Tampere University

Melany Mendoza Romero

MOBILE APPLICATION AND BIOFEED-BACK FOR AIDING STUDENTS WHO SUFFER FROM ANXIETY

Designing a mobile application that utilizes biofeed-back to provide a better user experience

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Faculty of Information
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Aino Ahtinen
Kirsikka Kaipainen
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ABSTRACT

Melany Mendoza Romero: Mobile Application and Biofeedback for Aiding Students who Suffer from Anxiety.
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Anxiety is a widespread issue among university students. Students with anxiety can experience detrimental consequences such as disruption of sleep, isolation, and deficient quality of life. There is a need for accessible mental wellness treatment options and mobile applications are a promising alternative to traditional therapy since not all students have access to a therapist. Thus, this thesis aimed to develop and test a demo wellness application that can aid students in managing their anxiety as well as evaluate the user experience of the students.

As a pre-study, we interviewed three mental health professionals to obtain insights that could be useful in our design, as well as to understand their professional opinions about our ideas. Then, we designed and developed a functional demo application based on Acceptance and Commitment Therapy principles. This application can be used in mobile as well as desktop browsers. The application has two versions: one that utilizes biofeedback and the other does not. The application contains a diary section in which the users can reflect on their day, a values section where the users can work on defining life values that can motivate them to live a more fulfilling life, and a section with videos of mindfulness meditations. Furthermore, the version of the application that uses biofeedback can connect to a wearable biofeedback device and send notifications to the users when their stress levels are high. In this manner, the users can use the application to help them calm down.

To evaluate the application, we recruited 10 university students and divided them into two groups of 5, one user group for each version of the application. While the users utilized their corresponding version of the application their usage logs were recorded on the application's database and later analyzed to measure their engagement. After they had used the application for three days, they were interviewed to understand their experience as a user.

The usage logs data contained the number of videos watched, the number of diary entries created, and the number of value entries created. This data was later statistically analyzed to compare the engagement level of both user groups. The findings of this analysis suggest that the engagement of the users with biofeedback seems more constant and greater than the other group. The findings of the interviews regarding the users who utilized the biofeedback device revealed some concerns about the device's size, among other insights.

Furthermore, there were other results from the interviews of all the users regardless of their group. These results generated various findings related to the general user experience of the developed application. In summary, the users had a mostly pleasant experience, and it was implied that the application has the potential to impact the mental wellness of its users positively. Moreover, the users reported some necessary improvements for the application.

Additionally, a list of design implications for similar applications was created with our gathered knowledge throughout the research process. These design implications could serve as a guide for future developers and researchers who are interested in exploring applications comparable to ours. The design implications include aspects related to improving the experience of the users while utilizing the biofeedback device as well as the interface of the application.

Keywords: Biofeedback, Mental Wellness, Anxiety, Human-Centered Design, Mobile Application, Web System, Web Application.

The originality of this thesis has been checked using the Turnitin Originality Check service.

PREFACE

My time as a master's student at Tampere University was a great yet challenging experience. I arrived in Finland from a very different location and culture. Additionally, I had never lived as far away from my family and friends. I have noticed growth professionally and academically in myself. However, I believe my real progress has been the personal growth and unique life experiences I had here.

I want to thank my family for always supporting me, especially my mom who called me almost every day to see how I was doing. When I was having a hard time, I knew I could look forward to her call.

My supervisor Aino Ahtinen for welcoming me to this school and for being a great teacher.

All my friends who were cheering me on and kept in touch with me, whether they were physically here in Finland or other countries.

And the good people at Moodmetric who lent us two biofeedback devices thus making this research possible, and who were kind enough to give me technical support when I needed it.

Tampere, 2 November 2023

Melany Mendoza Romero

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LIST OF SYMBOLS AND ABBREVIATIONS

AAQ-II	Acceptance and Action Questionnaire–II
ACT	Acceptance and Commitment Therapy
BD	Biofeedback Device
CBT	Cognitive Behavioral Therapy
HCD	Human-Centered Design
HR	Heart Rate
ITT	Intention-to-treat
MLM	Multilevel Modeling
MWA	Mobile Wellness Application
NRV	No Ring Version
P1	Participant One
P2	Participant Two
P3	Participant Three
PCa	Prostate Cancer
PP	Per-protocol
PPG	Photoplethysmogram
RQ1	Research Question One
RQ2	Research Question Two
RQ3	Research Question Three
RT	Radiation Therapy
SUS	System Usability Scale
USD	United States Dollar
WRV	With Ring Version

1. INTRODUCTION

1.1 Motivation and Theoretical Concepts

We have all experienced anxiety at some point in our lives. As mentioned by Ghinassi (2010) anxiety is a normal biological response to external factors; it is associated with our fight or flight response and can keep us safe in the face of danger. However, while anxiety is necessary for survival and can be helpful to make us perform better, too much anxiety can harm a person's daily life.

Students deal with a particular set of challenges caused by anxiety. Students who suffer from anxiety can experience poor sleep quality and low quality of life. Additionally, both these factors are likely to increase depression symptoms (Wen et al., 2022). Furthermore, Ayres and Bristow (2009) stated that social anxiety is a common occurrence among college students, they feel extremely uncomfortable in most social situations, especially when it comes to dating and romantic relationships. Thus, socially anxious students tend to isolate themselves, which puts them at a higher risk of developing depression and drinking excessively as a coping mechanism.

There is a need for more accessible mental wellness treatment options. According to The World Health Organization, around one billion people worldwide suffer from some sort of mental, neurological, or substance use disorder, nonetheless, it is not always possible for them to receive a diagnosis or treatment, particularly in low and middle-income countries (World Health Organization (WHO), 2022).

Efforts have been made to provide mental health services to the public by utilizing technology. There are various internet-based treatments that are relatively accessible and convenient to use, furthermore, they have been shown to positively impact the levels of anxiety, depression, and sleep in people, however, they also have some downsides such as low rates of adherence by the users (Becker & Torous, 2019).

Mobile applications are a promising alternative and complement to traditional psychological therapy. Smartphone wellness applications are accessible, affordable, and can be used in many locations around the world. They have been shown to help people suffering from stress, depression, and anxiety (Sargisson et al., 2019). Acceptance and commitment therapy (ACT) is commonly used in technological approaches to mental health

treatment (Ahtinen et al., 2013). ACT is defined by Harris and Hayes (2019) as focusing on accepting the fact that life is inherently difficult, and all people will face painful emotions eventually. Nonetheless, ACT can help us by: (a) defining what are our most important values in life – thus giving us direction and purpose, and (b) providing mindfulness skills to handle challenging situations.

However, there are various limitations that diminish user engagement with a mobile wellness application (MWA). Wong et al. (2021), found that is imperative to satisfy the users' need for good user experience, user-centeredness, and peer support. Additionally, Wong et al. observed that many users would interact with MWAs in a reactive manner rather than a proactive one, in other words, they would open the application prompted by feelings of anxiety or any other signs of distress. Another perceived issue affecting the adoption of MWAs is the inability to detect when a user might be experiencing an unfavorable situation, for example while having suicidal thoughts or engaging in self-harm (Salamanca-Sanabria et al., 2023). Furthermore, as stated by Ahtinen et al. (2013), some users prefer to utilize an MWA in a peaceful place that allows them to focus on more difficult tasks, thus she proposes that context awareness would be useful in finding appropriate moments to remind the users to engage in the application.

Biofeedback can be a useful addition to increase the engagement and user experience of MWAs. It provides information about a human's physical reaction to stimuli using biosensors (Pallavicini et al., 2009). In MWAs, the biological data provided through biofeedback is usually utilized to present a visual representation of the user's physical symptoms of anxiety and helps them track their progress so they can learn to self-regulate (Almeqbaali et al., 2022; Pallavicini et al., 2009). A biofeedback device (BD) such as the Moodmetric smart ring (Moodmetric, 2020a) can detect when a user is in a calm or stressed state, additionally, they can track the user's biological patterns through time (Moshe et al., 2021). Moreover, with this information, BDs could find the most suitable time and frequency to send notifications reminding users to use the MWA.

1.2 Research Goal and Questions

This thesis aims to explore the possibility of making ACT-based MWAs more engaging and user centered through the use of a BD that sends timely notifications to the users. To achieve this, we will implement a demo MWA based on ACT principles, a user needs study, and conduct a user evaluation to test its performance. The application will have limited functionality and will not constitute an in-depth adaptation of an ACT psychological treatment since the main focus will be on studying the quality of the user experience and the user interface of the application. Nonetheless, the application will be designed

following the guidance of experts on the subject of ACT. A BD will be included in the design of the MWA as a way to obtain input from the user and provide more accurate notifications. Moreover, when the user's stress levels are high, the application will notify the user and suggest using the application at that moment.

This thesis aims to answer the following research questions:

RQ1: What is the user experience of the developed application for students who suffer from anxiety?

RQ2: What is the perception of the BD integrated into the developed application for students who suffer from anxiety?

RQ3: Can timely notifications in the developed application increase the engagement of students who suffer from anxiety?

The first question will be useful in understanding how students who suffer from anxiety interact with this MWA as a whole in a natural environment, moreover, what they feel and think while using it.

The second question seeks to find how the users interact with the BD that will be used together with the mobile application. The main objective is to analyze their user experience and discover if this particular type of biofeedback is useful and suitable.

As previously mentioned, the application will send timely notifications when the BD detects that the user's stress levels are too high. Thus, the aim of the third research question is to discover if these notifications can make the application more practical to use and if it will make the users more likely to use it.

1.3 Structure of the Thesis

Chapter 2. Contains the relevant related work, it is divided into the following sections: psychology background, mental wellness applications, and biofeedback and notifications.

Chapter 3. Presents the methodology used thought this research. Moreover, it explains the research phases, research approach, data collection methods, data analysis methos, and research platforms.

Chapter 4. Explains the pre-study in which mental health professionals have been interviewed to obtain their guidance related to the design of a mental wellness application.

Chapter 5. Consists of the design phase of this research in which an application is created utilizing the knowledge gathered in the related work and pre-study sections.

Chapter 6. The evaluation of the designed application. In this chapter university students test the performance of our application.

Chapter 7. Contains the discussion chapter in which we analyze the findings from the previous chapter, and we aim to answer the research questions.

Chapter 8. The conclusion of this Thesis.

2. RELATED WORK

This section describes the related work supporting this thesis, furthermore, it includes three main chapters: psychology background, mental wellness applications, as well as biofeedback and notifications.

2.1 Psychology Background

This section explains the psychological theory relevant to this thesis.

2.1.1 Cognitive Behavioral Therapy

As stated by Eifert and Forsyth (2005), cognitive behavioral therapy (CBT) is the standard treatment for anxiety disorders, and it emphasizes the elimination of undesirable symptoms.

Hazlett-Stevens and Craske (2002) mention that CBT contains four main premises:

1. Psychological dysfunction is caused by learning mechanisms related to both classical and operant conditioning, as well as issues with information processing.
2. Human behavior is directly correlated to the environment and internal condition of each person. Thus, by identifying and treating the root cause, then the undesired maladaptive behavior or symptom would also improve or disappear.
3. Therapists can provide coping skills to patients so they can replace maladaptive thoughts and behaviors with adaptive ones, leading to a more positive short-term outcome. The patient would be able to observe a consistent improvement in their life after having successfully implemented the learned coping skills over a significant amount of time.
4. CBT is particularly compatible with scientific research because researchers can easily follow the scientific method while implementing CBT therapy during a clinical study. Moreover, they can form a hypothesis regarding a patient's behavior, create a personalized treatment, observe the results, and modify the hypothesis based on their observations if necessary.

However, while there is evidence that CBT can be effective, it does have some disadvantages when dealing with anxiety disorders: (1) undesired symptoms are not necessarily the main issue; (2) there is a discrepancy in negative responses being both a

symptom and part of the definition of the disorder; and (3) there might exist overlap between different types of anxiety disorders and their corresponding effective treatments, and it fails to acknowledge that controlling our thoughts and emotions is not a requirement to live a fulfilling life (Eifert & Forsyth, 2005).

2.1.2 Acceptance and Commitment Therapy

According to Harris and Hayes (2019), ACT is a relatively new kind of behavioral therapy that utilizes relational frame theory at its core. Furthermore, the main goal of ACT is to allow people to live a fulfilling life regardless of the struggles and challenges that they will inevitably face by enhancing their *psychological flexibility*, in other words, increase their ability to accept reality as it is and behave in a way that aligns with their values. This objective can be achieved by identifying the values that are truly important for each person, and by developing mindfulness skills that can help when dealing with painful thoughts and feelings.

Harris and Hayes (2019) present six core processes of ACT which represent different aspects of psychological flexibility:

1. *Contact with the present moment* refers to focusing on what is happening in the physical and mental world surrounding us at the present moment.
2. *Defusion* entails creating a separation between the patient and their thoughts so as not to become engrossed by them.
3. *Acceptance* means welcoming undesirable experiences, such as negative thoughts or overwhelming emotions, and avoid trying to evade them.
4. *Self-as-context* is usually referred to as *noticing self* or *observing self* in therapy, it aims to allow patients to become conscious of the part of the mind which produces the thoughts.
5. *Values* are the most important characteristics that a person wishes to possess. If obtained, they would make their life more meaningful and fulfilling.
6. *Committed action* pertains to the actionable steps that must be taken in order to pursue the defined values, they can be either physical or psychological actions.

According to Eifert & Forsyth (2005), ACT aims to reduce *experiential avoidance* in patients. Experiential avoidance happens when a person tries to avoid previously experienced negative symptoms associated with anxiety being physical, emotional, or mental. Thus, people can develop a fear of experiencing fear while being in a potentially trigger-

ing situation and will do everything in their power to prevent this from happening, however, this is not an effective tactic. In ACT theory this avoidance is considered to be a toxic coping mechanism because attempting to control or manage anxiety only makes patients more fearful and insecure about the future. Instead, ACT proposes these 4 premises: (a) striving to control anxiety is not a viable solution, (b) accepting the symptoms and situations associated with anxiety is an effective path to follow, (c) patients must strive to feel a diverse range of emotions, even negative ones, by practicing mindfulness and acceptance, and (d) people who suffer from anxiety are instructed to define their own core values, take steps towards them, and by doing this live a fulfilling life despite their anxiety.

In this section we have discussed the psychology background that supports this thesis. CBT is a well-studied theory which focuses on managing the undesirable symptoms of anxiety and it has been proven to provide good results for patients, however, it does come with disadvantages such as being too rigid and not always effective. On the other hand, ACT is a newer and more flexible theory that allows people to thrive regardless of the unfavorable aspects of anxiety through defining their values, acceptance, and mindfulness.

2.2 Mental Wellness Applications

This section explores three implementations in detail that combine technology and ACT principles to aid in the betterment of the mental wellness of its users and which serve as inspiration for the mobile application we will develop for the purposes of this thesis.

2.2.1 OIVA

Ahtinen et al. (2013) created a mobile application called Oiva targeting working-age users who suffer from stress derived from their work environment. It presents four intervention modules referred to as *paths*:

1. The first one is called *Aware Mind*, from an ACT perspective it aims to teach the users about the concepts of cognitive defusion and being present through awareness, breathing, and observation exercises.
2. Next one is *Wise Mind* which utilizes the ACT concepts of acceptance and self-as-context by providing tools that allow the users to observe and accept their thoughts and feelings.

3. The *Values* module implements the values and committed actions concepts from ACT by providing a way for the users to define their most important life values and aiding them in setting actionable goals to work towards fulfilling them.
4. Finally, the last section is *Healthy Body* that seeks to improve the user's physical wellness with an ACT-based perspective through techniques related to relaxation, mindful eating, and mindful physical activity exercises.

Each path contains 5 to 8 exercises arranged by categories called *steps*. The steps as well as the paths present information regarding the processes and abilities users will learn in them. There is a suggested order of navigation indicated by assigning numbers to the paths, steps, and exercises, however, users are free to choose which exercises they wish to work on at their convenience. Moreover, they can visualize their progress by seeing the number of completed exercises displayed in each step as well as observing a color change in the background of all completed steps and exercises.

Exercises are bite-sized, in other words, they are estimated to require around 1 to 3 minutes to be completed. Before starting an exercise, users are able to see the objective, approximate duration, and instructions. After the exercise is done, users are presented with a summary of the abilities they have acquired along with the option to write about their learnings in a diary which will be available on the main screen alongside the 4 paths for easy access. Furthermore, the image of a rose will appear as a reward for successfully concluding each exercise.

Oiva implements various methods in the design of its user interface. One of which is the *persuasive systems design model* (Oinas-Kukkonen & Harjumaa, 2009), this model is utilized in an introduction video presented to the users where an expert in ACT explains the purpose of the app and encourages the users to utilize the mobile application, additionally, this feature follows the *foster an alliance* guideline suggested by Morris (2012) providing the sensation of a therapeutic alliance. Another instance in which the persuasive design model is used is by implementing the *tunneling and reduction principles of persuasion* (Fogg, 2003; Oinas-Kukkonen & Harjumaa, 2009) in the navigation style of Oiva, more specifically, users can access all the exercises at any time without restrictions. Moreover, the *raise emotional awareness* guideline (Morris, 2012) is implemented by allowing the users to self-reflect on their learned skills by writing notes in the diary.

In their research paper, Ahtinen et al. (2013) recruited 15 participants of varying ages who were part of the technical staff at a Finnish University. At the beginning of the study, the participants attended an in-person meeting in which they were given information

about the study, procedures, and Oiva as well as smartphones with the application already installed. The users were expected to utilize Oiva, ideally every day, for one month.

Online questionnaires were provided to the users at baseline with the purpose of collecting background information regarding their exposure to smartphones and wellness applications. It was found that 14 users utilized smartphones on a daily basis, 14 had used smartphones for over 10 years, 11 were currently utilizing a mobile phone. Additionally, they discovered that 10 users had downloaded some type of mobile application related to wellness in the past, 11 had previous experience with web-based wellness applications, and 11 had prior understanding of ACT related notions.

