Lecture Notes in Mechanical Engineering

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Chapter 51
Digitalization of Mental Health Tracking Through a Mobile App to Monitor Anxiety and Depression: A Design Perspective

Eva Tausiet, Teresa Blanco, Diego Cajal, Álvaro Marco, Patricia Aznar, and Raquel Bailón

Abstract This work is developed within the framework of a national research project focused on designing and developing a system for monitoring depression using a platform based on wearable devices. In a preceding project, various physiological markers for depression monitoring were identified through the combination of physiological signals, capable of assessing the autonomic nervous system response to cognitive stress/stimuli and distinguishing between individuals with depression and control subjects. To ensure the applicability and utility of the findings in clinical settings, endeavors have been directed towards extracting these markers not from medical or research-grade equipment, but from low-cost and easily accessible devices, which can be utilized by a wide segment of the population, with minimal interference in daily life. We present the perspective from the design domain regarding the ideation and design process of the user interaction. Specifically, a mobile application has been designed and tested to be utilized by patients undergoing treatment. Through this application, the patient can autonomously and remotely register his physiological state, while the system generates valuable insights for the specialist, who could detect critical cases, adjust treatments, or prioritize

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consultations. As with any multi-user health-focused application, achieving this goal has been a complex endeavor. We have faced various design challenges, including user complexity, feedback integration, validation of results, and optimizing interface usability, some of them reflected in the scientific literature. Furthermore, the project has presented additional interesting challenges, such as digitalizing standardized neuropsychological tests which traditionally have been conducted in analog formats.

Keywords User interaction · Wearable devices · Physiological markers · Service design · Healthcare digitalization · Personalized medicine

51.1 Introduction

Approximately 15% of the Spanish population may experience a depressive episode during their lifetime, yet less than a third receive accurate diagnoses [1]. Currently, about 5% of the adult population suffers from depression, underscoring the critical need for continued research to optimize therapy methods [2]. Despite the availability of known treatments widely used against mental disorders, more than three-quarters of affected individuals receive no form of treatment, and those who do receive it often do so unsatisfactorily, mainly due to the lack of resources for mental health in public services [2, 3].

Mental health professionals face significant challenges in providing adequate care to patients in this field. To date, depression diagnoses are primarily based on scales, questionnaires, or interviews, the results of which may be biased for various reasons, such as self-perception, memory, the patient's condition on the day of the consultation, or proxy mediation. Following diagnosis confirmation, one of the greatest challenges is monitoring the progression of the disease, an extremely complex task that is often imprecise [4]. According to the research by Bruijnik et al. [5], a higher frequency of psychological therapy sessions results in a significant improvement in the symptoms of depression. However, resource limitations often make it impossible for the intervention time to be adequate, which can eventually lead to patient therapy abandonment.

Fortunately, growing awareness of the issue in recent years has opened previously inconceivable opportunities. Biological research in the field of psychiatry is helping to understand how the central nervous system works [6]. Long-term, continuous, and non-invasive monitoring of autonomic nervous system (ANS) activity might have great clinical value in outpatient settings, both for evaluating the progression of depression and for assessing treatment response and preventing relapses. The main premise is that the biological mechanisms related to stress, anxiety, and depression are mainly mediated by the ANS, which imparts characteristic patterns in certain physiological parameters (heart rate and variability, respiratory rate, arterial tone). Furthermore, it was demonstrated that what distinguishes patients with major depressive disorder from matched controls is the patient's response and recovery to a given stressor or cognitive stimulus, for example, through stress tests [7].

Within this context of significant and rapid technological advances in neuropsychology, it is essential to advance in parallel in how this technology will reach end-users, so as not to create a mismatch between technology and design [8]. It is fundamental to start from a user-centered approach, developing interfaces that allow the technology developed to be intuitively and coherently transferred to the user, non-invasively and empathetically, especially in the presented environment.

In this regard, the complexity of the health field and the constant change it undergoes, make design in this environment particularly challenging [9], requiring collaborative and interdisciplinary approaches [10]. Addressing the different user profiles involved in the technology is another issue that must be approached with special attention, developing interfaces that communicate among the different users and, at the same time, satisfy the needs of each of them individually.

In this article, we present the perspective from the design domain regarding the development of a medical application for the monitoring of mental health, with technology derived from the findings of Kontaxis et al. [7], and then validated with controls [11]. Specifically, we present the ideation and design process of the user interaction, including the first two iterations of prototype evaluation.

