Designing and evaluating a free weight training application

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DEPARTMENT OF DESIGN SCIENCES
FACULTY OF ENGINEERING LTH | LUND UNIVERSITY
2021

MASTER THESIS

SONY

Designing and evaluating a free weight training application

Multi-camera positioning system with IoT data

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Published by
Department of Design Sciences
Faculty of Engineering LTH, Lund University
P.O. Box 118, SE-221 00 Lund, Sweden

Subject: Interaction Design (MAMM01)
Division: Interaction Design
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Examiner: Dr. Joakim Eriksson

Abstract

Physical activity plays a significant role in people's health, and the market for fitness apps is today a large growing market. This thesis work was conducted in conjunction with Advagym, Sony's connected gym solution that tracks activity using IoT sensors mounted on fitness machines to log detected exercises in a smartphone app.

This work examines how to extend Advagym to include free weight training using multi-camera positioning. A human-centred design process has been applied to study use situations and create prototypes through several iterations, finally resulting in three smartphone apps. The apps are structured in three different ways regarding the amount of interaction, control and accuracy they provide when tracking and logging training with free weights. Lastly, comparative usability testing was performed with 18 participants to examine how fitness data is valuable to users and what level of interaction provides the best user experience.

Keywords: Interaction Design, User Experience (UX), Internet of Things (IoT), Multi-Camera Positioning, Fitness Apps

Sammanfattning

Fysisk aktivitet spelar en viktig roll för människors hälsa och marknaden för fitnessappar är idag en stor växande marknad. Det här examensarbetet genomfördes tillsammans med Advagym, Sonys uppkopplade gym lösning som spårar aktivitet med hjälp av IoT-sensorer monterade på träningsmaskiner för att logga upptäckta övningar i en smartphone-app.

Det här arbetet undersöker hur Advagym kan utvidgas till att omfatta friviktsstyrketräning med hjälp av multi-kamera positionering. En människocentrerad designprocess har tillämpats för att studera brukssituationer och skapa prototyper genom flera iterationer, vilket slutligen resulterar i tre smartphone-appar. Apparna är uppbyggda på tre olika sätt med hänseende till mängden interaktion, kontroll och träffsäkerhet som ges vid spårning och loggning av träning med fria vikter. Till sist utfördes jämförande användbarhetstestning med 18 deltagare för att undersöka hur träningsdata är värdefull för användare och vilken nivå av interaktion som ger den bästa användarupplevelsen.

Nyckelord: Interaktionsdesign, Användarupplevelse (UX), Sakernas internet (IoT), Multi-Kamera Positionering, Fitnessappar

Acknowledgements

We would like to thank Sony and Advagym for hosting this thesis work and making the project possible by providing workspace and the technology needed. A special thank you to Jakob Håkansson, Sangxia Huang and Andrej Petef for the great interest and all the feedback and knowledge you have contributed with during the project.

We would also like to thank our supervisor Günter Alce at Department of Design Sciences for consistently showing great interest and being very supportive and encouraging throughout the project.

Lastly, we would like to thank all the people who took the time to participate in the conducted surveys and usability test. Your contributions and the data that it generated has been of great value.

Lund, Januari 2021

Dominika Motylinska & Joakim Rudberg

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Chapter 1

Introduction

Training is vital for peoples health, and fitness apps have become a sizeable growing market. The purpose and research questions are to explore how Sony's Advagym could be expanded to make use free weights. A human-centred design process is applied to develop a proof of concept within the limitations that have existed.

1.1 Background

Physical activity is important for peoples health and the need for different types of exercise solutions is great. According to the Public Health Agency of Sweden, low physical activity is today one of the 10 biggest risk factors for illness and premature death in Sweden [1]. In line with the World Health Organisation (WHO) recommendations from 2010, it is recommend that people are to be physically active for a total of at least 150 minutes per week [2]. The Public Health Agency of Sweden also reported that in 2016-2018, 64 % of the inhabitants in Sweden stated that they were physically active for at least 150 minutes per week [1].

According to statistics from the Swedish Sports Confederation and Statistics Sweden, in 2016 strength training/gym was the third most common form of training in Sweden with as many as 2,348,000 regular practitioners [3]. With the current digitalisation that is taking place, the demand for digital aids and tools has grown rapidly and this also applies to training. According to Statista the worldwide market of the eServices Fitness segment *Apps* is projected to increase in online revenue by 165% in seven year, growing from 1988.3 million USD in 2017 to 5273.5 million USD in 2024 [4].