The researchers utilized *Wellness questionnaires* to gather data related to the Oiva mobile application. Three questionnaires were administered at the beginning and end of the study: (1) *the Acceptance and Action Questionnaire* (AAQ-II) was used to measure psychological flexibility, (2) the *Satisfaction with Life Scale* (SWLS) to quantify overall life satisfaction of the users, and (3) the *single-item stress scale* to assess changes in stress levels. In addition, a *custom questionnaire* designed by the research team was employed to measure the perceived wellness advantages derived from utilizing Oiva, said questionnaire was provided after one week and one month of using Oiva and it was divided into the following scales: (a) improvement or maintenance of wellness, (b) learning new skills, and (c) gaining new insights. To statistically analyze the data of the first three questionnaires the researchers used *Wilcoxon signed rank tests* to compare the data gathered at baseline and the data obtained after one month of use. To evaluate the custom questionnaire Wilcoxon signed rank tests were again used to observe how the median ratings of experienced benefits of the Oiva application by the users had evolved throughout the study. The results of these questionnaires (AAQ-II, SWLS, and single-item stress scale) show a statistically significant improvement in stress and life satisfaction; however, psychological flexibility did not present any notable increase. All the mean ratings of experienced benefits were positive and statistically significant, more specifically, there was an enhancement in the areas of improvement or maintenance of wellness, learning new skills, and gaining new insights.

Another method for collecting quantitative data in the aforementioned research was *usage log files*. These files contained timestamps of all the interactions each user had with the application, furthermore, with this information the researchers could deduce when and for how long the usage sessions took place. After analyzing the data, it was discovered that on average each user interacted with Oiva for 11.5 days, 16.8 times, and the median duration of each usage session was 12.6 minutes. Moreover, the mean total usage period lasted for 34.0 days, and the standard total usage time was 192 minutes.

Concerning qualitative data gathering, Ahtinen et al. (2013) used *semi-structured, in-person interviews* for each participant at the end of the study. The interviews had the purpose of discovering how the user experience, usage, and practicality of Oiva was perceived by the participants. To achieve this the authors designed the interview themselves and entrusted the interviewing process to one researcher who had previous experience in user studies. The audio of the interviews was recorded, transcribed, and analyzed using *thematic coding*.

The first main theme resulting from the data analysis was *usage habits and barriers* in which it was found that 12/15 users tended to use Oiva at home, 4/15 used the application at work, 6/15 took advantage of the mobile nature of Oiva and utilized the application in places such as public transport, however, this setting prevented most users from concentrating on the exercises. 10/15 participants reported the mobile presentation of Oiva to be convenient even while being at home because they could take their mobile device with them to different areas of their living space, additionally, 4/15 users considered a mobile application was easy and quick to use, especially for quick exercises that required less concentration as stated by 6/15 users, and the same was said about audio exercises according to 4/15 participants. The following barriers interfering with the usage of Oiva were found: a hectic lifestyle as reported by 7/15 users, quick exercises were preferred over long and complicated ones, and the total usage period was perceived to be too fast by 11/15 participants.

The second theme was *perceived benefits*. The prevalent benefit perceived by users was that Oiva allowed them to take breaks in the middle of their busy schedule, next it was found that positive thoughts and an improvement in their attitude were reported by 4/15 participants, finally, the research team discovered that the ability to separate themselves from negative thoughts and accept unfortunate situations was experienced by 4/15 users.

The third theme found was *user experiences of Oiva and its functions*. 7/10 participants considered that mindfulness-based exercises were suitable for the mobile application, 11/15 users preferred audio exercises yet considered written exercises useful while studying the information, 8/15 participants followed the recommended order of completion for the exercises while the rest (7/15) completed the exercises in a sequence that made sense to them, 6/15 users expressed that having a defined schedule for Oiva would have been ideal and 10/15 felt that receiving notifications would be useful, 9/15 participants pointed out that gamification could interfere with the mindfulness aspect of Oiva and instead felt that the positive impact observed in their lives was motivating enough, 9/15 participants utilized the diary functionality in Oiva and found it useful for keeping track

of their thoughts when repeating an exercise, 2/15 wrote their diary entries on paper because they needed the freedom to write and draw, 3/15 would have liked more guidance while writing their diary entries, overall, the touch screen text input in the diary section was considered inefficient, 12/15 felt disappointed that there was nothing left to do after completing all available exercises, and 9/15 participants expected a follow up program ideally with an emphasis on the most suitable exercises for each user or additional content.

Lastly, based on the previously mentioned results of their data analysis Ahtinen et al. (2013) inferred the following 5 design implications for mobile wellness applications:

1. *Provide exercises for everyday life*. Quick exercises are preferable because they can be merged into the user's tight schedule, and they provide an opportunity for pausing and dedicating a few minutes for selfcare.
2. *Find proper place and time for challenging content*. Some exercises demand close attention; however, they can be more beneficial. Ideally, the mobile application should find a suitable time through *context-awareness* and remind users to complete challenging exercises or allow users to filter exercises by context and needs.
3. *Focus on self-Improvement and Learning Instead of external rewards*. It is preferable to deliver consequential experiences that promote intrinsic motivation in the users instead of providing gamified rewards.
4. *Guide Gently but Do Not Restrict Choice*. Give users suggestions but don't force them to follow a rigid program. Furthermore, guide users throughout the application as well as provide them with options to complete the exercises in a time and manner that suits them.
5. *Provide an Easy and Flexible Tool for Self-Reflection*. It is relevant to provide a diary for self-reflection. Pre-made questions and possible answers can serve as a guide for some users who might be unsure what to write, preferably the application should allow for free text input and drawing, in addition, a structured approach for recording feelings and the option to view past entries are recommended.

2.2.2 YOLO

Viskovich & Pakenham (2020) developed a web-based intervention by the name of YOLO aimed at university students. The students were given access to YOLO's online platform consisting of 4 modules each relating to one or more of the main core processes

of ACT (see Table 1), they require 30 to 45 minutes to be completed and contain videos as well as written exercises.

Table 1. *Content of modules in YOLO web-based system (Viskovich & Pakenham, 2020).*

Module name	Content	Reflection prompt
Values and committed action	Videos and exercises related to values, committed action, troubleshooting, and experiential avoidance.	Think about a value that is important to you and how to implement it in your life.
Cognitive defusion	Videos and exercises about defusion.	Noticing your thoughts and separate yourself from them.
Acceptance	Videos and exercises concerning acceptance.	Quicksand as an analogy for reflecting on acceptance.
Mindfulness (contact with the present moment) and the observer self (self-as-context)	Videos and exercises pertaining to formal as well as informal mindfulness, presence, and observer self.	Practice mindfulness while completing a task.

The students were encouraged to complete one module per week; however, they could progress at their own rhythm as long as they followed the specified order. Also, it was possible to repeat previous exercises or skip them if needed.

The organizers could log into the YOLO system as administrators to monitor the students' progress and send messages to them. The messages could be in the form of emails or SMS, and they had the purpose of (a) reminding the students to engage with the platform or complete their assignments, (b) provide additional information for each module, and (c) presenting a review of a module's content, after its conclusion, as well as a preview of the next module.

The research team gathered 1,162 university students in Australia to participate in the study. According to Viskovich & Pakenham (2020) the participants were 67.8 % female, 70.6% local students, 63.9% undergraduate, 23.5% master's students, 12.5% research or higher degree students, their age range was 18 to 65 years, and they belonged to all existing faculties at the university.

The students were divided randomly into an *intervention group* of 596 and a *wait list control (WLC)* group of 566. Both groups were given a pre-intervention assessment, then

the intervention group was instructed to complete the Yolo program in the span of 4 weeks, during this time the WLC group remained inactive. Next, the two groups had 4 weeks to answer a post-intervention assessment. 12 weeks later, participants in the intervention group completed a follow-up assessment during a 4-week period. After answering the post-intervention assessment, the WLC group was given access to the YOLO program and was instructed to complete it in the same manner as the intervention group did before, the only difference was that no follow-up assessment was given to this group.

The data collection methods utilized by Viskovich & Pakenham (2020) can be organized into the following main categories, primary outcomes, ACT processes, usability, and user satisfaction. The first category contains the following standardized psychology questionnaires:

- *21-item Depression Anxiety and Stress Scale Short Form*
- *14-item Mental Health Continuum Short Form, dealing with well-being*
- *12-item Self-Compassion Scale Short Form*
- *5-item Satisfaction with Life Scale*
- To measure academic performance, the researchers created a 12-item questionnaire with a 10-point scale that dealt with topics such as study habits, motivation, and grades.

In the ACT processes category, we have:

- *7-item Acceptance and Action Questionnaire II*
- *7-item Cognitive Fusion Questionnaire*
- *9-item education values subscale of the Personal Values Questionnaire II*
- *16-item Engaged Living Scale*
- *15-item Mindful Attention Awareness Scale*

The *10-item System Usability Scale* was used to obtain information about the usability of the system. Lastly, a custom questionnaire containing four open-ended questions was designed by the authors to explore the user satisfaction of YOLO.

To analyse the data obtained in the primary outcomes and ACT processes categories Viskovich & Pakenham (2020) utilized two samples:

- *Intention-to-treat* (ITT) with a size of n = 1,162. It contains imputed data from all the randomized participants who completed the pre-intervention assessment. Another group referred to as clinical distress subgroup was created as a subdivision of the ITT group to separate the people whose distress scores were considered to be clinically severe.
- *Per-protocol* (PP) is conformed of 127 participants from the intervention group as well as 364 participants that followed the trial design (n = 491 in total). This sample group has no data imputations.

The data obtained from the intervention and WLC groups was analyzed statistically using one-way ANOVA and x^2 analyses to understand their development from pre-intervention to the end of the study. In the ITT group the participants displayed an enhancement in depression, stress, well-being, self-compassion, life satisfaction, academic performance, acceptance, cognitive fusion, education values, valued living, and present moment awareness. The clinical distress subgroup improved on depression and stress. Intervention participants in the PP sample improved on the all the measurements related to primary outcomes and almost all ACT processes excluding education values.

Regarding the system usability Viskovich & Pakenham (2020) found that 96% of participants used a laptop, 4% used mobile devices, 92% had no difficulty seeing the application, and only 9%encountered issues viewing YOLO in their device.

The custom questionnaire dealing with user satisfaction was analysed using thematic coding. The first question related to “program impacts” in which 42% of participants reported self-awareness related impacts, 31.3% experienced impacts regarding defusion, 30.5% had changes in perspective, and 27.1% reported an impact of the given tools/strategies. Second question delves into “program likes” and it includes aspects such as videos (28.6%), exercises/approach (22.3%), easy to use (17.7%), structure (13.8%), helpful nature of the program (10.6%), real life examples/relevance (9.2%), self-awareness/insight (9.2%), and values (8.1%). Third is “program dislikes” where 26.5% had no dislikes, 15.9% mentioned they disliked content/specific exercises, 11.3% believed the exercises were too long, and 9.5% considered access/time limits to be a problem. Next, there is a forced-choice question about recommending the program to other students in which 75% of users would recommend it, 3% would not recommend it and 19% are not sure. And the fourth question talks about the “helpfulness of emails and SMS”, 62% found them helpful, 9% thought they were unhelpful, 29% reported them to be sometimes helpful, 78% rated their preference for the frequency of reminders to be the right amount, 17% mentioned there was too many, and 5% considered them to be

not enough, 24 % indicated they viewed weekly recaps, 36% did not view recaps, 18% viewed them sometimes, and 22% watched them later.

2.2.3 ACT Daily

Levin et al. (2017) explored the possibility of complementing in person ACT therapy with a mobile application. According to his research, the different component skills of ACT can be applied to different challenging situations in a person's life. In other words, acceptance can be used to counteract maladaptive avoidance behaviors, defusion diminishes the impact of negative thoughts, mindful awareness of the present lowers rumination and promotes attention, and values definition increases sense of meaning and the persistence of positive behaviors. Thus Levin et al., decided to create an ACT-based mobile application called ACT Daily that can promote the most suitable ACT skills at the right moment for each user.

ACT Daily is a MWA meant for users who are attending face to face ACT therapy and battle with anxiety and/or depression. The application is mainly divided into 3 sections:

1. *Library of ACT skill coaching*. These can only be accessed by users if they complete a check-in and are categorized by four of the components, also known as processes, of ACT, namely, acceptance, defusion, mindful awareness, and values. The components contain five *quick skills*, and two *depth skills*, the former would take a minute at most to be completed and come in the form of written instructions explaining how to implement the relevant ACT skill, the latter required approximately 3 to 5 minutes for solving as they constitute in depth mindfulness and interactive exercises.
2. *Check-in system*. The users were expected to access the application a minimum of one time daily, if they did not then the system would send reminders randomly between the following time intervals: (a) 9:00 to 13:00, (b) 13:00 to 17:00, and (c) 17:00 to 21:00. In the event of a user dismissing a reminder, the system would send two more notifications after 5 and 10 minutes. This section is intended for users to keep track of their symptoms and experiential avoidance by giving them a numerical value from 0 to 100 (see Figure 1).
3. *Skill suggestions and browsing*. The mobile application will suggest skill exercises to the users based on their responses given in the check-in system. There are two different modalities for users to choose from, namely quick skills and browse skills. The former randomly selects a skill component for the user among

those that are suitable for them based on their previous answers. The latter allows the users to select any skill component they would like and additionally it will highlight a suggested one from the list. After having made their choice, the users would complete a skill coaching session, a post-check evaluation addressing the issues they expressed in the check-in, and if desired they could move on to another skill or simply stop using the app.

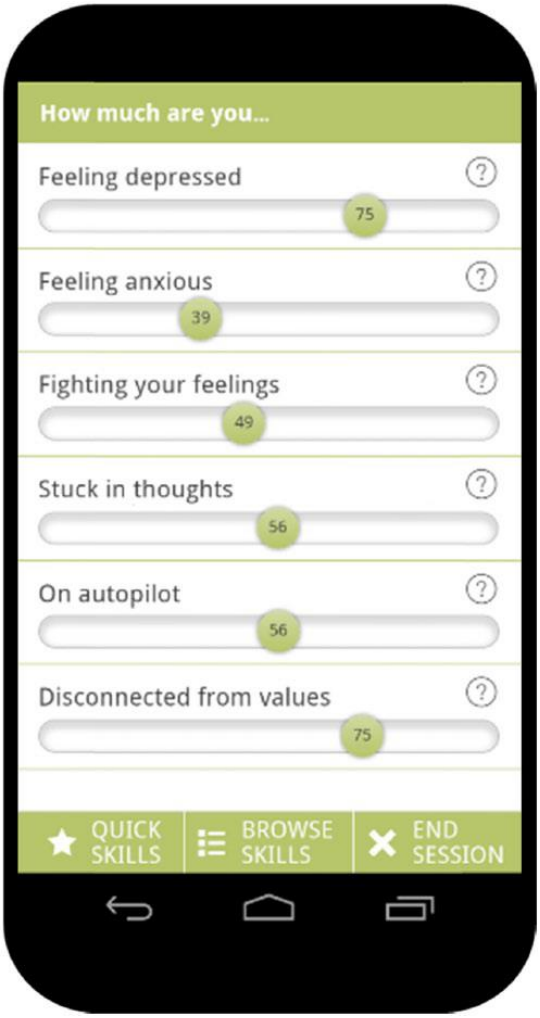

Figure 1. *Check-in section in ACT Daily app (Levin et al., 2017).*

Levin et al. (2017) recruited 14 participants in the United States who were receiving in-person ACT therapy with a professional, were 18 or older, suffered from depression and/or anxiety, could speak English, had access to an Android mobile device, and were clinically stable (did not experience issues such as suicidal tendencies, or psychotic/manic symptoms). The recruitment process was accomplished with the help of selected therapists who distributed information about the study to patients who they deemed eligible to participate. One of the original 14 participants was excluded from the study due to technological problems with the application, thus the researchers were left with 13 participants. From the remaining sample group of 13, 69% were female, their

average age was 29 years, 100% were Caucasian, 92% were severely anxious, and 62% dealt with extremely severe depression.

In their study the researchers had in-person as well as online users. The research team would meet with the in-person users and have an introductory session in which they would provide them with an informed consent form, an online baseline assessment through the Qualtrics online platform. Additionally, members of the research team would help the participants with the installation of ACT Daily app and explain how to utilize the application. For the online users the process would be virtually the same with the exception that instead of having an in-person meeting they would receive instructions regarding the installation of the application and a seven-minute-long training video about how to utilize ACT Daily app. Then, the participants were expected to use the application during the span of two weeks. Afterwards, the users would complete an online post assessment survey and a thirty-minute-long phone interview about their user experience with the app, in addition, they would be given a complementary gift card valid for $50 USD.

The pre and post treatment assessments consisted of the following online surveys:

- *Depression, Anxiety and Stress Scale* measures primary psychological outcomes.
- *Acceptance and Action Questionnaire–II* measures general psychological flexibility.
- Cognitive Fusion Questionnaire measures cognitive fusion.
- *Valuing Questionnaire* measures valued action.
- Philadelphia Mindfulness Scale measures mindfulness.
- *System Usability Scale* (SUS) measures the application's usability and acceptability.

Levin et al. (2017) intended to test three main aspects of the application while analyzing the obtained data from the experiment: (1) test its feasibility; (2) its efficacy; and (3) to understand how effective tailored, in-the-moment, app skill coaching is on psychological inflexibility, depression and anxiety outcomes.

The feasibility aspect dealt with the usage of the application and user needs satisfaction, for which *descriptive statistics* were used, as well as open responses to the online surveys and interviews, to understand this information the research team used *thematic coding*. The results showed an overall high engagement rate in app usage for check-in

assessments as well as for skill coaching sessions, regarding the app's user satisfaction the SUS survey resulted in a generally "excellent" rating (M=89.08, SD=7.69) from the users.

