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Conception and implementation of a mobile application to conduct a Mindful Walking Study regarding Clinical Psychology

Bachelor thesis at Ulm University

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Contents

1 Abstract

Mindfulness is a common concept spread across many cultures. The basic idea is to focus on usually automated body processes and hence feel more present in the moment.

It is assumed that mindfulness could be very beneficial in certain areas such as medicine or therapy methods in general. “Reducing stress-related symptomatology” and “helping patients cope with chronic pain” [9] are just a few upsides that come with mindfulness-based approaches.

A more specific form of mindfulness is Mindful Walking where the focus is on doing one step at a time very consciously during a normal outdoor or indoor walk. This should strengthen the feeling of being present in a moment even more by just focussing on each step during the very common process of walking.

The application presented in this paper should function as a supporting tool when walking mindfully using the combined data gathered by an Apple iPhone and an Apple Watch. It should also provide the possibility for a user to participate in a study of Mindful Walking and thus to contribute to research with the purpose of finding out whether Mindful Walking might be helpful to people in their daily lives.

2 Introduction

Mindful Walking is believed to come with great advantages in terms of stability and well-being both emotionally and physically. Exploiting and even intensifying these

benefits is a task where technology can help in various ways. This application supports the user in successfully absolving Mindful Walks without being distracted by environmental influences.

With the aid of this app the user should be able to very consciously complete such Mindful Walking sessions. However, the Mindful Walking application has a built in study feature, which allows every user to participate in the Mindful Walking study and thus to contribute to important research.

As the popularity of iPhone apps based on mindfulness is rapidly growing [4], hopefully the Mindful Walking application can contribute to the numerous beneficial effects as well. Of course to what extent such an application can help depends on the quality of such an app which is not automatically given. Therefore the Mindful Walking app is designed for maximum usability and a clean user interface.

2.1 Technical Perspective

The application's main goal is to enable the user to successfully accomplish sessions without being distracted by environmental influences and without losing focus on walking mindfully.

To comment on this from the technical angle the said goal could be accomplished by notifying the user as its pace exceeds a certain limit. With today's standard smart phones it is possible to keep track of the step count and the distance travelled within a certain amount of time which can then be combined to retrieve the user's current pace. It should not be forgotten that the focus is still on mindfulness and as a result it would be advantageous to additionally track health data such as heart rate, respiration rate, blood pressure and other indicators which give insight into the current physical condition of the user.

Smart watches can help out with some of the health related data but not with all of it. For example the respiration rate cannot be tracked without any additional devices (including smart phones and smart watches). This makes it more reasonable to restrict the application on the two most conventional devices - the smart phone and the smart watch.

2.2 Usability Perspective

For an app to be as useful as possible it must be designed as user friendly as possible. Because mindfulness has such a wide area to be used for and so much potential in helping patients it should be carefully designed in terms of usability and simplicity.

The user should be able to easily manoeuvre through the app and should not think for just one second where to tap to get to the desired view or option within the application. Usability has become a great quality feature when it comes to distinguishing between good and bad applications. Although one application might be implemented very efficiently and might have a lot more options to choose from than another application, the easier and less powerful one might then still be the preferred choice for a user.

Because usability is such an important aspect [10] the Mindful Walking application is designed for exactly this. A clean user interface with maximum usability. It is very hard to accomplish a good user experience but therefore Apple and Google provide useful information on this topic on their websites.

For example Apple has several guidelines for a proper, clean and user friendly design within an iOS application [13]. By using Apple's basic APIs when it comes to app development, most of the design, layout and structure is already automatically taken care of by Apple. However, if an application should have a very unique look and feel, then Apple's human interface guidelines come in very handy.

3 Background

Mindful Walking is an abstraction of a basic concept found in several cultures known as “mindfulness”. Mindfulness is said to have very attractive benefits in terms of therapy and the medical field itself such as “reducing stress-related symptomatology” and “helping patients cope with chronic pain” [9]. Knowing this it becomes very clear that mindfulness is an approach for therapies and one’s well-being that should be considered in more detail.

3.1 Mindfulness

To gain a deeper understanding of mindfulness it’s useful to take a look at the following description.

> Mindfulness means maintaining a moment-by-moment awareness of our thoughts, feelings, bodily sensations, and surrounding environment, through a gentle, nurturing lens. [12]

Concentrating on usually automated body processes can be found in many occasions of human history. The discipline of meditation for example is a common thing in many people’s everyday lives. Meditation is known to be beneficial for emotional problems such as depression, anxiety and stress and therefore is a very important practice and therapy method [11]. One basic exercise in meditation involves concentrating on your breath as you’re breathing in and out. The important thing here is that breathing also is an automated process that should, in terms of meditation, be concentrated on.

3.2 Mindful Walking

Mindful Walking uses the same approach as meditation by applying the principles of mindfulness on an activity where the body is not resting but active. Speaking more precisely those principles are applied during a walk. During a Mindful Walking session people tend to move slower than if they were to walk at their normal pace. This is totally natural as consciously processing easy tasks of our daily life is a power consuming and therefore time consuming procedure. Nonetheless this effort comes with beneficial properties as mentioned above and luckily can be quite precisely observed by common tracking devices such as smart watches and smart phones. Moreover, it is important to mention that this provides the possibility to share a helping tool with every smart phone owner across the world in form of an application.

