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Virtual Event, November 30 – December 2, 2022
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António Cunha · Nuno M. Garcia ·
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Editors

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Preface

We are delighted to introduce the proceedings of the second edition of the European Alliance for Innovation (EAI) International Conference on Wireless Mobile Communication and Healthcare (MobiHealth 2022). This conference, which was held online November 30 – December 2, 2022, brought together researchers, developers and practitioners worldwide who are leveraging and developing wireless communications, mobile computing and the healthcare application field.

The technical program of MobiHealth 2022 consisted of 28 full papers with oral presentation sessions at the main conference track and 1 Demo paper, and 1 Poster paper. Aside from the high-quality technical paper presentations, the technical program also featured two keynote speeches. The two keynote speeches were Emilio Luque from Universitat Autònoma de Barcelona, Spain and Hélder Oliveira from Institute for Systems and Computer Engineering, Technology and Science, Portugal.

Coordination with the steering chair, Imrich Chlamtac, was essential for the conference's success. We sincerely appreciate his support and guidance. It was also a great pleasure to work with such an excellent organizing committee team for their hard work in organizing and supporting the conference.

In particular, the Technical Program Committee, led by our TPC Co-Chairs, Anselmo Paiva, María Vanessa Villasana, Susanna Spinsante, Francesco Renna, and Paulo Salgado completed the peer-review process of technical papers and made a high-quality technical program. We are also grateful to all other organizing committee members for their support and all the authors who submitted their papers to the MobiHealth 2022 conference and workshops.

We strongly believe that the MobiHealth conference provides a good forum for all researchers, developers and practitioners to discuss all science and technology aspects that are relevant to the fields of wireless communications, mobile computing and healthcare applications. We also expect that the future MobiHealth conferences will be as successful and stimulating as indicated by the contributions presented in this volume.

May 2023

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Nuno M. Garcia
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Contents

Integrated Design Method and Usability Outcomes of a Mobile Application for Psychological Well-Being During Pregnancy

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Abstract. The last decade has seen a radical change in the use of technologies. Mobile computing is the main technology of this decade. More and more often we are dealing with portable tools, and portable devices; medical instrumentation such as portable and connected electrocardiographs, pulse-oximeters... is widespread, especially due to COVID-19 pandemic situation in the last two years. However, mental healthcare is a critical domain which however is often unexplored, especially in terms of human factors and ergonomics. Few studies analyze the ergonomics factor and usability of mobile applications in the mental health field. This paper reports a study on the creation of a digital system with a tailor-made application for monitoring the mental health of pregnant women. The paper proposes a methodological analysis carried out with future moms and different stakeholders, to identify the most suitable solution for the psycho-physical needs of mothers and at the same time those of the various actors during pregnancy (dads, psychologists, psychiatrists). The work shows the ergonomic effectiveness of an app for the collection of the Edinburgh Scale (EPDS), designed with the users, both from the point of view of usability and the data collected. The result shows good adherence in terms of the App's active users and EPDS data gathering, a decrease in the evaluation of the EPDS scale, and therefore a reduced severity of depressive symptoms using a combination of app and home interventions by psychologists.

Keywords: Mobile application design and ergonomics · User-centered design · Mobile application for mental health · Usability

1 Introduction

Mental health has become a global issue for public health service [1] and especially during and after COVID-19 pandemic [2]. Perinatal Depression (PND) affects up to 15% of women during pregnancy and 10% within 1 year after giving birth [3,4]. These percentages are higher in women living in poor socio-economic

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conditions or belonging to minority ethnic groups [5], in first-time adolescents [6], and in the female population of non-Western countries [7].

Local studies underline the amplitude of perinatal mental disorders despite the lack of national population-based studies. In fact, it must be taken into account that suicide and homicide have been identified as one of the main causes of maternal and newborn death within the first year after birth. Since 2017, the Italian public primary care service offers free psychological interventions dedicated to pregnancy and puerperium assistance, but yet half of those who were known to be prone to depression and suicide during the postpartum period had not been referred to this Family Care Centers.

Italy has about 60.3 million inhabitants and more than 430,000 live births per year [8]. If we take into consideration the Lombardy region about 80,000 births occur in a year: it is realistic to think that about 9,000 women suffer from perinatal depression and that only a minority of these are diagnosed today and receive treatment (about 9%).