Advagym is a connected gym product developed by Sony that uses data from sensors to let users track and log their training. With the use of IoT devices, Advagym transforms regular analogue gyms to connected ones [5]. It is done by installing sensors onto stationary machines and records data such as repetitions, distance, time, speed, acceleration and more. This provides the means to precisely review workouts by accessing data and evaluate how each repetition was executed. Advagym also lets users customise training programs and workouts.

1.2 Purpose & Research Questions

Sony wants to investigate how Advagym could make use of a multi-camera positioning system to incorporate free weight workouts. To examine how this could be done with regards to the academical field of interaction design, the research questions for this paper were formulated as:

1. How to implement free weight tracking with data from a multi-camera positioning system in an intuitive way while keeping it uniform with the existing Advagym system?
2. How can such data be presented in a user friendly way with a positive user experience?
3. Which data is valuable to users and when?
4. What level of interaction with a smart training app provides the best user experience?
5. What is ethically and by the users acceptable with regards to being tracked by cameras?

1.3 Scope & Limitations

The scope of this project is to incorporate the use of a multi-camera positioning system that tracks body poses to achieve a wider workout coverage for Advagym. This study will examine the possibilities of tracking free weight based training and how to provide such data to users with a desirable user experience and user friendliness. A human-centered design process will be implemented with several prototypes and qualitative usability testing to attain a proof of concept.

A project is always limited in resources and time, in this case two people and 20 work weeks. The limited time meant that the number of iterations for each phase in the design process had to be kept low. Limitations concerning resources also include the test environment and the technical systems used in the project. The tracking system was at an early stage and could only detect four different exercises well, which limited the implementation of the Hi-Fi prototypes to a narrow range of exercises. The system and its cameras were also not easy to move, which meant that all the tests had to be performed in the office environment where everything was already assembled. There was no easy access to the source code or other components from the actual Advagym app, which meant that the apps for the Hi-Fi prototypes were built independently from the ground up.

Due to the Covid-19 pandemic that was ongoing throughout the work, limitations arose out of the guidelines given by the Public Health Agency of Sweden to prevent infection [6]. Employers were urged to encourage their employees to work from home, which led to the office being mostly empty and limited the possibility of spontaneous communication with people who worked within Advagym. As the inhabitants of Sweden were urged to limit their contact with people other than those they normally met, it was not easy to recruit test participants who were not friends.

1.4 The Global Goals of Agenda 2030

The global goals for sustainable development, officially named as the Sustainable Development Goals (SDGs), were founded by the United Nations (UN) in 2015 [7]. The SDGs were created as a part of the UN resolution known as *Agenda 2030*, this agenda is a plan of action for people, planet and prosperity [8]. In September 2015 all 193 member states of the UN adopted Agenda 2030, pledging their countries to mobile efforts towards it for the upcoming 15 years [7]. The 17 global goals as presented in the agenda are shown in Figure 1.1. This thesis work aims to aid the third goal, good health and well-being, by conducting research to provide better tools that encourage physical activity.

Figure 1.1. The 17 global goals of Agenda 2030 [7].

Chapter 2
Technical Background

A variety of theory and technologies have been used through this work. Multi-camera positioning together with the communication protocol MQTT has been used for the tracking. Android Studio was used as a development platform to create the Hi-Fi prototype apps and features from the existing Advagym system. Furthermore, related work regarding free weight training and fitness apps is applicable to this work.

2.1 Multi-Camera Positioning

Computer vision and camera-based tracking has been around for a while with technologies such as traditional motion capture, also known as mo-cap. However, marker-less detailed tracking in real-time has mostly been a subject for the future because of the large amount of computing power needed to continually process the images. Today with the rise of more and more powerful computers together with the rapid development of deep neural networks, the challenge with large amounts of image data is made more manageable.

Three dimensional (3D) tracking with single-camera solutions fail in the presence of foreground occlusion, that is when objects block the cameras line-of-sight, and is thus unsuitable for tracking multiple people. Multi-camera solutions solve the moving foreground occlusion problem by using several views, but instead faces issues when static background cluttering occurs. Earlier work has shown that this can be solved by implementing a system with multiple calibrated cameras, to allow for reliable and accurate tracking of multiple people at once [9]. By exploiting the temporal consistency in videos to match the two dimensional (2D) inputs it is possible to achieve fast multi-human 3D pose estimation from multiple calibrated camera views, retaining the individual 3D poses for each individual [10].