3.3 mHealth Tools

Mobile Health applications or mHealth applications are smart phone apps that target health aspects in daily life by using the phone's sensors and combining the data gathered.

Those applications usually come with one big advantage which is the possibility to get user feedback immediately or shortly after symptoms occur [8]. Since questions about subjective feelings are very hard to answer objectively this approach might bring the most accurate data because the user is able to communicate emotional states right at the moment they occur in contrast to later the same day when the emotions might have flattened again.

Another important aspect when it comes to mHealth tools is the user's willingness to give away sensitive data in the process of using such an application [2]. Users in general show acceptance in many cases although some sorts of data tracking seem to bring up some concerns.

Privacy is a critical field in any application and especially when very personal and sensitive data is tracked, such as most mHealth applications do. Concerns where expressed especially in the fields of "Actimetry and geotracking" [2]. The Mindful

Walking application uses non of the two and therefore might be of greater acceptance among users than other Mobile Health applications.

3.4 Privacy

Since the introduction of smart phones the privacy [1] aspect in using such devices becomes more and more important. Especially in the case of this application or Mobile Health applications in general.

Mobile Health applications track a lot of data. In fact most applications need some sort of personalized data in order to work properly but mobile health apps usually deal with very sensitive data.

Of course the Mindful Walking application tracks sensitive data as well such as the heart rate. However, when first using the application a view is presented where the user is able to specify which data should be allowed to be tracked and which piece of data should not be tracked. This way the user has full control and insight of the data gathered by the application.

4 Requirements Analysis

In the field of Software Engineering a requirement analysis is indispensable. This is the preparatory work of determining exactly what an application should do, what features should be implemented and also how an application should do these things.

4.1 Functional Requirements

Functional Requirements describe what a user should be able to do within the ordinary use of the application (see Table 4.1 for iOS application / see Table 4.2 for watchOS application). This may include what actions should be available to the user, what the application should do automatically (e.g. notifications) and more.

4.1.1 iOS

No.	Requirement	Description
1	Registration	The user is able to create a new account by registering at the Questionnaire-API.
2	Login	The user is able to log in with an existing account.
3	Signing up for the Mindful Walking study	The user is able to sign up for the Mindful Walking study.
4	Questionnaire Overview	The user is able to see an overview of all existing questionnaires within the active study.
5	Select a questionnaire	The user is able to choose from several given questionnaires by tapping the screen.

6	Completion of questionnaires	The user is able to complete a selected questionnaire.
7	Correction of given answers for questionnaires	The user is able to correct already given answers to questions of a questionnaire.
8	Disabled questionnaires	A questionnaire is disabled if the user has already completed the questionnaire within a given period of time.
9	Statistics	The user is able to see a statistic of finished Mindful Walks.
10	Course of study	The user is able to reread how the study works at any given time.
11	License	The user is able to see all used licenses of the application.
12	Reset Application / Delete Data	The user is able to delete all gathered information within this application.
13	Logout	The user is able to log out at any given time.
14	Notification	The user is able to receive notifications whenever a questionnaire is scheduled for today.

Table 4.1: Functional Requirements for the iOS application

4.1.2 watchOS

1	Calibration	The user is able to calibrate the personal walking speed within the watch application.
2	Cancel Calibration	The user is able to cancel the calibration at any time.
3	Timer (Calibration)	The user is able to see how much time there is left until the calibration has finished.
4	Choose reduction of walking speed	The user is able to choose from a variety of percentage values which indicate the amount of reduction of the calibrated speed. This reduced speed limit is then the target speed during every Mindful Walking session.
5	Disabled Mindful Walking button	The Mindful Walk button is disabled if the user has not calibrated the application yet.
6	Mindful Walk	The user is able to start a Mindful Walk on the watch application at any time.

7	Cancel Mindful Walk	The user is able to cancel a Mindful Walk.
8	Pause Mindful Walk	The user is able to pause a Mindful Walk.
9	Resume Mindful Walk	The user is able to resume a paused Mindful Walk.
10	Mindful Walking statistics	The user is able to see values gathered during a Mindful Walk on the watch application such as heart rate or current pace.
11	Health Application	The gathered information during a Mindful Walk is stored within the Apple Health application.

Table 4.2: Functional Requirements for the watchOS application

4.2 Non-Functional Requirements

Non-Functional Requirements describe a few assets an application should have from a less technical point of view. For example that usability for this particular application is very important or that the application should be easily maintainable for future development and improvement processes (see Table 4.3 for iOS application / see Table 4.4 for watchOS application).

4.2.1 iOS

1	Usability	The user interface features a very clean design providing the user with all the options necessary for a fully functioning application.
2	Security	The application is secure to malicious attacks.
3	Reliability	User interactions do not lead to unexpected behaviour and upcoming errors are properly taken care of.
4	Performance	Tasks are processed efficiently to provide the user with a fluid user experience.
5	Maintenance	Future improvements and development processes can be implemented easily.

6	Update	Application updates can be deployed easily.

Table 4.3: Non-Functional Requirements for the iOS application

4.2.2 watchOS

1	Usability	The user interface features a very clean design providing the user with all the options necessary for a fully functioning application.
2	Security	The application is secure to malicious attacks.
3	Reliability	User interactions do not lead to unexpected behaviour and upcoming errors are properly taken care of.
4	Performance	Tasks are processed efficiently to provide the user with a fluid user experience.
5	Maintenance	Future improvements and development processes can be implemented easily.
6	Update	Application updates can be deployed easily.