If treated, the prognosis of perinatal depression results basically favorable; if left untreated, however, it has a significant risk of becoming chronic. About one-third of women are still suffering from depression one year after giving birth and the risk of subsequent depressive recurrences or independent from new pregnancies is high and equal to 40% [3,4]. Currently, the attention of health services is directed almost exclusively to the physical health of the woman, while the interest in her mental health is less systematic and structured. Today, many pregnant women and new mothers do not receive a correct diagnosis of the perinatal mental disorder and just as many, recognized as clinically affected by depression, do not benefit from adequate therapeutic care. Furthermore, their family members, including the child, are not routinely offered appropriate help by the local health and social health services responsible for safeguarding maternal, child and family health. These problems are mainly related to a lack of information. The information, under the dual profile of information to the woman on perinatal psychic disorders and collection of information on the mental health of pregnant and puerperium women, represents a critical element to intercept situations with emotional disorders in the perinatal period. On the one hand, women often do not have easy access to scientific information, expressed in a popular form, on perinatal emotional disorders; on the other hand, active and population screening activities, i.e. the systematic collection of information on women's mental health status through assessment tools, the Edinburgh Postnatal Depression Scale (EPDS) [9] and Whooley's question [10] are not structured in many areas at both regional and national level. Even today, even in the case of an active offer, screening is entrusted to paper tools and is carried out "forcibly" on the occasion of either the birth or the pediatric check of the newborn, not optimal moments for this activity both for the woman and for the operators.

The Thinking Healthy Programme (THP) [11], which is endorsed by WHO (World Health Organization), is an evidence-based intervention for perinatal depression. With the aim to ease the workload of healthcare operators, and to keep the rate of use by mothers-to-be/mothers high, this work shows the ergonomic effectiveness of an application for the collection of Edinburgh Perinatal Depression Scale, designed with the users for the users.

This work comes from the goals to encourage the screening activity, simplify it through the use of technological tools, and improve the information of the woman through the possibility of connecting to other informative tools.

2 Perinatal Depression - Baby Blues

Pregnancy and becoming a mother can be described as a wonderful experience in a woman's life. But the sudden changes in physiology and endocrine status, in addition to other social circumstances and predispositions, can also produce undesirable or even pathological effects in all human domains: physical, physiological, and psychological. Among psychological disorders, perinatal depression is one of the most important for incidence and prevalence.

Perinatal depression (PD) is a mood disorder that can affect women during pregnancy and puerperium [12]. PD is considered a medical disease and can affect any mother-regardless of age, race, income, culture, or education.

Mothers with perinatal depression experience feelings of extreme sadness, anxiety, and fatigue that may make it difficult for them to carry out daily tasks, including caring for themselves or others. The word "perinatal" refers to the time before and after the birth of a child. Perinatal depression includes depression that begins during pregnancy (called prenatal depression) and depression that begins after the baby is born (called postpartum depression).

Many women have baby blues in the days after childbirth. It is characterized by having mood swings or feeling sad, anxious, or overwhelmed, having crying spells, and accompanied by a loss of appetite or sleeping troubles. This situation rapidly evolves and baby blues disappear in the first 2 weeks after having a baby. So, the two conditions must not be confused.

There are several screening tools that have been developed to diagnose PD. Those specific to detect maternal depression in the peripartum or postpartum period include the Edinburgh Postpartum Depression Scale (EPDS) [9], the Postpartum Depression Screening Scale (PDSS), and the Pregnancy Risk Questionnaire (PRQ). Another very short test is represented by the Whooley Questions for depression screening, a 2 items questionnaire that also demonstrated its reliability [10]. Despite the severe consequences that PD has on both the mother and the child, due to tests still in paper format and with only occasional meetings with nurses and caregivers, up to 50% of these cases are undiagnosed.

The situation has only worsened in this specific moment of COVID-19 pandemic. The worsening occurs on two fronts: the lockdown measures emphasized the isolation from family and friends of some women and mothers, while security measures are anticipated to decrease the opportunities to meet operators, reducing to the strictly essential and therefore decreasing access to psychological or pharmacological diagnosis and treatment [13]. A Canadian study of the Program for Pregnancy and Postpartum Health, University of Alberta, recruited 900 women who were pregnant or within the first year after delivery to participate in an online survey. Among the questions, respondents were asked to self-report levels of depression/depressive symptoms, anxiety, and physical activity. The results showed 40.7% of respondents had survey scores indicative of depression, compared with 15% pre-pandemic, while moderate to high anxiety was identified in 72% of women versus 29% pre-pandemic [13]. An Italian cross-sectional study of 100 pregnant women showed that more than half of the respondents rated the psychological impact of the COVID-19 outbreak as severe, and about two-thirds reported higher than-normal anxiety. It's therefore important to formulate psychological interventions to improve mental health and psychological resilience during the COVID-19 pandemic [14].

