data integration, this phase can be especially daunting.

While User Interface (UI) tools like Figma and Adobe XD excel at creating high-fidelity prototypes for websites and mobile apps, their focus lies primarily on evaluating user interaction (front-end functionality and formal dimension). These tools often fall short when it comes to assessing the actual functionality and user experience of the complete system (back-end functionality).

Low-code and visual programming languages are emerging tools that empower designers to create basic prototypes. These techniques democratize software development, enabling participation beyond professional programmers. As described in literature, main low-code benefits are (i) improved collaboration between designers and developers thanks to visual interfaces that can be understood by both; (ii) faster development thanks to drag-and-drop interfaces and pre-built components; (iii) reduced costs by minimizing the need for extensive coding, specialized developers and software associated costs; (iv) increased agility that allows to adapt products to today's fast-paced environment where needs and technologies evolve rapidly; and (v) simplified maintenance of application updates and security patches [18–23].

This, combined with in-depth user context research, empowers designers to adopt a more user-centered design approach. Early and iterative user involvement, enabled by low-code tools, facilitates continuous feedback and refinement of functionalities, ultimately increasing the probability of meeting user requirements [18]. Additionally, low-code programming can be constituted as a cost-effective solution, which is a good asset to Frugal Innovation [24, 25].

49.2.2 MVP Requirements

The core functionalities to be implemented for the MVP were the following: (i) Patient records quantitative objective data from biosignal analysis, (ii) Patient records quantitative subjective data about their mood and activities, (iii) Patient records qualitative data as diary entries, (iv) Professional visualizes all Patient data in an interactive Dashboard (v) Professional filters data, and (vi) Professional generates printable reports (Table 49.2).

Table 49.2 Core functionalities related to users

Patient end	Professional end
Record biosignals	Visualize all patient data
Record mood and daily activities	Filter by patient and timeframe
Record diary entries	Generate printable reports

49.2.3 Architecture

The MVP combines three primary data sources: application data, survey responses, and the professional patient list. Google Sheets, Google Forms, and Looker Studio cloud services (Fig. 49.1) were used to prototype the solution:

1. Patient records biosignal data using a dedicated mobile app. This app automatically uploads the results in CSV format to the cloud for secure storage and analysis within the web application.
2. Patient records their mood and daily activities by completing a short, daily Google Form survey, based on a Likert-scale.
3. Patient records diary entries on an open-ended question embedded within the same Google Form, allowing the patient to articulate personal thoughts and experiences of the day in a more narrative format.
4. Mental Health Professionals visualize and interact with the data recorded by the patient in a dashboard designed with Looker Studio, where they can filter by patient and timeframe, and generate reports for future consultations.

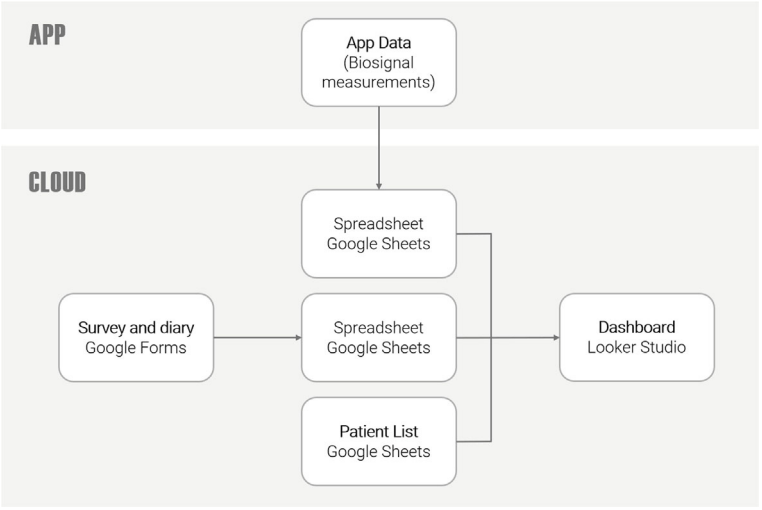


Fig. 49.1 Software architecture diagram

This data integration technique can be described as ETL (Extract, Transform, Load), since data is extracted from multiple sources, transformed into an interpretable form, and then loaded into a centralized system that also allows its visualization.

49.3 Results

49.3.1 Development of the Platform

The final dashboard utilized a segmented architecture with three distinct, interactive screens, including embedded buttons to enhance user interaction and real data accessibility. As mentioned, functionality took precedence over visual design.

The "Main Panel" (Fig. 49.2) act as the central hub, providing a high-level view of patient data across various timeframes. This design facilitated comparative analyses and patient progress tracking over time, with the following sections:

1. Patient and Date Selection: Professionals can easily select a patient for consultation by entering their identification number (ID) and choosing the desired time period using the filter box.
2. Navigation and reports generation buttons.