The exploration of the application's efficacy focused on measuring the changes in the depression and anxiety outcomes as well as changes in the psychological flexibility of the users from pre to post treatment, the data analysis was done through *paired-sample t tests*. The authors found a significant enhancement of depression, anxiety, experiential avoidance, cognitive fusion, obstruction to valued living, and mindful acceptance, no significant enhancement on stress, significant recovery (from 14% to 29%) on symptoms as well as psychological inflexibility (from 29% to 71%), lastly, there were no notable changes in valued living or mindful awareness.

The third aspect being tested aimed to understand how each of the ACT skill components affected every component of the users' psychological flexibility because this information could prove or disprove if custom ACT skill coaching based on which psychological inflexibility issues a user is dealing with would be effective. To achieve this analysis the researchers used *multilevel modeling* (MLM). Each ACT skill targets mainly one aspect of psychological inflexibility, thus the authors investigated how each skill affected every dimension of psychological inflexibility, their findings were as follows (see Table 2):

- *Acceptance* targeted the psychological inflexibility aspect of *"fighting with feelings"* did have a more pronounced impact on its target compared to other ACT skills.
- *Defusion* targeting *"stuck with thoughts"* as well as values targeting *"disconnected from values"*, has an overall similar effect on all aspects of psychological inflexibility.
- *Mindful awareness* showed a more meaningful effect on its targeted issue, namely *"being on autopilot"* compared to the other dimensions of psychological inflexibility.

With this information Levin et al. (2017) concluded it is likely that a custom approach to coaching would be beneficial for the users given the data analysis results.

Table 2. *Findings of Levin et al., regarding the effect of each ACT skill on every psychological inflexibility outcome using MLM. †p < .10. *p < .05. **p < .01. ***p < .001 (Levin et al., 2017).*

Psychological inflexibility outcome	**Versus accept**	**Versus defusion**	**Versus mindful**	**Versus values**
Fighting with feelings	-	13.18***	9.17***	13.77***
Stuck in thoughts	4.25	-	3.43	4.45
On autopilot	6.00†	8.57†	-	8.10**
Disconnected from values	−1.14	4.11	−0.30	-

In conclusion, this section has presented 3 mental-wellness applications that utilize ACT as their foundation. First, we have Oiva which provides its users with practical mindfulness exercises based on the ACT core processes of cognitive defusion, contact with the present moment, acceptance, and self-as-context to help them cope with their work-related stress. Additionally, Oiva offered a values module related to the ACT core process of the same name where the participants could define their life values so they could use them as a guide to live a life that is more aligned with them and thus more fulfilling. Lastly, the users had access to physical exercises, these had no exact correlation with any particular ACT concepts, however it offered an interesting additional physical wellness component. The results from the user study were promising since the users showed a significant improvement in their mental well-being after the treatment and seemed to engage with the application consistently. Their research also provided a list of design implications that can be useful in the development of other mental wellness applications.

Second, the YOLO web-based application that is targeted at university students and consists of informative videos and exercises related to all of the ACT core processes. At the end of the study the users experienced an enhancement in their mental wellness and rated the usability of the system positively.

Third, ACT Daily is an application that aims to provide a complement to in-person ACT therapy with a psychology professional. In its interphase this application has exercises that teach all the core processes of ACT to the users, it reminds the users to check in with the application to promote engagement, and it can suggest exercises to the users based on their input.

2.3 Biofeedback and Notifications

This section presents information regarding the practical implementation of BDs in combination with notifications in the context of wellness. The inclusion criteria consist of scientific papers that were published no more than 10 years ago, are available in English, have made the full text available to read, and are related to our topic of interest.

2.3.1 Spire Stone Device

Smith et al. (2020) utilized a device known as the Spire Stone by the company Spire Health to measure stress levels in employees during their work-related activities. The Spire Stone is a small device (32 mm x 44 mm x 14 mm), the users can wear it by attaching it to their clothes (see Figure 2a) and is able to perceive respiratory effort and physical activity in real time to measure respiratory rate, respiratory rate variability, steps, and sedentary periods.

The device comes with a mobile application containing a historical log in which the data obtained in real time from the user is stored, analyzed, and displayed with the purpose of letting users know how their physical state has progressed over time (see Figure 2c). The data is categorized as: (1) “tense” in which the user’s patterns were perceived to be fast and erratic, (2) “focus” meaning the patterns had a mild speed and were stable, or (3) “calm” when the breathing was slow and continuous.

Another feature of the application is allowing the users to visualize their current state in real time by representing their respiratory patterns as a sinusoidal wave graph as well as changing the color of the home screen’s background and providing written feedback depending on their state at that moment (see Figure 2b).

Lastly, the mobile app contains 5 guided breathing exercises in audio format based in *low dose mindfulness-based stress reduction*, which utilizes respiration techniques to improve concentration and self-regulation, the exercises lasted between 6 to 9 minutes.

As stated by Smith et al. (2020), the employees could receive notifications from the Spire Stone by its vibro-tactile motor and the mobile application through their mobile device notifications configuration. Moreover, in the configuration section of the app the users could choose to be notified when there were long intervals of “tense”, “focus”, or “calm” breathing patterns, if no slow breaths had been detected after a significant amount of time, as well as if the system detected continuous sedentary practices. The purpose of the notifications is to encourage the users to utilize the breathing exercises and to understand their breathing and emotional patterns over time.

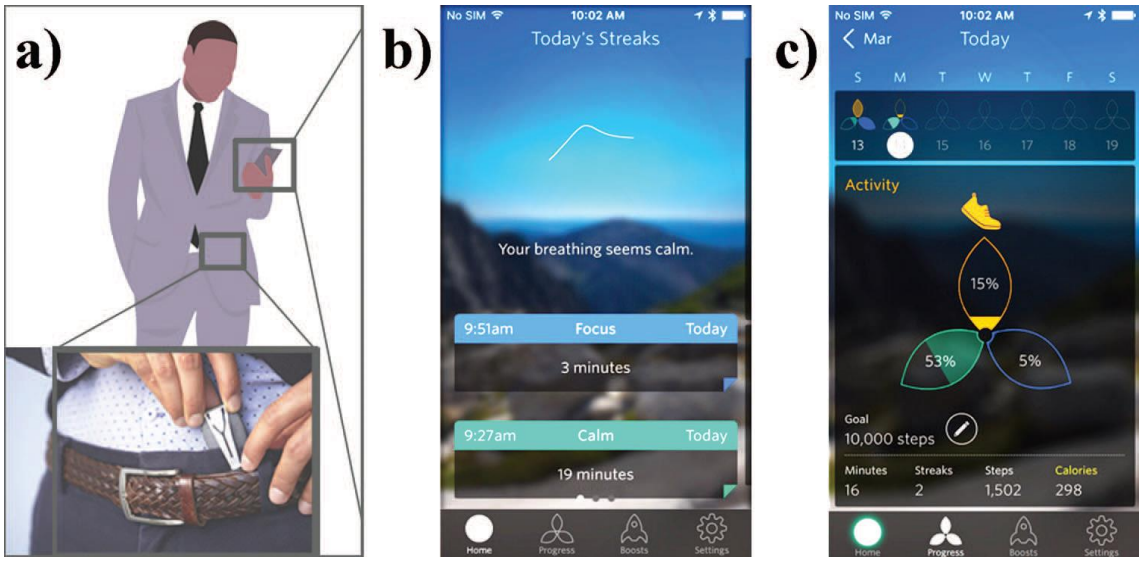

Figure 2. *(a) The Spire Stone wearable device, (b) the real time feedback seen by the users in the application, and (c) the historical log section (Smith et al., 2020).*

2.3.2 Sense-IT Biocueing App

In a research paper by ter Harmsel et al., (2023) a mobile application called Sense-IT biocueing app as well as the *photoplethysmography sensor* of a smartwatch were used to monitor the heart rate (HR) of users who experience anger management issues (see Figure 3).

According to ter Harmsel et al., (2023), the system has two main functions, the first one is to display the current HR level in real time on the mobile device as well as the smart-watch. The second one is to alert the users when their HR level is too high, this is achieved thought the comparison of the current HR and the user's mean HR, then based on the standard deviation of a measurement performed at baseline the application will assign a level between 3 and 5 to the current HR, furthermore, if the level exceeds a certain previously defined level the system will notify the user. The notifications come in the form of vibrations and messages related to assistance in conduct.

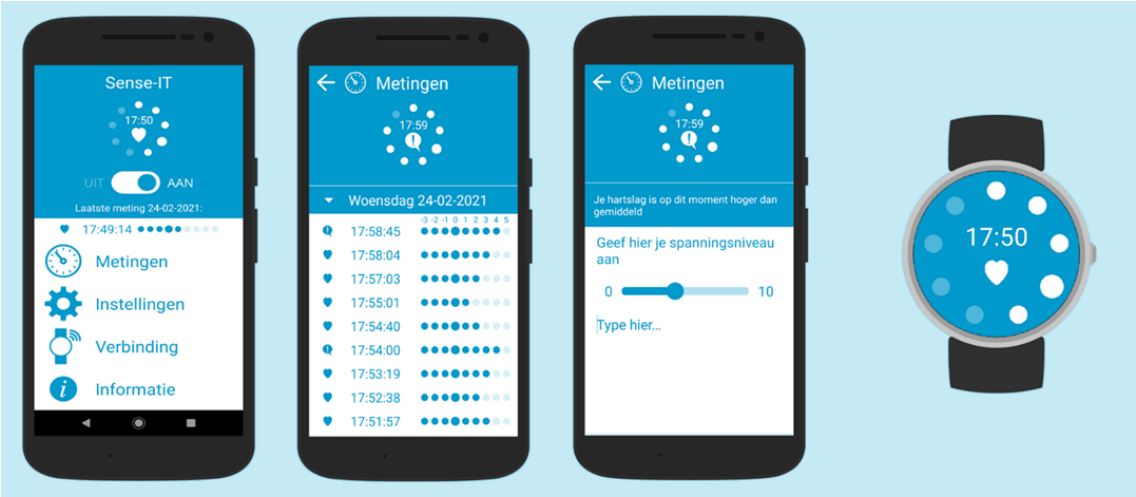

Figure 3. *Graphical interface of Sense-IT biocueing app (ter Harmsel et al., 2023).*

2.3.3 IoT System

LABUS et al., (2022) designed and developed an Internet of Things (IoT) system with the purpose of tracking the stress levels of the citizens in a smart city.

The hardware of the system contains a Raspberry Pi microcomputer, an Arduino Uno microprocessor, a *galvanic skin response (GSR) sensor*, an *oximeter*, and an *HR sensor*. The GSR sensor measures skin conductivity and it should be attached to the user's fingers, the oximeter estimates the level of oxygen in the user's blood, and the HR sensor, as the name entails, detects the pulse rate of the user and it must be positioned on the index finger.

A web application was developed to provide a graphical interface for the system. The application has three main sections:

- Control area. In this section we have three buttons: "load ponder values", "start monitoring", and "stop monitoring".
- Examinee information. Contains the user's personal information required for research.
- Monitoring table. Displays two subsections: in the first subsection, after the "load ponder values" button has been clicked, users can see the recorded starting values of pulse, SpO2 (measured by the oximeter) and GSR. In the second subsection users can find their live values after the "start monitoring" button has been pressed (see Figure 4).

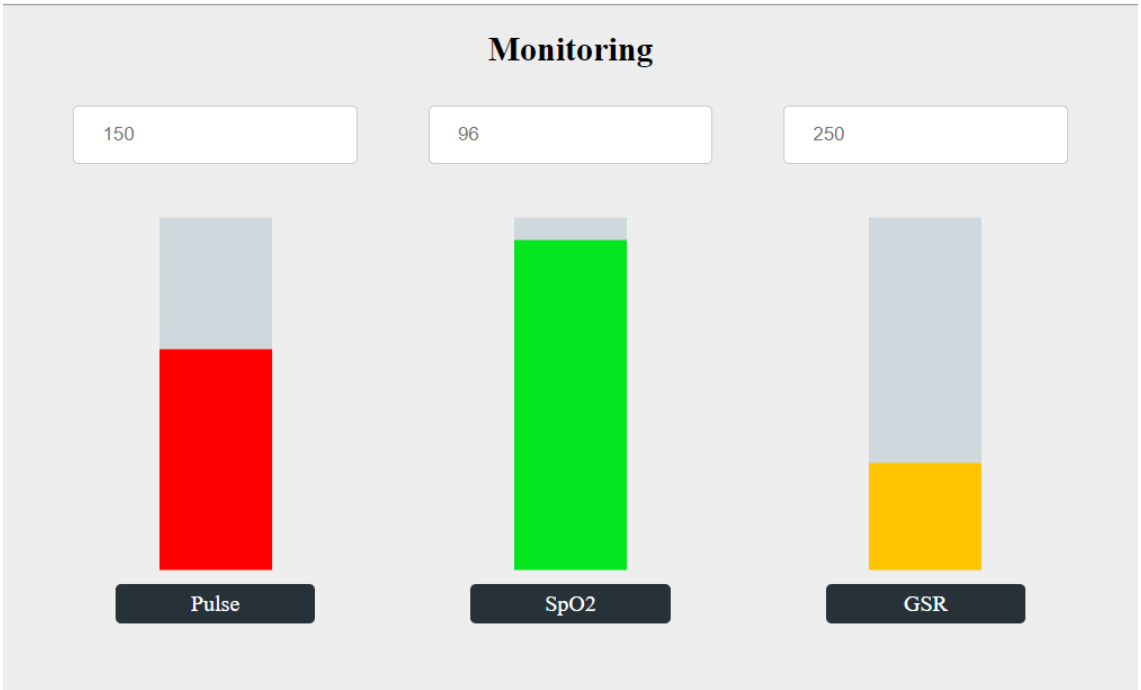

Figure 4. *What a user might see in the monitoring table section if stress has been detected (LABUS et al., 2022).*

As stated by LABUS et al., (2022) if any of the monitored values (pulse, SpO2, or GSR) indicate that the user is under stress then the system will notify the user and provide content that can help them return to a calm state. The content will be delivered through a mobile application, and it will come in the form of funny videos, nature images, or relaxing nature sounds. Additionally, the system will alert healthcare workers when their patient's stress levels have increased and allow them to send personalized treatment instructions to each patient. This functionality was not implemented by the researchers; however, it is a proposed feature in their design.

2.3.4 HIDRATE PRO Intervention

In their research Jin et al. (2022) tested the viability and acceptance of using a smart water bottle to aid prostate cancer (PCa) patients undergoing radiation therapy (RT).

As stated by the aforementioned researchers, when prostate cancer patients undergo RT, they must ideally have an adequately full bladder to prevent toxicities. PCa patients usually receive written or verbal instructions regarding these procedures, and this results in a low rate of adherence to the established protocols, thus this results in extremely negative consequences such as the loss of patient-valued time as well as linear accelerator-valued time. A linear accelerator (also known as radiotherapy machine or Linac) is a device used to administer external beam RT to cancer patients (*Prostate Cancer UK*, 2022).

To solve this problem Jin et al. (2022) proposed a digital behavioral intervention composed of an investigational device-exempt smart water bottle as well as a mobile phone application. The smart water bottle and application would remind the users when it was time to relieve their bladder and encourage them to drink a custom amount of water referred to as “volume goal”. Said reminders would take place 1.25 hours before their RT sessions. The PCa patients were able to edit their “volume goal” and notification times until they found the optimal values that allowed them to have a suitably full bladder.

The exact brand and model of the smart water bottle were not specified, additionally, no screenshots or further information about the mobile application was disclosed.

2.3.5 Body Sensor Network

Wannenburg & Malekian (2015) designed and implemented a mobile system to monitor the overall health of patients in rehabilitation, the elderly in assisted living, patients suffering of chronic diseases, or anyone who wishes to have frequent evaluations of their general physical health.

The system utilizes a custom photoplethysmogram (PPG) sensor created by the research team that can be attached to the users’ hand and arm (see Figure 5). The PPG sensor obtains four bio-signals: heart rate, saturation of oxygen in the blood, blood pressure, and skin temperature.

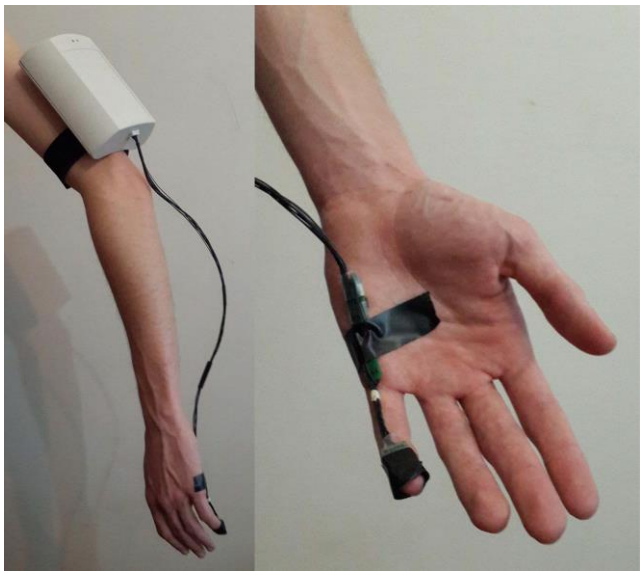

Figure 5. *PPG sensor and other hardware (Wannenburg & Malekian, 2015).*

Furthermore, Wannenburg & Malekian (2015) developed a mobile application compatible with Android operating system. This application can connect to the system’s hardware through Bluetooth to receive the user’s bio-signals in real time, additionally, it can display the obtained data in a visual way for the user’s convenience. See Figure 6 for an

illustration of the mobile application's graphical interface. The Android application has another important function; to produce biofeedback for the user in the form of notifications as well as notifying a healthcare provider if any abnormal signals are detected so they can be aware of their patient's physical state.

