Development of a mobile artifact to support adaptive iCBT using multi modality support and usage data

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Abstract

For the increasing number of women who survive breast cancer, many find themselves struggling with chronic symptoms like fatigue, stress, depression, anxiety and a wide range of physical and psychological symptoms. While CBT and iCBT are common and effective treatments for managing these symptoms, there are challenges related to the availability, cost and ability to scale when considering traditional approaches to delivering CBT. Self-guided iCBT has the potential to provide more scalable and affordable alternatives to traditional CBT, but faces significant challenges related to user adherence. By providing a more personalized experience, self-guided iCBT may provide a cheap, effective and available means of managing symptoms.

Throughout the master thesis project presented in this thesis, we have used design science methodology to develop an artifact for demonstrating potential useful functionality for facilitating adaptive iCBT using a mobile application. Our focus has been on developing functionality for providing multimodal delivery of CBT content, and functionality for facilitating the collection of usage data in order to enable the possibility for more personalized iCBT. As a part of this work, we have introduced the use of speech synthesis technology for providing multi-modality delivery of content through in-app audio on-demand. Also, we have evaluated the implemented artifact with respect to both user experience and content features with the help of experts within UX and CBT. The results from the UX evaluation was used to improve the design of the artifact.

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Lastly, I would like to thank my family for their support during these past years.

Statement

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Acronyms

- **ADL** Advanced Distributed Learning Initiative
- **API** Application Programming Interface
- **CBSM** Cognitive Behavioral Stress Management
- **CBT** Cognitive Behavioral Therapy
- **GCBT** Group-Based Cognitive Behaviroal Therapy
- **iCBT** Internet-Based Cognitive Behaviroal Therapy
- **ITS** Intelligent Tutoring System
- **MVVM** Model-View-Viewmodel
- **MVC** Model-View-Controller
- **SAD** Social Anxiety Disorder
- **SCORM** Sharable Content Object Reference Model
- **SDK** Software Development Kit
- **TTS** Text-to-speech
- **UI** User Interface
- **UX** User Experience
- **xAPI** Experience API

Chapter 1

Introduction

1.1 Motivation

Among women, breast cancer is considered the most prevalent form of cancer. In 2018, breast cancer was responsible for 22,9% of all cases of cancer among women in Norway, with a total of 3568 new cases (Larsen et al. 2019). While most commonly diagnosed in women of older age, adult women of any age can develop breast cancer, and in 2018 it placed fourth among the most deadly forms of cancer in Norway (Larsen et al. 2019). Approximately 6,6 percent of women in Western populations diagnosed with breast cancer are of age 40 or below, and a breast cancer diagnosis at a young age is often associated with reduced chances of survival due to aggressive cases being more common among women at the age of 40 or younger (Brenner et al. 2016).

For the increasing number of women who survive breast cancer, many experience chronic symptoms which contribute towards reduced quality of life. These symptoms can include fatigue, stress, depression, anxiety and a wide range of other physical and psychological symptoms. While many breast cancer survivors adjust remarkably well to their post-cancer treatment situation, younger women in particular are more susceptible to anxiety, depression and cancer-related distress. This applies especially to younger women with a history of emotional disturbance, who may require more tailored interventions (Costanzo et al. 2007). Consequently, there is a clear potential for improving the quality of life for a significant portion of breast cancer survivors suffering from these symptoms, hence managing these symptoms can be crucial for aspects not only related to quality of life. A literature review by Antoni & Dhabhar (2019) concluded that stress causes a counterproductive immune reaction in relation to cancer by promoting tumor growth mechanisms rather than controlling cancer cells effectively. Similar findings are reported in a study by Stagl et al. (2015) that highlighted the importance of managing stress. The study demonstrated how post-resection cancer patients using cognitive-behavioral stress management (CBSM) to manage their stress symptoms had a better long-term outcome in terms of mortality rates and recurrence rates. CBSM is a CBT approach to stress management, which similarly to CBT, also attempts to change cognition, develop coping skills and guide towards the effective application of taught skills (Brannon et al. 2013). A secondary analysis of the study by Stagl et al. (2015) suggested that the better long-term outcome is likely due to the positive immune response caused by proper stress management (Antoni et al. 2016).

With advanced screening programs and public awareness campaigns ensuring a better prognosis for surviving breast cancer due to earlier detection, an increased number of survivors will need help managing their stress-related symptoms in the future. A study on the cost-effectiveness of the Norwegian Breast Cancer Screening Program (NBCSP), which was initiated in 1996, estimated a maximal reduction in mortality rate by as much as 30 percent by 2022 when compared to a situation without any screening (van Luijt et al. 2017). While the screening program mainly targets women of age 50-64 years, advances in knowledge regarding risk factors and better treatment techniques has also contributed towards reduced mortality in young breast cancer patients. With both family history and family structure being important for determining the risk of breast cancer (Brewer et al. 2017), younger women considered to be at risk can also be screened for breast cancer, and younger women diagnosed with breast cancer are more likely to survive thanks to modern treatment methods. Overall, this contributes towards increasing the detection rates, while lowering the mortality rates.

The decrease in mortality rates related to breast cancer introduces new challenges in terms of managing chronic symptoms in breast cancer survivors, especially in relation to mental health. Considerable treatment gaps with regards to depressive and anxiety disorders exists worldwide (Thornicroft et al. 2017, Alonso et al. 2018), and even in Norway there are estimates suggesting significant treatment gaps for certain mental disorders (Torvik et al. 2018). For the many who never seek professional help for their mental health problems, modern technology has the potential to contribute towards closing the treatment gap by providing cheaper and more available treatment options. While psycho-social interventions like cognitive-behavioral therapy (CBT) has been proven useful in treating common disorders like anxiety, depression and PTSD (Beatty & Koczwara 2010), such interventions can be demanding from a cost and resource perspective, with patients often meeting a therapist for sessions over several weeks (NHS 2019). With the rapid development of web and mobile technologies, some interventions are instead being adapted for digital use for increased efficiency and availability.

Internet-Based Cognitive Behavioral Therapy is one such type of internet-based intervention. iCBT has been proven to be effective in relation to the common symptoms suffered by breast cancer patients (Atema et al. 2019), and enables therapists to consult with a significantly larger number of patients compared to traditional face-to-face therapy. Despite having the advantage of being scalable and cost-effective compared to traditional face-to-face CBT (Fairburn & Patel 2017, Weisel et al. 2019), guided iCBT (iCBT guided by a therapist) still require human supervision for normal operation in addition to showing better adherence for certain age groups than others (Edmonds et al. 2018).

This presents us with an opportunity to explore the use of mobile technology in order to provide a more available approach in helping breast cancer survivors manage their symptoms. With modern smartphones being capable of providing an interactive and flexible user experience, it is our belief that mobile technology can be leveraged in order to provide breast cancer survivors resources and guidance in order to better cope with the side effects of breast cancer treatments. By taking advantage of mobile technology's data collection capabilities, combining it with ideas from the field of Intelligent Tutoring Systems (ITS) (Morales-Rodríguez et al. 2012) and present it through an iCBT setting, we would like to explore the possibilities related to the development of a mobile application with the goal of creating an adaptive intervention for breast cancer survivors.

1.2 Problem description

Coping with Breast Cancer (COPE) is a collaboration project between the Centre for Science and Learning Technology (SLATE) at the University of Bergen (UiB) and Western Norway University of Applied Sciences (HVL). The project was initially based on incorporating CBT and/or Mindfulness into an application, in addition to features for tracking progress, patient modelling and decision support systems in order to enable an adaptive approach addressing mental side-effects related to breast cancer. By utilizing means of data collection, the application would provide a platform for further research into personalized internet-based treatment options and new ways to monitor and track patient progress.

In an initial meeting held together with SLATE, we decided on the development of a mobile application with functionality for supporting cognitive-behavioral therapy. Additionally, we agreed that the application would have to be able to track the patient's progress as they progress through the course. The application should also provide functionality for allowing the patient to perform the activities and view the content of the CBT program, while also collecting other relevant usage data that could have potential use for personalizing the program.

For this master thesis project, the front-end of the COPE project will be in focus. More precisely, this includes necessary mechanisms for collecting user data in addition to presenting content to the user in different modalities.

1.3 Objectives and solutions

In order to solve the problems described in section 1.2, we decided to define the requirements for four artifacts to be created. Furthermore, we decided to limit the scope of the project by focusing on the material presented through the module on stress in a CBT program developed and managed by professor

Michael Antoni at the University of Miami. The program is called VSMART [1], and focuses on stress awareness and relaxation training for older women with breast cancer through group therapy Antoni et al. (2016).

For different strategies and approaches to creating a mobile CBT program, we performed a literature survey on the use of mobile applications within mental health and CBT. Through searching in Google Scholar we found several references to work done in relation to mobile applications within iCBT and mental health, though we found few references to work done in relation to adaptive iCBT for mobile applications, and none on actual implementations.

1.4 Research Questions

The research questions of this thesis relates to the design, implementation and evaluation of an artifact capable of demonstrating functionality needed to personalize the program for performing CBT-related activities and data collection. More specifically, we will focus on the following research questions:

RQ 1 - How can material from a CBT module in a CBT program be used to develop a prototype for showcasing functionality that can facilitate adaptive iCBT on a mobile platform?

RQ 2 - How can we enable the use of multiple modalities for delivering stress-related CBT content on a mobile platform?

RQ 3 - Using the application technology developed for an artifact to answer RQ1 and RQ2, how can we collect data from users of the artifact to facilitate adaptive iCBT?

1.5 Research Method

We chose design science as our method for developing the artifact which represents the front-end aspect of the project. Design science is a methodology oriented around developing and evaluating artifacts in order to solve organizational problems. This aligned well with the initial goals described in section 1.3 considering one of the goals for the COPE project being the development of a set of artifacts. For this thesis project, we decided to use design science due to its artifact development and evaluation guidelines being intuitive and well-suited for the development of a mobile application supporting adaptive iCBT. The design science methodology is further described in section 3.1

[1] Cognitive Behavioral Stress Management (CBSM) was invented by Michael H. Antoni and is filed as Intellectual Property at the University of Miami Office of Technology Transfer as UMIP-483. UMIP-483 has been licensed from the University of Miami to Blue Note Therapeutics. All software in this thesis based on UIMP-483 is strictly for educational purposes, and cannot be used for commercial or non-profit purposes.

With this in mind, we designed and implemented a prototype for performing various CBT-related activities while simultaneously collecting and storing relevant usage data. Section 3.1 covers our research methodology in detail, and describes the various iterations performed throughout this part of the COPE project.

1.6 Thesis Outline

- **Chapter one** describes the motivation for this thesis project and presents the research questions as well as the chosen research method.
- **Chapter two** presents the theoretical background relevant to the work presented in this thesis. We describe cognitive-behavioral therapy and the digital adaptions available today. Additionally, we briefly cover the state of mobile applications in the context of health.
- **Chapter three** presents and discusses the research methodology adapted for this work as well as the process of designing the artifact presented in this thesis. We cover the various iterations performed during the design of the artifact and present the final artifact prior to evaluation by experts.
- **Chapter four** addresses the implementation of the artifact and the technologies used for implementing the artifact.
- **Chapter five** presents the evaluation of the artifact. We describe the feedback gathered from the various experts evaluating the artifact, as well as the resulting modifications performed based on the feedback.
- **Chapter six** Discusses our findings and presents our research contributions to the field.
- **Chapter seven** concludes this thesis and presents the final notes for this thesis as well as the remaining work and desirable features for a future prototype.

Chapter 2

Background

This chapter introduces cognitive-behavioral therapy along with its different variations and digital adaptations.

The first two sections describes cognitive-behavioral therapy and its digital adaptation, internet-based cognitive behavioral therapy. Then, we proceed by introducing mobile applications in the context of health and internet-based cognitive behavioral therapy before describing some relevant existing work.

2.1 Cognitive Behavioral Therapy

Cognitive Behavioral Therapy (CBT) is a widely used psychotherapy which can be applied to manage a wide range of mental and emotional disorders. Brannon et al. describes CBT as "a type of therapy that aims to develop beliefs, attitudes, thoughts and skills to make positive changes in behavior"(Brannon et al. 2013, pg. 113). Over the last 50 years, CBT has become an effective option for treating psychosocial disorders, and it has shown positive long-term effects when applied to patients suffering from phobias, anxiety, depression, pain management and a number of other disorders (CBT 2002).

According to Sweet (2012), CBT works by helping patients identify their core issues, in particular negative, repetitive thoughts (which may even exist subconsciously) while helping patients adjust their behavior and actions. Central and important aspects of CBT are among others identifying mechanisms in behavioral and thinking patterns which discourages people from addressing situations and actions considered to be difficult or unpleasant. In order to address this, CBT teaches patients techniques that help them to distinguish between behavior, thoughts and feelings.

CBT courses may vary in structure and format. Electronic material, books and group sessions are common delivery methods for CBT in addition to individual sessions guided by a therapist. A course may last for 5 to 20 sessions, with sessions lasting 30 to 60 minutes. During these sessions, patients work together with a therapist to break down problems and make changes to their behavior and thinking patterns (NHS 2019). Patients will also receive homework prior to sessions, possibly consisting of psycho-educational material in addition to various activities and techniques relevant for the course and their problems.

The traditional approach to a guided CBT session is through a face-to-face setting that requires the presence of both the patient and a therapist. Requiring patients to physically attend sessions adds additional restrictions and challenges based on demographic and geographic restrictions. One notable challenge Jameson & Blank (2007) mentions in their study, which discusses the role of clinical psychology in rural areas in the US, is the challenge related to educating and recruiting enough qualified health personnel needed to deliver quality services to rural areas. The study mentions *telehealth* (the use of communications technology in the educational, clinical, training, administrative, and technological aspects of health care (Jameson & Blank 2007)) and *telemedicine* (describes the aspects of telehealth involved in patient care (Jameson & Blank 2007)) as potential solutions to empower and increase efficiency for caregivers in rural areas, and as technologies with the potential to provide for better access to services for rural populations. Delivering interventions like CBT over the internet (also known as iCBT) also carries significant savings in terms of therapist resource usage and costs, increasing the overall efficiency of the therapy (Hedman et al. 2011).

2.2 Internet-Based Cognitive Behavioral Therapy

As briefly mentioned in section 2.1, internet-based cognitive behavioral therapy is an adaption of CBT intended to be delivered over the internet. Contrary to traditional face-to-face CBT, iCBT has the capability of circumventing many of the challenges and restrictions which limits traditional CBT. In many cases, iCBT may allow therapists to see more patients due to its increased efficiency over regular face-to-face CBT (Andrews et al. 2018).

While the efficacy of iCBT in comparison to traditional CBT is still a subject in need of more research, various studies in relation to different diseases and disorders has shown promising treatment outcomes for iCBT in comparison to regular face-to-face therapy. Studies have shown that applying iCBT for disorders like anxiety can be an effective counterpart to regular group cognitive behavioral therapy (GCBT, CBT performed in groups rather than or in addition to one-on-one sessions)(Wergeland et al. 2014), in addition to individual CBT sessions for disorders like fibromyalgia (Vallejo et al. 2015).
Two common approaches to iCBT are *self-guided* and *guided* programs. Karyotaki and colleagues defines guided iCBT as "an intervention based on CBT self-help material and delivered via the internet with some form of guidance related to the therapeutic content"(Karyotaki et al. 2019, pg. 2). Communication

with the therapist can happen either asynchronously (e-mails, text messages, messages through patient platforms) or synchronously (video and audio calls, live chat services). The therapist is able to follow up on the patient's progress, and provide guidance and advice based on observed progress. For self-guided iCBT, Karyotaki and colleagues defines this as "an intervention provided without any support related to the therapeutic content" (Karyotaki et al. 2018, pg. 2), meaning an intervention where therapist-to-patient contact is limited, excluding service or platform-related technical support. Studies have proven the efficacy of both self-guided and guided iCBT in comparison to regular face-to-face CBT. For guided iCBT, studies have shown that it can have a comparable effect to regular face-to-face CBT in relation to certain disorders like depression, anxiety, and social phobias (Andrews et al. 2011, Andersson et al. 2013, Titov et al. 2016). For self-guided iCBT, there are studies showing that carefully developed self-guided courses can have a similar effect compared to face-to-face CBT (Titov et al. 2016), though there are also studies showing significant drop-out rates (Andersson et al. 2012) as well as studies showing worse results for certain disorders (Johansson et al. 2012). Still, the advantage of lower costs and a better ability to scale remains for self-guided iCBT.

2.3 Mobile apps in mental health

Mobile applications related to health and fitness (also known as "mHealth" applications) has seen a substantial increase in number over the past decade. In 2017, there were over 325 000 available mHealth applications across the major mobile app stores, and in 2016 over 5.4 billion dollars were invested in digital health. Additionally, 3.7 billion mHealth app downloads were expected worldwide (Research2Guidance 2017).

These applications have made their way into many aspects of modern health, including the areas of mental health and psychology. Well-designed mobile applications has the potential to provide an engaging and educational experience for their users while also facilitating easy access to treatment-related homework, symptom monitoring and a means of continued access to useful content even after the treatment has ended (Price et al. 2014).

Even though mHealth apps within mental health has shown promising potential for use in treatments, there are still challenges that need to be addressed when considering mHealth apps for clinical use. As mentioned by Marley & Farooq (2015), the overwhelming number of available apps make them difficult to regulate, in addition to the effects potentially being dependent on characteristics of the patient population. The majority of commercial mHealth apps for mental health programs also lack scientific evidence proving their efficacy, making it necessary to educate health personnel on identifying the few existing evidence-based apps available (Donker et al. 2013). Also, studies have shown that mHealth apps for treating certain disorders may have challenges related to user dropout, making research into treatment retention important for creating successful mental health apps (Torous et al. 2019).

2.3.1 iCBT in mobile applications

The implementation of iCBT in the form of mobile applications has gotten increasing attention with the rise in smartphone popularity and availability. Modern smartphones carry a number of features that can potentially complement an implementation of iCBT, including the ability to collect user data in real-time, share user data with therapists, prompt the user to perform certain tasks according to schedules and store homework assignments for future use (Boschen & Casey 2008).

As mentioned in section 2.1, it is common for a therapist to provide homework during the course of a CBT program. Here, mobile technology can be used to enhance the user's ability to perform prescribed activities or remind the user to perform any uncompleted daily activities. As an example of the use of notifications in an application using iCBT to treat social anxiety disorder (SAD), Miloff et al. (2015) designed app elements referred to as "parachutes" in order to provide useful tips on smartphone lock screens to remind the users to do their exercises and visit the application. Watts et al. (2013) also mentions being able to set calendar reminders and being able to perform the assigned homework in the mobile application as advantageous features of mobile-driven iCBT.