For these reasons, there is a huge need for effective screening administration methods to ensure that all women with PD are identified. mHealth (Mobile Health) represents a possible exploitable solution [15]. It is defined as medical or public health practice supported by mobile devices [16], encompasses a variety of contexts: use of mobile phones to improve point of service data collection, care delivery, patient communication, use of alternative wireless devices for real-time medication monitoring, and adherence support [17].

mHealth could be an interesting solution to provide punctual and continuous monitoring to mothers and future mothers, as it is a rapid and remote "touch-point" with healthcare professionals to communicate feelings and moods.

Recent studies indeed suggest that the potential for mHealth tools to improve access to stepped mental health care for women with either perinatal depression or anxiety is now beginning to be realized [18].

This framework led to the idea to design and develop two digital tools within a public health service, with the aim of promptly intercepting cases of PD and offering a first treatment intervention.

3 The Bluebelly System

This project, called "Bluebelly", is developed with the aim of combining active psychological treatment and addressing continuity of care during the perinatal period to realize the potential of mHealth. An increasing number of Apps and websites for pregnant women and mothers are also now used as a source of information, despite research showing that information and how it is reported is often incomplete and inaccurate. A valid source of information should be provided by healthcare professionals to women, to avoid disinformation and unwarranted fears. Therefore, the project includes three different parts:

- *the website* (www.pensarepositivo.org/), where all the most important information - approved by the Istituto Superiore di Sanità Italiano (ISS) - are collected: the perinatal period and its related facts, problems, advice; information about the app and its use; material about the project, to reach easily help if needed and how to find it not far from home.
- *the Bluebelly mobile app*, downloadable from Apple store and Google Play store for the most popular smartphones' operative systems; the app was mainly created for the administration of the EPDS Scale, but also to ease

the management and the organization of the EPDS paper questionnaires. Moreover, the app eases finding information, help, and to follow the pregnancy. The app is designed to be used by as many people as possible, so it can be enjoyed in Italian and English.
- *the Bluebelly web-app*, accessible only to medical operators, allows to check the results of collected EPDS and automatically generates a warning in case of values outside the norms. Based on stringent GDPR regulations, the web app obscures most of the data so that privacy is always guaranteed. In case there is a need to intervene, the medical staff can request the telephone number with a few clicks in order to contact the mother.

In order to develop an ergonomic environment for searching information, EPDS gathering, and visualization, the User-Centered Design (UCD) approach has been implemented. User-Centered Design (UCD) is the commonly used approach to develop products and solutions by involving the human perspective (the users) in all the steps of the process [19]. Users (and stakeholders) have been involved since the first steps of project ideation; this allows the creation of a system that is fully tailor-made for users' needs. Research and design sessions for the website, web app, and mobile app were conducted by the TEDH group, from the Design Department of Politecnico di Milano, supported by psychiatrist Dr. A. Lora and psychologist Dr. S. Ciervo from ASST Lecco. The project has been divided into five main steps:

- Project Research: to identify requirements and concepts, and develop a first mockup of the website and apps.
- Focus groups with stakeholders: to test the system and find limits, difficulties, and suggestions from the direct users.
- System development: all three parts of the system were developed.
- Quantitative analysis: by means of digital tools, the developed system is tested in order to verify accessibility and usability.
- User test: the system is used to collect data from selected and limited users in order to test everything in an environment similar to the final one.

3.1 Project Research

The project research phase starts with the study of possible stakeholders. This allows clarifying which are the main users and which are the secondary or indirect ones. Main users correspond to people that use directly the system; these can be divided into two groups:

- Pregnant women and new mothers: they are the users of the mobile app and the website. Mothers would like to access the website for gathering homogeneous and certified information regarding pregnancy and the puerperium. They use the mobile application, as suggested by physicians, in order to insert EPDS ad Whooley scale based on the timing suggested by health professionals. The mobile application is also a tool that allows the women to keep in contact with their pregnancy, check the growth of the baby, and access a session where they can ask for help at the nearest center.