Table 4.4: Non-Functional Requirements for the watchOS application

5 Architecture

Taking a look at the application's basic architecture we can see it consists of three main actors - **Phone**, **Watch** and **API** (see Figure 5.1).

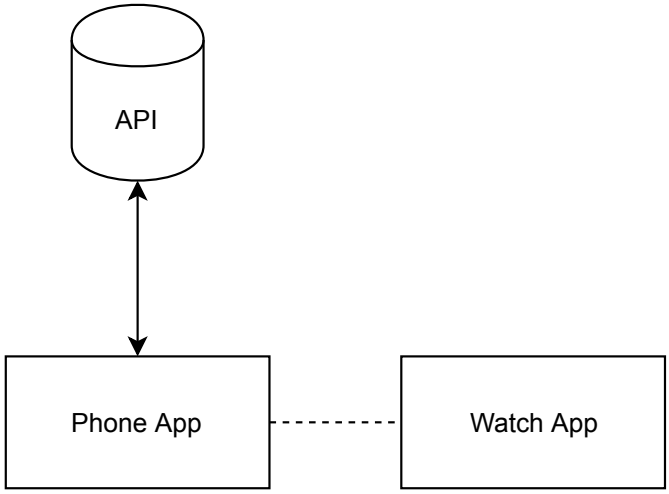


Figure 5.1: Mindful Walking basic application architecture

5.1 Phone Application (iOS)

The iOS side is where most of the logic is handled. Registering, logging in, participating in the study, overlooking gathered data and statistics, handling user settings, writing and retrieving data from Apple's Health app, communicating with the API and much more is handled on the iOS application.

Basically the core logic is done on iOS, while the data gathering, tracking and sensor tasks are handled on watchOS. This separation of logic allows the user to use the iPhone app although the watch app might currently be unavailable. For example subscribing to the study, looking at previously collected data, completing

questionnaires or resetting the application can be done within the standalone iOS application.

5.2 Watch Application (watchOS)

WatchOS side on the other hand is responsible for calibrating the user's walking speed and handling all Mindful Walking sessions. This is where very useful data is gathered including heart rate, active energy burned and total distance and later transmitted to the user's phone where it's stored within the Health app to have it accessible for the user at any given time.

The data gathered is the most valuable asset of the application and basically the core that enables the Mindful Walking app to be helpful in the first place. By evaluating information of individual users and combining the data of several different users conclusions can be drawn and tailored help can be provided for each user.

5.3 API (Application-Programming-Interface)

The API [7] does not only store the data received from the phone it also provides the questionnaire data and user information to consistently keep the application and API in sync. A lot of use cases can be covered with the questionnaire API developed by *Dr. Johannes Schobel*. For Mindful Walking only a few of those are necessary. Figure 5.2 shows the basic features of the questionnaire API used within the Mindful Walking application.

The most basic and equally important use case is login and registration. Since the data collected has to be somehow connected to an identity, a registration/login process is unavoidable. All data will be collected anonymously but will still be referenced to an identity within the database. Therefore an authentication token is needed and the corresponding functionality is provided by the API. For security measures a generated token is not valid forever and has to be refreshed once in a while.

As the user has completed the login/registration process it is then possible to subscribe to the Mindful Walking study, in case this has not already happened. If the