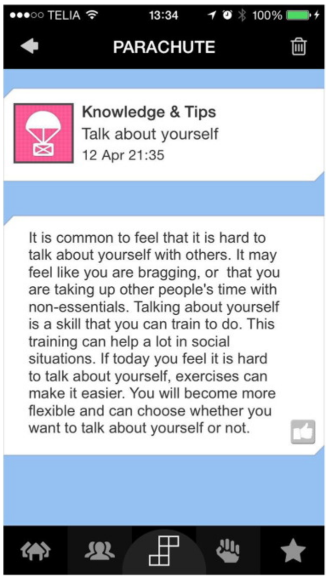


Figure 2.1: Screenshot from the Challenger App for SAD: A "parachute" (Miloff et al. 2015).

Real-time data collection capabilities in mobile devices allows for new ways of collecting important treatment-related data from patients to improve and personalize iCBT. In a study aimed at identifying the barriers to the dissemination of evidence-based psychological treatments, Shafran et al. (2009) mentions that traditional evidence-based treatments within CBT can face difficulties since the study often relies on the patient providing data at the end of therapy, and that the rates of missing data are high. Since patients who refrain from reporting their data tend to have a worse outcome, the absence of these data can leave an erroneous impression of the treatment working better than the actual average. Also, a study looking at the use of smartphone applications for mood disorders found that most available studies focus on active data collection rather than passive data collection, and that with the advances in mobile technology, there's a need for more and better studies into whether passively collected data can help influence clinical outcomes (Torous & Powell 2015).

2.3.2 Powering adaptive iCBT using mobile apps

As already mentioned in this section, mobile devices allows for new ways of data collection that can be used for creating more individualized treatment plans. We have also mentioned that CBT programs can vary significantly in structure and format. Still, it is common for many guided iCBT programs to provide guidelines and written guidance for therapists to utilize during training and during the course of a program. Written guidance can provide a number of advantages in practise, like ensuring the quality and transparency of the program (Milne 2016). This is a useful approach for enabling an evidence-based practise, but it fails to take into consideration the vast number of different problems that can be encountered during the treatment process. Lundkvist-Houndoumadi et al. (2016) describes an approach for individualizing treatment plans by assessing the treatment response of each patient through weekly feedback systems. The therapist creates the treatment plan by integrating evidence-based procedures which they find suitable. Despite showing promising results, this approach requires a therapist to spend a considerable amount of time on each patient.

While not directly inspired by Lundkvist-Houndoumadi et al., the idea of an adaptive system which evaluates the patient's progress and changes the treatment course correspondingly is part of the core principles which the COPE system aims to implement. By automating the tailoring process using data collection and adaptive algorithms, computers might be able to do the work which therapists otherwise would have had to spend valuable time performing in a guided iCBT setting.

2.3.3 The importance of digital tools and interventions

During the spring of 2020, a new pandemic swept across the world which changed the everyday life of millions of people in the majority of the affected countries. The pandemic, caused by the novel coronavirus known as COVID-19, had significant implications for the operation of a vast number of businesses and institutions across the world, and forced many to adapt in order to take advantage of technology for continued operation under strict social distancing measures and stay-at-home orders.

The new norms for interactions between humans has prompted swift changes not only within the commercial and educational sector, but also in various health care systems handling mental health and patient consultations. In certain countries, the threat posed by the virus has inspired the development of mobile applications and the opening of hotlines in order to safely provide mental health services (Li et al. 2020). For many health care providers, the pandemic has also served as a catalyst for the move over to telehealth and the use of technology for delivering mental health services. This has not only prompted the training of therapists in order to provide services digitally, but has additionally encouraged health care providers to consider how the treatment itself responds to technology (Taylor et al. 2020). With the adverse effects of the pandemic expected to increase the number of domestic violence cases, alcohol abuse and/or suicidal tendencies among vulnerable individuals (Gunnell et al. 2020), digital interventions can serve as an important element in a strategy for mitigating the mental health consequences of the pandemic.

2.3.4 Section summary

Mobile applications for health has seen an incredible growth across all major mobile app stores, and continues to rise in popularity with the continued growth of the smartphone market. The sheer scale of the smartphone market in addition to the ever-increasing availability of smartphones has made mobile technology an intricate part of our lives capable of serving as useful tools for making resources and services related to mental health more available for the general public.

While the development of mHealth applications faces significant challenges related to evidence-based practise and regulations, studies documenting the use of smartphone features for potentially enhancing existing treatment options suggests that there may be a place for mobile applications in the treatment and prevention of mental health disorders. With the potential for more tailoring within iCBT by utilizing modern technology, and an increasing reliance on digital services during times of limited access to physical services, mobile technology may have the potential to increase the availability and scalability of mental health services. Coupled with the need for more studies on the collection and usefulness of data from smartphones in relation to clinical outcomes (Torous & Powell 2015), there exists a significant potential for smartphones and mobile apps in relation to mental health.

2.4 Related Work

By using Google Scholar, we were able to find a number of studies where prototype applications had been created in relation to mental health or iCBT. Due to our case revolving mainly around managing the symptoms related to stress, studies where stress was one of the main focuses of the study were also included. We were unable to find any studies where a personalized, adaptive or individualized treatment plan using mobile apps was the main focus, and instead chose to include applications which either implemented an application relevant to our case (for instance an application facilitating learning and interaction in the context of stress or CBT) or in other ways were relevant for mobile computing and iCBT. Also, we included studies where a prototype application was used to facilitate user interaction with CBT-related content like exercises and other relevant tasks.

2.4.1 CBT Assistant: mHealth App for psychotherapy

Michelle et al. (2014) did a survey of existing mHealth solutions for CBT, and examined how mobile technology can potentially address some of the issues related to traditional CBT courses with a focus on social anxiety disorders in guided interventions. Some issues raised are for instance the overwhelming challenge of systematic review of homework for the therapists and the challenges related to the availability of therapists in many areas. The study is of relevance due to the approach the study's prototype takes towards homework in iCBT as well as data collection related to homework and self-assessment. The application implements a number of interactive elements relevant for a CBT course, like for instance exposure therapy where the user can interact with the application rather than resorting to pen and paper in order to complete their homework. Additionally, the prototype collects relevant information for assessing the patient by allowing for data to be exported from the device. For the COPE project, similar features are desired in the final artifact.

For the study, an application was developed supporting the end-to-end CBT process in addition to the relevant protocols for psychiatrists used in clinical practise. The application was designed as an extension of the therapist's hands in order to make it easier for patients to adhere to and perform recommended CBT interventions in their daily life. Additionally, the application attempts to reduce the burden on therapists in order to allow them to help more patients. The application allows patients to write diary entries, do exposure therapy, utilize self-assessment tools, set reminders and many other features related to the treatment. Figure 2.2 shows how one of the self-assessments looks inside the application.

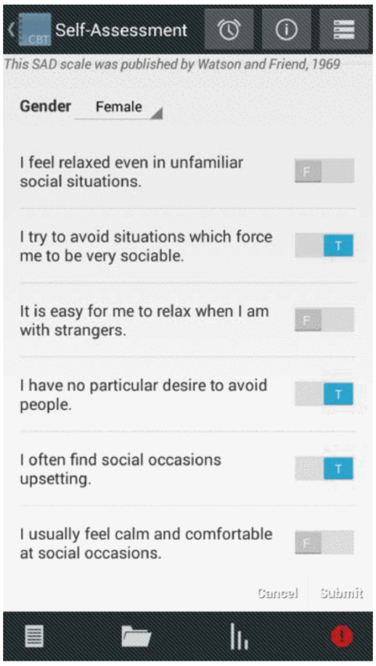


Figure 2.2: Screenshot of a self-assessment from the CBT Assistant (Michelle et al. 2014).

2.4.2 Design of a Mobile Phone App Prototype for Reflections on Perceived Stress

Smedberg & Sandmark (2012) presented the design of an application aimed at supporting self-reflection on stressful everyday situations. The application offers the user exercises and information, in addition to enabling interaction between experts and users.

For the study, a prototype was developed with the intent of operating within the domain of self-management and self-reflection in people with mild to moderate stress symptoms. The application's features were developed and designed according to research within the area of stress management and stress, and features functionality for registering and managing stressful situations in addition to functionality for displaying statistical data.

The application was qualitatively evaluated from an expert's perspective in terms of its usability. Furthermore, the different features of the application was modified in line with the expert's recommendation, for example with respect to the complexity of the application's functionality and design. The application was also evaluated against a set of criteria in order to ensure that the application satisfied the required functionality.

The prototype developed by Smedberg & Sandmark facilitates monitoring of stress levels in users and allows for collection of data which can later be sent to a server and further used through a web application. Figure 2.3 displays how the application can be used to register stressful situations by location and time. The artifact presented in this thesis carries functionality similar to the functionality of the application developed in the Smedberg & Sandmark study, and allows for users to enter information in relation to stress and keep track of relevant experiences by using the application. Additionally, the artifact in this thesis will be evaluated by similar means through expert opinions in regards to usability and design.

Figure 2.3: Screenshots from the application displaying stress locations(left) and distribution based on time of day(right) (Smedberg & Sandmark 2012).

2.4.3 Mobile-Application Based Cognitive Behavior Therapy (CBT) for Identifying and Managing Depression and Anxiety

Addepally & Purkayastha (2017) created a mobile application named MoodTrainer inspired by a CBT website called MoodGym. In order to address the usability issues related to MoodGym (accessibility issues, a lack of mobile-first design and the requirement of using a computer for access), a mobile application was made for the study with features for tracking users' location and isolation behavior. The study justifies these features by pointing out that isolation is both a common symptom and a risk factor related to depression. In these cases, the application can recommend various actions in order to improve the user's mood (like playing the user's favorite song or displaying motivational quotes).

Among MoodTrainer's key features is the ability to enable users to log their mood and behavior. This data is intended for use by researchers in order to evaluate the tool rather than for use by clinicans. This aligns with the intention

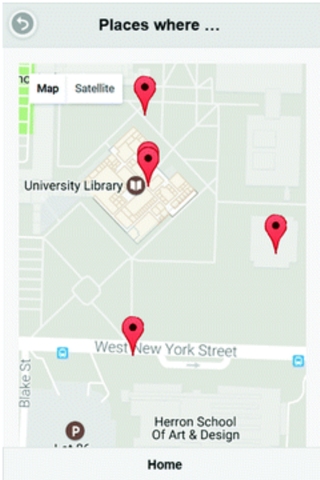


Figure 2.4: Location tracking in the MoodTrainer application (Addepally & Purkayastha 2017).

behind the application developed in this thesis project where the intended use of the data collected is for evaluation purposes, albeit by an algorithm for delivering a more personalized experience. The development of our artifact was also conducted in a similar manner as with the MoodTrainer application through rapid prototyping.

MoodTrainer was developed as a cross-platform, hybrid application using web technologies like JavaScript, HTML and CSS, enabling it to run on all major platforms as well as on a range of less popular platforms. The application is organized into various modules, like for example assessment (identify the severity of the depression and anxiety symptoms experienced by the user), feelings (takes the user through a series of tasks which helps the user to identify their feelings), thought (walks the user through a series of activities which aids the user in identifying their negative thoughts) and several others. The application also uses several scales to assess the user's mental state. Despite not referring to any results, the application demonstrates the potential usefulness of utilizing sensors in mobile devices in relation to improving mental health.

2.4.4 A Stress Management App Intervention for Cancer Survivors: Design, Development, and Usability Testing

Børøsund et al. (2019) report on the design and development of an app-based stress management intervention for cancer patients. The application was developed through an iterative process consisting of three phases; exploration, intervention content development and iterative software development.

The researchers established the requirements for the application by interviewing a number of cancer patients with various types of cancer. Feedback from patients, health care providers and eHealth experts drove the design and development of the app, and the content provided through the app was derived from evidence-based methods adapted for use with technology. The result of the study was an easy-to-use app with evidence-based content divided into 10 modules. The final intervention was called *StressProffen*, and provided a number of features and exercises for managing stress, including breathing exercises and interactive app elements (see figure 2.5).

Figure 2.5: Various screenshots of the functionality found in *StressProffen* (Børøsund et al. 2019).

StressProffen presents an approach to iCBT which shares a number of similarities to the artifact developed as a part of the COPE front-end. It engages the user by utilizing exercises and educational content backed by evidence-based methods. The artifact developed as a part of this thesis attempts to take a similar approach with respect to evidence-based methods and user interaction in addition to data collection capabilities.

2.5 Chapter summary

Cognitive behavioral therapy is a well-proven and effective means of treating a wide range of psychosocial disorders. Although traditional face-to-face CBT faces issues in relation to effective scaling, the advances within computer technology has allowed for the development of internet-based interventions for CBT (iCBT). Sporting similar outcomes as regular face-to-face therapy in relation to a number of disorders, these interventions scale better and increase the availability of treatments for a number of patients.

With mobile applications becoming an increasingly bigger part of our lives, the advantages modern smartphones bring to the table can enhance existing self-guided iCBT solutions in a number of ways. Advanced monitoring and data collection capabilities in addition to availability enhancements can contribute towards delivering a better and more personalized iCBT experience for patients. Improvements to current solutions are needed in order to combat some of the weaknesses of existing self-guided iCBT solutions like worse treatment outcomes and high dropout rates.

In this chapter, we covered the background for cognitive-behavioral therapy and its applications in combination with modern technology. We described the strengths and weaknesses of CBT and the different forms of iCBT available today, as well as the potential computer and mobile technology carries in terms of enhancing both the efficacy and the delivery of CBT. Also, we have presented examples of some relevant apps in use which have provided us with ideas for the design and functionality of our artifact.

Chapter 3

Design and Method

This chapter presents the research methodology as well as the various iterations performed during the design of the artifact.

The first section provides an introduction to design science as our research methodology of choice. The sections following describes the design activities and the progress made during each iteration.

3.1 Research Method

Design science was chosen as our preferred methodology due to our solution taking a practical approach in solving the problems of developing parts of an iCBT application for mobile platforms (the artifact presented in this thesis). Since design science revolves around designing artifacts in order to solve problems, we decided that it would be the most applicable methodology when considering our motivation and goals. Our artifact is a mobile application representing our contributions to the field, and is implemented in order to show the possible approaches to designing a mobile application for aiding in iCBT.

Design science

Design science is a problem-solving paradigm that has its roots in engineering. In the context of information systems and design science, IT artifacts are created and evaluated, with the intention to solve identified organizational problems (Hevner et al. 2004). In addition to the processes behind building these artifacts, the desire to improve an environment by introducing new, innovative artifacts is one of the driving motivations behind design science.

Hevner et al. (2004) defines seven guidelines for design-science research:

1. Design as an Artifact: Design-science research must produce a viable artifact in the form of a construct, a representation, a technique, or an instantiation.

2. The Relevance of Problem: The objective of design-science research is to develop technology-based solutions to important and relevant business problems.

3. The Design Evaluation: The utility, quality, and efficacy of the design artifact must be rigorously demonstrated via well-executed evaluation methods.

4. Research Contribution: Effective design-science research must provide clear and provable contributions in the areas of the design artifact, design foundations, and/or design methodologies.

5. Research Rigor: Design-science research relies upon the application or rigorous methods in both the construction and evaluation of the design artifact.

6. Design as a Search Process: The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.

7. Communication of Research: Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences.

The artifact presented in this thesis covers the first guideline. Our artifact is a mobile application facilitating aspects of self-guided iCBT and parts of data collection required to address some of the problems related to adapting self-guided iCBT for breast cancer survivors for better therapy with better adherence and scaling.

Chapter 1 explains the motivation behind the artifact and how it is relevant for solving the problems presented in this thesis, thus covering the second guideline. The artifact is designed to facilitate self-guided iCBT while simultaneously enabling collection of usage data for adaptive mechanisms to enhance the user experience in order to improve adherence and user satisfaction.

Chapter 5 covers the evaluation of the artifact and the third guideline for the research. We cover the evaluation of the artifact from two perspectives, with the first perspective being the application design and flow and the second perspective being the content presented within the application and how it contributes towards solving the problems discussed in chapter 1.

Chapter 6 discusses the research contributions of this thesis (guideline 4), while chapters 3 and 5 covers both the methods for construction and evaluation of the artifact (guideline 5).

The iterations performed in order to develop the artifact are described in section 3.2, and covers the process of searching for a solution through iterative feedback and development of the artifact (guideline 6). This thesis largely presents the communication of research, and presents our findings and results (guideline 7).

3.2 Design Process

The design of the application was performed incrementally. Weekly meetings were held where we discussed current implemented features, potential enhancements for existing functionality and suggestions for items to be considered for the next iteration. Monthly meetings were held where experts within psychology, UX and UI-design and modelling were present. The artefact was presented for the group and feedback was received and taken into consideration for the next iteration.

3.2.1 Determining project goals and requirements

For the first iteration of the project, we focused on determining the scope and initial requirements for the application. In the context of the COPE-project, the mobile application would serve as the front-end for the system. This meant designing a mobile application capable of:

- Delivering the intended therapy.
- Collecting relevant data in order to allow for the adaptive elements of the treatment to function.

Figure 3.1 illustrates the overall COPE system architecture, and the long-term vision for the project. The topmost layer represents the front-end aspects of the project, consisting of the user-facing mobile application which is intended to deliver the therapy. The mobile application's intended role in the system would be to communicate with the back-end system in order to make the necessary adaptions to the delivered therapy in a personalized format. Additionally, the application should deliver the therapy in an interactive manner which promotes user adherence and increases user satisfaction.

The COPE architecture is strongly influenced by the traditional architecture of an Intelligent Tutoring System (ITS) presented in figure 3.2, where the patient model in the COPE system resembles the student model in an ITS, the CBT and Mindfulness resembles the knowledge domain and the Monitor and the Adaptive Algorithm models resembles the more advanced version of the Teaching Strategies in the ITS. See Woolf (2008) and Morales-Rodríguez et al. (2012) for more information on Intelligent Tutoring Systems.

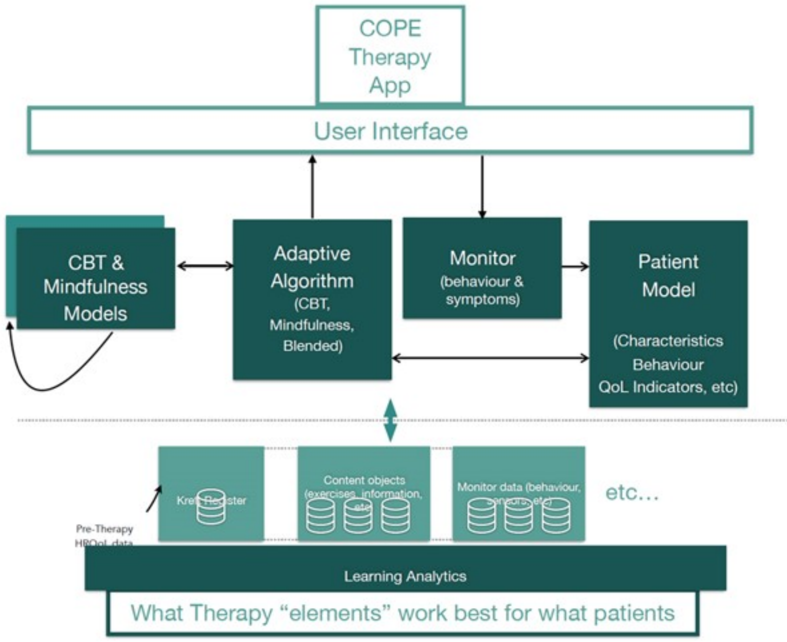


Figure 3.1: The architecture for the COPE platform (SLATE 2019).