51.2 Materials and Methods

51.2.1 Framework

The work presented in this paper is part of the project "System for Monitoring Depression: Development of a Wearable Device-Based Platform in Relevant Environments", which involved a multidisciplinary team of biomedical, design, and electronics engineers, along with healthcare professionals—psychologists, neuropsychologists, and psychiatrists—from public and private hospitals. A system is being developed to use a photoplethysmography (PPG) signal, recorded via a mobile phone camera, to provide physiological markers capable of measuring the ANS response to stress or cognitive stimuli, thus distinguishing between patients with depression and healthy individuals.

The project aims to bring the developed technology to low-cost and easily accessible devices that can be used by a large portion of the population without interfering with their daily lives, as advocated by several authors [12]. This approach allows for continuous monitoring, providing the opportunity to track and evaluate subjects' progress throughout treatment. This paper focuses on the design of one of the service's touchpoints: the mobile application for patients. The design of the entire service, encompassing on-stage and back-stage processes as well as a web interface for healthcare professionals, was also accomplished; however, a detailed discussion of the service design is left for future work.

The application was designed for autonomous patient use via their smart mobile device, to extract various physiological markers and to subsequently provide them

to the medical specialists for analysis. These insights may empower specialists to identify critical cases, adjust treatments, or prioritize consultations.

At its core, the application's main functionality lies in measuring basal and stress-induced heart rate and its variability, for which a series of tests must be conducted. For this initial version of the app, the Trail Making Test and the Stroop Test, both standardized neuropsychological tests, were selected in collaboration with a group of healthcare professionals.

51.2.2 Design Considerations

There were health applications in the market encompassing functionalities such as heart rate measurement [13, 14], daily monitoring of mental state [14–17], and conducting qualitative tests related to depression [13, 18]. However, none of them features the functionalities and technology developed in this project, which may allow for objective monitoring and continuous user tracking.

As with any multi-user health-focused application, achieving this goal was a complex endeavor. Challenges such as user variability, variability in usage scenarios, engagement of different user groups, integration of feedback, and optimization of interface usability were faced, some of which are reflected in the scientific literature [19]. To address these challenges, various user experience and service design methodologies were employed.

Of particular interest are the interaction challenges detected regarding the digitalization of standardized neuropsychological tests, such as the Stroop Test and Trail Making Test [20], used in this case, which traditionally have been conducted in analog formats [21]. Mainly, issues were identified regarding test visualization and interaction adaptation.

Regarding the visualization of the tests, challenges arose from transitioning from analog to digital formats and adjusting the format size, moving from the traditionally used A4 format to variable dimensions depending on the model of the smart device used. In terms of interaction adaptation, various issues related to user movement were observed: actions such as flipping pages, drawing, reading instructions, or selecting options translate into clicks, screen changes, and finger swipes across the screen.

The design of the prototype presented in this paper was evaluated with a sample of 10 individuals, in a series of evaluation iterations. Initially, a pre-test was conducted using the user testing technique [22], involving two design experts, to quickly assess the initial design decisions. Subsequently, a more evolved version was evaluated in two iterations by 8 users, 3 men and 5 women, ranging in age from 23 to 82 years, with varying degrees of technological literacy. The experiment was conducted in a controlled environment using the Thinking Aloud technique [23]. The session was recorded, and the conversations and comments of the tested users were transcribed.

51.3 Results

51.3.1 App Description

The functional prototype combines the visual and operational aspects of the application, with three main sections: (1) Home, a welcome page where the user accesses three test modalities: basal, stressor, and qualitative; (2) Reminders where the patient receives appointments or activities indicated by the doctor in between sessions; (3) User profile.

Once the user creates an account with the authorization and supervision of a healthcare professional, they access the mobile application, through which they can perform the tests recommended by the same professional. The professional can configure the most suitable types of tests for the user and the frequency of administration.

Upon entering the app, the user visualizes the tests that need to be completed, along with information such as the number and type of tests, as well as their duration. These tests can be of the following types:

- Basal: Using the mobile phone's camera with the flash on, measurements of the patient's PPG signal are taken until it stabilizes. These tests serve the purpose of daily monitoring and long-term tracking. To measure the PPG signal, the user must place their index finger on the mobile phone's camera and keep their hand steady during the process.
- Stressor: PPG signal measurement continues while the patient undergoes a series of neuropsychological tests that induce stress: the Stroop test and the Trail making test. It is important to note that the diagnosis is not determined by the user's score on the tests, whether high or low. Instead, the tests are used to induce a state of stress in the individual, similar to the stress that one might experience when playing a complex or challenging game. In a previous study, Kontaxis et al. [7] demonstrated that those tests induced changes in PPG signal differently in individuals with major depression and in healthy individuals.
- Qualitative: A qualitative test will be performed with the frequency indicated by the specialist, with questions about the user's state, such as a VAS scale [24] and a BDI-II test [25].