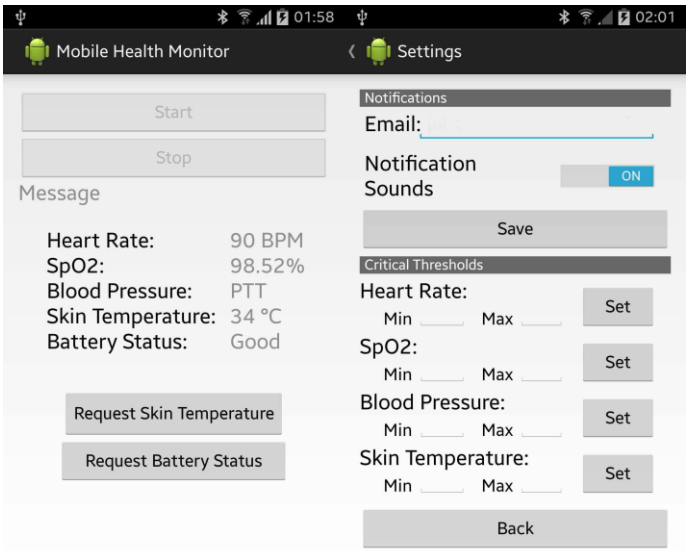

Figure 6. *The mobile application's interface (Wannenburg & Malekian, 2015).*

This section has presented five different practical implementations of BDs that utilize notifications in situations related to wellness. The first three, namely, Spire Stone, sense-IT biocueing app, and IoT system, aim to improve the mental wellness of its target users. The last two, HIDRATE PRO as well as the body sensor network, focus on improving the physical wellness of its users. Most of the implementations use mobile applications as its main graphical user interface, with the exception of IoT system which does make use of a mobile application as a complementary addition, however, the main graphical interface is a web-based application.

2.4 Summary

In conclusion, the related work section has introduced three main subsections: psychology background, mental wellness applications, and biofeedback and notifications.

In the psychology background subsection, we have discussed CBT, a very practical and well-researched approach to treat anxiety, however, there is another treatment option called ACT, which combines elements of the renowned CBT with mindfulness techniques and a more flexible treatment style.

The mental wellness applications subsection analyzes three applications that utilize ACT at its core to improve the mental wellness of its users. First, Oiva is a mobile application

that targets employees who deal with work related stress, it provides a friendly interface with nature elements, exercises based on the core processes of ACT as well as tools to allow users to handle stress through mindfulness. Second, YOLO is a web-based intervention to help university students manage their stress, similarly to Oiva, YOLO's interface consists of videos and exercises related to each of the core processes of ACT. Third, ACT Daily is a mobile app that offers skill coaching (again, based on the core processes of ACT), tracking of symptoms, and suggested content.

The biofeedback and notifications subsection presents five examples of implementations of BDs that employ notifications to improve the wellness of people. First, the Spire stone device was used in conjunction with a mobile application to alert users when their stress levels are high and provide them with breathing exercises to help them manage their stress. Second, the sense-IT biocueing app sends notifications if the heart rate of the user increases significantly. Third, IoT system monitors the bio signals of skin conductivity, level of oxygen in the blood, and heart rate, if any of these increases too much then it will notify the user as well as their healthcare provider. Fourth, the HIDRATE PRO intervention reminds prostate cancer patients to drink water and empty their bladder. Fifth, the Body sensor network observes the levels of heart rate, saturation of oxygen in the blood, blood pressure, and skin temperature. If any of these measurements reach an undesirable level the system will notify the user and a medical doctor.

3. METHODOLOGY

This chapter describes the overall research process and human-centered design approach. Then it covers the utilized collection and analysis methods which contain quantitative as well as qualitative data. Lastly, it presents the two utilized research platforms, the Moodmetric smart ring and a custom application created by the researcher.

3.1 Research Phases

In this section we will describe the five main research phases of this Thesis. Refer to Figure 7 for a diagram and summary of all the phases.

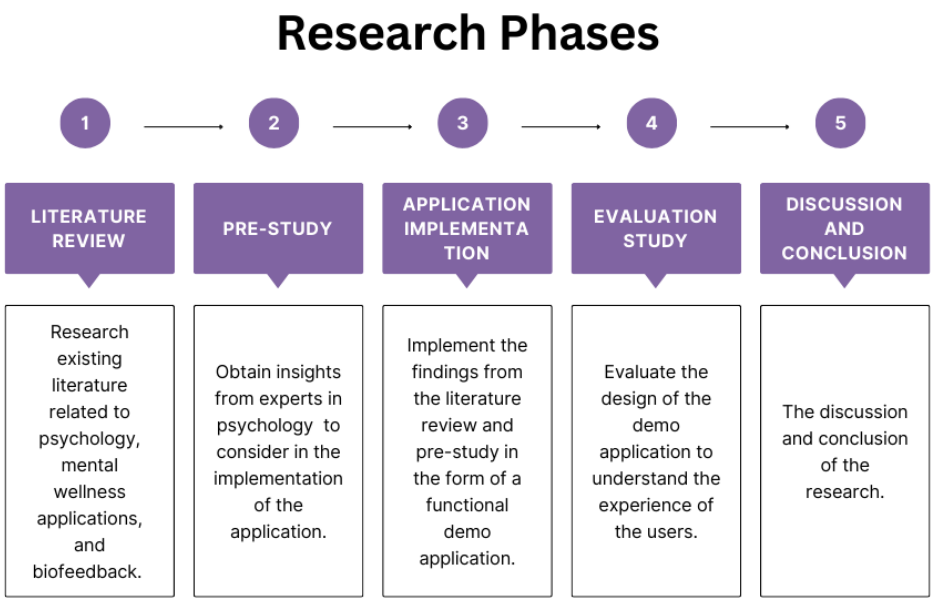

***Figure 7**. The research phases of this Thesis.*

Phase 1 – Literature review. This phase aims to explore relevant literature with the purpose of understanding how our research can complement the preexisting knowledge about similar technologies.

Furthermore, we investigated three main subjects. First, a suitable psychological treatment for anxiety which has the potential to be implemented in a mobile application. Second, analyze existing mental wellness applications that can serve as inspiration for the application that we will develop. And third, how biofeedback devices that utilize notifications are implemented to improve the wellness of people.

Phase 2 – Pre-study. During this phase we obtained the guidance of experts in psychology to design and develop a demo application that utilizes biofeedback to enhance the user experience of its users. Moreover, in an interview the psychologists were able to express their opinions on the basic idea of the application and then this information was considered while implementing an application in the next research phase.

Phase 3 – Application implementation. This phase consists of implementing the knowledge from the first two phases into a functional demo application. This application is targeted towards students who deal with anxiety, and it utilizes a BD with the aim of improving the experience of its users. Furthermore, the application has two versions: one that utilizes biofeedback and one that does not.

Phase 4 – Evaluation study. Ten students were recruited and separated into two user groups, one group for each version of the application. After a student used their corresponding version of the application for three days, they were interviewed to understand their experience. Additionally, their activity usage logs were recorded while they utilized the application. Once the data from all the students had been gathered, the researcher analyzed the data from the interviews and usage logs.

Phase 5 – Discussion and conclusion. This phase contains the analysis and interpretation of the obtained findings from previous phases.

3.2 Research Approach

The previously defined research phases are derived from *Human-Centered Design (HCD)*. HCD is defined as “an approach that puts human needs, capabilities, and behavior first, then designs to accommodate those needs, capabilities, and ways of behaving” (Norman, 2013, p. 8).

According to Harte et al. (2017), HCD consists of four phases: (1) definition of target users and context of use, (2) identifying the relevant requirements, (3) ideate a solution, and (4) evaluate if the proposed solution fulfills the established requirements.

Phases 1, 2 and 3 of this Thesis address phases 1, 2 and 3 of HCD, phases 4 and 5 of this Thesis correspond to phase 4 of HCD.

3.3 Data Collection Methods

Quantitative data collection methods were used in the evaluation study. Usage logs containing numerical data were recorded with the purpose of analyzing the level of engagement that the users had with the developed mental wellness application. As stated by

Grant et al., “quantifying allows us to make comparisons between, for example, individuals or groups according to some aspect of human behavior” (Grant et al., 2017, p. 5). Having this in mind we aimed to compare the level of engagement of the two user groups previously mentioned.

We gathered qualitative data from semi-structured interviews. In the pre-study the interviews obtained information from psychologists about requirements for the application. Moreover, in the evaluation study the interviews allowed us to evaluate the performance of the application from the target user’s perspective. According to Hammarberg et al. (2016), qualitative methods are suitable for exploring the users’ perspective and experience.

Additionally, we used a background questionnaire to gather information about the previous work experience of the psychologists who participated in the pre-study.

3.4 Data Analysis Methods

Statistical analysis was used to compare the usage logs of the two different user groups. As mentioned by Wettstein (2022), descriptive statistics can be used to discuss quantitative data that has been collected, moreover, they include numerical descriptions such as mean, median, mode, and standard deviation.

Thematic analysis was utilized to analyze the user interviews of the pre-study and evaluation study. In accordance with Nowell et al. (2017), this analysis method is commonly used in qualitative data analysis and is able to generate reliable results. X added that the thematic analysis consists of “identifying, analyzing, organizing, describing, and reporting themes found within a data set.” (Nowell et al., 2017, p. 2)

3.5 Research Platforms

The Moodmetric smart ring (Moodmetric, 2020a) is the BD we have chosen to use in conjunction with the developed application (see Figure 8). This ring is able to track the stress levels of a person in real time by perceiving the electrodermal activity on their skin. Moreover, the Moodmetric company provided two smart rings to be utilized in this research as well as the official SDK documentation which allowed us to connect to the smart ring via Bluetooth.

Figure 8. *A Moodmetric smart ring.*

A custom application was designed and developed by the researcher. The application is a web system built using React for its front end, JavaScript for various functionality, and Firebase for the database. Additionally, personalized images were created to enhance the appearance of the application. To send email notifications we have used the EmailJS library. Furthermore, the application communicates with the Moodmetric ring through a Bluetooth connection utilizing the Web Bluetooth API.

4. PRE-STUDY

In this section we will discuss the objective, procedure, participant information, data collection methods, data analysis methods, and findings of the pre-study. Additionally, we will present the ethical considerations that took place during the study.

4.1 Objective

The objective of this study is to obtain guidance from experts in the field of psychology to design and develop a demo MWA based on ACT theory that uses a BD to send timely notifications to the users. Furthermore, the basic idea of the application will be presented to the psychologists to evaluate it as well as acquire insights from an expert's perspective. With the development and later evaluation of this application it will be possible to answer all the research questions presented earlier.

4.2 Procedure

Each psychologist was contacted by email or personal phone number and explained the overall purpose of the study. After they agreed to participate, they were sent an informed consent form, a background information questionnaire, and a link to an online meeting. During the meeting the participants were given more information about the objective of the study, the BD to be used in conjunction with the MWA, and the main idea behind the MWA to be developed (see Figure 9). With this introduction the psychologists had a better understanding of the intentions and objectives of the researcher, afterwards, they were asked semi-structured questions with the purpose of orienting the author about the possibilities, usefulness, and characteristics that the MWA should have. See Appendix B for the full interview script.

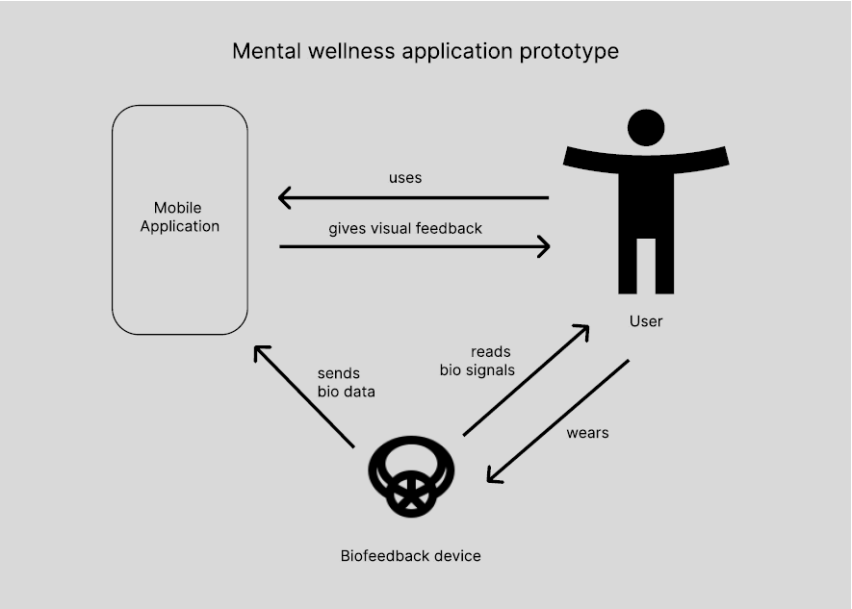

Figure 9. *Diagram presented to the expert participants during the introduction.*

4.3 Participants and Ethical Considerations

Three psychologists were recruited for the pre-study through convenience sampling. Two of them spoke English, however, one participant's preferred language was Spanish, thus the researcher created Spanish versions of all forms, additionally, their interview data and results were translated from Spanish into English by the author. According to the background questionnaires, all of the psychologists have a relevant educational background, practical experience in the field of psychology, an overall understanding of ACT, and familiarity with BDs (not Moodmetric specifically but BDs in general). However, one of the participants has not used ACT in their work. See Table 3 for a detailed description of the participant's background information.

Table 3. *Gathered background information of the participants.*

	Participant 1	**Participant 2**	**Participant 3**
Professional title	Study psychologist	Clinical psychologist	Psychologist
Bachelor's degree or equivalent	Bachelor's in clinical psychology	Clinical Psychology	Bachelor's in psychology

Postgraduate degree(s)	Master's in clinical psychology	Clinical Psychology	None
Years of experience working in the field of psychology	1	2	33
How familiar are you with Acceptance and Commitment Therapy (ACT) from 1 to 5 (1 = not at all, 5 =very familiar)	4	2	3
Have you used ACT in your work?	Yes	No	Yes
How many years have you used ACT in your work?	1	0	10
Are you familiar with BDs?	Yes	Yes	Yes

As previously mentioned, all participants signed an online informed consent form in which they were presented with the following information:

- The purpose of the study.
- What their involvement with the study consists of.
- Reassurance about their participation being voluntary. They can take a break, leave, or withdraw from the study at any time.
- How their data will be used. Only people involved in the study will have access to their data, and any comments or data that is published will be anonymous.
- Storage of their data. All gathered information will be stored securely and destroyed after it is no longer necessary.

At the end of the form, they were able to select if they agreed or not to the terms and write their name as a signature. See Appendix A for access to the full consent form and background questionnaire (English and Spanish versions).

4.4 Data Collection Methods

The data collection methods used in the study are listed below:

- ***Questionnaire:*** As seen in Appendix A, online questionnaires using Microsoft Forms were given to the participants before the interviews to understand more about their knowledge regarding psychology, ACT, and BDs.
- ***Semi-structured interview:*** All participants were interviewed in an online meeting. Two of the interviews were recorded using Microsoft Teams and the transcriptions were obtained through the integrated transcription functionality of said software. Moreover, one of the interviews was recorded on Zoom and later transcribed using Microsoft Word's transcription option.

4.5 Data Analysis Methods

All interview transcripts were downloaded as Microsoft Word files and later analyzed using the *thematic coding* method. Furthermore, the transcripts were read by the researcher, then the codes and themes were highlighted using the comments and highlighter functionalities in Word. Participants one, two and three are referred to as P1, P2, and P3 respectively.

4.6 Findings

The findings from the semi-structured interviews were categorized into the following eight themes:

Mindfulness exercises. P1 and P3 referred to guided breathing exercises as a good option to include in the mindfulness exercises for the mobile application to be implemented as part of this thesis.

P1: "It can be an audio that tells you for example, when you breathe in and breathe out, and then it has some kind of visual signal at the same time that tells you to start with the long exhale because that's the best way I think to activate the vagus nerve and then activate the parasympathetic nervous system."

As previously mentioned by P1, deep breathing has a correlation with activating the vagus nerve which is one of the most important nerves of the parasympathetic nervous system (Cleveland Clinic, 2022). According to the University of Toledo (n.d.), when the fight, flight, or freeze response is activated most of the oxygen is sent to the extremities, thus leaving the brain with less oxygen. When a person takes deep breaths, they allow

more oxygen to be transported to their brain and their body sends a signal to the parasympathetic nervous system to let it know they are safe and are able to relax.

P1 and P3 noted the importance of focusing on the current state of the body and accepting it.

P3: "The important thing is that they (the meditations) help you notice your current physical state, in other words, how your body feels, how much tension you are feeling, etc., this way the users can realize they were in fact very tense."

Moreover, P1 recommended the use of metaphors as a visualization tool in meditations.

P1: "For example, a video of a sky with some clouds and then having an audio file or someone saying this thing out loud. This kind of metaphor and exercise would be really useful."

Sources of inspiration for mindfulness exercises. P1 suggested the Student's Compass online program by Tampere University as a source of inspiration to implement mindfulness exercises in the application. P3 considered the search engine Yahoo to be a good source to find meditations, preferably containing music, guidance, and with a short duration.

Suggestions for notifications. In accordance with P1 as well as P3, the application should alert the users if their stress levels are too high. Furthermore, P3 added that after receiving the notification the application should suggest an activity that distracts the users from the cause of their tension.

P3: "The phone could let you know that your stress levels are elevated by alerting you with a sound. Then tell you to do an activity that distracts you such as going for a short walk or meditating."

P1 shared other ideas related to notifications such as reminding the users daily to use the application, allowing users to decide when to receive the reminders, and encouraging the users to utilize the application during another activity that is already part of their routine.

Suggestions for the application's functionality. P1 stated three main suggestions for this theme. First, it could be useful to block all other applications running on the user's device while they are using our application, with the purpose of reducing possible distractions. Second, the application would encourage users to "slow down" during their daily activities. And third, one of the functionalities should be to allow users to notice their avoidance behaviors (coping mechanisms that can feel good in the moment but are potentially harmful long term).