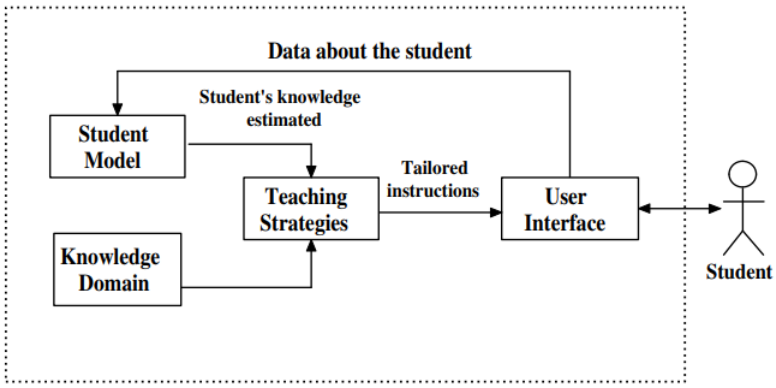


Figure 3.2: ITS architecture (Butz et al. 2006).

For the initial artifact, we decided to use a concrete case to work with in order to limit the scope of the project. We discussed some of the most relevant symptoms related to breast cancer which our first artifact could be based upon. Together with the psychology expert on the COPE research team, we decided that one plausible symptom to address was stress. Also, we found support for this choice in the literature (Holzner et al. 2001) with evidence suggesting that while many learn to cope with their physical symptoms like fatigue, pain and constipation, a number of survivors experience fear-related anxiety and distress regarding a possible relapse. Consequently, we chose to base our first artifact on an application which would implement a self-help program for managing stress.

We chose a CBT program developed by Professor Michael Antoni (2016) at the University of Miami (who is affiliated with the COPE project) as a starting point for the content delivered through the application and the implementation of a stress management program. The course, VSMART, contains a number of stress management techniques and relaxation techniques which are presented throughout the program. We primarily used the content from the participant manual, which contains useful learning material related to stress management in addition to material for rehearsing techniques. For the artifact, we looked at the second session presented in the workbook, which presents the topic of "stress awareness" and related activities. We studied the different activities presented throughout the session and discussed possible changes and enhancements which could be made to the different activities when presented in digital form.

3.2.2 Designing the first artifact

For the second iteration, we focused on designing the first artifact for a digital version of the mentioned session from the CBT program. The artifact consisted of a single activity from the CBT program where the user would go through an appraisal process, describing the event, their perception of the event, the appraisal and their emotions.

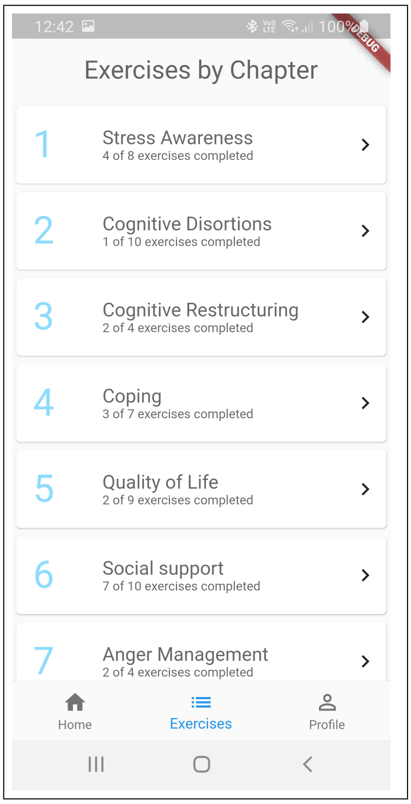
We decided initially to organize the different activities by chapters in the same manner which they are organized in the original program. For the first artifact, the activities are simply contained in a list which is presented when selecting a chapter. Figure 3.3 presents the initial design of both views.

Figure 3.4 presents the design of the first attempt at representing the appraisal process in a digital form. Figure 3.5 represents the original format of the activity. The activity was adapted by converting each single cell into its own page in the application, with a text box for text input and buttons for navigation, saving a draft of the current input and clearing the text box. The highlighted indicator dot serves as the page marker for the user, giving an impression of the number of remaining pages and the number of completed pages.

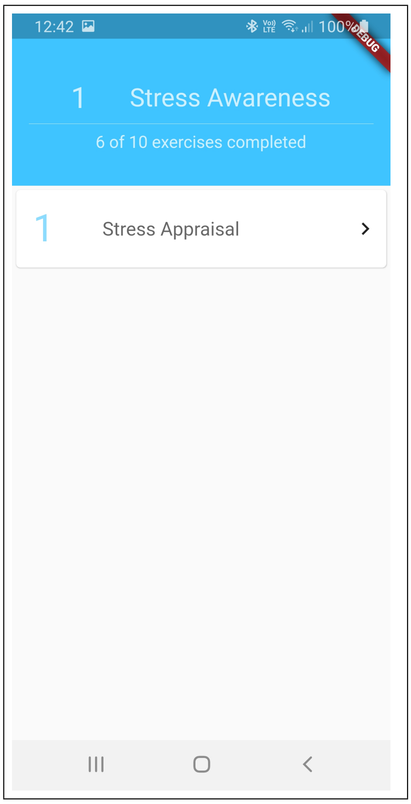
Some of the identified advantages of the digital format were the ability to repeat the activity and store the activity result on the device, eliminating the need for using pen and paper. Additionally, stored activity responses could potentially be submitted for review by a therapist or analyzed using natural language processing. For cases where an enumeration of words is sufficient, frequency graphs can also be created for the response.

Feedback was provided by a psychology expert, supervisors and other masters students present at the meeting at which the artifact was presented. Some key feedback on the artifact was:

- While the original CBT program is organized in chapters (or modules in some programs), this organization may or may not be meaningful when

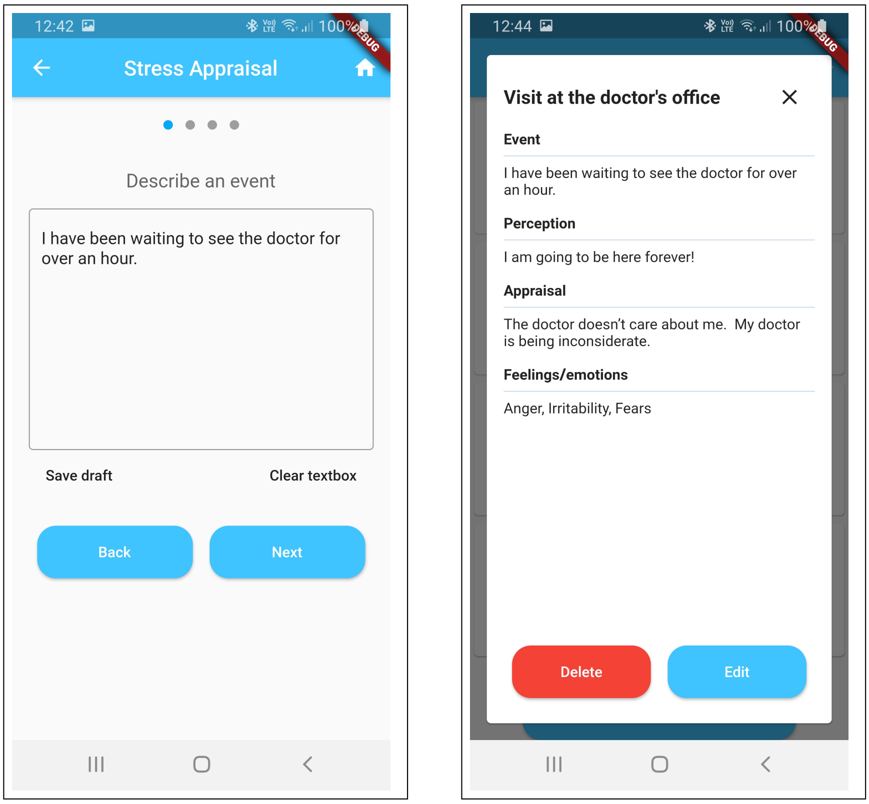


(a) The chapter overview page



(b) Listing the different activities for a chapter

Figure 3.3: Screenshots from an early version of the chapter overview and the activity list view (the numbers presented are random and for illustration purposes only).



(a) The appraisal process

(b) The result when submitted

Figure 3.4: Screenshots from an early version of the appraisal process activity, featuring a page from an activity and the response created upon submission.

considering the goal of an adaptive therapy. For a future artifact, it should be considered whether or not activities and other material should be organized based on a recommender system's choices rather than the traditional approach of a linear course of modules.

- Many breast cancer patients experience cognitive impairment to some degree after undergoing more invasive treatments like chemotherapy (Schagen et al. 1999), and it is therefore worth considering how activities in future artifacts can be adjusted to make it easier for users to complete their activities. Examples of ways to achieve this can for instance be to provide suggestions based on previous answers while performing activities, or by modifying existing activities in order to make them easier to understand and complete (by e.g. modifying questions and input methods).

Example of the Appraisal Process

Event	**Perception** (i.e., becoming aware)	**Appraisal** (i.e., what we think/say to ourselves)	**Emotion/Feeling** (i.e., how we respond)
I have been waiting to see the doctor for over an hour.	I am going to be here forever!	The doctor doesn't care about me. My doctor is being inconsiderate.	Frustrated, irritable, angry, afraid.

Figure 3.5: The appraisal process as presented in the VSMART workbook (Antoni 2016).

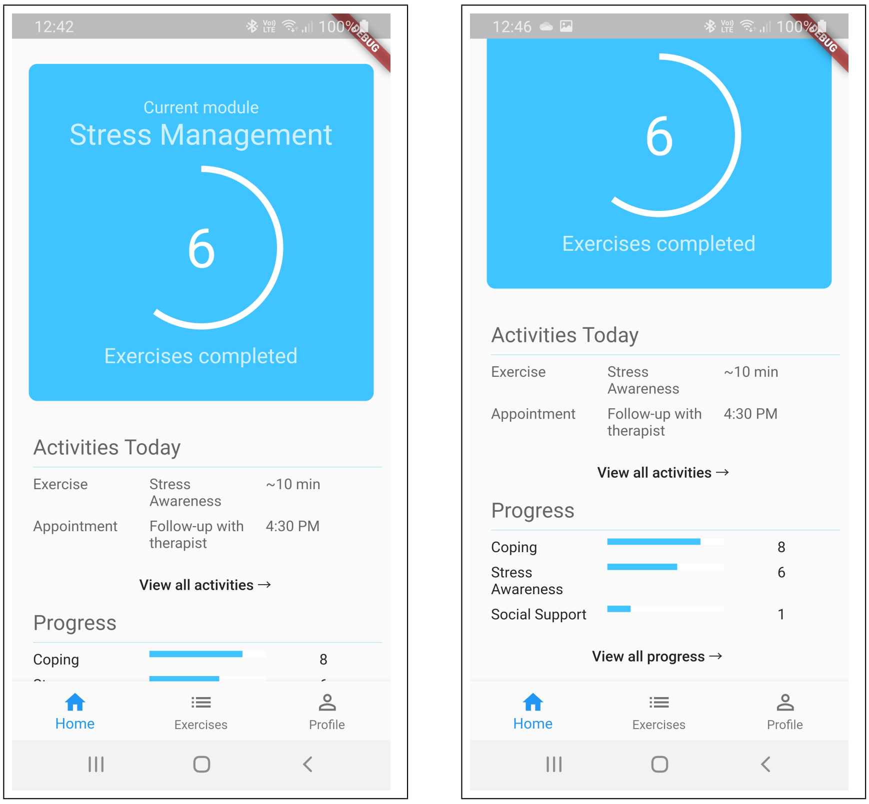
3.2.3 Expanding on the functionality of the artifact

For the third iteration, we expanded the artifact's functionality by implementing more activities from the workbook. Additionally, we designed a summary page intended to display the user's progress while using the application.

Designing a summary view

In section 3.2.1 we mentioned designing an application capable of delivering the intended therapy as one of our goals for our artifact. As a step towards that goal, we designed a summary view for the artifact in order to provide a better reference point for some of the possible features our artifact could incorporate. Consequently, we started designing a view related to tracking the user's progress during the use of the artifact.

Figure 3.6 shows the first design for a summary screen for the artifact. The initial design for the summary page consists of three elements; a circular widget displaying the user's current progress for a module, a table presenting some of the user's upcoming scheduled activities, and a table showing the user's progress for a given set of modules.



(a) Summary view(top) (b) Summary view(bottom)

Figure 3.6: Screenshots from an early design of the summary page for the artifact. Note that the text and numbers displayed are static values intended for demonstrational purposes only.

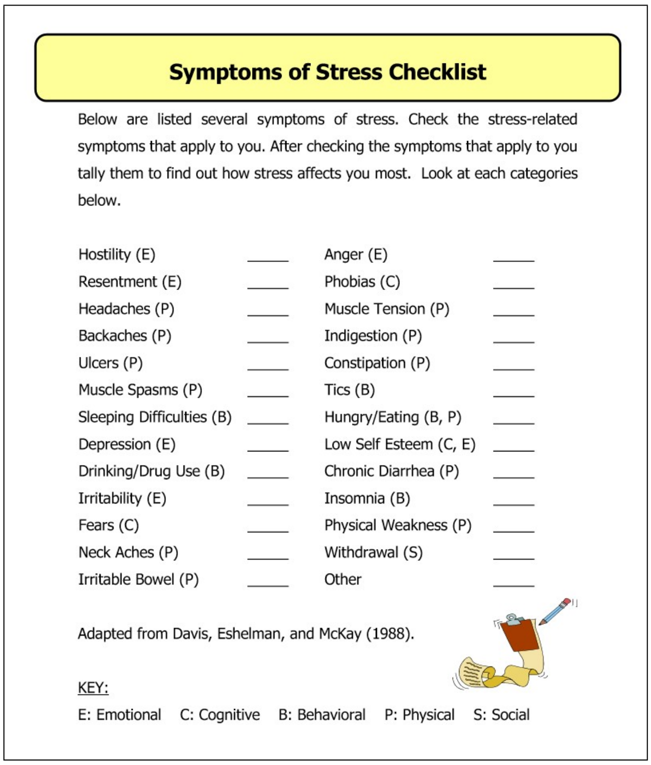
The circular progress widget is intended to present the module which the user last performed an activity within, and will show the current progress within the module in question. The length of the circular indicator represents the percentage completion based on the total number of activities contained in the module. The indicator expands in length whenever a user completes an activity for a given module.

The two tables in the bottom section of the view represents a list of upcoming activities and more progress tracking for the activities. There should be mechanics in place in order to remind users to use the application and perform their activities on a regular basis. Also, notifications should be provided when the user forgets to perform an activity according to a set schedule.

For this iteration, the purpose of the summary view was to provide a better context for the artifact's intended use and theme. It was implemented to inspire better feedback from supervisors and experts by illustrating how collected activity data could be presented to the user.

Implementing activities of different formats

During the second iteration we implemented a demonstration of a single activity from the workbook. For this iteration, we implemented an additional activity in a slightly different format. Figure 3.7 presents the activity called the "Symptoms of Stress Checklist" where patients check off the stress-related symptoms which apply to them, before counting and finding the most frequent class of symptoms.


Symptoms of Stress Checklist

Below are listed several symptoms of stress. Check the stress-related symptoms that apply to you. After checking the symptoms that apply to you tally them to find out how stress affects you most. Look at each categories below.

Hostility (E)	_____	Anger (E)	_____
Resentment (E)	_____	Phobias (C)	_____
Headaches (P)	_____	Muscle Tension (P)	_____
Backaches (P)	_____	Indigestion (P)	_____
Ulcers (P)	_____	Constipation (P)	_____
Muscle Spasms (P)	_____	Tics (B)	_____
Sleeping Difficulties (B)	_____	Hungry/Eating (B, P)	_____
Depression (E)	_____	Low Self Esteem (C, E)	_____
Drinking/Drug Use (B)	_____	Chronic Diarrhea (P)	_____
Irritability (E)	_____	Insomnia (B)	_____
Fears (C)	_____	Physical Weakness (P)	_____
Neck Aches (P)	_____	Withdrawal (S)	_____
Irritable Bowel (P)	_____	Other	_____

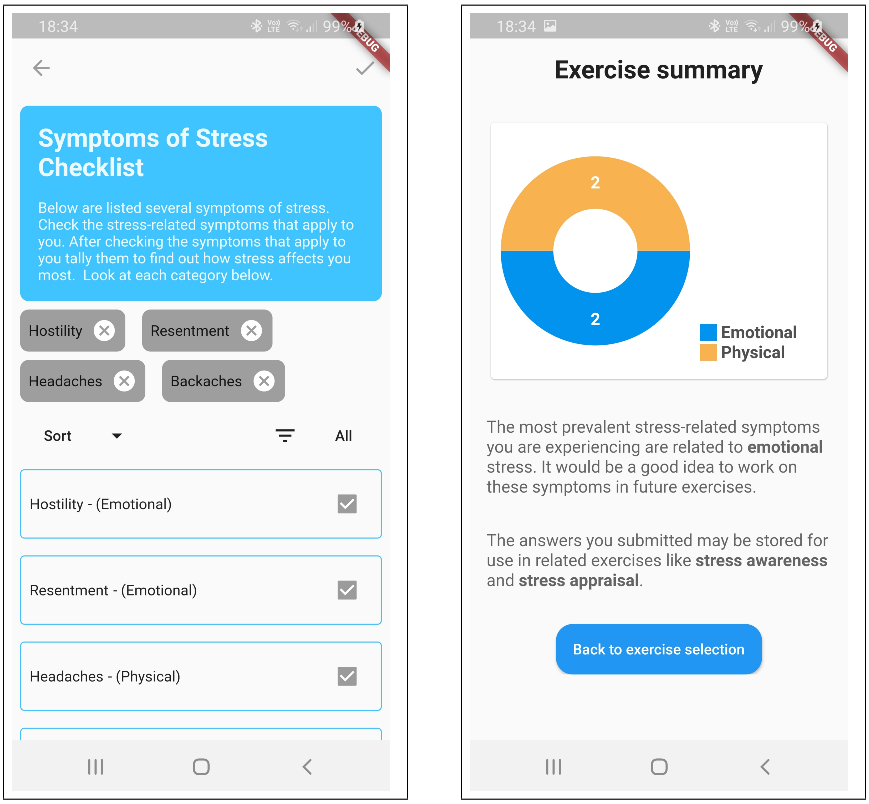
Adapted from Davis, Eshelman, and McKay (1988).