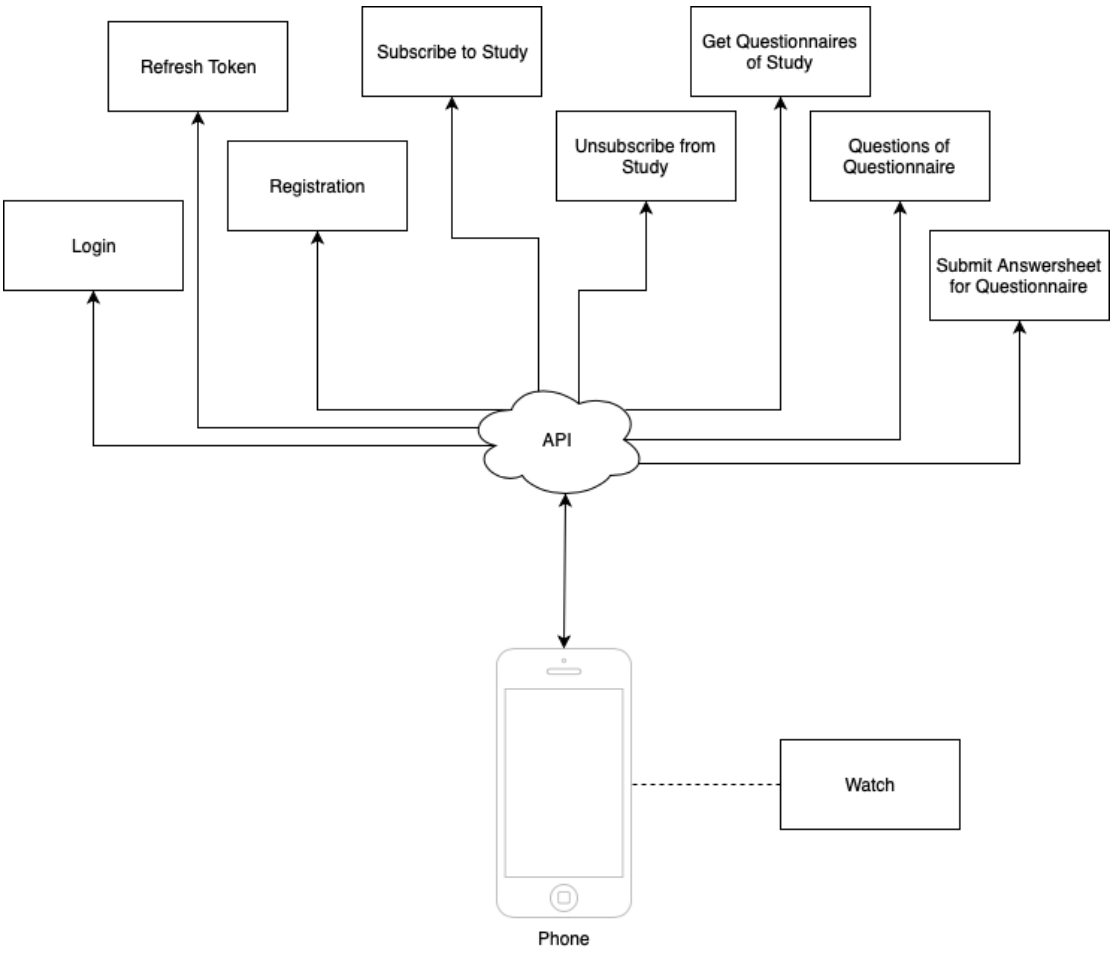


Figure 5.2: Basic illustration of the communication between phone and API.

user is logged in, has subscribed to the study and is able to provide a valid token, the questionnaire structures for the Mindful Walking study are fetched from the API. The user is then able to select a questionnaire and complete it. When finished the answers are wrapped into answer sheets, which are sent to the API and evaluated there. Evaluation does not take place within the Mindful Walking application.

6 Implementation

This chapter describes the basic implementation of the Mindful Walking app covering the most important aspects such as how the phone and watch communicate with each other, the way workouts are stored in Apple's Health app and much more.

6.1 Mindful Walking Session

Mindful Walking sessions need to be handled in a concrete way. In order to access and use the Apple Watch's sensors it is necessary to start or rather create a "Workout" to be later stored to the Health app.

With iOS12 and watchOS5 Apple introduces two new classes called *HKWorkoutBuilder* (for iOS) and *HKLiveWorkoutBuilder* (for watchOS) which make it very uncomplicated to collect data, evaluate data and save it to the Health application.

Mindful Walking therefore uses the *HKLiveWorkoutBuilder* on the watchOS side to collect, handle and store data. This is key to handling sensor data and keeping the application running in the background although the user might have lowered the wrist and the watch's screen is turned off which sends the running application into background mode.

6.1.1 Workout App Lifecycle

Such a workout can be modelled in an abstract form to emphasize what a typical workout app lifecycle looks like (see Figure 6.1). As the user raises the wrist the watch screen is turned on and the user interface is laid out and set up. Afterwards the user may choose to start a Mindful Walk where a timer is started to keep track

of the elapsed time dated from the beginning of the workout. At this point the application is in an active workout state where data is collected and background mode is enabled which allows the app to continue running in the background although the user lowered the wrist and the watch screen is turned off. As soon as the user raises the wrist again the user interface is updated with the most recent data collected by the Apple Watch. Thereby the user is constantly kept up to date with the latest and most relevant data during an active workout.

As the user decides to end a workout no more data is collected and the created workout object (created by *HKLiveWorkoutBuilder*) is saved to Apple's Health app.

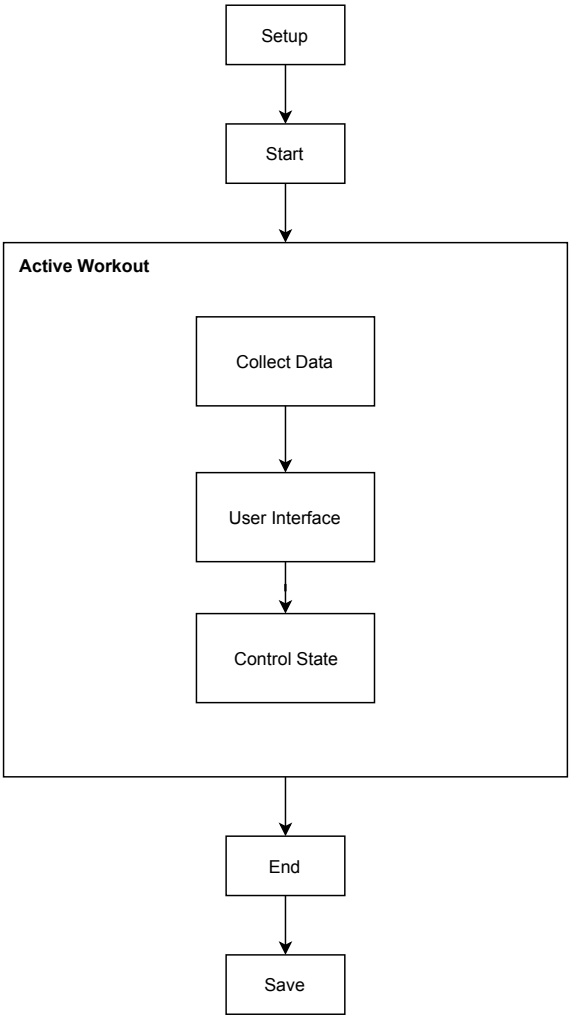


Figure 6.1: Illustration of a typical workout app lifecycle [5]