– Healthcare professionals: they are the users of the web app. They would like to access inserted EPDS in order to check warnings and the status of every woman. They need to access also private data such as the telephone number in order to contact the woman in case of EPDS values are out of the norm.

Secondary users are instead people that come into contact with the system, but without using it directly; an example is a "new dad" searching for information about feeding time who accesses the website. The system needs to be developed also with secondary users in mind, in order to optimize the experience. In fact, optimizing the experience avoids frustration, in a difficult period such as the one of the puerperium.

The definition of main and secondary users allows for defining the features of the system from different points of view.

3.2 Mockup and Prototype

Designing an app means bringing an idea to reality. There are four main steps in the development phase before starting coding:

1. Sketch: a low-fidelity freehand drawing of how the app should look like.
2. Wireframe: the drawing of the overall structure of the app. This allows the understanding of all the functionality; e.g. what happens when a button has been clicked.
3. Mockup: a medium-fidelity visual representation of how the app will look. It gives the user an impression of the final product.
4. Prototype: a high-fidelity representation of the UI and functionality. It focuses on interactions and shows also how the app will work.

As described above, the mockup is a detailed outline of the appearance of a mobile app. The difference between an app mockup and a wireframe is that the first one is more detailed and contains an almost defined design system with colors, layout, images, and typos... There are many advantages to creating an app design mockup. The first one is that it gives you an opportunity to make revisions to the final appearance app without spending time coding. Another benefit of creating a mockup is that it allows you to explain precisely what you want from stakeholders. This is essential to rally your team in the early stages of the app development process. A mockup is the best way to give everyone a clear vision of what the final app will look like and how it will function.

By means of all these steps, designers can understand the usability of the app and validate it by means of Heuristics [20]. In the project, different mockups have been created via FIGMA software. We decided to build different mockups in order to test different Design Systems, layouts, and also features with all the stakeholders. During the project, two mobile app mockups and one for the website have been created.

These mockups have been used in the focus group in order to gather information regarding usability, but also aesthetics, and interaction Fig. 1 shows the two main screens in the app: the dashboard and the question screen. The mockup implements also two different ways for login: a standard layout and a conversational layout which is a simulated chat to interact with the users. Focus Groups and user tests have been run in order to understand also the capability of conversational layout and clarify if they generate a more comfortable feeling for the users.

3.3 Focus Groups

Three different focus groups were organized to test the first prototype of the website and the app. Most of the stakeholders (expectant mothers, women who had recently given birth, and healthcare workers) were involved in the focus groups, in order to extract opinions and feelings from every possible future user.

We collected information from a total of 19 expectant mothers and women who had recently given birth; 17 healthcare workers (midwives, psychologists, and psychiatrists). In every focus group, a team of moderators composed of 1 engineer, 1 designer, and 1 psychologist was present. All the participants filled out a survey to investigate the relation they have with technologies; this allowed us to verify the level of digital literacy, in order to better understand the suggestions and errors reported during the focus group.

The result of the survey shows that the group participants are used to smartphones, mainly because most of the group use social networks and app daily (84%). There isn't a significant difference in this data between the population of healthcare workers and the mothers.

Pregnant women are users that are more familiar with apps (75%), and they are almost entirely in an age between 26 and 35 years old.

The opinions regarding the website and app helped define the best structure and form of the content. Other received suggestions are about the website on the clarity of the text, the structure of the content, how to make it more readable, and what information could be the most wanted. For the app, by means of FIGMA mockup, login and EPDS administration have been tested.

3.4 User Tests

All the advice acquired during focus groups and questionnaires has been used to redefine information, components, interactions, and UI inside the website and the mobile application. This allows the creation of a new mockup to test internally mainly with psychologists and designers. The new mockups have then been used for creating prototypes with most of the interactions, making it possible to test them with real users. The tests have been accomplished in two different steps:

- on real users via direct observation (ghosting); the designer's team observes the user's behavior while using the website and the app and tries to get information from the latter's expressions and speeches. At the end of the test, an interview is also made.