KEY:
E: Emotional C: Cognitive B: Behavioral P: Physical S: Social

Figure 3.7: The Symptoms of Stress Checklist as presented in the VSMART workbook (Antoni 2016).

Due to the differences in format, this activity required a different approach compared to the already implemented activity. The activity structure is represented as a question with a list of potential answers, and each entry is represented by a value (the name of the symptom) and a classification or key (the type of symptom). The activity requires the user to select their relevant symptoms from a list of predefined symptoms (or define their own). Since there is a high likelihood of users selecting a predefined symptom, the activity allows for computing frequency graphs for each symptom in addition to allowing us to compute the most frequent key.

Figure 3.8 shows the two views associated with the activity. In the first view, the user could select from a range of symptoms and add them to a list. When this list was submitted, the results could be presented in the following view where the frequency of each symptom class could be displayed together with a short comment on the result.



(a) Symptom selection (b) Results presented

Figure 3.8: Screenshots from an early design of the "Symptoms of Stress Checklist" activity.

3.2.4 Creating data models and implementing educational material

For the fourth iteration, the issue of scaling up the implementation of activities was addressed, as well as the issue related to the application missing sufficient material to teach the user how to perform the different activities.

Artifact data models

During the previous iterations, data models were tailored for each specific activity. While this provides a great level of flexibility for each activity, each activity consequently requires it's own implementation for this approach. We therefore designed a simple data model for the artifact, based on the observed characteristics of the content found in the workbook. Contrary to the initial model where each activity was backed by its own model and implementation, this approach allows us to generalize (Poo et al. 2008) the activity model in order to capture the similarities shared by certain activities, thus allowing us to design a more scalable approach for defining activities.

A module defines a collection of activities and other content which together make up a part of the treatment intended to teach the user a specific set of skills and knowledge in the context of the program. Each piece of content refers to a relevant module which it is organized by. The status of a module will depend on the number of completed and uncompleted activities referencing this module.

An activity defines an interactive component within the program which requires the user to interact by answering questions, selecting relevant alternatives to a question or perform other tasks. In the VSMART workbook (Antoni 2016), the "Symptoms of Stress Checklist" and "Appraisal Process" tasks are examples of interactive elements where user input is required for completion. Studies have found correlations between homework completion and symptom improvement (Rees et al. 2005), which makes tracking activity completion partly relevant for outcome prediction.

When an activity has been completed, a response is submitted referencing the completed activity. In addition to timestamps/other metadata, the response contains the user's submitted answers to the activity as well as the context for the user's answers in the case where an activity changes in content or structure. The answers can in theory also be sent to a server for analysis or for review by a therapist.

Figure 3.9 provides a minimal illustration of how the different components are organized in the artifact. An activity carries a reference to a module, while an ActivityResponse stores a reference to the relevant activity from which it was submitted. Although it may be beneficial to allow an activity to reference several modules for cases where module contents and topics overlap, our initial model limits each activity to a single module reference in order to limit the complexity of the implementation.

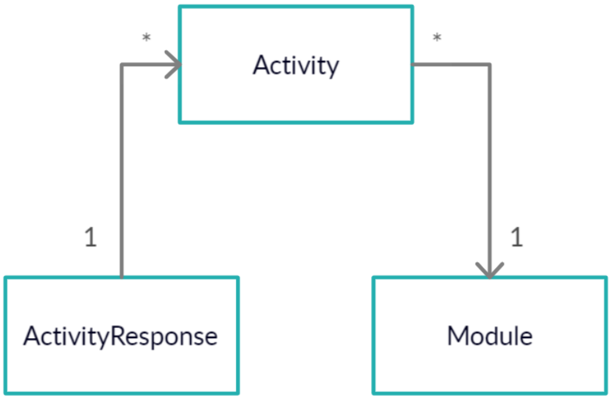


Figure 3.9: The relationships between the core components in the application.

Designing activity structures

Even though there are numbers of different activities in the VSMART workbook, a considerable amount of the activities and content take on the same general structure when engaging with the patient. While implementing each activity or piece of interactive content separately is a plausible approach, it would ultimately require a significant amount of development time. In order to simplify development and reduce complexity, we therefore generalized a number of the activities in the Stress Awareness chapter.

One example would be the "Appraisal Process" section and the "Monitor Your Stress" chart. Both activities require the user to respond to a sentence or word in a specific context provided by the current chapter in the workbook. Figures 3.10 and 3.11 demonstrates how two activities can share the same basic structure despite the differences in presentation. The *question* part of the activities is indicated using red colors, while the *user input* or *response* part is marked using blue colors.

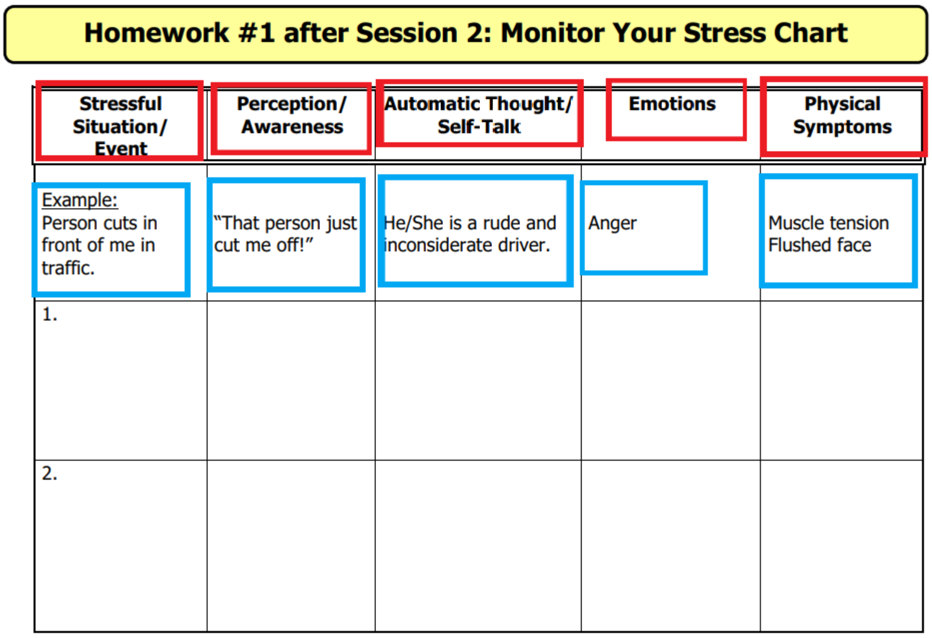


Figure 3.10: Monitor Your Stress Chart (Antoni 2016). Red indicates the *question* or *description* part of the chart, while blue represents the *user input*.

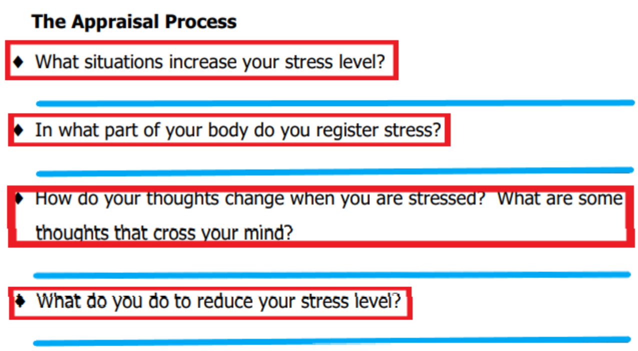


Figure 3.11: The appraisal process (Antoni 2016). Red indicates the *question* part of the content, while blue represents the *question response* section.

Based on the interactive content found in the first session of the VSMART workbook, we can derive two structures capable of representing the activities in their most basic form. The first structure covers the case of a series of question-answer pairs as illustrated by figure 3.10 and 3.11, while the other structure covers the case where a question or description is provided together with a set of selectable alternatives. Figure 3.12 shows two simple structures for these cases.

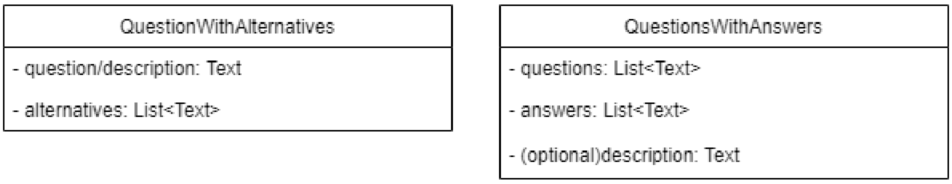


Figure 3.12: Two simple structures for representing the activities in the first session.

While these two generalizations of the chapter content may be sufficient for the chapter in question, activities and interactive content in subsequent chapters will likely require new structures and simplifications. Also, it is not possible to provide any guarantees for the re-usability of these structures unless the entire program is considered during the design.

Implementing educational material

So far, we mainly focused on defining and implementing activities. Some activities require the user to possess knowledge related to the topic which it belongs to. Consequently, the artifact needed a means of teaching the user the required knowledge and skills in order to correctly perform the implemented activities. We attempted to achieve this by implementing the educational material from the VSMART workbook inside the artifact.

Similarly to the approach taken while designing activity structures, a simple structure for the learning material was designed based on the observed structure of the content from the workbook. The educational material in the workbook consists mainly of text and images, making two basic structures supporting images and text the only necessity for representing the content from the workbook. Figure 3.13 illustrates how the text and image content is defined in the artifact. In the initial model, the classes defining image and text content extends a base class which defines the content type attribute in order to aid the artifact in rendering the correct 'widget' for each component.

These simple relationships and structures allowed us to construct educational material in a similar manner to the structure presented in the VSMART workbook. Organizing these structures in pages gave us a flexible and functional approach to present the user with educational material relevant to the activities.

Figure 3.14 shows a side-by-side comparison between the VSMART workbook representation and the application representation of the educational material. While there are some missing components for accurate representation (e.g. ordered and unordered lists), the majority of the content in the first session can be adapted using our current structures in a manner which mostly resembles the original representation. The comparison in figure 3.14 notably shows the

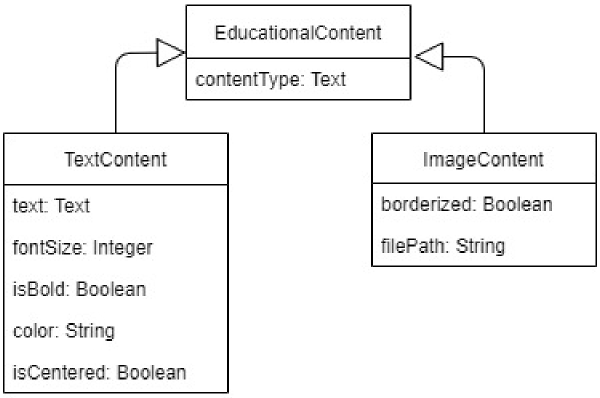
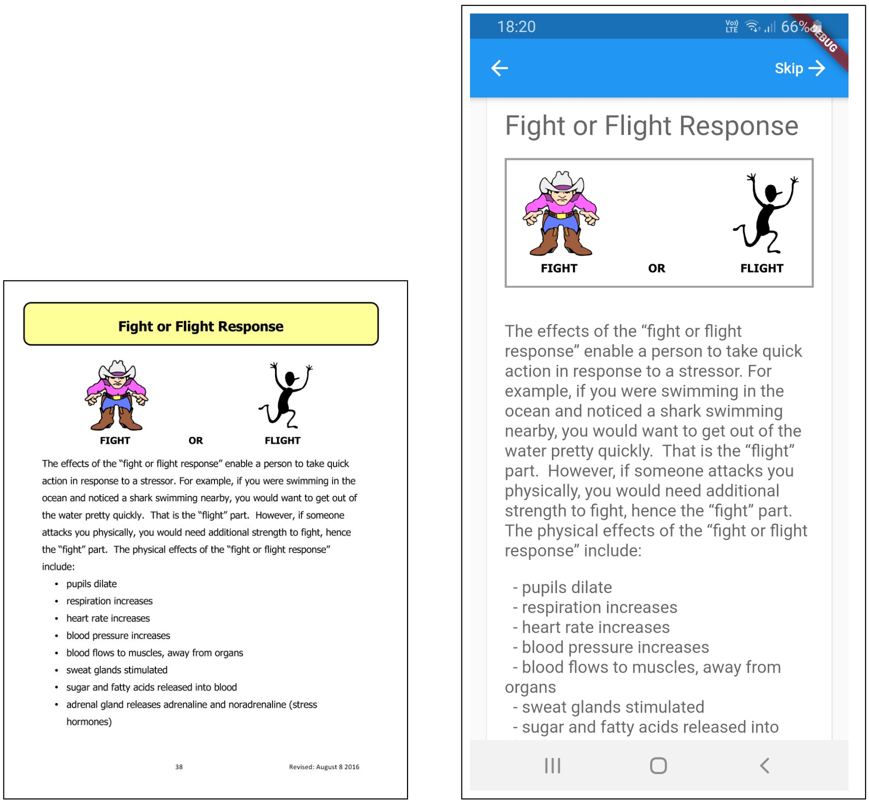


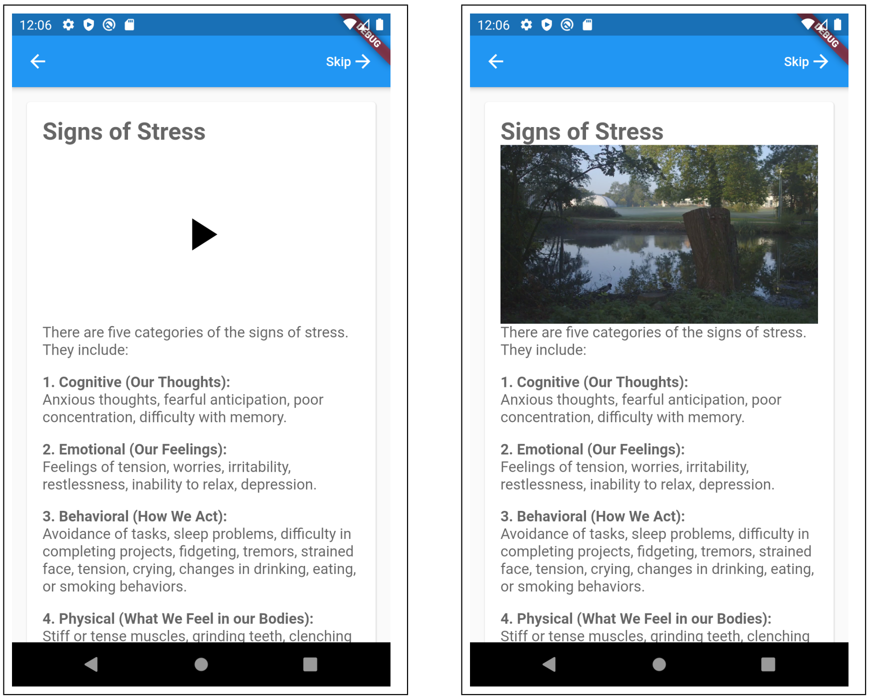
Figure 3.13: Educational material initial structures and relationships.

lack of functionality for rendering lists. Also, it shows that this can be somewhat mitigated by formatting sentences in a specific manner until a proper list rendering implementation can be provided.



(a) VSMART workbook (Antoni 2016) (b) Application

Figure 3.14: Comparison between the VSMART workbook representation of some specific learning material (Antoni 2016) and how this material is presented by the artifact in the fourth iteration.



(a) Before playback (b) During playback

Figure 3.15: Before and after pressing the play button for a video widget. The video played was primarily for demonstration purposes, and is not of relevance to the workbook content.

3.2.5 Implementing support for audio and video content

The fifth iteration included the implementation of video and audio content within the application. While the VSMART course does include educational videos (and highly encourage utilizing these during the course), they are delivered through a separate system available to participants via tablets. Making videos and audio available directly through the application rather than having to rely on a separate system, may lower the bar for users to access them. Additionally, implementing the ability to listen to the educational material in audio form may promote increased adherence and learning among users with a preference for audio over reading. Figure 3.15 shows how a video player can be embedded into a page and how triggering the video playback renders the video. Due to the limited usefulness of the video player without relevant video content available, playback controls was not implemented for the video player.

Implementing support for video and audio content was done using the same approach as with the other types of educational material. Audio and video content is represented as their own structures within an educational material page, and is defined by a name, description and a URL referencing the location of the resource to be played. For our artifact, only the functionality for playing local files was implemented. Figure 3.16 shows the structures created for representing video and audio content.

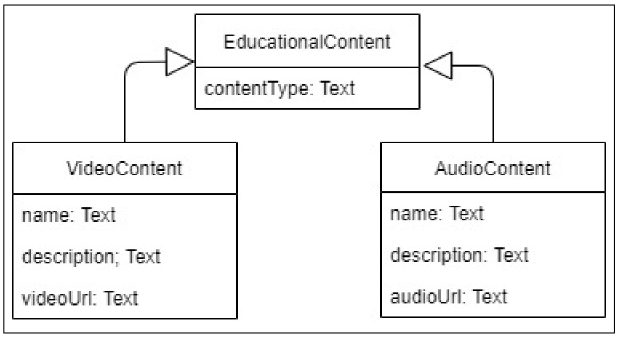


Figure 3.16: Structure and relationships for audio and video content.

Audio playback of educational material

While implementing support for playback of video and audio content can be done with limited effort from a purely technical perspective, the artifact still requires meaningful media content in order to take advantage of these features. In the case of video content, significant effort and knowledge is required in order to create quality content suitable for the program. For this reason, we chose to not tackle the challenge of creating meaningful video content for the application.

As goes for the audio content, we decided to use Google's text-to-speech (TTS) service for speech synthesis on the content from the workbook. Using this approach, we were able to create working samples for two of the implemented pages using the demonstration feature available from the Google site. A few paragraphs from the text was played and sampled from the TTS demonstration feature before adding it as a local MP3-asset within the application. A simple media player with pause and play functionality was implemented as a widget available in the educational material.

While we could have implemented a client for sending text to the TTS service and receiving synthesized audio on-demand, we chose to use local audio file samples for the artifact. We decided that this approach provides an adequate demonstration of the concept which the artifact's audio functionality attempts to display.