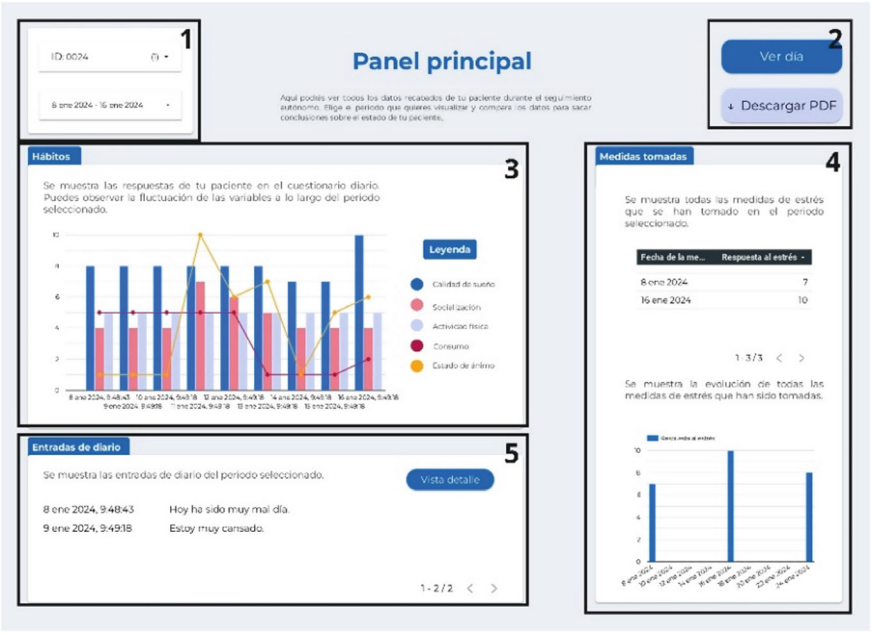


Fig. 49.2 Sections of the main panel

3. Habits Tracking: Visual representation of the patient's responses from the daily form.
4. Measurements Analysis: A table displays measurements for the selected period with associated notes. Below, a graph provides a visual representation of all measurements over time, enabling professionals to track patient progress.
5. Diary Entries: This section chronologically lists the patient's diary entries with the "Detailed view" button leading to the dedicated Diary Panel (*see below*).

The "Day Panel" (Fig. 49.3) focuses on in-depth exploration of data for specific days. This screen allows mental health professionals to examine daily metrics in detail, enabling a closer look at a patient's status and activities on a particular day. This detailed view is crucial for identifying potential relationships between different data points. The panel includes following sections:

1. Patient and Date Selection: Professionals can easily change the patient or time period for consultation, using the filter box.
2. Navigation and reports generation buttons.
3. Day Habits Visualization: Visual representation of the patient's responses from the form completed on the selected day.
4. Detailed Measurement Breakdown: A graph presents a breakdown of the measurements taken on that day, including more detailed data and the different tests performed. Additionally, a table displays all measurements taken over time to visualize the patient evolution.



Fig. 49.3 Sections of day panel

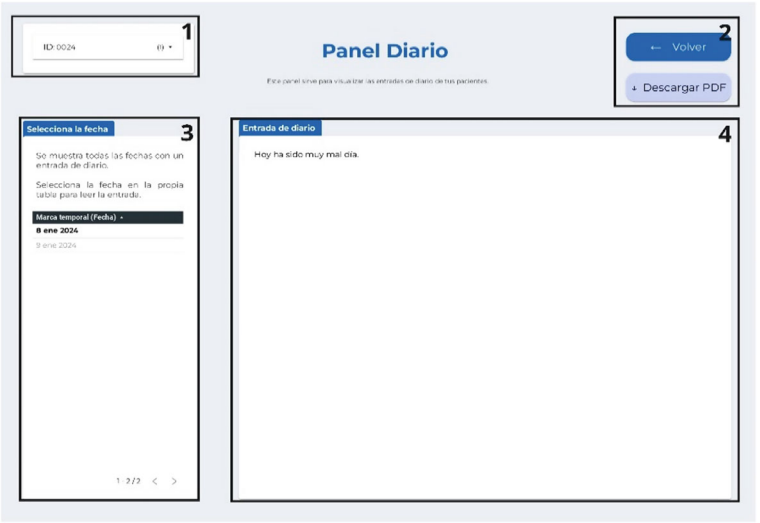


Fig. 49.4 Sections of diary panel

5. Day-Specific Diary Entry: If available, the diary entry of the selected day is displayed. A "Detailed view" button leads to the Diary Panel (*see below*).