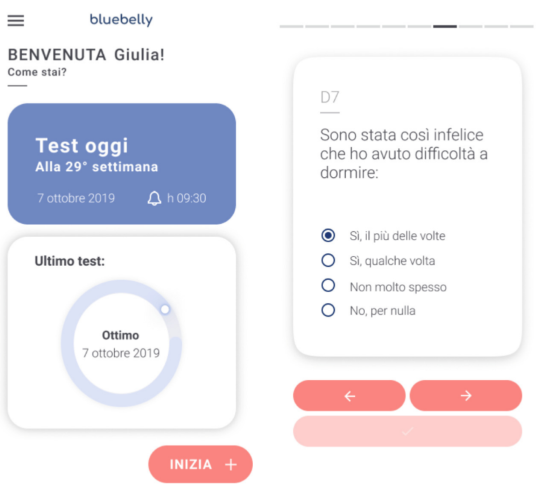

Fig. 1. Example of the main screen and question screen developed for the mockup

– with software tools. Two different software have been used: maze.co [21] allows the remote testing of prototypes and rapidly collects user insights across teams and creates better user experiences; visualeye.design [22] and VAS 3m [23], two software for visual attention detection which simulate eye-tracking studies by means of machine learning algorithm with 93% accuracy.

Two main task have been analyzed by maze.co:

– first-time sign-in;
– EPDS administration.

The first task has been analyzed in order to understand which solution between test sign-in and conversational sign-in fits better for this particular app. EPDS administration has been tested to measure the average time taken to fill the EPDS questionnaire and the two Whooley's questions. This average time depends on the question's text length but also on the interaction for the answer selection. Maze.co allows to automatically collect information regarding the interaction with app screens (number of clicks, the position of the clicks, miss-clicks, correctness of the path, time for the screen...), but gives also the possibility to implement ad-hoc questions for gathering other data. For both tasks, we add two ten-level Likert scale questions:

1. First-time sign-in task:
   – Taking into account that the required data are the bare minimum, how easy do you think creating an account is?
   – Do you think that the conversational mode can make it easier to interact with the app, especially during first use?

2. EPDS administration task:
   – Taking into account that the text and the questions shown are standard and cannot be changed, how easy do you think it is to insert the test?
   – How long do you feel about the test administration?

These questions give the possibility to clarify some doubts that arose mainly during the implementation of the mobile application.

VAS software like 3M VAS and VisualEye allows to speed up the test times on visual attention that usually involves the use of an eye tracker, and therefore requires a lot of time and subjects. These software have the capability to simulate an eye tracker thanks to thousand of data used for training the algorithm. The software are able to compute visual attention maps (a color map that indicates where the user focuses most - e.g. Fig. 2), and a clarity index that gets information from the app screen and computes how much it is clear to understand, or if there are too many information, colors, text... Figure 5 shows an example of clarity analysis done on two different versions of the dashboard screen.

Fig. 2. An example of a visual attention map generated on an app screen.

4 Results

In this chapter, the results of the analysis, both with users and software, are reported. Focus groups and questionnaires gave the possibility to collect different information about the website and the mobile app. The need for implementing the web app for generating alerts and displaying data came after the focus groups; however, being an app for healthcare professionals only, it was developed with them to their specifications and for this reason, it was not analyzed in the focus groups. Focus group participants pointed out that the website has excellent and useful content, but is too long and dispersive. The mothers stressed the importance of a simple structure to consult, and the need to insert a search option. Furthermore, it was requested not only the inclusion information related to mental health problems but also information regarding pregnancy in general (breastfeeding, visits ...).

The website is the core of the project, being the collection of the most relevant information and notions; for this reason, thanks to the advice of the users, we restructured the website. As one enters the website, a pop-up about COVID-19 appears. There is a dedicated page about maternity, and perinatal periods related to the pandemic situation. All the organized sections refer to the website of Istituto Superiore Sanità [24]. The menu is divided into three main sections: Becoming a parent; Emotional well-being; Get support.

In the first section, all the main topics of the perinatal journey are described, together with all the findings that could create anxiety or insecurities in the parents.

In the second section, a description of conditions, symptoms, and feelings that should be monitored or, on the other hand, are exactly normal, are described in detail.

The third section is dedicated to the description of the various supports women and families can count on, and centers where one can find healthcare professionals, contacts, and main information.