3.3 Description of pre-evaluation artifact

This section presents the final state of the artifact developed throughout the various iterations described in section 3.2 prior to evaluation. The artifact is a cross-platform mobile application, primarily for use with smartphone devices running Android or iOS. The application's primary purpose is to enable the

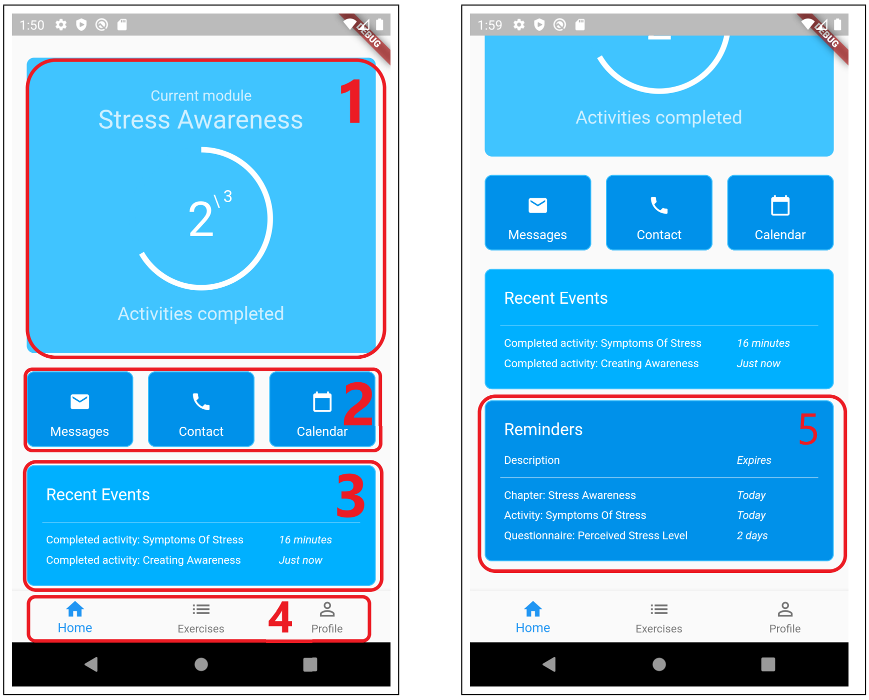
Figure 3.17: Widget for playback of audio content. Cartoon from (Antoni 2016).

delivery of iCBT through workbook-based content coupled with basic logging capabilities and activity tracking.

The final artifact consists of:

- A summary page presented upon a successful launch of the application.
- A list containing the available modules.
- An overview of the available content within a module, in addition to relevant activity submissions.
- A screen for answering questionnaires.
- A media player for playing soundtracks.
- A page for displaying educational material.

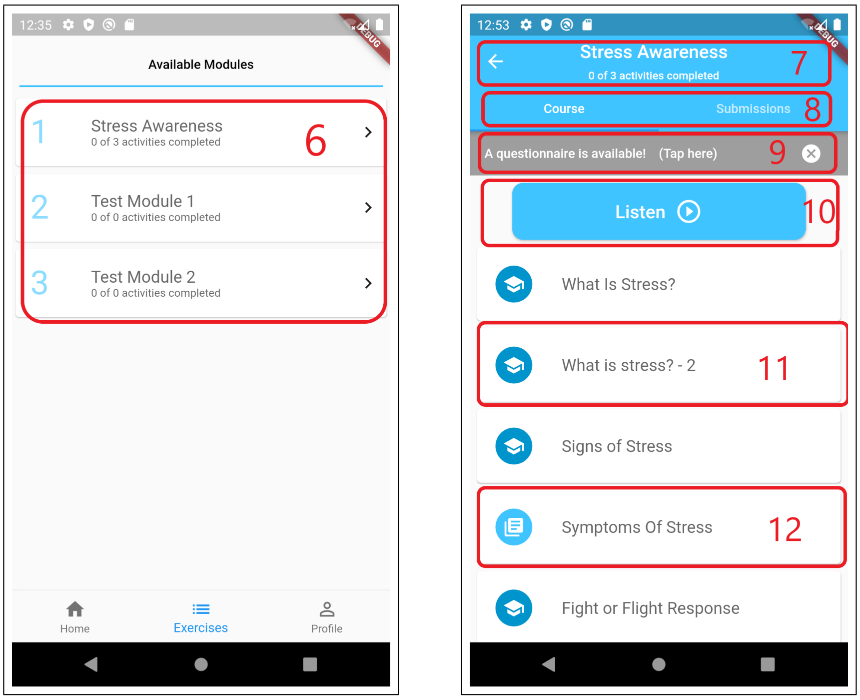
Additionally, the pre-evaluation artifact is capable of collecting and storing various usage-related data. The data collected by the artifact is listed in subsection 3.4.2.



(a) Top half (b) Bottom half

Figure 3.18: The top and bottom half of the summary page.

Figure 3.18 presents the summary page with its respective sections labelled. The circular progress indicator (1) presents the user's progress in the most recent module where a response to an activity was submitted. The length of the indicator arc represents the percentage completion of a module, and will be displayed for any positive progression percentage value above zero. For cases where there's no recent progression (the percentage value is zero), a message describing the case of no displayable progression is presented instead. The widget serves to remind the user which module is being currently worked on, and how much the user has progressed in the respective module. The row below the progress indicator widget (2) contains action buttons for various utilities and actions which a complete implementation of the application could benefit from. The artifact does not provide an implementation for any of the utilities or actions available in the button row. Instead, these buttons are included to showcase potentially useful actions and utilities which are beyond the scope of this thesis project, but still relevant for creating a better picture of the final concept. Below, the table (3) displays recent events, and triggers an entry whenever the user performs an action within the app. These events can include activity completions or other events which are tracked by the application. By default, the application filters and displays only the three latest events in the summary page. A similar table (5) for calendar events is presented below the events table. Similarly to the button row (2), no implementation has been provided for this table, and the functionality demonstrated by the table is mainly to contribute towards the completeness of the concept. In a complete implementation of



(a) Module list (b) Module contents

Figure 3.19: The module list and the contents of a module.

the application, a system for scheduling events and reminders would likely be of importance for encouraging timely completion of content within the application, in addition to activities unrelated to the application itself. The navigation bar (4) is presented at the very bottom of the application screen, and enables easy access to the most central aspects of the application.

Navigating using the bottom navigation bar's second item takes the user to the overview presenting the available modules within the application. Figure 3.19 shows the view listing all available modules and the view which is presented when selecting a module. The list presented within the page (6) displays the available modules by their names in addition to the number of completed activities within each respective module. Tapping a valid module takes the user to a page displaying the available content within the selected module. The top section of this page presents the name of the module as well as the number of currently completed activities (7) within the module. A tab bar allows for navigation between the course content and the user's submissions to each activity (8). A questionnaire for assessing the user's state becomes available after a set number of activities has been performed. It is indicated by the prompt under the tab bar (9). Additionally, each module contains a button which opens a media player for the audio content within the module (10). The list within each module contains a number of educational material pages (11) as well as activities related to the educational material (12). The content is presented in the same order in which it is presented in the VSMART workbook.

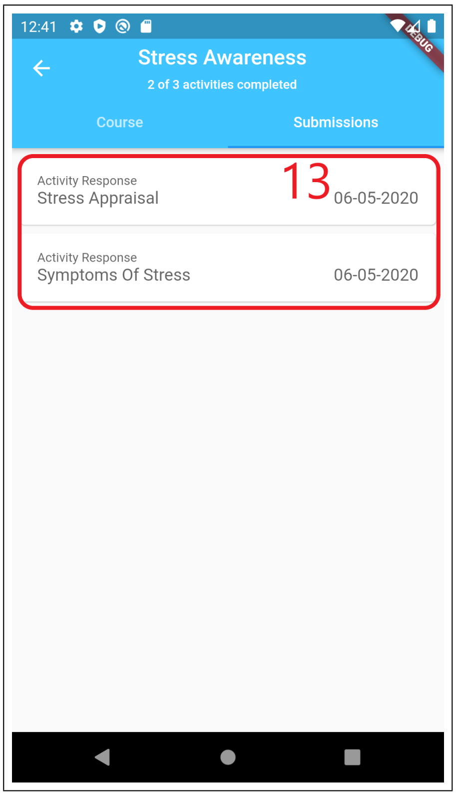
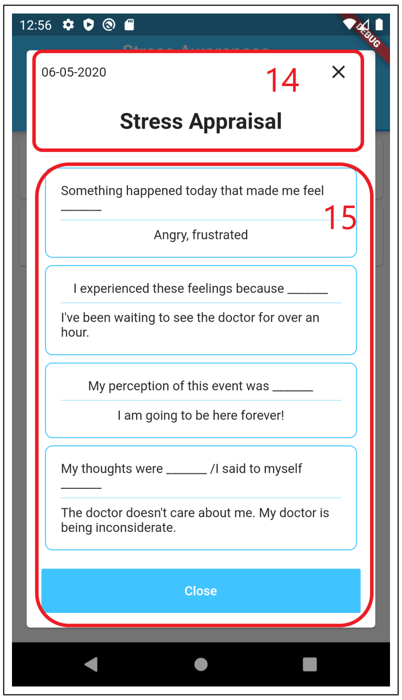


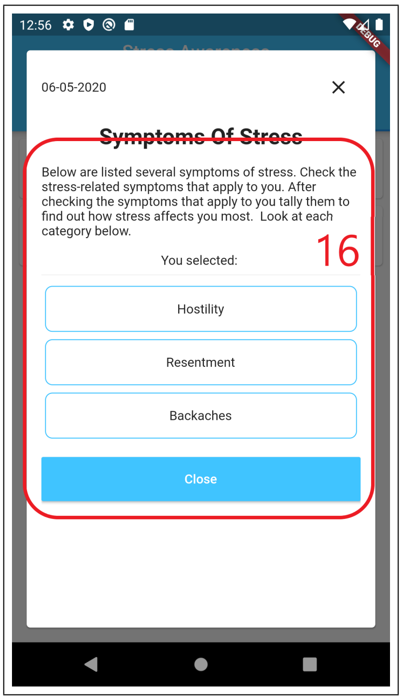
Figure 3.20: The list displaying the user's submissions.

As illustrated by figure 3.20, tapping the rightmost tab button takes the user to the list displaying their submissions for each activity within the module (13). Each list entry consists of the activity name and a timestamp. Tapping a list entry displays the complete activity response as displayed by figure 3.21. For all responses, a header containing the activity name and timestamp is displayed (14). For the stress appraisal activity, each question is displayed with its respective answer (15), while for the symptoms of stress activity, the instructions or question is displayed together with the selected answers (16).

With the final screen we provide an example of a design for a media player for playing local or remote audio files available in the current module (figure 3.22). The screen displays the name of the current page or track name being played back together with a cover photo (if available) as a simple visual identifier for the current track being played (17). The section below presents the media controls (18), with buttons available for skipping tracks and playing/pausing the current track. The final section of the screen displays the next available track for playback (19).



(a) A submission for the stress appraisal activity.



(b) A submission for the symptoms of stress activity.

Figure 3.21: Dialog windows for displaying activity submissions.

Figure 3.22: The media player for playing audio content. Cartoon from (Antoni 2016).

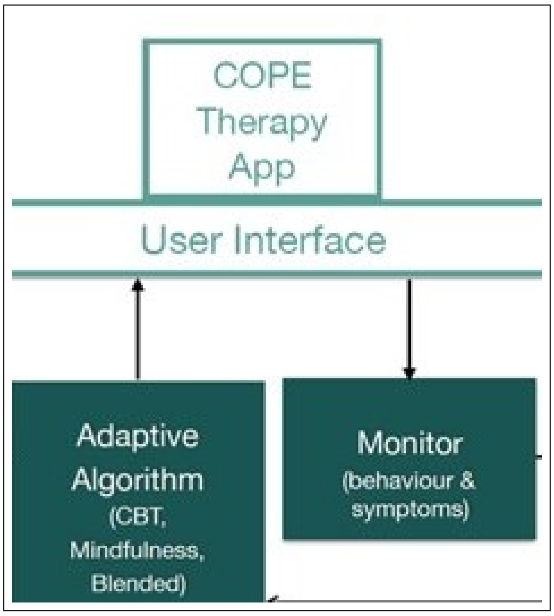
3.4 Collecting user data

In chapter 2 we discussed some of the shortcomings related to self-guided iCBT and the lack of personalization within existing treatment options. Tailoring of interventions requires knowledge regarding the user's state, preferences, goals and other relevant information needed to create an individualized learning path for the user. Existing knowledge related to adaptive learning systems highlights the potential benefits of tailored learning paths and the need for data to drive adaptive solutions (Aleven et al. 2016), and the lack of research related to net-based, adaptive iCBT raises the need for more data collection within digital interventions (Liu et al. 2017). Furthermore, in order to enable a data-driven approach to personalizing the user experience, the artifact collects and logs a number of events occurring during the use of the application.

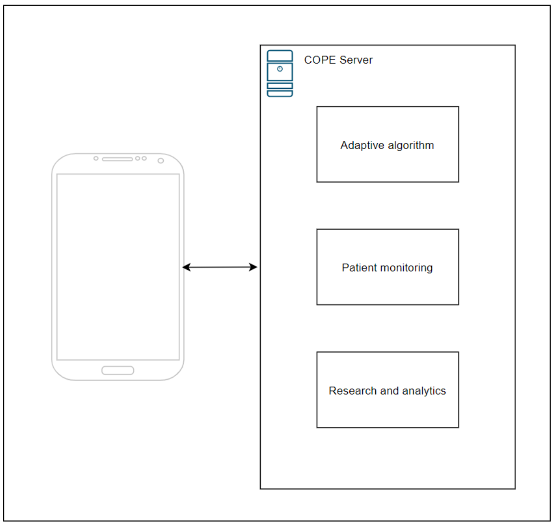
In addition to the case of collecting activity responses submitted by the user, the application also collects usage data related to the actions the user performs within the application. Actions like browsing through learning material and toggling playback of media content are logged and stored within the application's local database, making it possible to later synchronize recorded data with a server. *Educational data mining* and *leaning analytics* are established practises for aiding in understanding users in relation to distance learning (Baker & Inventado 2014), and there exists research documenting the use of log data in *Virtual Learning Environments* (VLE) in order to classify interactions and make performance predictions based on correlations. Tools and functionality for collecting log data may have the added potential for being relevant in examining user behavior and detect uncommon or undesirable behavior among users (Agudo-Peregrina et al. 2014). Furthermore, log data can be used within adaptive learning systems where collected user data may for instance be used for driving design-loop adaptivity or task-loop adaptivity in order to make data-driven decisions for enhanced learning (Aleven et al. 2016). Therefore, collection of log data can enable a range of possibilities related to adaptive learning, and may provide a means of personalizing learning paths based on individual needs (Liu et al. 2017).

While we describe the artifact's architecture and design pattern later in section 4.2, we do not describe the bigger picture which the artifact is intended to operate within when considering the collected data and the adaptive mechanisms they are intended to aid. Figure 3.23 describes the functionality which is intended to be supported by the data collected through the artifact in relation to the COPE system (which we presented in section 3.2.1).

The COPE-system depends on a number of different components in order to provide the level of service as originally intended. The adaptive algorithm requires a constant supply of information in order to provide the best possible content suggestions for each user. In section 3.2.1 we also described the architecture of a traditional ITS system and mentioned the fact that the COPE patient model is based on the student model in an ITS system. For feeding this model, certain characteristics of the user like learning styles, background knowledge, cognitive styles, preferences and motivation may also be valuable as sources of adaption (Nakic et al. 2015) in addition to collected log data. Additionally, the ability to easily collect quality data forms the foundation for developing a research platform for further research on important research topics such as the long-term efficacy of adaptive iCBT and how it can be improved for future use.



(a) Relevant modules for the COPE architecture (SLATE 2019).



(b) Clarified image of the functionality enabled by collecting data.

Figure 3.23: The app interactions in the context of the COPE system, and a sketch of the functionality enabled by collecting user data.

3.4.1 Activity response data

In section 3.2.4 we described how we implemented a set of simple data models for representing activities and activity responses within the application. During the iterations involving these data models, we mainly focused on the purpose they served as a part of the application structure and the interactions they enabled. While they serve an important role for the core functionality of the user interface and application interactions, they also serve the additional and important purpose of enabling logging of activity data on a basic level. In section 2.1 we mentioned that therapists commonly prescribe homework as an integral part of the CBT program. There exists evidence suggesting that homework completion is associated with better coping skills during treatment (Carroll et al. 2005) and more consistent and substantial improvement (Burns & Spangler 2000), making data related to homework completion particularly interesting. The activity data recorded by the artifact is essentially the homework section of the CBT program, making it possible to monitor adherence using data from stored activity responses.

Using the activity responses (or homework submissions in the traditional CBT programs), we can monitor the user's progression as they advance through the program. This potentially allows us to detect dropouts and users who are slowing down or improving based on the speed and consistency at which they are progressing.

3.4.2 Usage data

During the last iteration, we implemented mechanisms for collecting usage data. Similarly to storing activity responses, log entries containing events related to interactions performed by the user are stored in the application's local database. A wide range of interactions can be logged and later retrieved, though the artifact only stores the following interactions:

- Start/stop interactions with media players.
- Toggling the next/previous buttons for the educational material pages.
- Time spent on a page while browsing the educational material.
- Application launches.
- Activity submissions.
- Content bookmarking/remove bookmark events.

The usage data collected by the artifact can be of interest in relation to several cases relevant for research. For instance, the logging of media consumption allows for closer monitoring of user preferences in relation to content modalities. Since the artifact captures the playback frequency and duration of media playback, the user's preferences in relation to content modality can be mapped and later used for delivering a more personalized experience by adjusting the content delivered in order to better fit the user's preferences. Additionally, the logging of content consumption allows for the application to monitor to which degree the user consumes the intended content in a timely manner.

3.4.3 The value and use of usage data

One of the overarching goals of the COPE project is the ability to provide a personalized intervention in order to study the effects of individualized treatments for better adherence and effect. The mechanisms for providing the personalized intervention itself through activity recommendations and questionnaire responses is investigated and described in a different master thesis within the COPE project. Consequently, we will not cover the use of activity data and questionnaire responses in relation to the adaptive mechanisms for executing the treatment, but rather try to justify the need for data in order to provide a personalized learning experience.

In subsection 3.4.2 we listed the data which the artifact actively collects and stores locally. Due to the lack of studies on self-guided, personalized iCBT, it is difficult to draw conclusions regarding the real-world use of these data in regards to the COPE project.

Still, there exists a number of studies related to how interactions with multimedia content can provide valuable data of potential usefulness for facilitating a more personalized experience based on user characteristics. For instance, a study by Ozan & Ozarslan (2016) looking at the behavior of students watching video lectures used the *seek* functionality available in video players to analyze the behavior of students when presented a number of different video styles, and were able to find behavior characteristics for male and female viewers when considering the amount of skipping in the video. Additionally, they were able to find correlations between the percentage who watched a video to the end and the length of the video using the data collected during the study. Similarly, Xie et al. (2017) used video player events in their study in order to gather data on the active video-viewing time of users. For other e-learning systems, we mentioned how educational data mining can aid in tracking user behavior in section 3.4.

Sieverink et al. (2017) addresses the need for eHealth research to extend beyond the classic effect evaluations, and suggests how the analysis of log data can be used for better insight into the usage of technology. Based on the examples presented in this section, we believe that there may be potential for using the collected usage data in order to improve the tailoring of delivered iCBT content on a mobile platform. We assume based on the examples that some degree of content adaption would be possible in a mobile app designed with this in mind or a future version of the COPE application. For future research into self-guided, personalized iCBT, we believe these are important for advancing our current knowledge regarding self-guided, adaptive iCBT.