6.2 Data Collection

Depending on the workout configuration used to initialize the *HKLiveWorkoutBuilder* watchOS automatically collects data in reasonable time intervals. If for example the specified workout type is *running* the Apple Watch's sensors will collect data and update the user's location in much shorter intervals than given a workout type like *walking* which as a result leads to more exact data in a shorter period of time.

watchOS ensures the user is aware of every bit of data that is collected by an application running on the user's iPhone or Apple Watch. Without the user's explicit permission to collect specific types of data the application won't be able to collect any. To make this possible Apple does not grant access to the sensors of any device without using their intended API. This includes asking for the user's permission as soon as an application tries to access any device's sensors or as soon as data is shared between two or more applications such as the Health app. However, Apple's APIs have much to offer as well and make data collection for a Mindful Walking session very easy.

6.3 Communication between Phone and Watch

While the *HKLiveWorkoutBuilder* handles transferring created workouts to the phone and saving them to the Health app there still are several use cases to be considered when it comes to transferring messages or data apart from workout objects. Apple offers the *WatchConnectivity* API to communicate and transfer messages between the phone application and the watch application.

A *WCSession* object is instantiated on both the iOS side and the watchOS side. Those instances are responsible for safely transferring data between the two devices. It is possible to wake up the phone at any given time by sending a message from the watch to the phone. In contrast, it is not possible to wake up the watch at any given time by transferring a message from the phone to the watch in purpose of saving battery power. However, if the watch application is not currently active but a message is sent from the phone to the watch it is sent to a queue. watchOS then decides what's the most efficient time to process the message recently sent.

One specific use case is resetting the application. Initiating the deletion process in this case is only possible within the iPhone app but not within the watch application. Since the iPhone and the Apple Watch do not share one common space to store the *UserDefaults* in, it's necessary to notify the watch via the phone as the user would like to have all corresponding data deleted. In order to achieve exactly this, a message is sent from the phone to the watch. At one point watchOS will consider the current moment as appropriate to process the latest message received and will then delete all the user data on the watch side as well.

7 Walkthrough

To gain a deeper understanding of the application itself, a quick walkthrough with underlying screenshots is provided. The following screenshots show what the user would see at each point while using the application on both the phone and the watch.

7.1 iOS

Basic management of finished walks, completed questionnaires and more is handled by the phone application. The phone functions as the central management point of the Mindful Walking app. This does not only include finished walks and completed questionnaires, but also more basic functionalities such as registering an account and logging in, subscribing to the study or deleting collected data.

7.1.1 Start Study UI

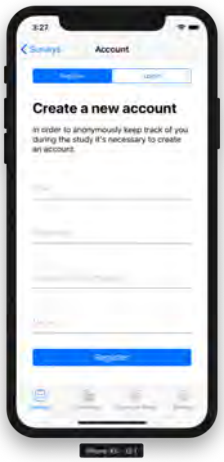
When the application is first opened the user will be confronted with a very simple user interface. There is no more to see than a little text and a button that says “Start Study” (see Figure 7.1).

As the user taps the “Start Study” button the application checks if an authentication token is stored in the *UserDefaults*. If so, the token is refreshed and updated in the *UserDefaults* and the user is forwarded to the “Survey Overview” view (see Figure 7.4). If not, the user is redirected to the “Login” (see Figure 7.3a) / “Registration” (see Figure 7.2a) view and is then able to log in if an account exists, or register if there is no account yet.

Figure 7.1: Initial view when launching the application.

7.1.2 Registration

In order to participate in a study the user has to register first. The registration process is managed on the “Registration” view (see Figure 7.2a). To register successfully, the user must provide an email address, a password and a name (see Figure 7.2b). If those credentials are not yet registered somewhere in the database the registration will be successful.

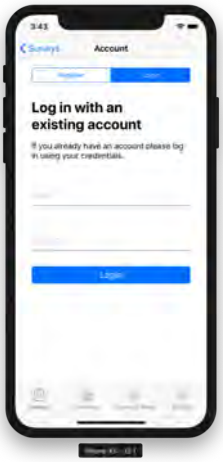


(a) Empty Registration View

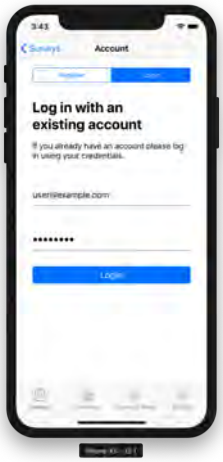
(b) Filled Registration View

7.1.3 Login

Given the user already has an account but no authentication token is found locally on the device, the user can tap the login panel and will then be sent to the “Login” view (see Figure 7.3a). In case valid data is provided the user is redirected to the “Start Study” view (see Figure 7.1), else an error message will be shown.



(a) Empty Login View



(b) Filled Login View

7.1.4 Survey Overview

The “Survey Overview” view (see Figure 7.4) is a collection of all questionnaires belonging to the Mindful Walking study. Some of these questionnaires must be completed at the very beginning and at the very end of the study interval. Others must be completed once a day.