The app was mainly created to administer the EPDS questionnaire to women. In order to be used by as many people as possible, the app was developed in both Italian and English. The fundamental idea is to install the app during the first meeting with a healthcare professional; then the app asks women to insert recursively the EPDS questionnaire. This method is the gold standard that should be implemented in hospitals, but - for reasons of timing and logistics - it is almost never carried out correctly. Usually, the EPDS questionnaire is given only once, a couple of days after the baby is born. It is rarely given during pregnancy or during the first year. This means that many cases of perinatal depression go undiagnosed. Using the mobile app can solve this problem. In fact, gynecologists or midwives are in charge to present and inform women about the app. They will explain how the app works and for whom the results are intended. The app is used to fill the EPDS at least 5 times in 10 months, and the scheduled timing of each questionnaire is automatically set in relation to the peak of risks for depression symptoms in the perinatal period. Figure 4 shows the entire system service blueprint. As described above, at the first visit the gynecologist or midwives introduce the system to the pregnant woman and give her a one-time code to enable the app; she can access the website to gather information and access the link for downloading and installing the application on an iOS or Android smartphone. At the first access, the app requires a login. The login phase is carried on by means of a conversational agent that follows the woman in all the steps. The one-time code is mandatory to create an account; this was a very important aspect discussed with the medical stakeholders; limiting access to the system only to users who have received the code allows to avoid system congestion and gives operators the possibility to correctly view the collected EPDSs. The EPDSs are automatically labeled with three different colors:

– green, if less than 9 and different from 0;
– yellow, if between 9 and 11;
– red, if more than 11 or the answer to the last question is different from the fourth.

Depending on the history of the woman and the value of the EPDS, the healthcare professional can then call her to ascertain the state of her mental health. The web app allows the physicians to access the woman's personal data in order to contact her and shows the answers to the last questionnaire inserted. The standard schedule for the EPDSs is related to the expected delivery date; the first EPDS is inserted when the app is installed; then a new questionnaire is requested thirty days before delivery, ten days after delivery, and then every three months until the tenth month. The time schedule for the EPDSs is automatically changed based on the previous EPDS inserted. Figure 3 shows the modified schedule based on the previous EPDS result. All the data are recorded on the cloud (by means of Firebase cloud service) in an anonymized form. Only when it is necessary to contact the user, personal data are correlated by code and shown to health care personnel. The system in this way is GDPR compliant and has been verified by the data protection officer of the Politecnico di Milano.

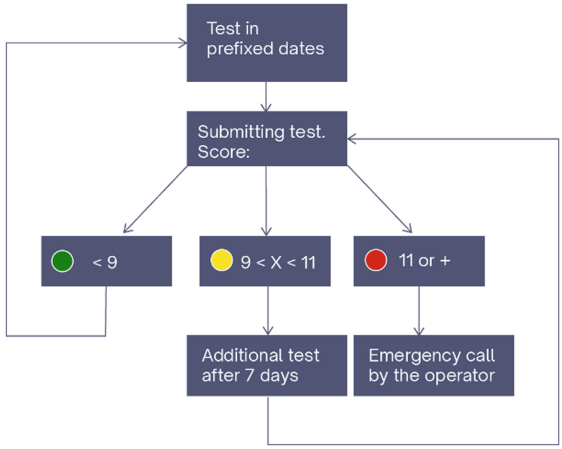

Fig. 3. EPDS schedule related to the score.

The left image in Fig. 1 shows the final dashboard. In the bottom part of the image, there is a circle that represents the feedback on the evaluation of the last EPDS inserted. Previous research [25] mentions the importance of feedback in this kind of app to promote and ensure the engagement of the users, but there is a need to explore more factors that influence it and the effect they could create in the users. During focus groups and conversations with midwives and psychologists, they were worried about the feelings or the implications that "score feedback" shown at the end of the questionnaire could arise.

In particular, a numeric score would not have an immediate meaning if not properly communicated, and could impoverish the perception of the test. Users could try to focus on beating the previous score, or they could lose the reliability in completing the answers [25]. The same effect, or worse, would be created if given "good or bad" feedback. Those results could be interpreted as a judgment on the person, or on her doing.

Everyone in the focus group agreed on the awareness that a user has during the test, implying that the feedback would be only a confirmation of what the user feels. Nonetheless, the feedback most likely could not be a surprise, everyone agreed on being extremely careful with the response after the test. The main idea of this feedback is to offer a hint, a constructive approach to keep the users engaged: in this way they know the results are controlled and checked by their professionals, and they know that there is always someone available to help or simply to listen. If the EPDS has an intermediate score (between 9 and 11), the users are informed that they will have to complete soon (in a few days) a new questionnaire; if it is over 11, the users are informed that they will have to complete a new questionnaire the day after and they will be reached out in the next days by a caregiver. If the results are under 9, the users receive a simple message which informs them that the next date for the EPDS follows the standard scheduling.