P2 mentioned that while being a patient of a cognitive therapist, they had to notice challenging situations in their daily life that would bother them or cause them fear and write them down as soon as possible. Thus, it would be helpful if the application detected that something has troubled the users and reminded them to make a note, this could facilitate taking notes at the right time.

According to P3, users would be more likely to utilize the application if they were somehow informed about how high levels of stress affect the human body and can result in developing chronic illnesses. Additionally, P3 believes implementing music in the application can have a positive impact on the users' stress, and it would be ideal to let them choose amongst different options, however, music that can be potentially triggering should be excluded.

P3: "Maybe there could be a function to let the users choose the music within certain limits, not loud music, such as heavy metal, and preferably without lyrics".

Suggestions for the application's graphical interface. All three participants shared their opinions about the most suitable colors for the application. P1 believed colors related to nature would be best, P2 chose calm and warm colors, and P3 mentioned the colors should be interesting yet calming.

P1 stated the application should have an overall slow and soothing appearance and recommended the use of nature images, videos, and audios.

ACT implementation. P1 and P2 mentioned the importance of allowing the users to work on their life values in the application, as we previously learned in the related work section defining life values is one of the core processes of ACT.

P1: "If you want to have an application that's based on ACT, it has to have something about life values. Make sure that the users are living life according to their values and they should take actions that are aligned with their values."

P2: "I understand that according to ACT, you need to see what your values are, set goals and make a plan."

P1 explained that ACT frequently uses metaphors in mindfulness meditations to represent the workings of the human mind and help patients to understand as well as accept their emotions. P1 gives a common example of this kind of symbolic meditation:

"Imagine that your mind is like the sky and your feelings are like the clouds. You might not like all the clouds. You might not like the rain clouds for example, or you might not like the Thunder clouds, but because it is the sky, you know that the clouds will always pass, so there's no point in being angry or mad at the clouds."

As stated by P2, the application should have a diary in which the users can focus on understanding how they feel.

Usefulness of the BD. P1 and P3 mentioned that some people do not notice when they are experiencing high levels of stress and thus it would be helpful if the biofeedback device could sense when the users are anxious and then notify them. P2 considered that alerting the users when they are stressed can be a good addition to a mental wellness application and it is more innovative than a regular anti-stress application.

Considerations when using the BD. P2 made some interesting observations regarding the use of the biofeedback device. They mentioned that because stress can be positive or negative, for example if a person is playing a video game they can feel positive stress in the form of excitement, and this fact should be kept in mind while developing the application. Furthermore, they indicated that the size of the BD could potentially cause it to be uncomfortable for the users.

4.7 Summary

Three psychologists were contacted and interviewed to obtain their expert opinions and insights. According to the results obtained from our background questionnaires they all had relevant experience in the field of psychology and at least some familiarity with ACT theory.

The findings from the semi-structured interviews resulted in eight themes. First, the MWA to be developed should have *mindfulness exercises* that help users to focus and accept the present moment through breathing techniques, additionally the use of metaphors was encouraged. Second, as *sources of inspiration for the creation of the mindfulness exercises* the psychologists recommended the Student's Compass program as well as the Yahoo search engine. Third, the psychologists suggested the following ideas regarding the *notifications* to be implemented in the MWA, an alert when the users' stress levels are too high followed by an activity that helps distract the users, daily reminders to use the application, allowing users to decide the timing of the notifications, and integration into the users' routine. Fourth, various *suggestions regarding the MWA's functionality* were expressed such as blocking other applications to prevent distractions, notes, music choices, etc. Fifth, the *graphical interface* should have calming colors and nature related elements. Sixth, some elements of *ACT* were highlighted by the psychologists to be implemented in the MWA including definition of life values, metaphoric meditations, and a diary. Seventh, regarding the *usefulness of the BD* it was mentioned that it was a good thing that the device could detect high stress levels and notify the users. Eight, some

considerations regarding the use of the BD were indicated such as the device detecting positive as well as negative stress and issues related to the size of the BD.

5. DESIGN

It was necessary to develop a functional web based MWA to be able to implement the knowledge gathered from the related work section as well as the findings from the pre-study section. This application will be later evaluated to answer all the research questions defined previously. Additionally, since the users must utilize the application during their own personal time, a mock application would not have been sufficient to evaluate their user experience. In this chapter we will explore the design of the MWA created for the purposes of this research.

5.1 The Biofeedback Device

As previously stated, the BD used in conjunction with the application is the Moodmetric smart ring (Moodmetric, 2020a). The BD connects to the MWA through Bluetooth and streams the stress level of the user in real time until the connection is lost or turned off.

Each user must wear the device and then connect it to the application. If the BD detects that the stress level of the user has been high continuously for five minutes, it will send them an email notification to an address provided at the time of registration into the system. The email address should be connected to an email mobile application (e.g., Gmail, or Outlook) which can send them push notifications when they receive a new email. In this way the users can receive timely notifications in their phones when they are stressed by outsourcing this functionality to the email mobile application. See Figure 10 for an example of what the email notification would look like.

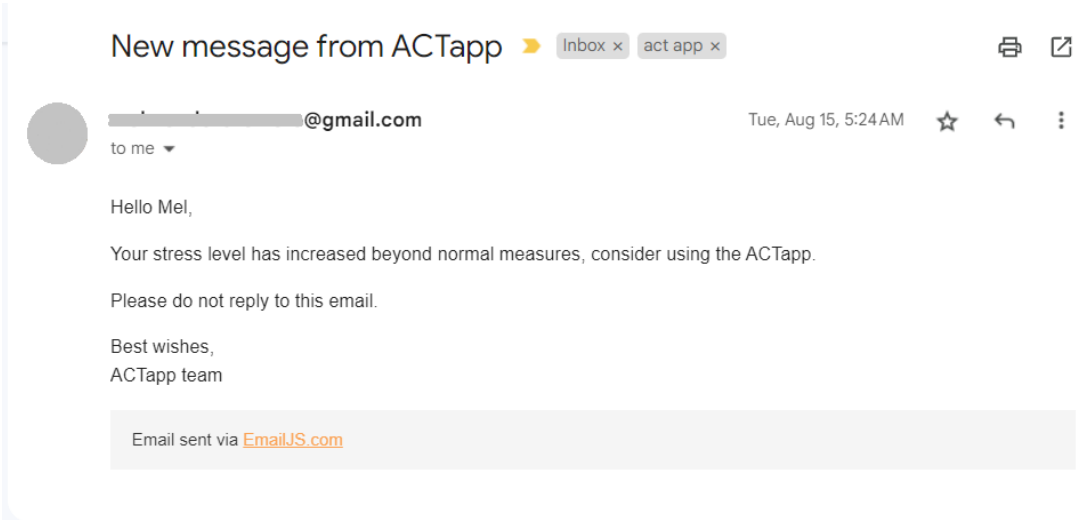

Figure 10. *An email notification is sent to the users when their stress levels are high.*

The Moodmetric smart ring (Moodmetric, 2020a) was considered to be a good option for this research. As explained to the psychologists in the pre-study (see Appendix B), this device measures the electrodermal activity of the users' skin which is connected to the sympathetic nervous system (Moodmetric, 2020b). Moreover, this measurement as well as this device have been used successfully in scientific research (Moodmetric, 2021; Venho, 2020).

5.2 User Interface Versions

As previously mentioned, a web-based application was created to be evaluated by the users. The user interface of the MWA has two versions, one version interacts with the BD and the other does not, we will refer to them as "With Ring Version" (WRV) and "No Ring Version" (NRV) respectively. The links for both versions of the application are listed below:

- WRV
- NRV

In both versions the application must be accessed through an internet browser, preferably Google Chrome web browser (mobile or desktop version) should be used to ensure optimal performance. Furthermore, the application can be utilized in both desktop and mobile devices, however, the WRV can only be accessed in Android mobile devices since it is not currently compatible with iOS. The NRV is compatible with both Android and iOS.

We chose to create a website since the researcher in charge of developing the MWA was familiar with web system development and due to time restrictions it was not possible for them to learn how to implement a native mobile application. In addition, a website can be accessed in mobile devices as well as desktop computers giving the application more flexibility and allowing participants who do not have access to an Android device to be a part of the study by using the MWA in their personal computers. See section 3.5 for information about the technologies used to develop this application.

5.3 Images and Colors

In accordance with the requests of the participants in the pre-study, the graphical interface of the application contains colors and images that relate to nature but are still interesting to the eye. The inspiration for the overall look of the application was Finland in the autumn season with a minimalistic cartoon appearance.

A background image was created for desktop devices consisting of a forest with birch trees and a bear (see Figure 11). These elements were chosen since birch trees are commonly found in Finnish landscapes and the brown bear is the national animal of Finland.

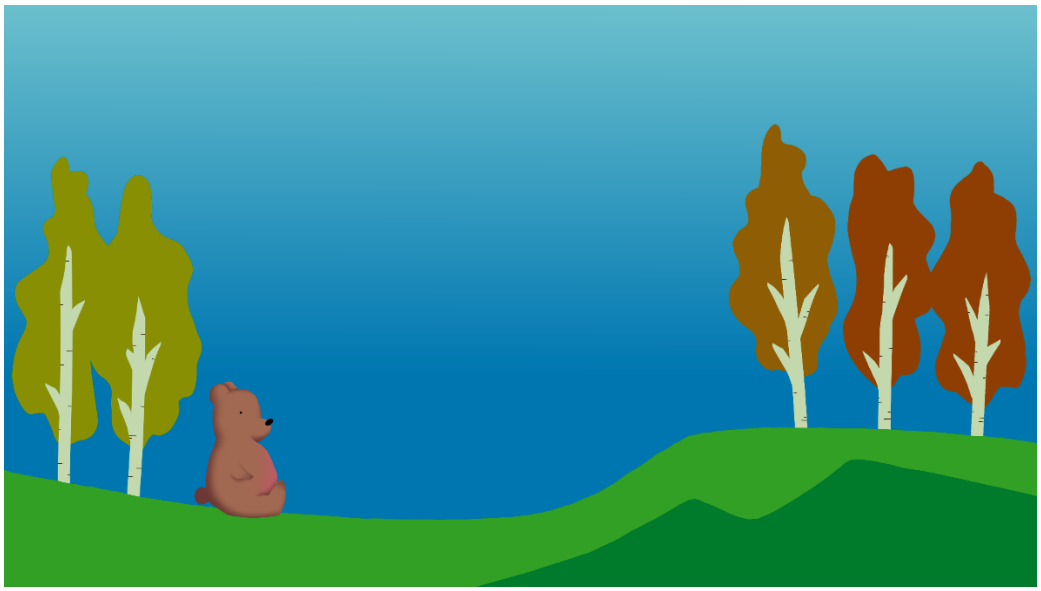

Figure 11. *Desktop background image.*

The background image for mobile devices is similar, however, the bear was omitted to maximize the space in small screens (see Figure 12).

Figure 12. *Mobile background image.*

The background images appear in the landing and home pages of the application, we will explain more about these pages later in this chapter.

The application has a logo that complements the rest of the design (see Figure 13). It contains red and yellow tones that are reminiscent of autumn and a simple shape which complements the overall minimalistic cartoon appearance of the application.

Figure 13. *Logo of the application.*

In the WRV there is an icon that represents the Moodmetric smart ring (see Figure 14). It has a minimalistic and simple design that is cohesive with the rest of the interface as well as colors that match the color palette of the application.

Figure 14. *Icon representing the BD.*

5.4 Registration and Login

The first time the users access the application they will encounter a landing page preventing them from moving forward until they complete a registration (see Figure 15). In the landing page the users will be unable to access any other sections of the website, moreover, if they click on the menu options, they will be redirected to the landing page. This page contains a welcome message and instructions to sign in or register.

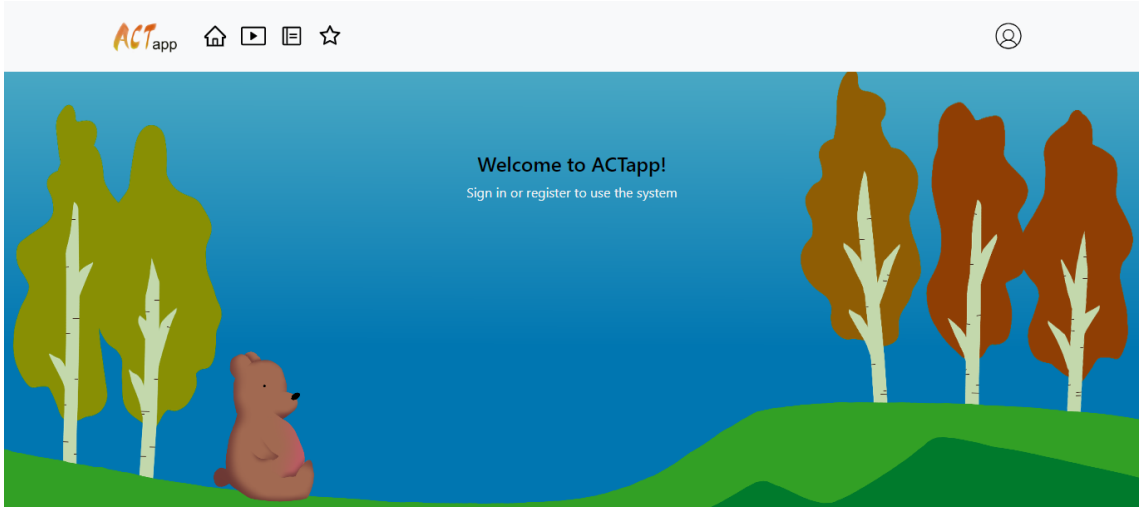

Figure 15. *Landing page.*

To register the users must fill in a form (see Figure 16) with their desired username, email, and a password. After they have registered into the system successfully, the next time they access the website they can log into their account by entering their email and password (see Figure 16).

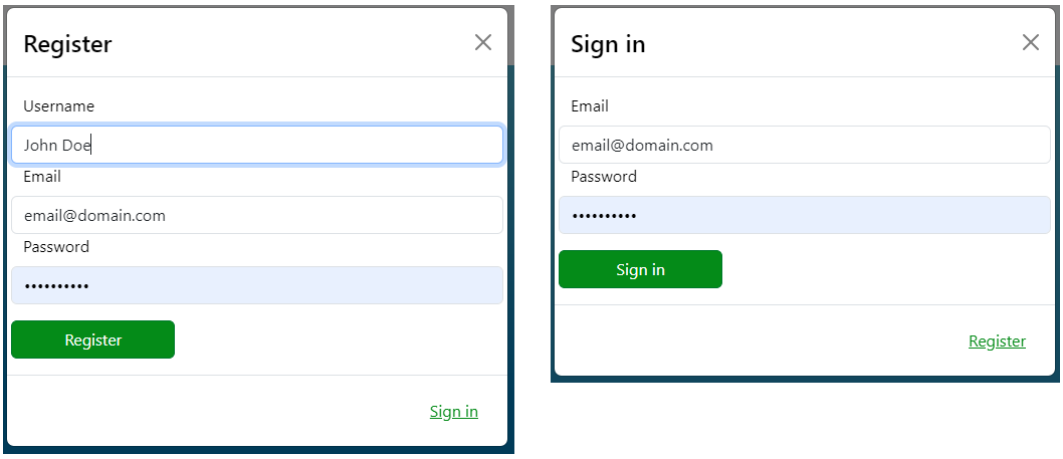

Figure 16. *Register and Sign in forms.*

It was necessary to have accounts for each user so they could access their corresponding saved entries and their usage logs could be correctly organized in the database.

5.5 Navigation and Home Page

The navigation of the MWA is achieved through a menu bar that is always visible at the top of the screen (see Figure 17). From left to right, it has a logo (which doubles as an extra link to the home page), links to all sections of the application represented by icons, a greeting message containing the username, and a logout button.

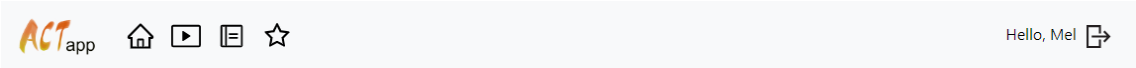

Figure 17. *The application's menu bar.*

The menu bar was created in this way to achieve a well-balanced design. The application's logo is displayed at the top left corner since this is a common practice in other applications. Each icon has an image that is related to the content of the section it is linked to; the home page has a house icon, the mindfulness exercises/learning videos section has a play button, the diary section has a little notebook, and the values section has a star. Icons were chosen instead of labels to create a more dynamic look and maximize space. The greeting message serves as feedback, once the users have registered or signed in it is reassuring to see their corresponding username on the screen. The logout button is placed at the top right corner as is frequently found in various applications.

The home page in the WRV (see Figure 18) contains the functionality related to the BD. It consists of an icon that represents the Moodmetric Ring, a label that indicates the state of the connection to the BD, a number that represents the stress level of the user, and a button to start or stop the connection to the BD.