To help the user find the pending questionnaires a red batch is shown in the top right corner of an element that says “due today” to indicate that it should be completed today. In addition a notification is scheduled if at least one questionnaire should be completed that day.

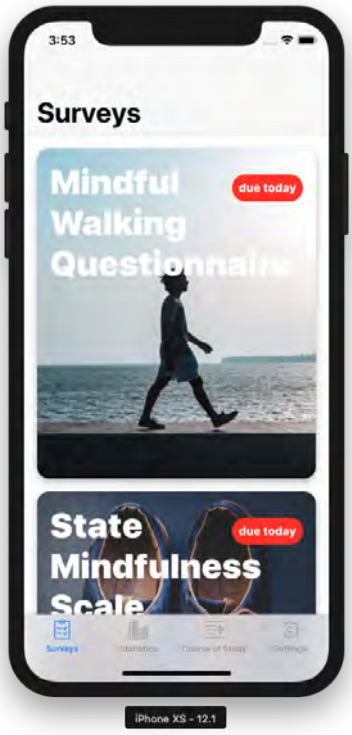


Figure 7.4: A list showing all questionnaires belonging to the Mindful Walking Study.

The user is supported even more in choosing the correct questionnaire by disabling those which were already completed in a certain period of time. Therefore the element is not tappable anymore as shown in Figure 7.5.

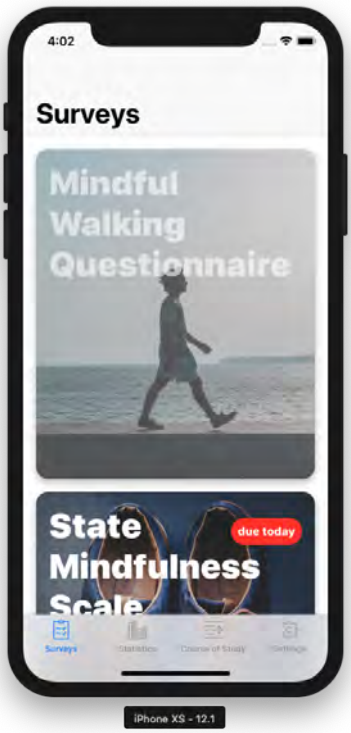
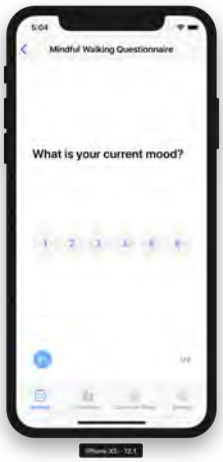


Figure 7.5: Showing a disabled questionnaire cell to help the user recognize that this questionnaire was already completed.

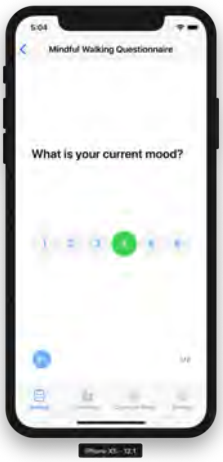
Questionnaire

When a questionnaire is selected in the “Survey Overview” view (see Figure 7.4) the corresponding questions of the questionnaire are displayed to the user one by one (see Figure 7.6a). To answer a question the user taps one of the numerical options and is then automatically forwarded to the next question.

By tapping the back arrow previously answered questions can be re-answered. To help the user remember what answer was given to a certain question, the previously selected answer to this question is saved and coloured green (see Figure 7.6b) while navigating already answered questions.



(a) A single question of a questionnaire.



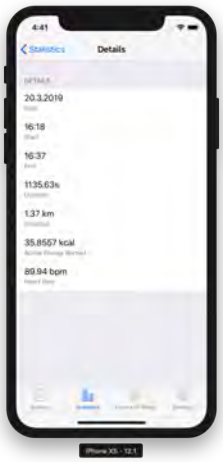
(b) Questionnaire View after the user chose an answer.

7.1.5 Statistics

Of course the user should be given insight into the data tracked during a Mindful Walking session. The “Statistics” view (see Figure 7.7a) provides this exact feature. It displays a table filled with all the data collected by the application. Shorthand information is shown as the subtitle in each table row. This makes it easy for the user to select the session by just taking a quick look at the table.

When tapping a specific table row additional information is shown such as when the sessions was recorded, when did it start, when did it end, the total distance travelled and more useful information (see Figure 7.7b).

(a) Statistics View



(b) Statistics View Detailed

7.1.6 Course of Study

In case the user cannot remember the exact course of the study a detailed explanation can be found in the “Course of Study” view (see Figure 7.8). A list constructed of four items explains step by step how the study works, what questionnaires to complete and when they should be completed.

This way the user can reread the course of the study whenever necessary.

Figure 7.8: Detailed explanation of the course of the study.

7.1.7 Settings

Settings can be managed in the “Settings” view (see Figure 7.9). This view consists of two sections: One redirects the user to the “License” view (see Figure 7.10), the other handles the deletion of all user data stored locally on the watch and the phone.