5 Discussion

As described in the previous chapter, all the parts of the system have been tested both with user tests and quantitative tests. The quantitative tests were executed with maze.co on 5 Italian users and 25 international users (women aged between 22 and 35). Maze.co allows the collection of data via screens, Likert scale-based questions, and final notes from the users.

For the first-use sign-in analysis, we found out that all the users succeeded in creating the account, with an average time of 4 min and 37 s for the entire procedure.

The most complicated part seems the estimated date of delivery selection and notification time; this was underlined by the timing for each screen and from the number of misclicks on the calendar and on the clock. It seems that the input method is not easy to use, despite being the standard for Android calendars and alarm clocks. The use of a conversational login interface was appreciated with 89% of positive responses; the user feels more familiar with and easy to use this method, as also underlined in the focus groups.

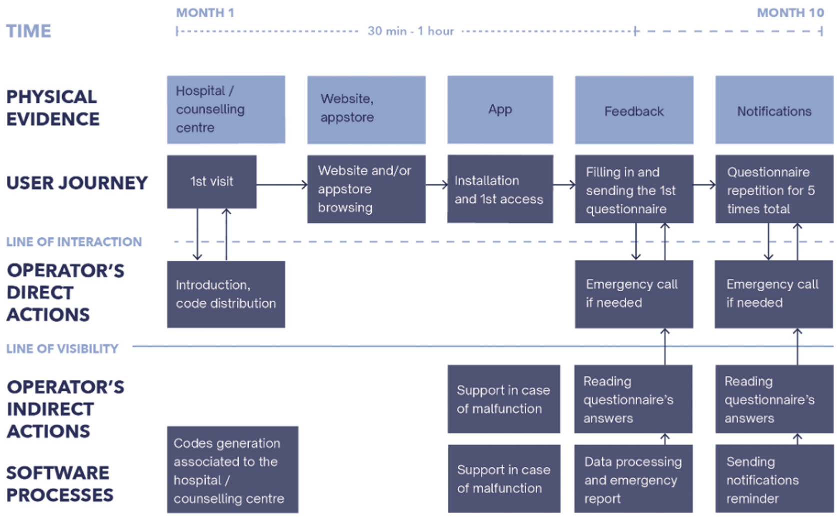

Fig. 4. Service blueprint for the entire system. The blueprint shows all the steps for using all three components of the system.

The selection of the notification time is considered very useful by all 30 users who responded to the test (Likert score average greater than 8).

The second task analyzed was the EPDS administration. The app provides two ways to start the test: by clicking on the fab button with the plus or by clicking on the card with the reminder for the next test. The success rate also for this task was 100%; all users were able to complete the insertion of the test, although some of them did not immediately understand which button to press to start EPDS (some misclick on the first screen).

From the analysis of the taps/clicks, it appears that the app is very usable; each screen has only a few interactions, which are suggested by a different contrast of colors and shadows. This allows users to better identify the possible buttons on which they can interact by reducing misclicks to a minimum. The presence of the "back" button and the possibility to go back to modify the data entered at login, facilitates the correction of any errors.

The administration of the EPDS questionnaire does not foresee a temporary interruption and resume, because this could affect the results. For this reason, to satisfy the requests of women to be able to stop the compilation, a back button has been added that allows users to return to the dashboard. This proved to be very useful because often the new mothers have to stop everything they are doing to meet the needs of their newborns.

During the analysis, we evaluated the Screen Usability Score (SCUS). The score, reported by maze.co, reflects how easy it is for a user to perform a given task (mission) with the prototype. A high usability score indicates the design will be easy to use and intuitive. This score goes from 0 to 100 and usability points are lost when a user:

- clicks on another hotspot than the expected one. This means the user got off the expected path(s), which is a live product results in frustration or a lost user;
- gives up on a task. This is a clear indication something isn't right and should be checked;
- misclicks. It's common that in a prototype not every area is clickable, but a misclick in a live product would take the user to an "incorrect" page which leads to the first point;
- spends too much time on a screen.

For every percent of users dropping off or giving up, 1 usability point is lost.

Not every misclick is an indication of a wrong action so for every percent of a misclick, 0.5 usability points are lost.