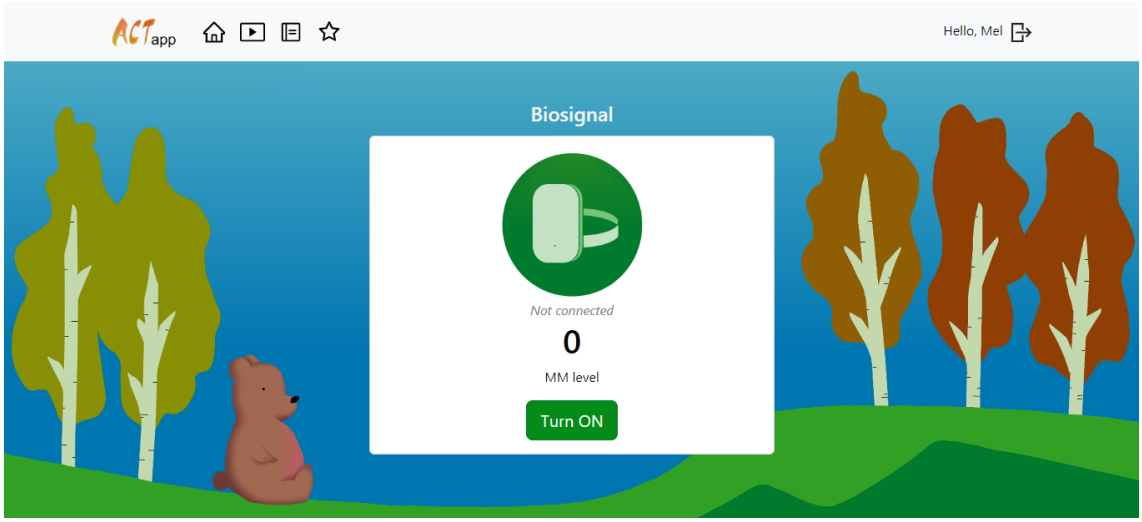

Figure 18. *Home page of the WRV.*

Since the NRV does not have any interaction with the BD, the biofeedback functionality in the home page has been replaced by a quote that evokes feelings of calmness and acceptance (see Figure 19).

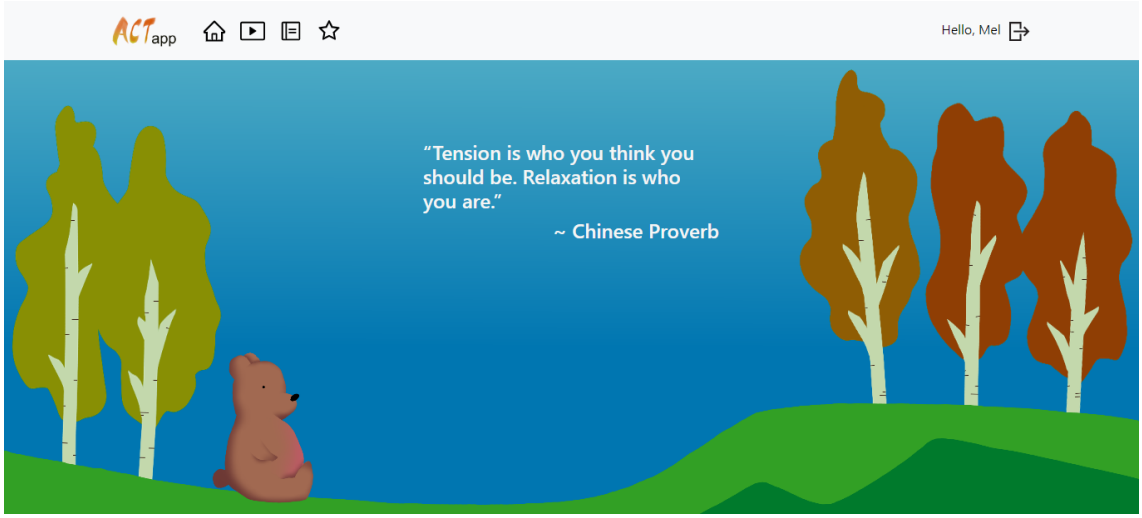

Figure 19. *Home page of the NRV.*

5.6 Mindfulness Exercises and Learning Material

According to the related work chapter, ACT intends to help people connect with the present moment (*contact with the present moment*), practice acceptance of undesirable feelings (*acceptance*), and create distance between them and their thoughts (*defusion*). To address this, we have provided mindfulness exercises that the users can follow when they are stressed.

Moreover, the psychologists in the pre-study suggested certain characteristics for the mindfulness exercises such as guided breathing techniques, directing the attention to the state of the body and conforming to it, as well as utilizing metaphors.

Thus, we have included the following video mindfulness exercises in the application:

- I'm Noticing the Thought: A Mindfulness Exercise. This video (University of Utah Health, 2021) has nature imagery and sounds, calming music, as well as a guided meditation that uses the *"leaves on a stream"* metaphor. As seen in the video, this metaphor consists of leaves, which represent thoughts, that are floating away on a stream. This allows to create separation and acceptance of challenging thoughts.
- Dropping Anchor - ACT Mindfulness Practice. It displays a person who guides the mindfulness exercise and gives information about the technique being used in the meditation. As stated by the video creator (Russell, 2022), this exercise utilizes the *"dropping anchor"* technique that helps people acknowledge thoughts and feelings, come back into their body, and focus on what they are doing.

- Mindfulness of breath - (ACT) Meditation. As mentioned by the author of the video (Well Mind & Body Psychology, 2022), the mindfulness exercise consists of a guided breathing technique that allows people to focus on their current physical state.
- Leaves on a Stream Meditation. This exercise (Eating Recovery Center, 2020) used the previously mentioned *"leaves on a stream"* metaphor. However, it contains a calming cartoon animation, offering a different visualization style than the first guided video.
- Meditation For When Emotions Feel Too Big - Guided ACT Skills. This video (McLaughlin, 2023) contains ocean related images, a guided meditation, and no music. As mentioned by the author of the video, the guided meditation uses a technique known as "urge surfing" that aids the listeners to cope with difficult emotions.

All videos have different styles, techniques, and durations to offer the users a variety of options.

Furthermore, we have included the learning material in the form of videos that are optional to watch and can offer additional insights for the users. We will list the learning videos below:

- What is Acceptance Commitment Therapy? This video provides general information about ACT in a simple and quick way (Psych Hub, 2019).
- How stress affects your body - Sharon Horesh Bergquist. The author of this video (Bergquist, 2015) explains how high levels of stress can affect our physical health. We have decided to include this video since one of the psychologists in the pre-study considered it was important to inform the users about the impact that stress has on their body and potential health risks.
- Values vs Goals - By Dr. Russ Harris. This video presents the difference between life values and goals (Harris, 2015).
- How do you work out your personal values. The video creator provides a guide to create personal life values (Ash, 2021).
- Committed Action: Acceptance and Commitment Therapy (ACT Core Processes). This video contains information about the committed action core process of ACT as well as guidance to set committed actions that are in alignment with a person's values (Borushok, 2022).

The last three videos are meant to help users who might struggle to define their life values and committed actions plan.

5.7 Values Section

As stated in previous chapters, one of the six core processes of ACT is to define our *values* to use them as a guide or motivation to live a more fulfilling life. Another important core process is *committed action* which consists of creating actionable steps meant to fulfill a person's life values. Additionally, in the pre-study the psychologists mentioned the importance of including an implementation related to life values in the application. With this in mind we have created a section dedicated to values (see Figure 20).

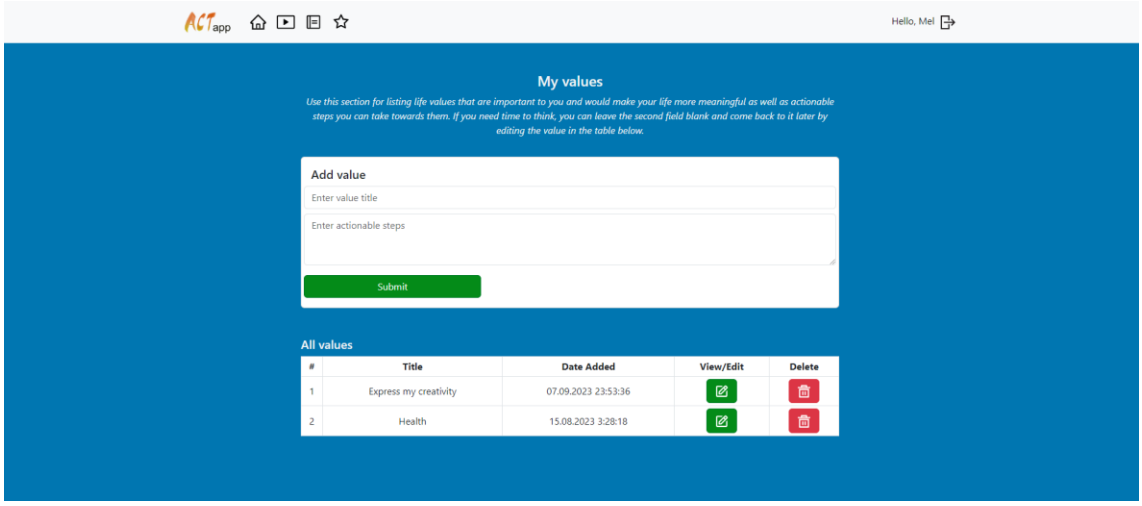

Figure 20. *Values section.*

In this section of the application the users are able to work on their life values and committed actions. The main objective is for the users to reflect on what their life values are as it is possible that they have not taken the time to do this before, in addition, the users can create an actionable plan to incorporate their values into their lives. There are written instructions that explain to the users how they should proceed, a form in which they can create new values, as well as a table in which they can see, edit, or delete existing values. If the users click on the view/edit button of a value, they will see a pop-up window containing the full description of the value as well as an option to edit the value which will prompt a form that allows them to edit the value's title and description.

5.8 Diary Section

According to the psychologists interviewed in the pre-study, it is useful to help users notice their *avoidance behaviors* as well as the challenging situations in their daily life, for this reason it can be useful to have a diary. Moreover, as stated in the related work

section, Ahtinen et al. (Ahtinen et al., 2013) recommends providing a diary that allows the users to self-reflect. In addition, we have learned in the related works chapter that ACT aims to minimize *experiential avoidance* in people. Considering this information, we have included a diary section in the MWA (see Figure 21).

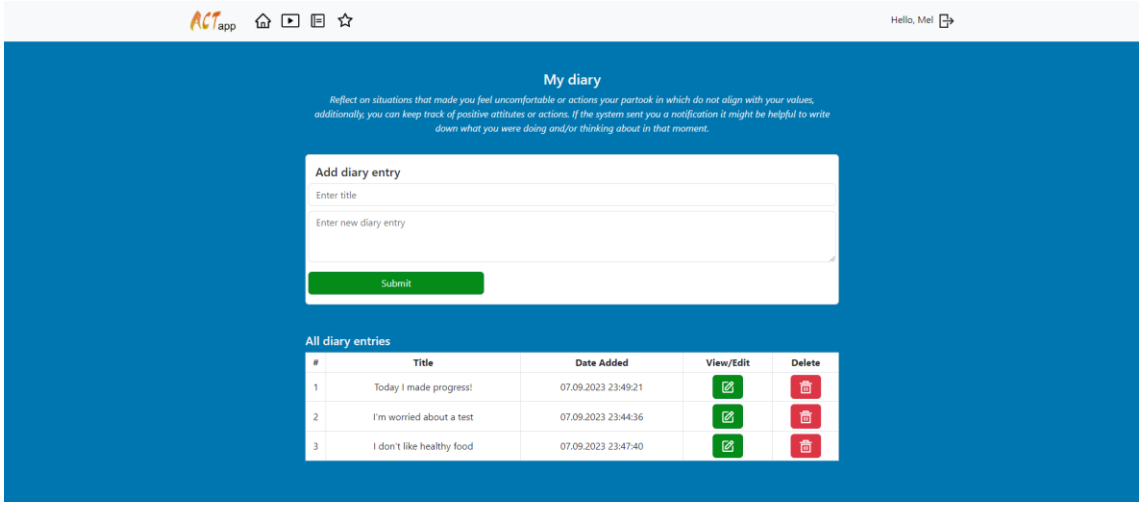

Figure 21. *Diary section.*

The interface of the diary section is similar to that of the values section. It contains written instructions, a form to create new diary entries, and a table with all the corresponding diary entries. The existing diary entries can be viewed, edited, and deleted in the same way as in the values section. The purpose of this section is to allow the users to reflect on their positive and negative actions related to their life values as well as situations that make them uncomfortable, furthermore, this way they can keep track of how and if their values are being assimilated as well as how they are dealing with the challenges that arise in their lives.

6. EVALUATION

In this chapter we will discuss the objective, procedure, participant information, data collection and analysis methods, as well as the findings of the evaluation study for the application mentioned in the previous chapter. Moreover, we will explain the ethical considerations that took place during the evaluation study.

6.1 Objective

The aim of this user study is to evaluate the design of the application we have developed as well as to understand the users' perspective during their interaction with the system and the BD. Furthermore, we will answer the first two research questions *(RQ1: What is the user experience of the developed application for students who suffer from anxiety? and RQ2: What is the perception of the biofeedback device integrated into the developed application for students who suffer from anxiety?)* with semi-structured interviews after the users have utilized the application. In addition, to address the last research question *(RQ3: Can timely notifications in the developed application increase the engagement of students who suffer from anxiety?),* we will analyze the saved usage logs of the application.

6.2 Procedure

To better understand the impact that the BD has on the experience of the users we have divided them into two groups: *With Ring Users (WRU)* and *No Ring Users (NRU)*, both groups containing 5 users each, thus having a total of 10 users for the evaluation study. Since the WRU group has used the BD in conjunction with the application and the NRU group has used only the application without the BD, we aim to compare the experiences of both groups to understand how the BD and notifications have affected their interaction with the application.

Each user in the WRU group would join an in-person introductory meeting, calibrate the BD by wearing it for 12 hours, use the WRV of the application for three days, return the BD to the researcher, and participated in an interview to understand their experience using the MWA (see Appendix E).

During the introductory meeting the researcher would provide an informed consent form, an overview of the application, instructions for the procedure and expectations of the evaluation study (see Appendix C), and technical support for configuring the necessary

software as well as starting the calibration process of the BD. See Appendix A for access to the informed consent form shared with the users.

Each day that the users were utilizing the application, they were expected to achieve the following objectives:

- Wear the ring for at least 12 hours.
- Do one of the meditation exercises.
- Create one diary entry.
- Create one value.
- If the system sends you a stress notification (by email) please follow one of the meditation exercises to help you calm down.
- If you feel very stressed, do one of the meditations or write a diary entry even if the system did not send a notification.

Additionally, they had these optional tasks:

- Wear the ring for longer.
- Do more meditation exercises.
- Watch some learning videos.
- Create more diary entries and values (you can create as many as you want per day).
- Edit a diary entry and/or value.

The users in the NRU group had a similar process, excluding the aspects related to the BD. Since this group was not intended to have any interaction with the BD, they were given access to the NRV of the application which does not send any notifications and is independent from the BD. The user study process of this group took place fully online. See Appendix D for the instructions document shared with this group, Appendix F for the full interview script, and Appendix A for access to the informed consent form.

6.3 Participants and Ethical Considerations

Ten university students were recruited for this evaluation study through convenience sampling. The initial requirements for them to participate were to be studying a graduate or postgraduate degree at the time of the study, they had to be able to speak English,

and they had to have access to a desktop and/or mobile device for the duration of the study.

However, the researcher decided to divide the users into two groups: WRU and NRU, containing 5 users each. There were additional requirements for the WRU user group. Namely, they had to be physically present in Tampere Finland, which is where the researcher resided at the time of the study, and they had to be able to attend at least one in-person session. There were no additional requirements for the NRU group other than the initial ones.

All the recruited students signed an informed consent form in which they were presented with the information listed below:

- The purpose of the study.
- What their involvement with the study consists of.
- Reassurance about their participation being voluntary. They can take a break, leave, or withdraw from the study at any time.
- How their data will be used. Only people involved in the study will have access to their data, and any comments or data that is published will be anonymous.
- Storage of their data. All gathered information will be stored securely and destroyed after it is no longer necessary.

At the end of the form, they were free to select if they agreed or not to the terms and write their name as a signature. See Appendix A for access to the full consent form and background questionnaire (WRU and NRU versions).

6.4 Data Collection Methods

The data collection methods used in this evaluation study are the following:

- ***Semi-structured interview:*** After using the application to be evaluated, the users participated in an interview with the purpose of understanding their impressions and experiences while using the application.
- ***Usage logs of the application:*** While the users utilized the application, their usage logs were automatically recorded in the application's database. The logs contained information about their actions such as videos watched, diary entries created, and values created.

6.5 Data Analysis Methods

All interview transcripts were downloaded as Microsoft Word files and later analyzed using the *thematic coding* method. Furthermore, the transcripts were read by the researcher, then the codes and themes were highlighted using the comments and highlighter functionalities in Word.

Statistical analysis was used to understand the information obtained from the usage logs of the application.

6.6 Findings

In this section we will present the findings of the evaluation study. We have divided the results into those pertaining to quantitative as well as qualitative data. The former consists of the statistical analysis of the usage logs of the application and the latter contains the thematic analysis of the semi-structured interviews. The users 1 to 5 belong to the WRU group and users 6 to 10 correspond to the NRU group.

6.7 Quantitative Data

As already stated, we have statistically analyzed the usage logs of the developed MWA to compare the engagement of both user groups in an effort to answer the RQ3. We present in Table 4 the relevant raw usage log data that was used as input for the statistical analysis.

Table 4. *Usage log data sets of all users containing the number of videos played, diary entries created, and value entries created.*

	Videos Played	Diary Entries	Values
WRU GROUP			
User 1	5	3	0
User 2	5	5	3
User 3	4	3	2
User 4	6	3	3
User 5	4	1	1
NRU GROUP			
User 6	10	5	4

User 7	3	3	3
User 8	1	3	5
User 9	9	3	3
User 10	2	3	2

Each time the users clicked play on a video, regardless of whether they watched the entirety of the video or not, the system would count that interaction as a video played and stored the information in the database. This includes videos that are classified as both mindfulness exercises as well as learning material in the application.

As we can see in Figure 22, we have compared the quantity of videos watched per user group. The mean is 4.8 and 5 for WRU and NRU respectively, which means on average the users from both groups watched a similar number of videos. However, there is some variation in the median values of both groups, in WRU the median is 5 and in NRU it is 3. The mode in the WRU groups is 5 and, in contrast, Excel returned #N/A (No value is Available) in the NRU group as no value was ever repeated in the data set (see Table 4). This information shows that there is a lot of variation in the values of the NRU group compared to the WRG which has more uniform values. Similarly, there is a significant difference between the standard deviation of both groups. Moreover, WRU has a standard deviation of 0.83 and NRU has 4.18. Clearly, there is a large variation in the values of the NRU group, compared to the WRU group which has an overall homogenous data set (refer to Table 4).