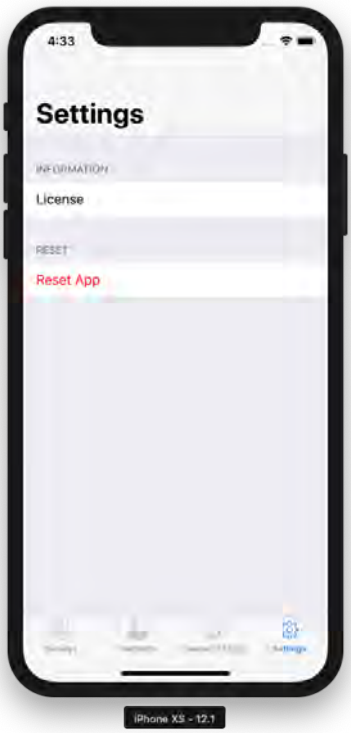


Figure 7.9: Manage settings in the Settings View.

License

For legal purposes it's required to show the licenses of third party libraries used within the application. In this case three different libraries or sources where used.

1. Icons from icons8.com (https://icons8.com)
2. Images from pexels.com (https://www.pexels.com)
3. Alamofire: A swift networking library. (https://github.com/Alamofire/Alamofire)

Figure 7.10: Shows a list of licenses used for the Mindful Walking app.

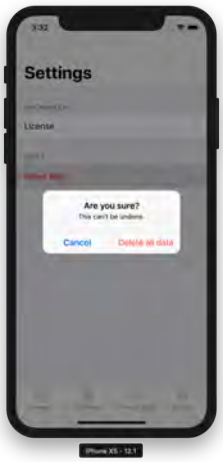
Reset App

The user is able to reset the app and delete all data collected at any given time. This process can be triggered in the “Settings” view (see Figure 7.9) by tapping “Reset App”.

When the user taps the “Reset App” button (see Figure 7.9) a dialogue is displayed. If the user taps “Delete” (see Figure 7.11a), another prompt appears on the screen (see Figure 7.11b) to ensure the user is aware that all of the data will be deleted and that this is an irreversible action.

If the user still continues in the process of deleting all data, an error message is displayed in case something went wrong while deleting the data, or a success message in case of success after which the user is redirected to the “Start Study” view (see Figure 7.1).

(a) First Prompt



(b) Second Prompt

7.2 watchOS

While the phone has a mostly managing functionality, the watch is capable of actually capturing and tracking important data. This data is crucial for the Mindful Walking app to function correctly and being useful. By tracking the user's pace, distance travelled, heart rate and more the application is able to send this data to the API and have it evaluated there which makes the application valuable to users and researchers in the first place.

7.2.1 Menu

The watchOS application starts with a menu screen (see Figure 7.12a). At this point the user may choose between calibrating the app to a custom pace or doing a Mindful Walk based on the latest calibration settings. If no calibration is present the "Mindful Walk" button is disabled (see Figure 7.12b).

(a) Menu

(b) Menu with “Mindful Walk” button disabled.

7.2.2 Calibration

When pressing the calibration icon the user is sent to a view containing a big start button (see Figure 7.13). As soon as this start button is tapped the calibration process begins.

Figure 7.13: Calibration View

Next, a countdown timer is started that indicates the amount of time left until the first step of the calibration process (tracking pace) is completed and a brief explanation is shown below (see Figure 7.14).

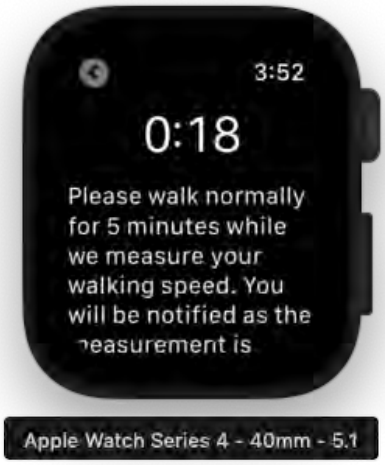


Figure 7.14: Calibration active - tracking pace

When the countdown reaches zero, the user's average pace is displayed on the next view (see Figure 7.15a). By scrolling down the user can choose a percentage which represents the amount of reduction of the average speed for future Mindful Walking sessions. When exceeding this limit during an active Mindful Walk, the watch gives a signal by vibrating on the user's wrist.

(a) User's average pace during calibration.

(b) Selection for reduction of pace.

When an option was chosen, a success view (see Figure 7.16) is presented to notify the user that the calibration was successful.

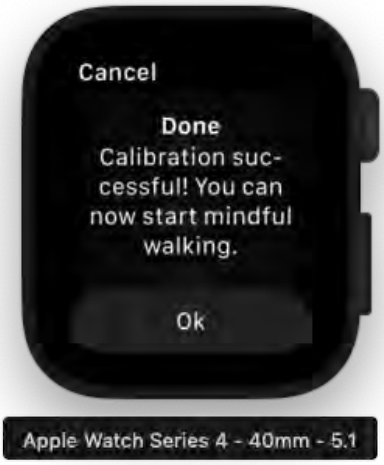


Figure 7.16: Calibration done with a success message displayed.

7.2.3 Mindful Walk

The main goal of the application is to track the user's speed, heart rate and other helpful data in order to find out whether Mindful Walking has beneficial effects. Tracking this data is done within this part of the application.

Figure 7.17: Mindful Walking View

As the user taps the start button in the Mindful Walking view (see Figure 7.17) a new view is displayed (see Figure 7.18), the session is started and data is collected. To keep the user updated about the information collected by the watch a small list presents the current statistics of the Mindful Walking session.