Heart rate and its variability is derived from the PPG and, together with the results of the qualitative tests, sent to the healthcare professional in charge of the treatment, whose system will return them in the form of graphs that can be explored and interpreted by them. These tests will run in parallel with consultations with the specialist, during which the results obtained in the between-session periods can be discussed. The professional will decide when it is appropriate to conclude monitoring through the app.

51.3.2 Digitalization of Neuropsychological Tests

The two neuropsychological tests are based on standardized analog tests. Attempting to maintain the same format caused problems with visibility, comprehension, and usability. Therefore, both tests were redesigned to allow for digitalization and facilitate an initial usability validation (Fig. 51.1).

The Stroop Test begins with two introductory screens that offer simple instructions with adjustable text size. This format proved effective in capturing user attention and facilitating their understanding of the test's operation, eliminating the need to revisit the instructions later. Unlike the traditional test where words are grouped by columns, the digital version presents words individually, one per screen. Furthermore, instead of requiring users to verbally state their answers, the test offers three answers choices displayed as buttons.

The Trail Making Test also starts with two introductory screens. The method of connecting different numbers and letters remains the same, with the execution method adjusted from using a pen to using the user's finger. As an option for healthcare professionals, the digital version can allow (or not) marking the paths in a straight line

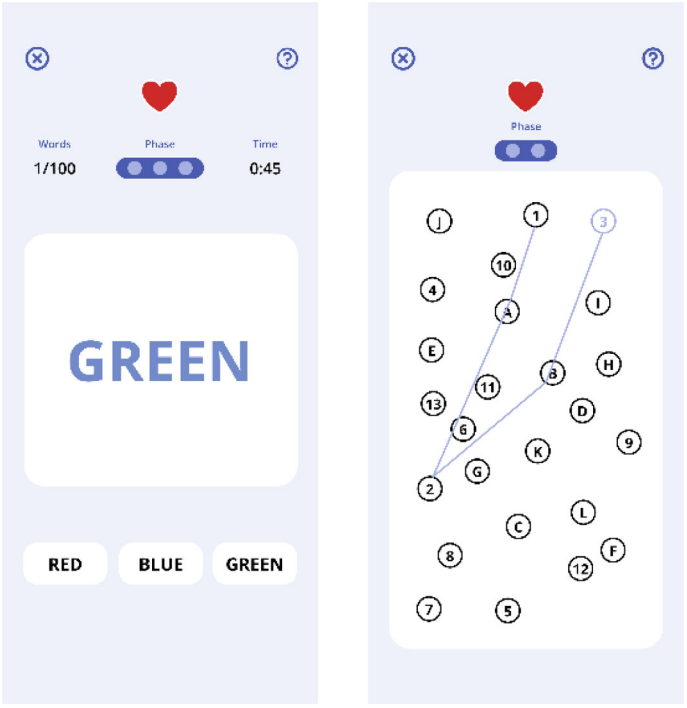


Fig. 51.1 Examples of neuropsychological test digitalization. **a** Digitalized Stroop Test screen. **b** Digitalized Trail Making Test screen

and visually indicates the touched points with a temporary color change. The instant feedback lets users know if they made errors, improving the user experience, but it must be evaluated if this feature could influence a reduction in stress in subsequent attempts.

51.3.3 Evaluation

The evaluation process covered both transversal usability dimensions, such as the user's cognitive adaptation to the application, and specific issues arising from the unique characteristics and complexity of the user group and the technology (Fig. 51.2).

The former category primarily involved addressing minor usability issues, such as users spending limited time carefully reading instructions, especially for screens with blocks of text. Some changes to ensure comprehension and capturing users' attention included concise and straightforward texts, highlighting key terms, and different distribution of information along screens. Also, usability issues in some interaction items such as some buttons and text sizes were identified and addressed in subsequent versions.