3.4.4 Other kinds of collectible data

There are multiple other kinds of data which could potentially be collected either directly through the artifact or through external connected devices communicating with the artifact. Here we will mention a few points which may be relevant for adaptive iCBT

Position data

Position data can potentially be useful in a number of situations for monitoring patients' isolation patterns and other patterns related to the patients behavior. In section 2.4, we mentioned a study by Smedberg & Sandmark (2012) where they allowed the user to record a place and time where a stressful event occurred using their smartphone as a part of an app-powered self-reflection and self-management solution for stress. We also mentioned the MoodTrainer app presented in the study by Addepally & Purkayastha (2017) which allows for the logging of a location, though in this case in relation to the user's mood in order to monitor isolation patterns.

This shows the potential usefulness of position data for patient monitoring purposes, though there are examples of apps deemed controversial due to their handling and use of the users' position data. One recent example of this is the Smittestopp-app (Helsenorge 2020) which was developed in an attempt to limit the spread of COVID-19.

User activity data

Many modern smartphones and wearable devices are capable of detecting common movement patterns when worn by a user, for instance walking, running, sitting, various physical exercises and others. Smartphones can for instance use data from several sensors in order to determine what the user may be doing, and modern smartphone operating systems like Android have special APIs for this purpose (Google 2020). With help from machine learning, modern smart watches are even capable of recognizing a wide range of activities which even modern smartphones may not be unable recognize (Weiss et al. 2016).

Data related to a user's physical activities can be valuable for determining if a user for instance is adhering to a treatment plan. With the existence of evidence for physical activity as a potentially effective treatment for depression and anxiety disorders (Ströhle 2009), a smartphone and smartwatch would for instance determine if the patient is performing their daily exercises and activities. While potentially useful for patient monitoring, we decided to define the use of data related to physical activities as outside the scope of this thesis project due to the complexity of working with data from wearable devices. The topic could be of interest for a possible new master thesis project within the COPE project.

3.4.5 Section summary and remarks

In this section, we described how we designed the mechanisms for collecting data in the artifact. The approach taken towards data collection within the artifact takes much of its inspiration from traditional educational data mining strategies in order to gather information about the users and their behavior and preferences while using the artifact. The profiling of users is intended to provide the patient model in the COPE system with the data required to create a more personalized experience for users according to the principles behind ITS systems (Morales-Rodríguez et al. 2012) which the COPE architecture is based on.

We designed the artifact to be capable of collecting questionnaire and activity response data in order to enable the adaptive mechanisms which are described in a separate COPE-related thesis. In addition to iCBT-related data, the artifact is designed to track and log a number of interactions with the learning material and module contents, with the potential to expand the logging functionality if needed in the future. As mentioned, there exists several additional data points of interest for adaptive iCBT and patient monitoring, though we decided to limit the scope to data easily collectible within the artifact in order to limit the complexity and scope of the project.

With the lack of research into self-guided, adaptive iCBT and the need for a better understanding of eHealth technology with regards to more than only descriptive statistics (Sieverink et al. 2017), the artifact presented in chis chapter serves as a tool for enabling further research into adaptive iCBT. The topic of self-guided, adaptive iCBT is an area in need of more research which the COPE project will provide further research on.

Chapter 4

Implementation

This chapter presents the frameworks and technologies used in order to develop the artifact, as well as the system architecture and other technical aspects of the project that are of relevance.

The first section describes the framework used for developing the artifact. The second section explains the choice of architecture and design pattern used for developing the artifact. The third section describes how the data logging is implemented within the artifact. The final section within this chapter comments on security in relation to the implementation of the artifact.

4.1 Application framework

As the artifact is a cross-platform application intended for use with iOS and Android devices, a framework for developing cross-platform applications was needed. We chose to use Flutter (Google n.d.) for the development of our artifact, which is an application software development kit (SDK) developed by Google for creating performant cross-platform mobile applications. It consists of a modern, react-style framework with a 2D rendering engine, ready-made widgets and development tools to help developers create, test and debug apps. Flutter is designed with productivity in mind, and allows developers to create apps for iOS and Android using a single codebase. It allows for easy prototyping and fast iterations, while also making it easy to create beautiful and highly custom user experiences (Google n.d.).

Despite React Native (Facebook n.d.) being the most popular framework for cross-platform mobile development (JetBrains 2019), we still chose to use Flutter as our framework for development. Even though the Flutter framework lacked the same level of maturity and community support as React Native at the time of developing the artifact, it showed great promise with an intuitive programming language and a easy-to-use framework for creating user interfaces and application components. Therefore, we chose to test out this technology in the development of our artifact.

4.2 Architecture and design pattern

The following section presents the architecture and design patterns chosen while designing the artifact. The choice of architecture was mainly derived from existing popular architectures used for mobile applications. Driving the UI from a model and providing abstractions through repositories has been a common practise for Android app development (Google 2019), and the same pattern serves as the inspiration for the architecture of our artifact.

The artifact is primarily a prototype for demonstrating possible functionality, and therefore lacks a proper back-end system for exchanging information. Consequently, the artifact's architecture is designed with an "offline-first" approach to storing and fetching data. The prototype utilizes a local database as its main "source of truth", with the majority of the available content being read from the local storage for subsequent access after first-time synchronization. This has the added advantage of making it considerably easier to create a working prototype without relying on having a back-end, while still allowing for interactions with the application representative of a real-world scenario.

4.2.1 Model-View-Viewmodel

The application uses the model-view-viewmodel (MVVM) pattern (Tripathi & Narang 2017) for separation and communication between the different layers of the application. This is achieved using a plug-in called Flutter Provider (Provider n.d.) for exposing and listenting to values in a class. Values are exposed by a viewmodel, which the view listens to and uses when building the user interface. Actions are performed by invoking methods on the viewmodel, which in turn signals the view to rebuild upon request from the viewmodel.

Figure 4.1 presents the architecture of the application. Each layer within the application can only access the next layer directly below it, creating a data flow from the bottom database layer to the top view layer when working with locally persisted data within the application. The repository serves as the application's branching point for local and external data sources, and would serve as the synchronization point when working with external data sources.

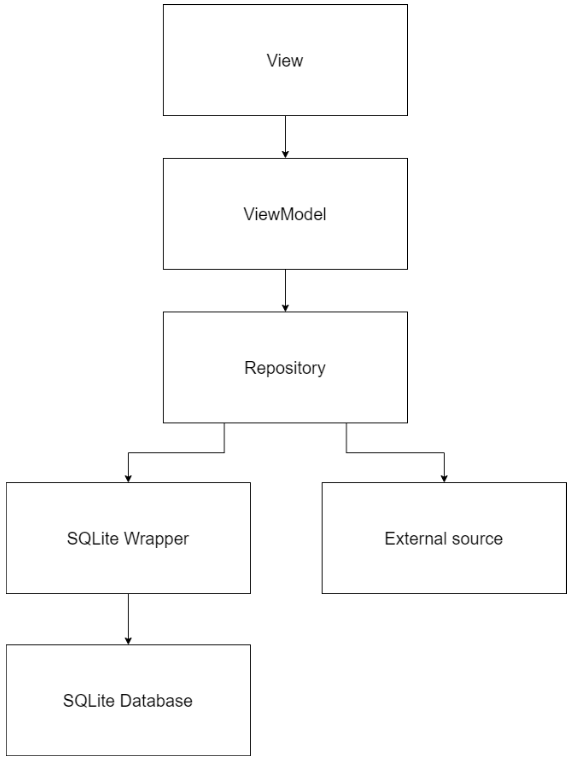


Figure 4.1: The architecture for the application.

View Layer

The view layer is responsible for building and rendering the user interface as well as responding to user input. When using the Flutter SDK, the view is built by composing view components called widgets in a hierarchical manner, which are internally represented as tree structures and rendered by the engine. The view builds its layout based on the defined widget structure as well as information exposed by the viewmodel, making the view dependent on the state of the viewmodel. Additionally, the view is responsible for handling user input and invoking the correct methods on the viewmodel when user interaction is performed.

Viewmodel Layer

The viewmodel serves as an abstraction of the view, and exposes functionality for modifying its values. When actions are forwarded by the view, the viewmodel performs the appropriate actions to modify its internal state before notifying the view to rebuild. Contrary to a controller traditionally used in a MVC pattern, the viewmodel carries no reference to the view which it is bound to, and has no information regarding the caller when receiving method calls.

Repository Layer

The repository layer serves as the application's "single source of truth" for each respective resource the application needs to access, either from an external API or the local database. Whenever the viewmodel requests data, the repository fulfills the request either by calling an external API or by fetching data from the storage layer. As the repository can contain references to both local storage and external APIs, it can also serve as an important component in a synchronization service if remote synchronization with a service were to be implemented.

The repository classes in the developed artifact does not call methods to fetch data from remote servers. Instead, sample data is inserted from local sources using the repository when needed for demonstration purposes.

Storage layer

The storage layer contains the SQLite (SQLite n.d.) database where application data is locally persisted. A community-developed plug-in called Flutter Moor (Binder n.d.) serves as a wrapper for the SQLite database. It provides a range of useful functionality like automatic generation of database entities and tables, data access objects, queries and stream support. The database serves as the container for the state of the application.

4.2.2 Data Persistence and State Management

Data persistence is achieved through the use of the SQLite wrapper and the SQLite database. Since the SQLite wrapper supplies stream functionality for notifying other components whenever changes are made to a database table, components listening to specific database changes can be rapidly notified and subsequently propagate events to other listening components when the state of a view/viewmodel depends on the contents of a database table.

Figure 4.2 illustrates the event flow whenever a change is made to the database when using streams as a listening mechanism. Upon insertion, modification or deletion of a table row, the SQLite wrapper can notify the repository of the changes being made to the relevant table. The repository further transforms and returns a new stream to the viewmodel, which is responsible for managing the state of its respective view.

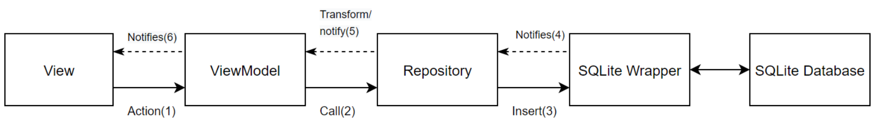


Figure 4.2: The flow of data when performing data insertions and listening to database events using streams.

Since each viewmodel manages the state of its respective view, state management is achieved by making each viewmodel responsible for fetching and persisting their part of the application state by interacting with the repository.

4.3 Data logging implementation

The first iteration of the logging mechanism implemented utilized a basic structure in order to demonstrate the concept of logging data. Later, however, we later decided to utilize a more standardized means of logging events in the prototype by using xAPI for storing the structures containing information regarding the user's interactions with the prototype.

4.3.1 Experience API

The Experience API (also known as xAPI, or the "Tin Can project") is a specification for learning technology. It is oriented around capturing the activities of a person or group in a consistent and flexible format. The specification is owned and maintained by the Advanced Distributed Learning Initiative (ADL), and improves on previous standards for e-learning like the Sharable Content Object Reference Model (SCORM) (Rustici Software LLC 2020*a*) by providing a simple and flexible API which is community-driven and free to implement (Rustici Software LLC 2020*b*).

In its simplest format, a statement in xAPI can be formed by following a "actor-verb-object" pattern:

Actor

The Experience API revolves around recording *experiences*. The *actor* within xAPI refers to the person within the statement who is having the experience. When recording data related to people's experiences, it's essential to know who is having the experience in order to make the other parts of the statement relevant.

The example below uniquely identifies an actor by their name and e-mail address. While the name "John Doe" may belong to several people, the e-mail address must belong to a single person.

```
{
  "name": "John Doe",
  "mbox": "mailto:john@example.com"
}
```

Actors can also be identified through other systems. In the example below, the actor is identified through a twitter handle.

```
{
  "name": "John Doe",
  "account": {
    "homePage": "http://twitter.com",
    "name": "johndoe20914"
  }
}
```

Verb

While the actor defined *who* or *what* experienced something, the *verb* describes what the actor experienced. The verb is identified by a (unique) URI which resolves to the action being performed. Developers and organizations can define their own verbs or use existing verbs defined in the existing xAPI registry.

A verb statement usually contains an identifier for the verb in addition to a short display string for the verb. Any full URI can serve as a identifier for the verb, and the display string handles the issue of internationalization in cases where several display languages are needed. The example below demonstrates a simple verb statement.

```
{
  "id": "http://activitystrea.ms/schema/1.0/confirm",
  "display": {
    "en-US": "confirmed",
    "nb-NO": "bekreftet"
  }
}
```

Object

The last piece of the core statement structure is the *object*. While usually an activity, an object can also be another actor or another statement. The object is typically described by the reporting system rather than existing xAPI definitions, and are uniquely identified by an id.

```
{
  "id": "http://example.com/activities/mountain-climbing",
  "definition": {
    "name": { "en-US": "Mountain Climbing" }
  }
}
```

An object can be further described by providing a more detailed definition of the object. In the example below, we provide an activity type, a description and set of extensions containing additional information describing our activity.

```
{
  "id": "http://example.com/activities/student-satisfaction-survey",
  "definition": {
    "type": "http://id.tincanapi.com/activitytype/survey",
    "name": {
        "en-US":"Survey"
    }
    "description": {
        "en-US":"A survey where the students answers questions."}
    ,
    "extensions": {
      "http://example.com/surveyId": "survey-935"
    }
  }
}
```

4.3.2 Dart implementation

The Tin Can API contains a number of elements in addition to the three concepts mentioned above. Regardless, we chose to focus on the core concepts when creating an implementation in Dart for the prototype. The Dart implementation used by the prototype supports actors, verbs and objects defined within statements.

A statement consists of an actor, a verb and an object:

```
class Statement {

  Actor actor;
  Verb verb;
  StatementObject object;

  Statement({this.actor, this.verb, this.object});
}
```

While there are a number of ways to describe an actor, our implementation describes an actor by name and e-mail only:

```
class Actor {
  String email;
  String name;
  String objectType;
```

```
  Actor({this.email, this.name, this.objectType});
}
```

Verbs are described by an id and a map containing the display strings by locale.

```
class Verb {
  String id;
  Map<String, String> display;

  Verb({this.id, this.display});
}
```

Lastly, the object contains the activity id, the statement definition and the object type description. The implementation calls the object a "StatementObject" in order to avoid naming conflicts and confusion.

```
class StatementObject {
  String id;
  StatementObjectDefinition definition;
  String objectType;

  StatementObject({this.id, this.definition, this.objectType});
}
```

The object definition contains the object name, description, extensions and interaction type description.

```
class StatementObjectDefinition {

  String type;
  Map<String, String> name;
  Map<String, String> description;
  Map<String, String> extension;
  String interactionType;

  StatementObjectDefinition({this.type, this.name,
    this.description, this.interactionType, this.extension});
}
```

Using the classes above, we can create xAPI statements by passing the relevant parameters to the methods constructing the statements:

```
Statement userOpenedEducationalMaterialPage
```

```
  (int moduleId, int educationalMaterialPageId){
  return Statement(
      actor: Actor(
          email: "person@mail.com",
          name: "Some Person",
          objectType: "Agent"
      ),
      verb: Verb(
          id:  "http://activitystrea.ms/schema/1.0/open",
          display: { "en-US" : "opened" }
      ),
      object: StatementObject(
          id: "http://cope.no/expapi/activities/educational-material-interaction",
          objectType: "Activity",
          definition: StatementObjectDefinition(
            name: {"en-US": "Educational Material Interaction"},
            type: "http://cope.no/expapi/activities/page-interaction",
            description: {
              "en-US": "Interaction with a page from the VSMART workbook."
            },
            interactionType: "other",
            extension: {
              "http://cope.no/courseModuleId" :
                  moduleId.toString(),
              "http://cope.no/educationalMaterialPageId" :
                  educationalMaterialPageId.toString(),
            }
          )
      )
  );
}
```

4.4 Performance and security

In the following subsection we will briefly cover the security and performance aspects of the artifact. The focus in this thesis project has primarily been on the development of features useful for adaptive iCBT. Consequently, performance and security has not been among our primary concerns during the development of the artifact. Despite this, we still find it useful to briefly discuss these aspects of the artifact due to their importance in relation to mobile development.

4.4.1 Security considerations

Considering that smartphones can be exposed to theft or software vulnerabilities capable of compromising application data, a natural approach to protecting the personal information stored on the device would be to introduce an encryption layer between the persistence layer and the business logic in order to prevent the contents of the local database to be read by extracting the database files or from being accessed by other applications or malicious software. Encryption keys can be stored in the device's secure storage (e.g. using Keychain for iOS devices (Apple Inc. 2020) or using the keystore system for Android devices (Google Inc. 2020)) in order to prevent easy decryption of data.

Secure exchange of information between the server and the application can be facilitated using HTTPS (CloudFlare Inc. 2020) and token-based authentication. JSON web tokens (JWTs) are commonly used for server-client authentication due to their stateless nature and compact size (Auth0 Inc. 2020) together with the OAuth protocol (Hardt 2012). The server would be responsible for the majority of the authentication logic, while the client-side would primarily be responsible for requesting and sending valid tokens with each response. Consequently, these details are to be addressed at a later stage with the COPE project when considering details of the authentication mechanisms required for a production-ready application.

4.4.2 Performance

Due to the lack of focus on writing performant code, the potential for significant performance enhancements within the artifact is likely present. Considerable gains in performance are likely achievable by adopting better caching strategies for more efficient loading of content in the background. Additionally, there are likely considerable performance and stability enhancements available through better control and optimization of the number of UI rebuilds performed. When data is fetched asynchronously from the local database, the UI may perform several redundant calls to rebuild depending on the number of data sources and the type of mechanism for fetching (e.g stream or future).

Still, the artifact shows no signs of significant slowdowns when not considering the initial caching performed by the rendering engine. Using the performance profiling tools available in Android Studio 4.0, we examined a variety of parameters related to the performance and efficiency of the artifact while interacting with the artifact. We performed a simple test run using a real Android device in order to review the basic performance metrics of the application. We ran the application under Profiling Mode in Android Studio (in order to simulate a real-world performance scenario) and performed a walk-through of the application where we ran all features at least once:

- **Model** Samsung Galaxy S8
- **Operating system** Android 9.0 Pie
- **System-on-Chip** Exynos 8895 Octa (4x Exynos M2 @ 2.31GHz/4x Cortex-A53 @ 1.69GHz, ARM Mali-G71 MP20 @ 546MHz)
- **Memory** 4GB LPDDR4
- **Storage** 64GB (UFS)

Most notably, the artifact manages to retain its target frame-rate of 60 frames-per-second for the majority of the time despite occasionally dipping below the target number while navigating between different views. Figure 4.3 shows the frame rendering times during a test run, showing promising results despite the lack of optimization.