The list displays the most recent information collected of:

- Distance (in meters)
- Pace (in km/h)
- Heart Rate (in beats per minute)
- Active Energy Burned (in kilocalories)

Figure 7.18: Mindful Walking Active View

From here the user can tap anywhere on the screen to pause the Mindful Walking session (see Figure 7.19a). This will stop the timer and data collection. An appearing menu provides a “Resume” button and an “End” button. If the user taps “Resume” the session is resumed and the timer continues. Else the session is ended and the collected information is stored within Apple’s Health app.

The user is then informed that the session was successfully ended (see Figure 7.19b).

(a) Mindful Walking Paused View

(b) Mindful Walking done with success message displayed.

8 Related Work

The Mindful Walking application is not an entirely new approach in terms of improving a person's well-being. Of course there are related works or helpful tools that are clearly related to the success or functionality of this application.

8.1 Mindful Walking for Android

A very similar application was developed by *Dennis Kozlowski* in 2018 [3]. His work is based on the same approach, to support people with stress-related symptomatology, and is implemented for the Android phone platform.

One big difference is that his application does not work with a smart watch. The only data gathered is by the phone. This can be very advantageous since users do not additionally require a smart watch to use the application but it can also be disadvantageous because the data gathered might be less and of lower accuracy.

If less usable information is available, then less conclusions can be drawn just by the plain data. The power behind most of this information comes from the possibility to combine different types of data and discover new correlations. This approach is known and used in many fields of data science and turns out to be meaningful. However, it's always recommendable to draw conclusions from as much data as possible, but this doesn't mean that there is no usable result if the collected data does not exceed gigabytes.

8.2 Mindful Walking for iOS

Another very similar application was developed for the iOS platform [6]. This approach is very much the same as for the applications presented in this paper. The application should also function as a supporting tool in walking mindfully by tracking the user's data during a Mindful Walk and providing haptic feedback to notify the user. The possibility to participate in a study is given as well.

9 Summary and Outlook

In summary, the Mindful Walking application is a helping tool which allows the user to successfully finish Mindful Walking sessions by tracking and monitoring valuable health data. These different types of data can bring greater insight in how properly a Mindful Walk is completed. The app functions as a supporting tool in preventing the user from being distracted by environmental influences while using it, which leads to a positive effect in any case. This makes the application a really valuable asset in terms of medical support tools in an everyday life.

The health benefits of mindfulness are presumed to be enormous as described in Chapter 2. But besides benefiting from positive effects on health and life, the Mindful Walking application provides a functionality to participate in a study, which makes the app very important for research as well. Given that many users use this application and participate in the study, it might bring a unique and advantageous contribution for research. With the newly gained insights through the app it might be possible to help patients suffering from stress-related symptomatology or chronic pain even more.

9.1 Improvements

When it comes to software development an application basically can never be finished. There always is something to improve. The Mindful Walking application as it is right now is also missing some features users and researches would benefit from that should be implemented in the future.

9.1.1 Sending Health Data to the API

The current state of the Mindful Walking application does not send health data gathered to the API such as the heart rate or the user's current pace. Evaluating this data is very important and would result in clearer and more precise results.

However, the data is stored locally on the user's phone and can be accessed by the user at any time. This provides a good overview about all the data collected and gives the user some insight in what is going on during a Mindful Walk.

9.1.2 Third Party Support

For the future a few more improvements are conceivable. One of these would be improving the data tracked by the watch sensors and combining it with data gathered from third party devices such as respiration rate, blood sugar levels, blood pressure and many more. The more data retrieved, the more conclusions can be drawn, and the more patients can benefit from the effects of precisely applied mindfulness.

9.1.3 Experimental Groups and Control Groups

Another conceivable improvement would be to use a different approach for the study. This includes using experimental groups and control groups for a clearer distinction of results. By this strategy more probable conclusions can be drawn concerning the differences between an experimental group and a control group.

9.1.4 Social Platform

Since mindfulness is said to have very beneficial effects for patients suffering from stress-related symptomatology or chronic pain it is not far-fetched to assume using mindfulness in an everyday life might have generally advantageous effects for any person applying those principles. Hence a huge number of people using the Mindful Walking application would be imaginable. Of course first of all more research has to be done to back up this hypothesis but still, if it turns out that any person can and is likely to benefit from using the Mindful Walking app, this would be a scenario

where one software might help thousands of people through their everyday life and support these people in terms of their general well-being.

Moreover a social platform could be attached to the core of this app where users are able to share ideas, tips and problems with each other. To furthermore motivate a user using the application a social score system could be added. Users could then invite each other into teams, meet for walks, absolve Mindful Walking sessions to score points and compare the own score to those of the community. Such an approach might additionally encourage users to keep applying mindfulness principles in their everyday lives.

9.1.5 Offline Usage

One feature that should definitely be implemented in the future is offline usage of the Mindful Walking application. Because as it is right now, only a very limited amount of features can be used when there is no network connection available and the application is unable to reach the API for things like fetching questionnaires, submitting answer sheets or even basic functionalities like logging in or registering. But since an unstable network connection can occur at any time this is a very important aspect. To store questionnaires, answer sheets and more Apple's "Core Data" should be used.

The local application's data and the API should be kept in sync and both sides, local storage and API, should be checked and synced regularly and in appropriate intervals.

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