On the other hand, the app presented more significant functional complexity when integrating user feedback. At the beginning of biosignal measurement, some interactive elements caused users uncertainty. Beyond improving instructions and supplementing actions with images, displaying the biosignal continuously demonstrated

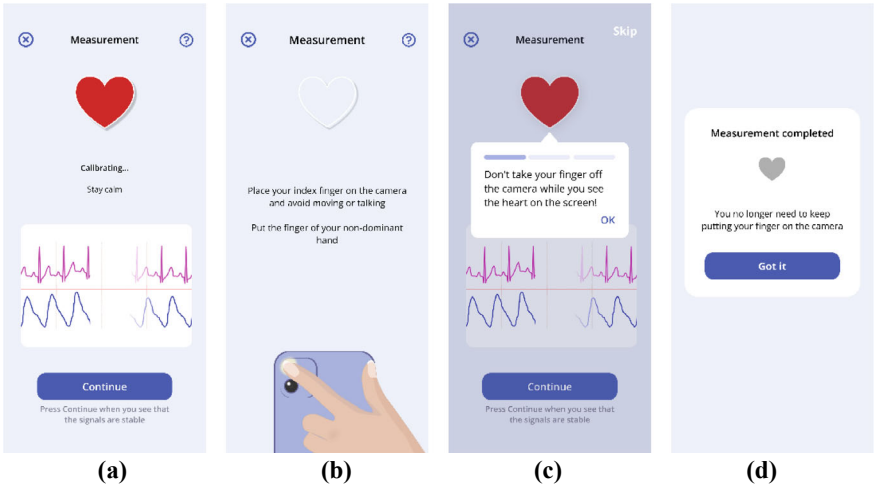


Fig. 51.2 Examples of feedback integration and usability adaptation. **a** Pulse calibration screen. The hearth icon is colored by the user finger through the camera. **b** Initial measurement screen. **c** Calibration screen. **d** Measurement completion screen

the most effectiveness. In addition to informing the user about when the recording is in progress, feedback on whether the recording is being conducted properly or not must be provided. This is essential for the measurement to be effective. Especially noteworthy is the fact that during stressor tests, users must keep their finger placed on the camera for an accurate measurement. It was noted that this action could pose problems in maintaining the necessary position for the required duration (several minutes), due to mobility issues, fatigue, or distractions. To address this, a feedback system was designed using the heart icon, which is colored based on the real-time image of the user's finger: when the user correctly positions their finger on the camera, they should see the entire heart colored because it is covered by their own finger.

Finally, as mentioned earlier, the digitalization of the tests was carried out as a first iteration and to enable an evaluation of the technology's usability. The results with users were very positive, and we are on the right track. Based on this evaluation, various interesting research lines have also been identified that will delve deeper into this matter.

51.4 Conclusions

This paper presents the results of a research project that proposes a technological system for monitoring patients with mental health issues. The project includes the design of a service to facilitate continuous monitoring of patients with innovative and low-cost technologies, easily accessible, and with minimal interference with individuals' daily lives. This approach aims to support diagnosis and treatment, minimizing problems that arise between consultations.

Specifically, this paper focuses on the initial stages of design and development for the patient's mobile interface touchpoint. This interface was ideated to enable effective use of the technology, which relies on capturing phone camera-based biological signals and utilizing neuropsychological tests to measure an individual's stress response.

The design process focused on identifying and addressing specific challenges arising from both the user group and an innovative technology context. User testing evaluated usability aspects such as user feedback, cognitive and motor adaptation, and tests digitalization. Some issues were successfully addressed during the testing process, leading to significant results, including the seamless integration of feedback. Additionally, neuropsychological tests like the Stroop Test and Trail Making Test were digitalized and adapted for use within the mobile environment.

To date, user testing has been conducted in a controlled environment with a limited number of users. The long-term goal, once major issues are identified and resolved, is to conduct further evaluation with users in a long-term assessment. This will allow for the evaluation of factors that short-term tests might miss, such as user engagement.

Future studies will explore broader validation of the stressor tests on mobile devices. This will involve determining whether they induce measurable stress and

whether their consecutive use can lead to user habituation, potentially decreasing their effectiveness in inducing stress. Additionally, the research will investigate whether interaction with the device produces movements that transfer to the signal. In anticipation of these challenges, several solutions have been proposed for exploration. Some, like the described feedback mechanism from finger registration on a "hearth window", have been tested, while others, such as the design of a simple external support device to assist with hand positioning, remain to be explored. Other alternatives, such as voice interaction for the Stroop test, will also be considered. Finally, native tests specifically designed for the mobile environment, rather than adaptations of analog tests, can be designed and validated.

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Part III
Design and Management of Industrial Processess