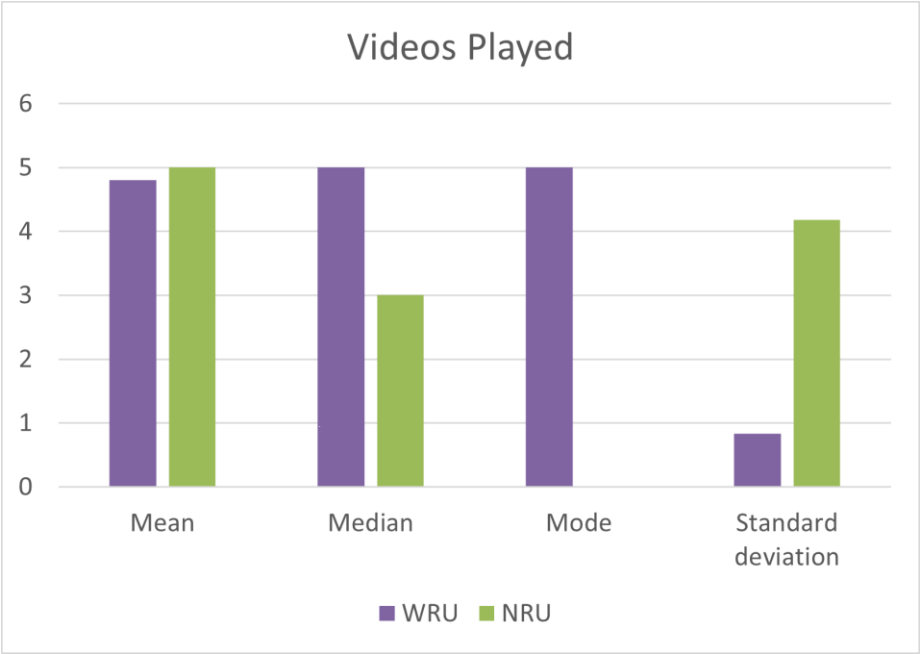

Figure 22. *Statistical data of the usage logs related to the meditation exercises and learning videos in the application.*

As we can see in Figure 23, there is comparable data in the usage logs of both user groups regarding the created diary entries. Moreover, the mean quantity of created diary entries is 3 in the WRU group and 3.4 in the NRU group, both values being vastly similar. The mean and mode values are 3 in both groups. Likewise, the standard deviation is 1.41 and 0.89 in the WRU and NRU groups respectively, thus not having a significant variation among the values of both data sets.

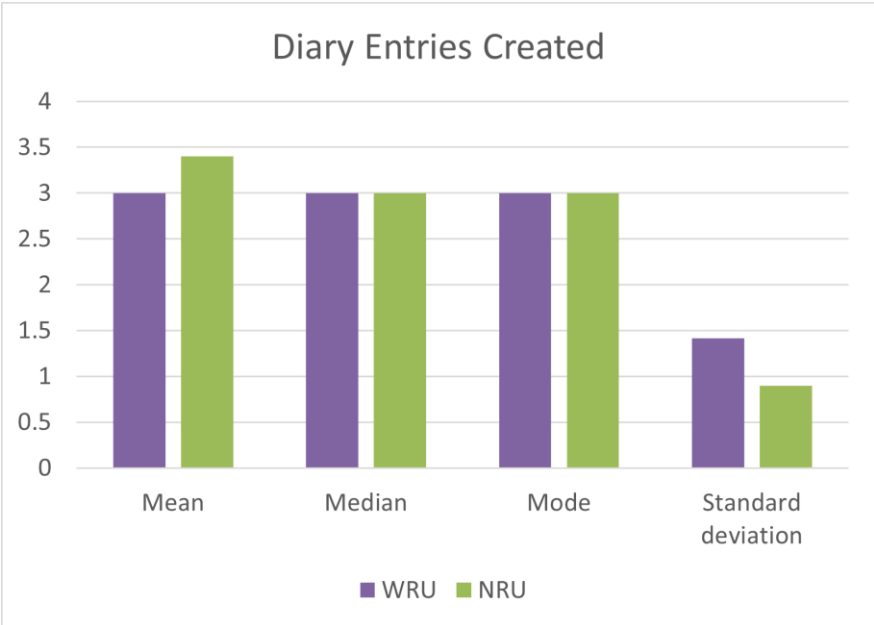

Figure 23. *Statistical data of the usage logs related to the diary section of the application.*

Similar to the previous analysis, there is an overall consistency among the data sets of both groups in the case of the number of created values (see Figure 24). However, there is an average number of 1.8 created values in the WRU group and 3.4 in the NRU group, both values have a greater difference compared to the mean values of the last two analyzed date sets (videos played and diary entries created). Moreover, we can deduce that the users in the WRU group created significantly less values than the users in the NRU group on average. The median is 2 and 3 in groups WRU and NRU respectively, which does not represent a great difference. The mode is 3 in both groups. The standard deviation is 1.30 in WRU and 1.14 in NRU, meaning, the variation of the values in the data sets of both groups is not greatly significant.

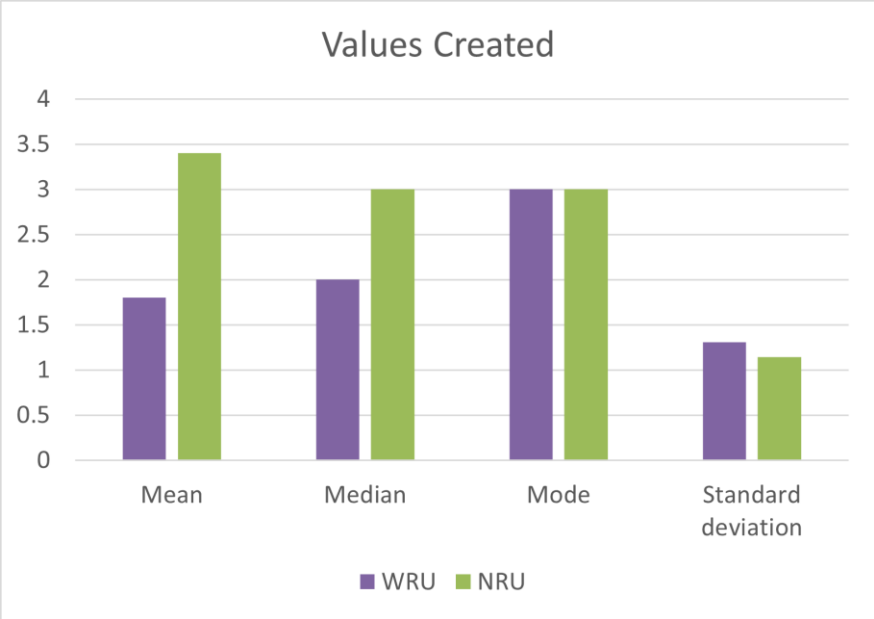

Figure 24. *Statistical data of the usage logs pertaining to the values section of the application.*

6.8 Qualitative Data

This section presents the findings related to the qualitative data of this study. This data has been gathered from the semi-structured interviews mentioned before and it aims to answer RQ1 as well as RQ2.

It is worth noting that in the WRU group, only Users 2 and 3 had access to an Android phone, thus they were the only users in this group with the ability of using the application in mobile as well as desktop devices. Since, as previously mentioned, the WRV of the application is compatible with most desktop devices, however, it is only compatible with

Android mobile devices. Thus, the users in this group who had iPhones were able to use the application on their desktop computer only.

All users in the NRU group were free to use the application in mobile and desktop devices as the NRV of the application is compatible with most desktop as well as mobile devices.

The results from the thematic analysis of the interviews were grouped into the following fifteen themes:

Navigation. All the users in the evaluation study believed it was mostly simple to navigate across the application. User 1 mentioned that the minimalistic design of the application made it easier to find everything. Users 2 and 8, did not consider the star icon in the menu bar to be suitable for the values section. Moreover, User 2 mentioned the star icon reminded them of a bookmark or favorites functionality. User 8 stated that the star icon seemed *"misleading"* to them. User 7 indicated that they did not understand what the icons meant at first, however, it was simple to discover where the icons lead to because the menu bar had few options.

Appearance of the application. Users 1,2,5, and 7 mentioned that the images and colors of the application seemed suitable to them. User 3 stated that they enjoyed the overall appearance of the graphical interface. Users 4 and 6 stated that their opinion regarding the colors and images of the application was neutral, however, User 6 added they felt that the colors could be more relaxing. Users 8 and 9 had opposing opinions about the colors of the MWA. Moreover, User 8 believed the colors were too bright and overwhelming, additionally, they would prefer more neutral colors. In contrast, User 9 enjoyed the colors of the application and perceived them as calming.

Meditation exercises. Users 2,9, and 10 mentioned that they enjoyed the meditations, however, User 4 stated that they do not like meditations in general because it makes them feel tired. User 5 added that instead of meditating, they preferred to do an activity that allowed them to *"turn their mind off"*.

Users 1 and 5 had never meditated before using the application. User 1 believed it was challenging to meditate at first but then it became easier over time. User 5 considered that the meditations were calming but they would not continue to practice meditation in the future. In contrast, Users 7 and 9 had previous experience meditating. Additionally, User 7 considered they would prefer more advanced meditations since these types of meditations seemed to be created for beginners.

Users 2, 8, 9 and 10 experienced relief from a stressful situation with the meditation exercises. Users 2, 9, and 10 considered that the meditations allowed them to see their troubles from a different perspective. User 2 enjoyed the ocean meditation because it

helped them to direct their attention away from themselves. Users 9 and 10 considered the leaves on a stream to be their favorite meditation exercise.

User 3 stated that they do not like meditations that contain music, and they prefer nature sounds instead.

Learning videos. Users 2, 4, 7, 8, and 10 did not watch any of the learning videos. However, User 4 felt motivated to research about ACT on their own, and User 10 stated that they would have watched some learning videos if they had more free time during the study.

Other users did watch some learning videos. Users 5, 6, and 9 mentioned that watching videos related to creating values helped them in defining their own life values. User 1 explained that the learning videos were helpful to understand other people around them who may be dealing with stress. User 3 watched the learning videos about ACT and thought it was interesting. User 9 watched most of the learning videos and found them informative, they considered that the videos were the right length and easy to understand.

Diary section. Users 1,3, 5, 6, 7, 9, and 10, did not experience any major issues while utilizing the diary section. User 1 considered that having a diary could be good practice for their mental wellbeing. User 3 said the instructions in this section were clear. Users 5 and 10 considered that keeping a diary can help make their thoughts clearer. Users 6 and 7 mentioned it was mostly easy to use this section. User 7 added that every time they had an idea, they would open the application and create a diary entry. User 9 stated that they enjoyed having a journal. They liked having something that encouraged them to start journaling and to be consistent. In addition, User 10 indicated that they had never kept a diary before, and it was a nice experience.

On the contrary, Users 2,4 and 8 did experience some difficulties in this section. User 2 had problems deciding what to write in the diary, however, they mentioned that after they wrote about a stressful situation it helped them to stop thinking about it. User 4 stated that they do not like journaling and found it hard to remember what had happened during their day and to summarize their thoughts. User 4 also mentioned that it would be helpful for them to have more specific questions about what to write in the diary section since they are not always sure if what they are writing is relevant. The experience of User 8 in this section was overall pleasant, nevertheless, it was overwhelming for them to write in the diary if they were already stressed. Additionally, User 8 declared that occasionally it was difficult for them to understand how they were feeling.

Values section. Users 5, 7 and 9 were the only ones who did not report any major issues while defining their values. In addition, User 5 said that writing down their values helped them to focus on them and define them further. User 9 stated that they enjoyed thinking more deeply about their values and it made them discover their importance.

The rest of the Users experienced difficulties while using this section. User 1 believed it was complicated to define their values and that it seemed like *"a very philosophical thing"*. User 2 struggled as well to define their values and were not sure if the values they wrote were correct. User 3 stated that it was difficult to decide what to write in this section and they were confused as to how this section was related to the rest of the application. User 4 considered it challenging to define their values but not as difficult as the diary. User 6 said defining their first value was easy, but the rest of the values were burdensome. User 8 had trouble defining their values as well and even more so while they were stressed. User 10 did not exactly understand what the values meant.

User 8 added that defining their core values allowed them to better understand themselves and deal with stressful feelings. Furthermore, they would like to continue this practice in the future.

The application's impact on the users' mental wellbeing. Users 3,4,7, and 10 did not experience any significant improvement on their mental wellbeing after using the application. However, User 4 noted that they did not have any stressful situations during the evaluation study.

Other users reported a subtle impact on their mental wellbeing. Users 1 and 2 considered it was beneficial to have a form of external feedback on their physical state. User 2 added that the reminders to calm down seemed helpful. User 5 stated that the application made them reflect on their wellbeing more than usual. User 6 mentioned that they had stopped smoking, and they believed an application such as this one could be a better way to take a short rest from work than a cigarette.

Users 8 and 9 felt a positive impact on their mental wellbeing after using the application. User 8 mentioned that the application allowed them to reduce their stress and manage their time more effectively. Furthermore, they indicated that the application made them feel more in control of their mental peace.

User 8: "It really helped me to manage my stress and worries. I was able to clearly think and understand my situation in a more concise way and I was able to plan my life in a way that has a little less stress."

User 9 stated that the meditations helped them to calm down on a stressful day and see their situation from a better perspective.

User 9: "I had a bit of a frustrating day, so when I watched the meditation video that helped me to calm down and realize that I sometimes overreact. So, in this sense, it helped."

General suggestions. Some users had suggestions about the variety and quantity of videos. Users 6 and 9 believed it would be better to have a wider variety of videos. On the contrary, user 10 preferred fewer videos and considered it was overwhelming to have too many options.

Users 4 and 7 indicated they would prefer to have daily reminders to use the application. User 7 added that it would be ideal to have the possibility of setting the time at which the reminders would happen.

User 4 had three main suggestions for the application. They believed it would have been helpful to have an example of values and diary entries and they mentioned it would have been ideal to have the application running in the background automatically.

User 7 indicated that they would prefer to see data about each video such as its duration and description. Additionally, they would like to have a functionality that helps with creating actionable steps in the values section.

User 8 would have liked to have more help with the diary section. As an example, they mentioned choosing from preexisting emotions to make the process faster and easier. They said the same could be helpful in the values section.

User 10 considered it would be ideal if the application made it clearer that it was based on ACT so that people could find it more reliable.

Desktop vs mobile. As previously stated, among the users in the WRU group, only Users 2 and 3 were able to access the application in mobile devices. User 2 explained that they enjoyed having access to the application on both desktop and mobile devices. User 3 did not make any comments about this topic.

The rest of the users in the WRU group had contrasting opinions about this subject. Users 4 and 5 believed it was not practical to use the application in a desktop environment. Moreover, User 4 stated they would have preferred to use the application in a mobile device, and User 5 added that they visited many places at the university. On the contrary, User 1 mentioned that the desktop version of the application worked well for them because they work and study mostly from home.

In the NRU group, only User 10 made comments about this topic. They indicated that they would have preferred to have access to a native mobile application, instead of a mobile web application such as this one.

Finding the time to use the application. Some users considered it difficult to find the time to use the application. Users 2 and 5 indicated they are not near their computer all the time. Users 7 and 10 expressed it was extremely difficult to find the time to use the app since they were quite busy.

The rest of the users did not have any major issues regarding this subject. User 1 mentioned it was not hard for them, User 3 said the notifications made it easier, User 4 stated it was not particularly hard, User 6 considered it easy as they were working from home, and User 9 stated it was not difficult since improving themselves is important.

Remembering to use the application. Users 4, 5, and 10 struggled to remember to use the application. User 4 reported they forgot to use the application one day, additionally, User 5 stated they tended to forget using the application and remember until late in the evening. Users 4 and 5 also considered if they had used the application for a longer period of time (longer than three days) they would forget to use it. User 10 mentioned it was challenging to remember to use the application, especially at first.

Users 1, 2, 3, 6, 7, 8, and 9 did not encounter significant issues regarding this topic. Users 2 and 3 reported that the applications notifications helped them remember to use the app. User 1 stated they would leave the BD on their desk and seeing it made them remember. User 2 said they had a personal to-do list which included using the application. User 6 mentioned it was easy to remember to use the application. However, if they were not working from home or if their kids were at home with them, then this situation might have changed. User 7 added that this kind of technology can be exciting at first but once the novelty is lost, they could forget to use it. User 8 stated that remembering to use the app was overall easy, but it did require some effort. User 9 had no difficulty in remembering to use the application and they would use it whenever they had free time.

Experience with the notifications. Users 1 and 4 mentioned that the stress notifications would sometimes happen at inconvenient times, and they could not stop what they were doing at that moment.

Some users experienced technical errors with the notifications. Users 2, 3, and 4 reported that the notifications did not always seem accurate. Moreover, they expressed that the stress notifications would occasionally happen during a moment in which they felt calm. User 5 did not receive any stress notifications; however, they did experience elevated stress.

User 4 added that receiving a notification made them feel increased stress.

Perceptions while wearing the BD. Remarkably, *all the users* in the WRU group reported that the size of the ring seemed too big for their liking. Moreover, they were referring to the external oval-like part and not the band of the ring itself. In addition, User 3 referred to the ring as *"blocky"* and said it would be better if the ring had only the band without the external part if it was possible. Also, User 5 considered it as being *"quite bulky"* and mentioned it felt inconvenient to wear. Finally, User 4 stated that the ring's great size could be annoying, and they would prefer a smaller overall size.

User 1 stated they are not used to wearing rings and it felt strange to wear the BD.