Finally, the "Diary Panel" (Fig. 49.4) prioritizes in-depth presentation of patient diary entries. This section complements the quantitative data presented in the other panels by offering a qualitative perspective on patient experiences. By integrating diary narratives, the dashboard fosters a holistic understanding of the patient's condition, encompassing both objective data and personal reflections. The panel includes the following sections:

1. Patient Selection: Professionals can easily select a patient's ID using the filter box.
2. Navigation and reports generation buttons.
3. Diary Entry Calendar: A table displays all dates with available diary entries that the professional can select.
4. Selected Diary Entry: This section displays the patient's diary entry for the selected day.

49.3.2 Evaluation

Two psychologists were involved in several rapid iterations of codesign and evaluation of the MVP specific content and interface. The process included activities such as workshops, focus groups, and informal meetings aimed at two goals: the first to agree on and define the functionalities and minimum interface requirements, and

the latter to present and discuss the results of the field use and functionality of the prototypes. In this sense, they acted as co-designers and evaluators.

In addition, they collaborated with the team to develop and evaluate qualitative patient survey questions that could be adapted to individual needs. While this was not the primary focus of the project, the qualitative patient survey was also pretested in a healthcare setting as a preliminary step to user interface design. This pretest helped to obtain two good insights to undertake the design: to what extent the importance of different daily aspects related to subjective data would vary depending on the patient's profile, highlighting the need of a high personalized user experience, and to what extent the type of input data (strings, numbers, etc.) would influence how the data would have to be processed and visualized (Fig. 49.5).

The project team itself also evaluated the process. At the team level, the MVP was considered a very useful tool for early field testing of functionalities, for enhancing communication among team members from development and design teams, as well as for laying the groundwork for a more robust and user-centered future design. From the perspective of the designer who implemented the low-code MVP, the process was a valuable learning experience that highlighted the benefits of using a low-code approach for rapid prototyping and testing.

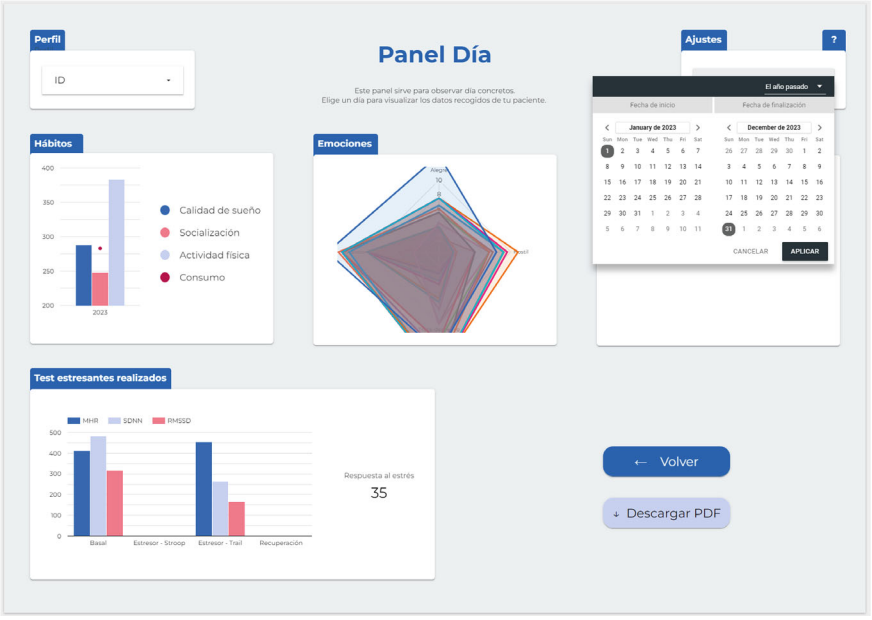


Fig. 49.5 MVP evolution: an iteration result of qualitative pretests

49.4 Conclusions

In the design process, prototyping and evaluation are fundamental for achieving a successful outcome. This work explored the potential of design-driven development empowered by no-code tools for creating early Minimum Viable Products (MVP) that enable early and rapid evaluations of product functionality.

The framework is the development of a research project to create a digital ecosystem aimed at improving mental health treatment and monitoring. The development of this ecosystem required a service design process with different touchpoints using innovative technologies in a complex environment. This paper presents the prototype of one of the service touchpoints: the web for use by healthcare professionals, where physiological data of the patient is collected, along with subjective records of the patient's mood and daily activities. In addition, conclusions and challenges are presented derived from the comparative study of current healthcare technology ecosystems.

In the early stages of the design, a strategic decision was made to prioritize the evaluation of functionality over user experience in the case of the web. To this end, low-code tools were used in the design team to generate an MVP that could be used in the field with real users and make rapid iterations. This can be very useful in environments where intervention needs to be especially careful, as in health realms.

It is true that in these cases the selection of evaluator users is very important. The user must be aware that they are using a prototype that is visually very different from the final one. Therefore, in this work the prototype was co-designed and evaluated with healthcare professionals and the process was evaluated by the project's technical team, as part of an action-research process.