Time on screen is expressed in average duration and the lost point are:

- From 0 to 15 s: no usability points lost
- From 15 to 45 s: 1 usability point lost every 2 s
- From 45 s and on: 10 usability points lost

These timing values are optimized based on the length of the questions to be read. Here is the SCUS formula:

$$SCUS = MAX(0, 100 - (DOR * dW) - (MCR * mW) - (MIN(10, MAX(0, \frac{AVGD - 5}{2}))))$$

Which has these variables:

- SCUS for Screen Usability Score;
- DOR for drop-off and bounce rate;
- dW for DOR weight; The dW equals 1 point for every drop-off/bounce;
- MCR for misclick rate;
- mW for MCR weight; The mW equals 0.5 points for every misclick;
- AVGD for Average Duration in seconds.

The main task (EPDS administration) gets a SCUS total usability score of 84: a very good starting point for a new application. The value 84 mainly depends on the misclick on the main page, the only page where there is more information. This is underlined also by means of the VAS analysis. Examples of VAS results are reported in Fig. 2 and Fig. 5. Figure 2 shows the visual attention (red is a hot point, blue is a cold one) on-screen elements for a single EPDS question. The color map shows great attention to the question and answers, less on the navigation button below, and no attention to the status on the top. This underlines that the screen is well-defined because the question gets most of the attention without distraction. The top bar is an Instagram-based stories bar that underlines the completeness of the number of answers filled in. The top bar starts to get visual attention after the user filled some questions when the users need to know how much time he needs to complete the questionnaire.

Figure 5 shows the clear difference between two different versions of the dashboard on the main screen. The image on the left uses fewer colors and elements than the right image. The analysis of the two screens underlines a loss of clarity of 7 points in the screen with more elements and colors.

The notification process to request the insertion of a new EPDS is a very delicate part of the system: it is very important that, when a notification appears, the user chooses to open it. During focus groups, pregnant women and new mothers underlined the importance of not to over-stress themselves with many notifications. For this reason, the system is programmed in order to send the notification once a day, at the pre-selected time, and repeat the notification the day after only if the woman does not insert the EPDS. The sentence used for the notification is very important in order to convince the user of the importance of inserting the test, without pressing too hard, so as not to inadvertently change the result. The sentence is a way to create confidence and reassure that the test won't take too much time but only a few minutes. During the focus groups, we tested different sentences and feedback with real users in order to understand which one could fit better in this use case. The notification needs to be personal, informal, and inviting; here is the final result: "(Name of the user), how are you? It's time to fill in the test, it will take only 3 min."

Answering the requirements of women, opening the main menu of the app, the user could see an icon with the mom's belly, and on the side her name with the reminder of what month she (and her baby) are in and the selected name of the baby. In fact, customizing the application allows for creating a greater involvement with the user, in order to have her more willing to continue the path and to insert the EPDS when required.

Fig. 5. Clarity difference between two UI versions

The system described in the previous chapter has been tested before by a small number of caregivers (ten psychologists and midwives from ASST Lecco - Italy). After this first bench test, the system move to production and was tested with real users in the restricted area of ASST Lecco, before being released to all health organizations taking part in the project.

6 Conclusion

Preliminary tests carried out on the developed system first only with health personnel, and subsequently with some volunteer mothers have given excellent results. The pre-tests have in fact made it possible to optimize both the UI part of the application and the structure of the site in order to make them more usable and complete.

The app is now used daily for the administration of EPDS in the Lecco area. During use, a new need has emerged: being able to insert the way in which the baby came into the world (natural birth, cesarean...), as it is often related to perinatal depression. Given the optimized structure of the application, it was possible to easily add it as an application update to the store, without invalidating the data already collected.

The app continuously collects usage times and any errors and crashes generated. This allows for checking both the stability of the entire system and how it is used by new users.

The web app proved to be stable and clear for healthcare personnel, as it was developed in a minimal way as a list of inserted EPDSs. Healthcare personnel only access the EPDS in their area and are able to immediately check, through the color code, which user needs an intervention. Thanks to the user-centered approach, based on the involvement of stakeholders from the initial stages, the system is still stable and usable after 6 months of use. The number of errors found is minimal (and largely depends on the use of old Android versions that struggle to support the app). As for the timing of use, the SCUS index remains stable at around 80. This shows high usability despite the different form factors of the supported devices.

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