Similarly, User 4 was not accustomed to wearing rings and indicated it took them some time to get used to wearing the BD. They added that wearing the ring seemed unpractical but not overly disruptive.

Concerns while wearing the BD. Users 1 and 2 were worried they could potentially get the ring wet by accident.

User 1 felt that washing their hands was inconvenient while wearing the ring and this increased their concern of getting the ring wet unintentionally.

User 2 mentioned they were afraid to lose the ring and that the external oval-like part would hit objects and hurt their hand.

User 4 added that it was annoying for them to have to take the ring on and off to wash their dishes and hands.

Suggestions related to biofeedback. Users 2 and 4 stated they would prefer to wear a wristband instead of a ring. User 4 believed that wearing a wristband would avoid some problems such as having to take the ring on and off every time they wash their hands.

Users 3 and 5 suggested a functionality that analyses the stress levels of users over time and gives information about this.

User 1 believed it would be ideal if the BD could connect automatically to the application as soon as they start wearing it.

6.9 Summary

This chapter aimed to evaluate the design of the application that was developed for this Thesis. Ten university students voluntarily participated in the evaluation and were divided into two groups called WRU and NRU. The students in the first group utilized a version of the application (WRV) that integrated a BD in its functionality, and the users in the second group utilized a version of the application (NRV) that did not include a BD.

The evaluation study had quantitative data obtained from the usage logs of the application which were automatically recorded while the users utilized the application. The statistical analysis of this data showed three main types of results. First, regarding the number of videos watched, there is much more variation in the data set of the NRU compared to the WRU. Second, for the number of diary entries created, there were not great differences between both groups. Third, similar to the number of diary entries, in the case of the number of values created there is an overall consistency between the user groups.

The other type of data analyzed in the evaluation study was qualitative data obtained from semi-structured interviews that took place after the users had used the application. The results of the thematic analysis of the interviews will be summarized below.

Most users reported having no major issues with navigation. Additionally, some of them did not agree with the use of a star icon. The majority of users enjoyed the colors and images of the application. However, one of the users considered them to be too overwhelming. Some users enjoyed the meditations while others did not, and some users experienced some type of relief from stress. Half of the users did not watch any of the learning videos. The users that did watch them found them informative in some way. Most of the users did not experience any major issues in this section. The rest of the users had trouble deciding what to write or simply did not enjoy it. Nearly all users struggled to define their life values. Users experienced either no impact at all, a subtle impact, or a positive impact in their wellbeing. The users suggested improvements such as a wider variety of videos, additional information about each video, and guidance in the creation of diary and value entries. Some users had problems while using the application in a desktop environment while others did not. Four users reported difficulty finding the time to use the application. Three users struggled to find the time to use the application. A few users received notifications at inconvenient times and some experienced technical issues. Importantly, all of the users in the WRU group considered the size of the ring to be too large. Some users were concerned about getting the ring wet accidentally and found it troublesome to take it on and off while doing their daily activities that involved water. Regarding the biofeedback the users indicated they would prefer a wristband instead of a ring, and would like to have extra functionalities involving the BD.

7. DISCUSSION

This chapter will present the discussion, summary of findings, and limitations related to this research.

7.1 Discussion and summary of findings

The first research question *RQ1: what is the user experience of the developed application for students who suffer from anxiety?* Can be addressed by the questions of the user interviews that are related to the general experience of using the application.

Some users reported confusion with understanding what the menu icons meant, thus, even when the icons in the menu bar can complement the appearance of the application, they are not practical without some type of label.

1/10 users believed the colors and images of the application were too overwhelming and bright. 3/10 users had a neutral opinion, and 6/10 enjoyed the colors and images.

3/10 users enjoyed the meditations, however, 1/5 users do not like the classic style of meditations and prefer meditating by doing an activity that allows them to focus their attention on the activity instead of stress.

Previous experience in meditating could potentially play a role in the users' perception of mindfulness exercises. 2/10 users reported this was their first time meditating and found the exercises challenging in the beginning. On the contrary, another 2/10 users had previous experience meditating, and one of them stated they would prefer more advanced meditation techniques.

4/10 users experienced relief during a stressful event as a result of the meditations. Thus, the meditations in the app have the potential of implementing the ACT core principle of defusion. 3/10 users had a positive change in their perspective. This seems to indicate that mindfulness exercises can be helpful as a tool for practicing the core principle of acceptance of the present moment.

5/10 users did not watch any learning videos. The remaining users mentioned that the learning videos were informative and/or helpful. Thus, it seems beneficial to include learning videos in an application such as this one.

7/10 users did not experience major issues while utilizing the diary. 3/10 users struggled to decide what to write in this section.

In the values section most users (7/10) encountered difficulties in the values section. They explained that it was hard to define their values and struggled to understand if what they wrote was suitable for this section. More guidance could be needed in this section, nevertheless, it is not a good idea to oversimplify this process since the personal life values are not a generic concept. Also, they are extremely important and particular to every person.

Regarding the impact on the mental wellbeing of the users, 4/10 did not have any particular change after using the application, 4/10 has subtle improvements, and 2/10 experiences significant enhancements in their mental wellbeing. Moreover, this application has the potential to enhance the mental wellbeing of some users.

2/10 users preferred a wider variety of videos, on the contrary, 1/10 users believed the number of videos was overwhelming and would like fewer options. 2/10 users suggested daily reminders for using the app. 2/10 users requested a functionality that would help them with creating diary entries and value entries. 1/10 users believed that the application would be more reliable if it was made clearer that it was based on ACT.

2/5 users did not enjoy utilizing the application on a desktop environment, 1/10 declared that they preferred access to a native mobile application. The rest of the users did not comment on this.

4/10 users considered it challenging to find the time to use the application and 6/10 did not have major issues.

3/5 users experienced trouble in remembering to use the application and 7/10 did not have any problems. Furthermore, 2/5 users in the WRG experienced difficulties remembering to use the app, while 4/5 users in the NRG did not experience any difficulties. Thus, it does not seem as if the notifications had a major impact in prompting the users to open the application.

Overall, it seems that the users had a mostly pleasant experience using the app, and the app has the potential to positively impact the mental wellness of its users. As reported by the users, there are some improvements that must be made to the application. Nevertheless, the troubles experienced by the users did not appear to be extremely overwhelming or uncomfortable.

The second research question *RQ2: what is the perception of the biofeedback device integrated into the developed application for students who suffer from anxiety?* Can be answered by the questions of the user interviews that pertained to using the application in conjunction with the BD.

The stress notifications seemed to present some disadvantages for the users such as receiving them at an inconvenient time, making their stress worse and having technical errors. However, the technical errors could be the result of bugs in the implementation of the application.

Surprisingly, all the users (5/5) in the WRG expressed discomfort with the size of the BD, they believed it is too big to wear comfortably. This seems like a remarkable finding since 100% of users had the same opinion, in addition, they were all interviewed individually so it was unlikely that they influenced each other's answers.

2/5 users stated that they were not accustomed to wearing rings and this made it harder to get used to wearing a ring. There might be a more negative view of rings in general by people who are not used to wearing them, thus negatively influencing the perception of the BD.

3/5 users felt that it was inconvenient to do daily activities which involved water (e.g., washing hands, or dishes) and taking the ring on and off was burdensome.

2/5 users preferred a wristband over a ring since they believed it would be less likely to get wet and they would not need to take it on and off.

There were some positive findings regarding this topic. 2/5 users believed it was positive to have external feedback about their current physical state and 2/5 users reported that the notifications made it easier to remember to use the app.

Considering the findings related to utilizing the BD, it appears that the users experienced strong setbacks and disadvantages while wearing the ring. The most remarkable one being the size of the ring which is considered to be too large by all the users in the WRU. Additionally, there are some positive perceptions about the BD, however, the struggles while wearing the BD appear to overshadow the positive aspects.

The third research question *RQ3: Can timely notifications in the developed application increase the engagement of students who suffer from anxiety?* Can be resolved by analyzing the usage logs of the application. Three main activities in the usage logs were statistically analyzed, namely, videos watched, diary entries created, and values created. However, only the first activity type showed key differences among both user groups.

The first analyzed activity (videos watched) showed some significant differences between the user groups. The median was 5 in WRU and 3 in NRU. The mode is 5 in the WRU group, however, in the NRU a null value of #N/A (No Value Available) was returned since the values in the data set had no repetitions. Additionally, in WRU the standard deviation is 0.83 and in NRU it is 4.18. Furthermore, the median shows that the users in

in the WRU group tended to watch more videos than the other group, the mode as well as the standard deviation indicate that there is significantly more variation in the number of videos watched in the NRU group than in the WRU group.

In other words, the users in the WRU group seem to have a consistent number of views and the NRU group appears to be very inconsistent in its engagement. Thus, we can imply the possibility that the WRV of the application has more engagement than the NRV.

7.2 Design implications for similar applications

Having analyzed and discussed the main findings of this Thesis, we have defined the following design implications for mental wellness applications that utilize biofeedback:

1. The BD must be compatible with the target users' lifestyle and aesthetic preferences.
2. Ensure that the BD will not significantly disrupt the users' daily activities.
3. Minimize the possibility of users receiving notifications at an inconvenient time.
4. Prioritize practicality over an aesthetically pleasing interface.
5. Colors and images are subjective, they can be calming for some users and overwhelming for others. Offering customizable themes could solve this issue.
6. It is preferable to have a wide variety of mindfulness exercises and arrange them in an organized manner in the graphical interface's layout. The use of filters and categories could be helpful to achieve this.
7. Present "difficulty" levels for meditations. While meditations are subjective, some can be more suitable for beginners and others for experienced users.
8. Provide guidance and feedback for the users. This could come in the form of learning videos, articles, or even communication with a mental health professional. Choose feedback functionalities that work with the application's design and are possible to implement with the available time and budget.
9. Aim to develop a native mobile application instead of a web system as it seems to be preferred and more practical.

7.3 Limitations

There was a small number of participants in the evaluation study. This is especially troublesome in the statistical analysis of the usage logs since it is unreliable to draw statistical conclusions from small groups. Nonetheless, we considered it could still be informative

and act as a complement to the rest of the findings. In future works, we recommend striving to gather a bigger group for this type of statistical analysis.

Due to time restrictions, there was not a proper testing phase for the developed application. It was only tested by the developer, however, ideally it would be tested by users in a realistic environment before being launched to reduce technical errors. Thus, some of the users experienced errors during the study. Nonetheless, the errors were not significantly disruptive.

Additionally, due to our limited time, we could only have the users utilize the application for three days, which is an extremely brief amount of time to utilize a mental wellness application. It is unlikely to see any significant improvement in this time frame. Even so, it was still useful for gathering various insights and can hopefully serve as a steppingstone for someone in the future.

8. CONCLUSION

As seen in the results of the evaluation study, most users reported a subtle to null improvement in their mental wellbeing after utilizing our application. However, there were a few users who believed they experienced a positive change. Considering the short amount of time that the users utilized the application, it is encouraging that there was improvement reported by some of the users. Furthermore, modest enhancements in a person's life can result in significant achievement over time. After all, mental wellness is usually a long-term goal.

The findings are not particularly conclusive; however, a list of design implications has been created as a result of the knowledge gathered during this research. These implications could potentially help as a reference for future work.

Finally, an application such as this one could be beneficial for its users if properly developed. Preferably more time and resources could be invested in a project similar to this one and a better product could be created.

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10. APPENDICES

10.1 Appendix A: online forms

- Informed consent form (pre-study):
  - English version
  - Spanish version
- Background Questionnaire (pre-study):
  - English version
  - Spanish version
- Informed consent form (evaluation study)
  - WRU group
  - NRU group

10.2 Appendix B: Pre-study Interview Script

Say hello, ask for permission again to record, then start recording.

Objective

Mental wellness applications that have some scientific research behind them seem not to be sufficiently satisfying or engaging, this results in them not being able to attract many users (Wasil et al., 2022).

About the biofeedback device (Moodmetric ring)

The Moodmetric smart ring measures electrodermal activity (EDA) of the skin, also called galvanic skin response (GSR), which provides accurate data on the user's sympathetic nervous system activation in real-time (Moodmetric, 2020b).

"In experimental research settings, it has been found that physiological measures vary with task performance. The participants showed greater electrodermal activity change in the failed tasks than that in the successful tasks" (Moodmetric, 2021, p. 4).

As stated in the Moodmetric website (Venho, 2020), an example of a use case: in video games chasing, fighting, racing, and performing dangerous tasks is stressful. This activates the player's sympathetic nervous system. Additionally, a video game can be calming, such as in the case of puzzle style games. Game designers can use Moodmetric to measure these levels of emotions and understand the user experience of their games.

My ideas for the application prototype:

(Show the picture, and explain the user study)

User study will be in school, the user will come and interact with the mobile application prototype and wear the Moodmetric ring, the ring will read the user's stress levels in real time and send the information to the app. The app will show visual feedback to the users such as images, graphs, text, etc., potentially the users can also input information and interact with the app through buttons, text, menus, etc.

Interview Questions:

1. I've been thinking about implementing coping skills related to ACT like meditation or breathing exercises. Do you think it would be helpful for users?

2. If so, what exactly could I implement? (If you would like to think about it more, we can get back to this over email)

3. Do you have other suggestions for a mobile application, maybe something that could complement therapy?

4. The BD provides information in real-time about the stress levels of the user, I think this could be helpful as encouragement for the user so they can see their progress in self-regulating or accurate feedback for the system to adapt to the user, do you think it would be helpful in that way?

5. Do you have other suggestions (besides the ones mentioned above)?

6. Do you have any suggestions to make the application engaging for the users?

7. Do you have any suggestions to make the application pleasant for the users?

Stop recording.

Say thank you and ask if they can be contacted in the future, completely optional.

10.3 Appendix C: Evaluation Study Instructions (WRU)

Overall process

1. In-person introductory session
2. Calibrate ring for 12 hours
3. Utilize the app for three days
4. Return ring to researcher
5. User interview (can be online)

Apps needed

- Moodmetric official app (for calibration)
- Google Chrome (desktop or mobile if it's Android)
- An email app that can send you push notifications to your phone (for example the Gmail app)

When the ring is done calibrating

After the ring is done calibrating, disconnect the ring from the Moodmetric app so you can connect it to ACTapp.

To disconnect the ring from the Moodmetric app go to the menu, then choose 'Select ring', select ring from the list, and then click on 'Forget.'

Using ACTapp

What to do every day:

- Wear the ring for at least 12 hours.
- Do one of the meditation exercises.
- Create one diary entry.
- Create one value.
- If the system sends you a stress notification (by email) please follow one of the meditation exercises to help you calm down.
- If you feel very stressed, do one of the meditations or write a diary entry even if the system did not send a notification.

Optionally:

- Wear the ring for longer.

- Do more meditations.
- Watch some learning videos.
- Create more diary entries and values (you can create as many as you want per day).
- Edit a diary entry and/or value.

Things to keep in mind

App

- Use Chrome (desktop or mobile if it's Android) browser.
- You will need to be close to the computer or device (no more than 5 meters) so that the Bluetooth connection is not lost.
  - If you have to be far away from the computer or device just reconnect the ring.
- Use *only* one tab and one device at the same time while connected to the ring.
- While the ring is connected leave the Chrome tab open on the home page then continue to use your computer or device normally.
  - You can minimize the browser if you need to (just don't close the tab).
- If you navigate to another page on the ACTapp website, then the connection to the ring will be lost so after you are done exploring the site please reconnect to the ring.

Ring

- Battery life is supposed to be 4 days, however, because it's an older ring I recommend trying to charge it every day. When the yellow light turns off it means that it's fully charged.
- Charging time approximately 2.5 hours.
- The ring *cannot* be connected to two devices at the same time so make sure you disconnect from Moodmetric app after calibration.

10.4 Appendix D: Evaluation Study Instructions (NRU)

Overall process

1. Introductory session (online)
2. Utilize the app for three days
3. User interview (online)

Apps needed

- Google Chrome. Mobile or Desktop (the application has not been tested in other browsers).

Using ACTapp

What to do every day:

- Do one of the meditation exercises.
- Create one diary entry.
- Create one value.
- If you feel very stressed, do one of the meditations or write a diary entry.

Optionally:

- Do more meditations.
- Watch some learning videos.
- Create more diary entries and values (you can create as many as you want per day).
- Edit a diary entry and/or value.

10.5 Appendix E: Evaluation Study Interview (WRU)

Website

1. Were you able to navigate easily across the whole site?
2. What is your opinion about the background images and colors of the website?
3. How was your experience with the meditation exercises?
4. Did you watch any of the learning videos? If so, what did you think about them?
5. How was your experience with the diary section?
6. How was your experience with the values section?

General

7. Do you feel this application has affected your wellbeing in any way?
8. What is your overall opinion of the application?
9. Did you run into any issues, or struggles while using the application? If so, please explain.
10. Do you have any suggestions for improving the application?

Engagement/practicality

11. Was it easy or difficult to find the time to utilize the application?
12. Was it easy or difficult to remember to use the application?

Moodmetric ring integration

13. What was your experience like while wearing the ring?
14. Did you receive stress notifications from the system? If so, how did they affect your experience?
15. What is your general opinion on utilizing the Moodmetric ring in conjunction with the application?

10.6 Appendix F: Evaluation Study Interview (NRU)

Website

1. Were you able to navigate easily across the whole site? Why or why not?
2. Did you run into any issues, or struggles while using the application? If so, please explain.
3. What is your opinion about the background images and colors of the website? How do they make you feel?
4. How was your experience with the meditation exercises?
5. Did you watch any of the learning videos? If so, what did you think about them?
6. How was your experience with the diary?
7. How was your experience with the values?

General

8. Do you feel this application has affected your mental wellbeing in any way? If yes, how?
9. What is your overall opinion of the application?
10. Do you have any suggestions for improving the application?

Engagement/practicality

11. Was it easy or difficult to find the time to utilize the application? How so?
12. Was it easy or difficult to remember to use the application? Why?