The MVP provided a valuable interface and a solid foundation for further evaluation, improvement, and validation of hypotheses regarding the health data ecosystem's benefits in mental health treatment. The process was also highly valued by the technical team. Moreover, this work reinforces the importance of designers' technological literacy, and the key role they could play in the first steps of developing products.

Now further research is being developed to refine the platform and assess its effectiveness in clinical settings.

Acknowledgements This work was supported by 'Ministerio de Ciencia, Innovación y Universidades' and 'European Regional Development Fund (FEDER)' co-funded with ERDF funds under projects TED2021-131106B-I00 and project PDC2021-120775-I00, and by Gobierno de Aragón (References Group BSICoS T39-23R, Group Howlab T27_17R, and project PROY_T38_24).

References

1. World Health Organization (2021) Disorders management, depression—Disponible en: https://www.who.int/health-topics/depression#tab=tab_1
2. Lopez D, Mathers CD, Ezzati M, Jamison DT, Murray CJL (2006) Global and regional burden of disease and risk factors, 2001: systematic analysis of population health data. Lancet Lond Engl 367(9524):1747–1757. https://doi.org/10.1016/S0140-6736(06)68770-9
3. Trevino K, McClintock SM, McDonald Fischer N, Vora A, Husain MM (2014) Defining treatment-resistant depression: a comprehensive review of the literature. Ann Clin Psychiatry Off J Am Acad Clin Psychiatr 26(3):222–232
4. Best Clinic Management Software (2024) https://themedicalpractice.com/tools/best-clinic-management-software/
5. Qué es Google Health—Google Health (s.f.) Recuperado 2 de noviembre de 2023, de https://health.google/intl/es-419/
6. Apple (s.f.) IOS—Salud. Apple (España). https://www.apple.com/es/ios/health/
7. Samsung Health | Apps y Servicios | Samsung España. (2023, 2 Octubre). Samsung es. https://www.samsung.com/es/apps/samsung-health/
8. CernerHealth (s.f.) Personal health record. CernerHealth https://cernerhealth.com/
9. Patient Engagement Platorm (s.f.) Veradigm. https://veradigm.com/followmyhealth-patient-engagement-platform/
10. The Healow Apps and Trackers: Better Care and Lifestyle Management (s.f.) eClinicalWorks. https://www.eclinicalworks.com/products-services/patient-engagement/healow-apps-trackers/
11. Remote Patient Waveforms (s.f.) AirStrip. https://www.airstrip.com/usecases/remote-patient-monitoring
12. Fully Integrated Remote Patient Monitoring (RPM) and Telehealth Solution (s.f.) Qardio. https://www.qardio.com/qardiomd-qardiodirect/
13. The Platform (s.f.) Welldoc. https://www.welldoc.com/solutions/chronic-care-management-platform/
14. Google Health (s.f.) Mejorar el acceso a la información de salud. https://health.google/intl/es-419/consumers/
15. Google Fit (s.f.) Google Fit. https://www.google.com/intl/es_es/fit/
16. Google Health (s.f) Herramientas de autoevaluación de salud. https://health.google/intl/es-419/consumers/self-assessments/
17. Blanco T, Casas R, Manchado-Pérez E, Asensio Á, López-Pérez JM (2017) From the islands of knowledge to a shared understanding: interdisciplinarity and technology literacy for innovation in smart electronic product design. Int J Technol Des Educ 27:329–362
18. Care Studio: Software clínico de Google Health (s.f.) https://health.google/intl/es-419/caregivers/care-studio/
19. Kuhail MA, Farooq S, Hammad R, Bahja M (2021) Characterizing visual programming approaches for end-user developers: a systematic review. IEEE Access 9:14181–14202. https://doi.org/10.1109/ACCESS.2021.3051043
20. Hirzel M (2023) Low-code programming models. Commun ACM 66(10):76–85. https://doi.org/10.1145/3587691
21. Luo Y, Liang P, Wang C, Shahin M, Zhan J (2021, October) Characteristics and challenges of low-code development: the practitioners' perspective. In: Proceedings of the 15th ACM/IEEE international symposium on empirical software engineering and measurement (ESEM), pp 1–11
22. Galhardo P, Silva ARD (2022) Combining rigorous requirements specifications with low-code platforms to rapid development software business applications. Appl Sci 12(19):9556
23. Rokis K, Kirikova M (2023) Exploring low-code development: a comprehensive literature review. Complex Syst Inform Model Q 36:68–86
24. Prinz N, Rentrop C, Huber M (2021, August) Low-code development platforms—a literature review. In: AMCIS

25. Weyrauch T, Herstatt C (2016) What is frugal innovation? Three defining criteria. J Frugal Innov 2(1):1. https://doi.org/10.1186/s40669-016-0005-y