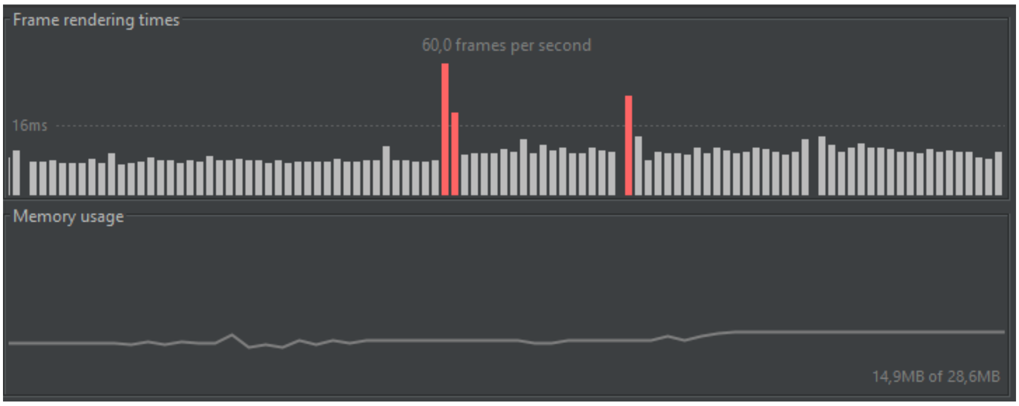


Figure 4.3: Memory and frame-rate graphs for the artifact. The top graph displays frame times while the bottom graph displays GPU memory usage.

The artifact's memory and CPU usage remains low and steady while performing common tasks like navigating between the different views in the artifact. Short CPU spikes are seen for a brief time during the first few minutes of starting the application, with the most intensive bursts reaching just short of 25% utilization. For the majority of the run, the CPU follows a pattern of brief bursts utilizing 10-20% of the CPU while performing basic interactions like navigating and storing data.

The memory usage remains steady as well, with the artifact's usage usually remaining between 120MB and 254MB of RAM without any significant increases in memory usage displayed while monitoring. Since most of the data within the application is fetched and stored directly in the SQLite database, the overall memory usage is low (as expected). Figure 4.4 shows the performance statistics for a test run with numbers for memory, network, CPU and energy performance. The brief spikes in network usage is the result of requesting an audio file from the Google text-to-speech API during testing. Lastly, the power usage generally stays within the threshold of "light" usage.

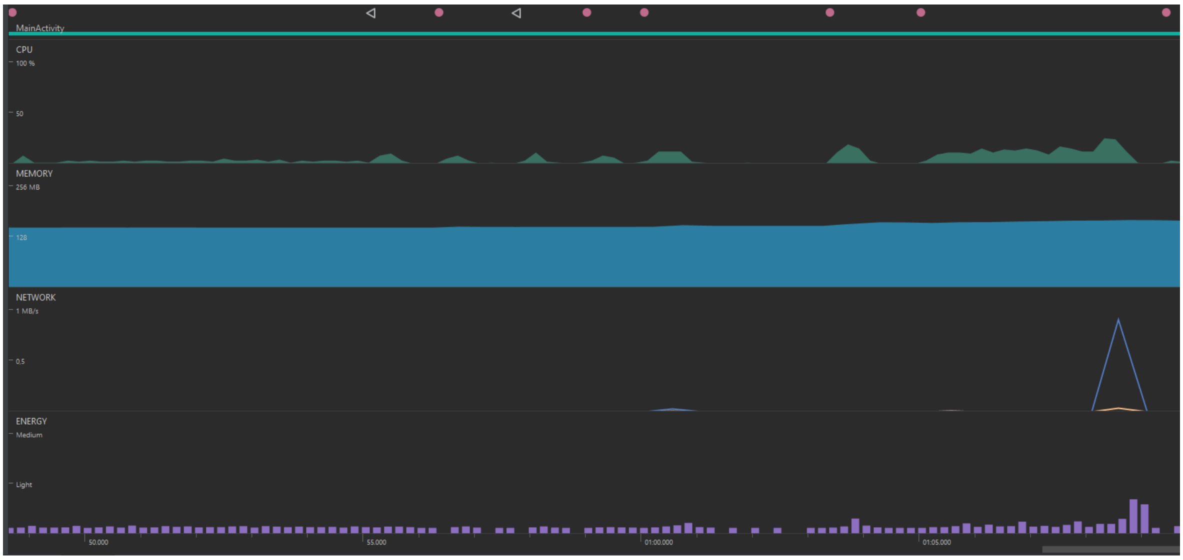


Figure 4.4: The performance profiling tool. The graphs displayed (top to bottom) represents CPU, memory, network and power usage.

In terms of performance optimization, it is therefore a clear potential for better performance and responsiveness. Our limited testing does, however, show little evidence to support the need of any urgent performance optimizations. With that said, our review of the application's performance metrics is extremely limited, and more data should be collected before drawing conclusions.

Chapter 5

Evaluation

The following sections presents the evaluation of the artifact developed in this master thesis project. The evaluation was performed through two sessions, with each session focusing on a different aspect of the application. In the first session, we evaluated the design and the user experience of the application, while in the second session, we evaluated the content presented by the application.

5.1 Design and user experience

The evaluation of the design and user experience of the application was conducted with help from the content and UX expert in the COPE project team. We primarily performed a qualitative evaluation of the artifact where expert feedback was the main driver behind the resulting changes to the artifact.

As our method for evaluating the user interface of the artifact, a heuristic test was performed where different aspects of the application was evaluated according to guidelines for user interface design. A heuristic evaluation is performed by having evaluators study a user interface in an attempt to determine if the elements of the user interface satisfies a set of rules (Nielsen & Molich 1990). Due to the restrictions caused by the COVID-19 pandemic, the evaluation had to be performed using a service for digital meetings, and the artifact was demonstrated through a screen-sharing feature available through the service.

The artifact was demonstrated using a virtual Android device with the following properties:

- Operating system: Android 10 (API level 29)
- Memory allocated: 1.5GB
- Screen: 1920x1080, 420dpi

The virtual device was running on a host system with the following properties:

- Operating system: Windows 10 (build 1909)
- Processor: Intel Core i7-4790K
- GPU: NVIDIA GTX 970
- Memory: 16BGB DDR3

The suggested improvements to the application's design and flow would be considered before the next evaluation of the application. Thus, the evaluation of the application's design and flow would additionally serve as a means of inspiring better feedback in future evaluation sessions by addressing the most glaring design issues present in the artifact. The following subsections presents the main issues raised during the evaluation session.

5.1.1 Accentuate important features

With the pre-evaluation artifact, we did not provide the user a means of quickly getting started or continue from where they left off from the home screen. It was therefore suggested to enable quick access to the most important parts of the application by implementing shortcuts to the parts of the application where users are likely to spend the most time.

The new shortcut feature exhibits three different options depending on the current state of the most recent module with recent activity registered:

No progress	The application navigates the user to the most relevant module to start with.
Partial completion	The user is taken to the module which is currently in progress in order to continue the course.
Completion	The user is taken to the list of available modules in order to select a new module.

Based on the feedback from the evaluation, a number of changes were made to the home screen. Figure 5.1 presents a slightly redesigned home view where modifications to the icons below the circular progress widget were made. In order to emphasize the most important features, the icons were moved to the upper right corner of the screen. This allowed for a more breathable design without the need for scrolling in order to see the complete view. Other notable modifications were the removal of the calendar list widget in order to fit the entire layout without scrolling.

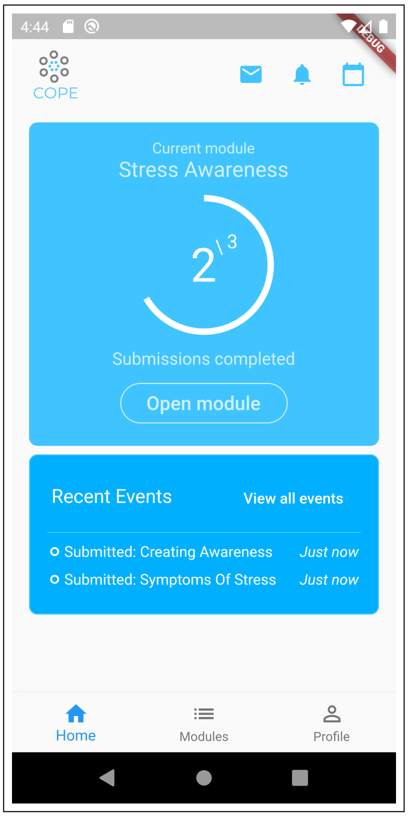


Figure 5.1: A screenshot of the redesigned home view and a demonstration of how content within a module can be marked as completed.

5.1.2 Provide feedback on completed actions

The pre-evaluation artifact allowed for only interactive activities to be marked as completed. As it might be desirable for users to also track their progress related to the educational material, it was suggested during the evaluation to provide completion markers for the available educational material within a module.

The revised version of the view presenting the module contents allows for the tracking of read and unread pages through the check mark shown on each list entry. This allows for better tracking for finished and unfinished content within each module.

5.1.3 Enforce consistency in text and design

Finally, consistency in design and displayed text was addressed. Completed activities were instead referred to as completed submissions, and a few other UI elements were cleaned up and corrected.

Questionnaires were previously displayed as banners below the module top bar. It was suggested to include the questionnaires as an entry in the list of content belonging to the module for the sake of better consistency and a cleaner look in the module contents overview. Additionally, this reinforces the idea that the questionnaires are important elements within the module, and should be treated as a part of the course. Figure 5.2 demonstrates how the module contents overview would look with the questionnaires a part of the contents list.

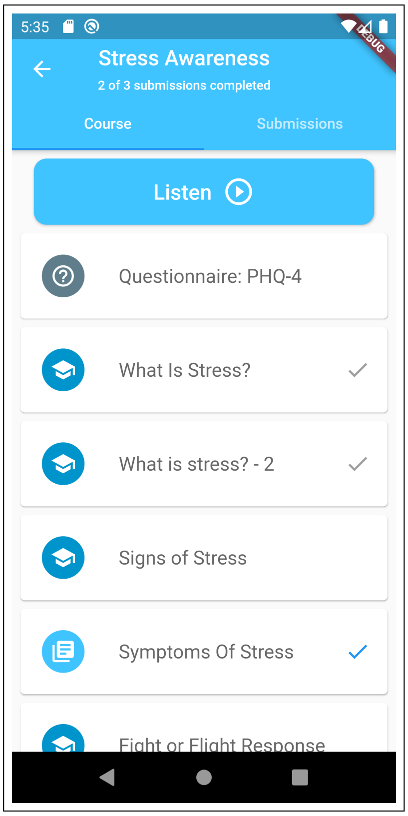
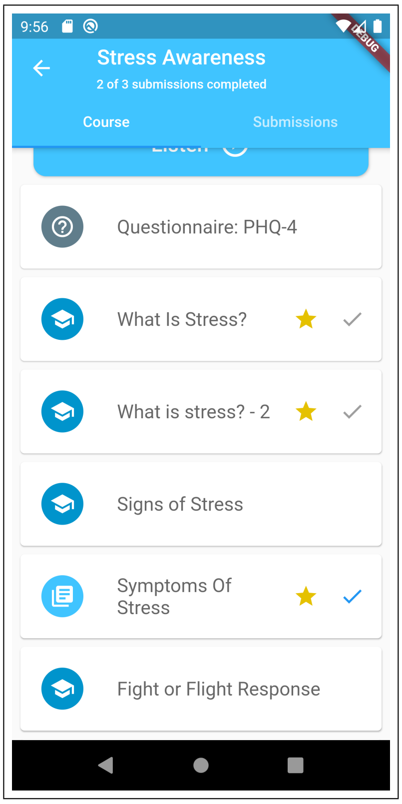


Figure 5.2: A screenshot illustrating how content within a module can be marked as completed.

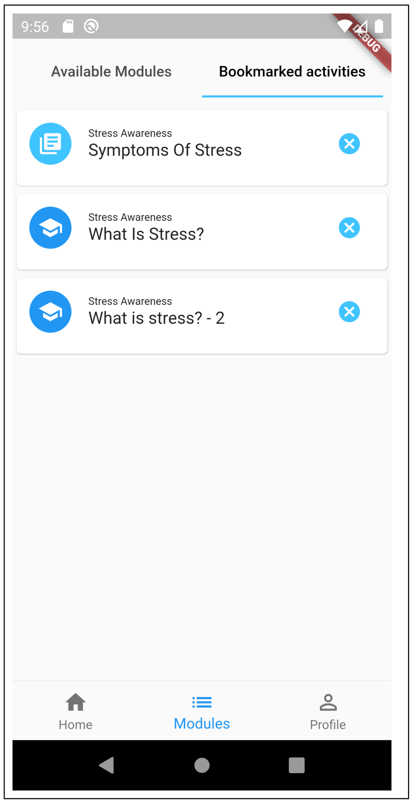
5.1.4 Enabling quick access to preferred content

Due to the possibility that some users may want to read or interact with the same piece of content several times, it was suggested to make preferred content easily accessible through a "bookmarking" feature. For users with a preference for a specific set of activities and/or educational material, this feature may provide value through increased user satisfaction.

This feature allows for "bookmarked" content within a module to be easily found while browsing modules rather than selecting a module in order to find the desired piece of content. Bookmarked content is marked with a star icon, and becomes available as a tab item when accessing the "Modules" element using the bottom navigation bar. The list of bookmarked content allows the user to either directly launch the selected content, or remove it from the list (thus removing the "bookmarked" status for the respective item). Figure 5.3 shows how bookmarked items appear under the "Bookmarked activities" tab item.



(a) Bookmarked content inside a module



(b) List of bookmarked content

Figure 5.3: Bookmarked content presented in the module overview tab after being marked.

5.1.5 Final notes on the UI evaluation

Despite our artifact being incomplete in certain aspects of the design of UI elements and functionality, the UX expert managed to grasp the meaning of the majority of the UI elements in addition to the navigation flow.

We interpreted this as a promising result for the majority of the basic design and navigation aspects of the artifact. With the incorporation of the suggestions made by the expert, we concluded that the artifact would be ready for further evaluation by the psychology expert with regards to the content included within the application.

5.2 Content and features

The second evaluation session was performed in cooperation with the psychology expert on the COPE research team. Due to the limitations caused by the COVID-19 pandemic, the session was performed using the online video conferencing service Zoom (Zoom n.d.). The same setup which was used in section 5.1, was also used for the evaluation presented in this section.

While this allowed us to demonstrate the artifact remotely, there were a number of disadvantages related to this approach. Most notably were the disadvantages related to remote interaction with the artifact using an emulator running on a computer due to the unnatural input methods and high latency. Hence, this has to be considered in respect to the results of the content and feature evaluation.

The evaluation was conducted as a semi-structured interview (Longhurst 2003) where a number of questions related to the artifact and related theory was asked both before and after a brief demonstration of the artifact. During the demonstration of the artifact, the interviewee was allowed to access the artifact through a remote controlling feature available through the video conferencing service used during the interview, thus allowing for remote interaction with an emulator running on the host system.

In a semi-structured interview, the interviewer attempts to gather information from the interviewee by asking questions. Despite the preparation of questions, semi-structured interviews takes place as conversations which allows for the exploration of relevant issues and topics during the interview (Longhurst 2003).

Newcomer et al. (2015) describes a number of advantages and disadvantages related to the use of semi-structured interviews. On one side, semi-structured interviews are excellent for when more than a few of the open-ended questions require follow-up queries, and when the interviewee's individual thoughts are of interest. In addition, semi-structured interviews are useful for asking questions where an interviewee may not be comfortable answering certain questions in a particular setting (e.g. in a focus group). On the other side, semi-structured interviews are time-consuming and labor intensive, while additionally requiring a degree of interviewer sophistication.

The feedback gathered from the interview is summarized in Appendix A. With regards to the results, a number of remarks and suggestions were made in relation to the artifact's content and features. There was a request for more options and improvements in relation to the formatting of text content and images. Additionally, a feature for language selection was identified as missing during the interview. With regards to the potential usage of the artifact, it was pointed out that the presented artifact would be well-suited as a tool for prevention and learning rather than a treatment option, and that the artifact would be suited for general use. Among the improvement suggestions was the ability to adapt the application to specific demographics by modifying the design and behavior to better fit different groups of users. With regards to the potential effect of providing multiple modalities, it was noted that the effects likely depend on individual preferences, but that having the freedom of choice was a positive aspect of the artifact. Additionally, the freedom of choice in terms of modality was pointed out as an area of interest where the artifact could aid in future studies for determining the effectiveness of providing multi-modality content. Questions were also asked in relation to collecting user data, and while initially all collected data was of interest, concerns were expressed in regards to suggestions about location data. Among the suggestions for data which could be of interest to collect in the future, data related to artifact usage (e.g. time of day, usage duration) was suggested. Lastly, questionnaire data was considered important in relation to collecting data.

While there were room for improvements in terms of the artifact's functionality based on the evaluation, the overall impression from the evaluation suggested that the features presented through the artifact has the potential to support for better net-based therapy in the areas of prevention and management of stress. Additionally, new features were identified as useful for conducting further research into the effects of multi-modality content delivery within net-based therapy.

5.3 Evaluation summary

In this chapter we described the process and results of two evaluation sessions with the UX and psychology experts on the COPE research team. We evaluated the artifact respect to both the UX and usability aspects of the artifact as well as the content and feature set of the artifact, and identified a number of potential changes and improvements which could potentially enhance the user experience and efficacy of the artifact.

In the UX and usability evaluation, we identified a number of potential changes in order to make the artifact more consistent and intuitive in design. By analyzing the results collected from the heuristic evaluation, we made a number of changes to the navigation flow, presentation of content and convenience changes in order to make the user experience more efficient and approachable in preparation for the following evaluation.

During the evaluation of the implemented features and content, we reviewed the usefulness and potential improvements which could improve the artifact from a psychology expert's point of view. In addition to discussing smartphone use in relation to iCBT, we discussed potential improvements to the existing artifact functionality in as well as potential future additions to the artifact's feature set. We discussed the potential uses for the application, and concluded with the artifact being a tool better suited for prevention and management rather than a treatment option, as well as being useful for further testing on the effects multi-modality content. Overall, the feedback was positive in relation to the artifact's purpose of facilitating multi modality iCBT and data collection.

The results from these evaluations serves as useful indicators for whether the artifact's functionality serves the purpose of enabling the mechanisms which the COPE system and adaptive iCBT relies on. While there are a number of issues and improvements to be made, our current findings suggests that there is potential for the functionality provided by the artifact.

Chapter 6

Discussion

In the following chapter we will present and discuss the results achieved throughout the various iterations performed as a part of the design science methodology. We will present our findings based on the iterations and evaluations performed, as well as the answers to the research questions presented in the first chapter.

6.1 Research question answers

RQ 1: How can material from a CBT module in a CBT program be used to develop an artifact for showcasing functionality that can facilitate adaptive iCBT on a mobile platform?

The answer to this question is mainly presented in chapter 3 where we developed our initial proposal for the presented artifact. Our initial proposal for a self-help solution for iCBT took inspiration from an existing CBT program for managing stress. We implemented our solution using the content available in the participant manual, and found that several key elements of the relevant chapters could be represented using a mobile application. Using this content, we developed an artifact for proposing functionality useful for supporting adaptive iCBT and multi-modality content delivery.

We found in chapter 3 that we could represent a number of the elements from the workbook using generalized data models for storing key information related to these elements. We achieved this through analyzing the general structure of these elements in order to develop the models and functionality needed for the representation of these elements in a mobile application. In addition, we developed functionality for tracking user activity and event logging related to the elements implemented from the workbook. This was done in order to provide the user with progress metrics and enable the use of logging data for analytics.

The initial feedback gathered during the evaluation of the artifact provided promising results for the approach taken towards implementing the CBT program as a mobile application. The experts interacting with the artifact provided feedback indicating a satisfactory user experience, and while the psychology expert expressed the need for possibly collecting even more data than what the artifact already collects, the data collected by the artifact was deemed interesting for further research.

The resulting artifact is a prototype and a piece of a system for facilitating further research and problem-solving in relation to iCBT within the COPE project. Consequently, and despite the promising results from the evaluation, our prototype is primarily an artifact serving as a medium for further innovation and problem solving in relation to adaptive iCBT through the COPE project.

RQ2: How can we enable the use of multiple modalities for delivering stress-related CBT content on a mobile platform?

During our iterations in chapter 3, we implemented features for enabling the delivery of both audio and video content within the application. We implemented and integrated media players into the educational material for playback of local and remote video and audio content, in addition to functionality for supporting the use of Google's WaveNet-based Text-To-Speech API for realistic speech synthesis of the text content available in the application.

Our intention behind the implementation of these features was to provide a means of variation and flexibility in the learning process while using the application. During the expert evaluation, the ability to adapt to each users' preferred modality was pointed out as a positive feature capable of promoting better learning and adherence for auditory and visual learners. Additionally, multi-modality support opens opportunities for additional features like for instance a podcast-like content delivery model and interactive video content. In our current artifact, these features simply allow for the freedom of choice, while a future version on of the COPE app may be able to determine the most suitable modality by evaluating a user's *open patient model* (user's representation in the Patient Model, fig. 3.1).

The textual content was designed with preserving a structure resembling the original course in mind. While we were unable to test and discuss the use of video content in the context of the CBT course, a lot of valid points were made during the evaluation of the audio features. The quality of the course would benefit significantly from better speech synthesis for languages other than English and related dialects. Also, intelligent transformations of the text fed to the API could provide better results in a number of situations where the text synthesis would fail to produce satisfactory results (for instance with ordered/unordered lists and sentence endings). Despite some of the shortcomings, speech synthesis could provide a quick and cheap means of generating audio content in situations where manual recordings cannot be created. Additionally, it is reasonable to assume that these services will improve in the future as they did during the months we worked with the WaveNet technology from Google.

RQ 3: Using the application technology developed for an artifact to answer RQ1 and RQ2, how can we collect data from users of the artifact to facilitate adaptive iCBT?

In addition to activity, video and audio features, we implemented several mechanisms for collecting usage data within the application. The logging of usage data and activity data generated through usage of the application is a part of the larger COPE system meant to provide the means of creating a more individualized experience based on analytics. The use of an adaptive algorithm for making recommendations based on available user data has not been addressed in detail in the design and implementation of this thesis project, but serves as an important motivator behind the collection and analysis of user data. This topic is addressed in more detail within another master thesis project within the COPE project.

The process of implementing usage and activity tracking is covered in chapter 3. The final version of the artifact collects a range of activity and usage-related data, including:

- User interactions with CBT activities (submission-related data)
- Learning material (browsing duration, which pages have been read)
- Media playback (start/stop/duration log entries)
- Content bookmarking events

The semi-structured interview indicated that many of the data points collected by the application may have practical use for running analytics, and that there are even more collectable data which could prove useful for individualizing elements of the application like for instance when and for how long the application is used. Questionnaire data was considered especially important for mapping the state of users, and could potentially be used for future predictions and analysis of the user's outcomes while using the application. While not addressed in this thesis, the issue of privacy was also discussed during the interviews due to its importance in practise, and the potential danger and controversies related to collecting sensitive data.

6.1.1 Research contributions

As mentioned in section 3.1, Hevner et al. (2004) describes design science as a problem solving paradigm where IT artifacts are created and evaluated with the intention of solving organizational problems. We have used the design science methodology in order to solve identified problems discovered in relation to iCBT by developing an artifact, and the evaluations performed in collaboration with experts provides evidence of the artifact potentially being able to solve a number of the issues presented in chapter 1 and 2. More specifically, we were able to answer the following through the design and evaluation of the presented artifact:

- **RQ1** Certain modules from an existing CBT program for stress can be transformed for mobile use by analyzing the structure of the content and implementing similar models in order to represent them in a digital format. By building our artifact based on an evidence-based program, we address some of the concerns related to the lack of evidence-based practise in mHealth app development (Donker et al. 2013).
- **RQ2** Multiple modalities can be implemented by providing the means of playing audio and video content in addition to allowing for speech synthesis of available text content, thus allowing for flexibility and variation in the delivery of content. In addition to better catering to differences in learning preferences, variation and user engagement have shown to be preferred and beneficial for users of digital interventions (Kerr et al. 2006, Wright et al. 2005). Together with the results from our evaluations, we consider this a useful means of delivering multi-modal, stress-related iCBT content on a mobile platform, and therby also contributing to the development of technology features that can facilitate for unguided, net-based therapy.
- **RQ3** Collecting a number of data points through the use of the application opens the future possibility for more individualized content in delivering iCBT and better analytics. There is evidence to back up the efficacy of interventions tailored for individual needs (Forsell et al. 2019). Personalized iCBT is nothing new, and therapists are already capable of creating individualized treatment plans using data provided by patients. Albeit effective, tailoring interventions is expensive and time-consuming (Lundkvist-Houndoumadi et al. 2016). There is also a need for more data collection to gain better insight into the use of technology and to see past the descriptive statistics and the classic effect evaluations wich currently limits eHealth research (Sieverink et al. 2017). Based on this, we suggest the use of data collected from users in order to provide tailored interventions without therapist assistance.
- **Also:** The findings and the artifact presented and discussed through this thesis will through the COPE project contribute to addressing the shortcomings of guided and unguided iCBT in chapter 2 (lack of guidance and individualization with the possible effect of lower adherence) and facilitating for adaptive, individualized net-based treatment.

6.2 Reflections

6.2.1 Design science as a methodology for this project

The use of design science as our methodology has been largely beneficial in relation to the work presented in this thesis project. In the case of our project, the creation of an artifact and the evaluation of the created artifact aligned well with the overall project goals of creating a prototype for showcasing features for supporting personalized iCBT.

The design science methodology also provided us with useful guidelines for conducting and reflecting on our research and development. This made the structuring and the execution of the design, implementation, evaluation activities within the project significantly easier, in addition to providing a structured and more focused approach towards presenting the work done within this thesis project.

6.2.2 Tools and frameworks

Flutter

The development of the artifact presented was performed using the Flutter framework developed by Google as described in chapter 4.1. Due to the relatively low maturity of the framework at the time when we started the iterative process of design and implementation, developing the artifact using this framework was considered a slight risk due to the scarcity of available third-party libraries compared to the available alternatives.

Despite the lacking maturity of the framework, developing the artifact using the Flutter framework proved to be extremely beneficial to the project workflow and development process. A significant portion of the development time was spent prototyping functionality for demonstration and reacting to feedback gathered from supervisors and experts. For these situations, the Flutter framework provided the advantage of fast prototyping and a easy means of creating functional user interfaces for demonstration. This meant that many feature suggestions and changes could be implemented quickly with minimal development time in cases where retrieving and storing complex data was not necessary.

Even though the framework offered significant benefits for prototyping, implementing features requiring native code still required significant time investments. This meant that while features and third-party libraries relying purely on Dart code worked flawlessly, features requiring interaction with native features like notifications would in many cases prove too much of a hassle to be worth considering, thus reducing the number of features we could implement based on the complexity limitations of the framework.

For a future version of the COPE therapy app, Flutter would be a good framework for cross-platform mobile development. With the framework regularly receiving new features and improvements, a future COPE app could potentially benefit from a more feature-rich and performant framework with more support from both the community and official channels in terms of available software libraries and APIs.

Google Text-To-Speech Synthesis

The Google Text-To-Speech API for speech synthesis was initially proposed as a solution to provide dummy content for the demonstration of the application's audio features. The service sparked interest as the recorded audio samples using the WaveNet technology presented significantly more realistic speech compared to traditional computer synthesized speech. The intention behind researching the feasibility of this service was the potential for enabling quick and cheap audio content capabilities with minimal human intervention.

Initially, the service only provided satisfactory results in a limited set of situations due to the complexity of synthesizing paragraphs consisting enumerations and sentences requiring contextual speed and pronunciation. The Speech Synthesis Markup Language (SSML) used for adjusting various speech and pronunciation-related parameters for the API did provide sufficient flexibility for producing satisfactory speech synthesis results. However, it did not eliminate the need for fine-tuning in certain sentences and contexts.

While the speech synthesis service failed to meet our expectations in a number of situations, the cost savings, as well as the potential it enabled for delivering multi-modality educational content, made it worth considering for the artifact. Future improvements to the text-to-speech API, and more specifically to the synthesis of non-English text, will make the service better for use in practise.

6.2.3 Reflections on problem identification and design process

For the front-end and data collection part of the COPE system, it was particularly difficult to find a fitting starting point for the foundation which the data collection aspect of the project would rest on. Consequently, a considerable amount of time was spent on discussing and prototyping ideas which never made it further into the design phase.

With more time available, it would have been desirable to put a greater focus on the monitoring and gathering of data rather than the development of a fully functional artifact for delivering CBT content. This is due to the tedious feedback loops the development of the user interfaces and interactive functionality required. In addition, we made significant progress in relation to data collection during our last design phases with the introduction of the xAPI components. The collection of more data was also brought up as a potential topic of interest during our interviews with experts where collecting data from for instance "wearables" was suggested as an interesting topic for research in relation to user monitoring.

6.3 Limitations

A number of limitations affected the design and evaluation of the artifact, varying from circumstantial limitations to framework-related limitations.

During the evaluation of the artifact, the COVID-19 pandemic prevented us from performing the evaluations in person. This resulted in the evaluation being performed online instead, potentially affecting the evaluation outcome due to the poor responsiveness and difficulties related to navigation and handling this method caused. The resulting evaluation may therefore not be fully representative of the real-world user experience in certain cases where the affected functionality is crucial for the final impression. Also, the circumstances prevented us from planning and performing regular user tests in order to gather feedback at a larger scale. For these reasons, the limited sample size of our user tests should be considered when studying the results.

Due to requirements related to building and deploying on different platforms, we faced limitations related to which operating systems we could deploy the artifact on. For devices running the Android operating system, deployment can be performed in a straight-forward manner trough manually installing the provided APK or by utilizing the Google Play Store. As the project can be built for Android using any operating system (Windows/macOS/Linux), there were no limitations related to the deployment on Android-based devices.

For devices running the iOS operating system, deployment of the artifact required access to a system running macOS in order to just build the project. This limited the testing and evaluation of the artifact on operating systems other than Android, and prevented us from deploying the artifact on devices running iOS.

Chapter 7

Conclusions and Further Work

This thesis presents the design and implementation of an application prototype, an artifact, to demonstrate the collection of usage data and the execution of parts of an iCBT program in order to facilitate adaptive iCBT for prevention of stress and related conditions. The purpose of the artifact is to demonstrate the use of multimodal delivery of content in order to facilitate personalized iCBT in addition to the ability to collect data from users for further research and improvements. The artifact serves as a demonstration and a foundation for further research and development into adaptive, mobile-driven iCBT, in addition to being a part of a larger project related to providing breast cancer survivors with more effective and available self-guided options for managing symptoms related to cancer treatments. This chapter concludes the design process and implementation of the prototype in addition to discussing possible future work with relevance for the artifact.

7.1 Conclusions

Using the design science methodology, we designed and implemented an artifact for facilitating various aspects of adaptive iCBT. We developed the artifact as a mobile application based on material within a module from an existing CBT program, and through suggestions, discussions and evaluations with experts, created an important artifact for the COPE project serving as a foundation for further work.

Throughout the design process, we demonstrated how CBT-related content can be delivered using different modalities in addition to the strengths and weaknesses related to providing audio content through speech synthesis. We implemented and evaluated different ways of interacting with an application presenting CBT content and activities, in addition to different ways of collecting usage data. We found that various collectible data points related to application usage and user progress can be leveraged in order to personalize the user experience, in particular questionnaire data and data related to usage patterns and preferences. We found that speech synthesis can provide acceptable audio content under the optimal circumstances. Lastly, we found that adapting and modifying existing iCBT content for mobile use is plausible when considering the strengths and limitations of traditional approaches to CBT.

7.2 Further work

This project has been a research project within the scope of a master thesis project, and as so, a sub-project within the larger research project COPE. The goal was to demonstrate functionality relevant for supporting the goal of a personalized approach towards metal health and iCBT. Consequently, the scope of the project was limited to handing user interactions in a local setting without regards to security and remote information exchange. This section briefly describes relevant future work which fell outside the current scope of the project.

7.2.1 Application server and information exchange standards

Due to the limited scope of the project, server-client communication was not considered in the final design of the artifact. The implementation of an application server was considered too time-consuming and complex when considering the required development time during the design and implementation of the artifact. Consequently, a decision was made to contain the majority of the required business logic on the client side was therefore made in order to simplify prototyping, development and testing.

Despite the complexity and effort required in order to develop an application server, we explored a number of possible technologies and solutions which could be utilized in the implementation of a server application for the project. We explored the possibility of creating a GraphQL-driven NodeJS application server for providing an efficient and scalable means of client-server communication, in addition to the possibility of utilizing standards for health information exchange like HL7 FHIR for standardized client-server communication when handling certain types of health data (for instance questionnaires and questionnaire responses).

GraphQL is a query language for APIs, enabling clients to query the server for data rather than resorting to fixed REST endpoints which are typical for traditional web-APIs (GraphQL Foundation n.d.). This provides added flexibility and efficiency due to GraphQL allowing for more data to be fetched with a single request compared to REST, drastically reducing round-trip delays in addition to allowing for more flexibility in the design of client-side applications.

HL7 FHIR is a new standard for electronic exchange of healthcare information aiming to simplify implementation without sacrificing information integrity (HL7 n.d.). HL7 FHIR's approach to standardizing healthcare information exchange is based on a set of basic building blocks called *resources*. The purpose of these building blocks is to completely, partially, or combined satisfy the majority of the most common use cases encounterable in the world of healthcare information exchange.

For a future prototype version of the COPE app, partly based on the results from this master thesis project, developing an application server using these technologies would provide a flexible, scalable and interoperable approach to collecting relevant usage data, user preferences and healthcare information, in order to power the adaptive elements of the COPE system.

7.2.2 Data collection using wearables

During our first iterations, we briefly discussed with experts the idea of collecting data related to user behavior and activity patterns using modern wearable devices. Modern wearable devices carry a number of interesting data collection capabilities like monitoring sleep patterns (Renevey et al. 2017), measuring the user's heart rate (Ding et al. 2019) and track user activities (Weiss et al. 2016). A number of these features are of significant interest when considering if a user is adhering to the application or showing disinterest in completing their scheduled activities.

During our expert evaluations, these measurements and calculations were deemed useful in the context of providing useful information to a system for tailoring the user experience. Consequently, collecting data using sensors from smartwatches running Google's Android Wear or Samsung's Tizen operating system, as well as integrating functionality for processing and sending the collected data are functionalities which should be to consider for a future COPE prototype.

7.2.3 Text-to-speech improvements using SSML

While experimenting with the Google text-to-speech API, we discovered how the Speech Synthesis Markup Language could potentially improve the contextual performance of speech synthesis while using the application.

Despite being straight-forward to implement, time restrictions prevented us from providing a working implementation for demonstration and evaluation purposes. A useful addition to a future prototype of the COPE app would therefore be features for enhancing the situational performance of the speech synthesis functionality by taking advantage of SSML.

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Appendix A

Due to the length of the complete transcript, the questions and answers from the semi-structured interview with the psychology expert has been translated and summarized below. Each question is summarized by a number of points representing the essence of the response provided for the respective question.

Questions

1. Can you say something about your experience with CBT?

- Experience within cognitive sports psychology.
- Worked within a number of research projects related to CBT and performed evaluations within groups.
- Mainly works with "healthy" people in relation to clinical work.

2. Which previous experiences do you have with digital or web-based self-help solutions for mental health?

- Involved with StressProffen, though not on the development side.
- Otherwise mostly experimenting and testing on a casual/personal level

3. Do you have any experience regarding the use of mobile technology or smartphones in treatment or prevention of stress?

- Slight experience from a user perspective.
- Mainly interest-driven experience and knowledge.

4. How are patients screened in relation to StressProffen?

- Users enroll themselves online

- More recent versions will recruit using Kreftregisteret's systems for inviting women who has suffered from breast cancer.

5. What are the most important indicators when screening patients' mental health in StressProffen?

- SF-36 and stress
- Also fatigue, anxiety, depression and a range of breast cancer specific questions

6. How do you think the presentation of content and the functionality of the demonstrated prototype can be improved?

- Better formatting of textual content
- More use of images and drawings
- A language selection feature implemented

7. How do you imagine a more complete version of the prototype would be used in the future?

- General usage, with possibly specialized design decisions for different demographics.
- Preserve the content, adapt the application design.
- Gives the impression of being more suited towards prevention and learning rather than a treatment option.

8. In which situations do you think a future, more complete version of the prototype would be used?

- For people who are reporting stress and perceive stress negatively.
- A tool for situations where learning skills in order to handle different situations and creating awareness is important, and preventing future stress-related issues.

9. How do you think different media types/modalities can affect different users' learning process?

- Effect may vary from individual to individual, and probably requires more user testing.
- Freedom of choice is positive.

- Can test the effect of being able to choose in future projects, and compare preference to what the user actually learns.

10. Which of the data that the prototype creates do you think can be useful for mapping/screening users?

- Intially, all data is interesting.
- Must consider privacy challenges.
- Would not collect position data (ref. 'Smittestopp')
- Questionnaire data is important, and can be used for prediction and analysis

11. Are there other kinds of data the prototype could or should collect?

- Time of day the app is used
- For how long the app is used at a time
- Collect data from wearable devices in the future

12. Do you have any other comments related to the demonstration?

- Nothing.