This thesis work makes use of a calibrated multi-camera positioning system that with computer vision and 3D pose estimation tracks when people perform exercises. The multiple cameras continuously records video that cover a given area from multiple angles. With these multiple 2D images, the computer vision can then by using deep neural networks build a

3D environment that detects objects in real time. The computer-vision used to track exercises operates by building anonymised 3D-skeletons based out of key-points in a space that is mapped to physical space of the tracking area, as shown in Figure 2.1. 3D pose estimation is then used to predict when any of the skeletons performs a movement corresponding to a defined exercise.

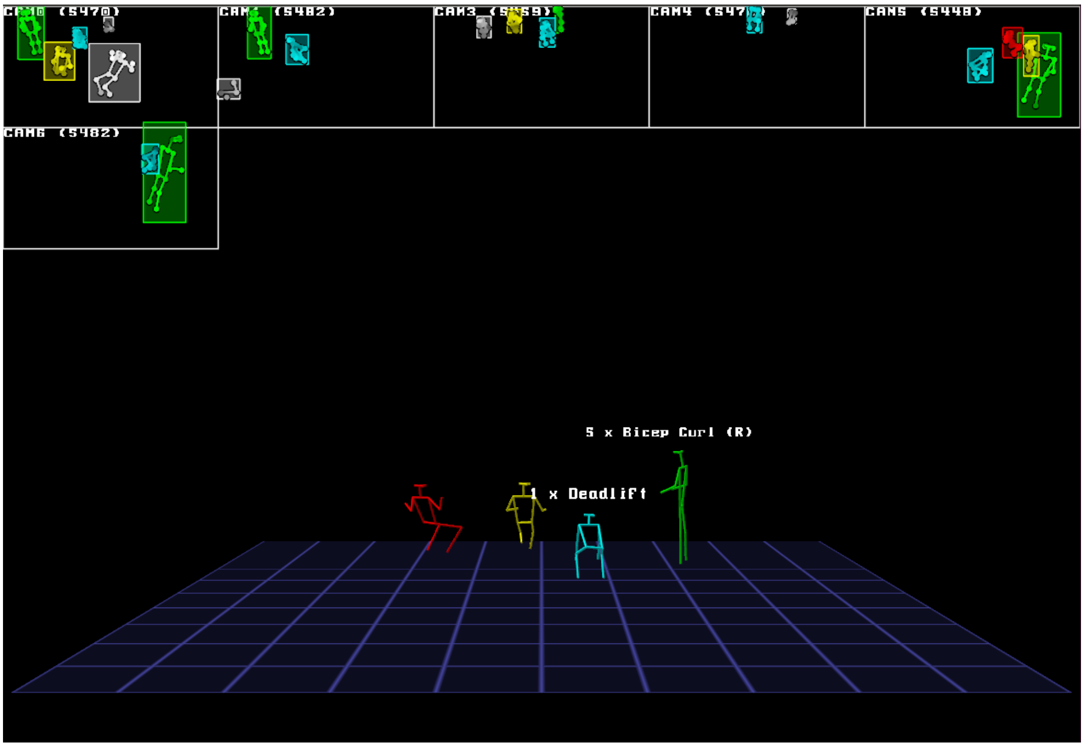

Figure 2.1. Visualisation of Multi-Camera Positioning System, image courtesy of Sony.

2.2 IoT & MQTT

Internet of Things, IoT, is a wide term used to describe the technologies of connecting everyday appliances and objects to the internet. There is no general definition [11] but one widespread within the field of interaction design describes IoT as a system of connected computing devices, mechanical and digital machines, objects, animals or people that are provided with a unique identifier and the ability to transfer data over a network [12]. However, most people are probably familiar with and have encountered it through the commonly used marketing term "smart" products such as smart light bulbs, smart power-plugs, smartwatches and other smart appliances.

MQTT, an acronym for MQ Telemetry Transport, is an OASIS (Organization for the Advancement of Structured Information) and ISO (International Organization for Standardization) standard messaging protocol for IoT [13]. It has a small code footprint and requires minimal network bandwidth, making it ideal for use with IoT devices where such properties are of great importance [14]. The communication is based on a client-server publish/subscribe architecture to transport messages between devices, as exemplified by Figure

2.2. MQTT uses a hierarchy of topics to organise information, e.g. "myhome/temperature" or "myhome/temperature/outdoor". Clients can either publish a message to a topic, or subscribe to a topic to receive any messages posted to it. The server, also referred to as the broker, is responsible for receiving all messages, determining which topic they belong to and then send the messages to all devices subscribing to that given topic. The multi-camera positioning system described in section 2.1 uses MQTT to send messages to other devices with information about the tracking and when exercises are detected.

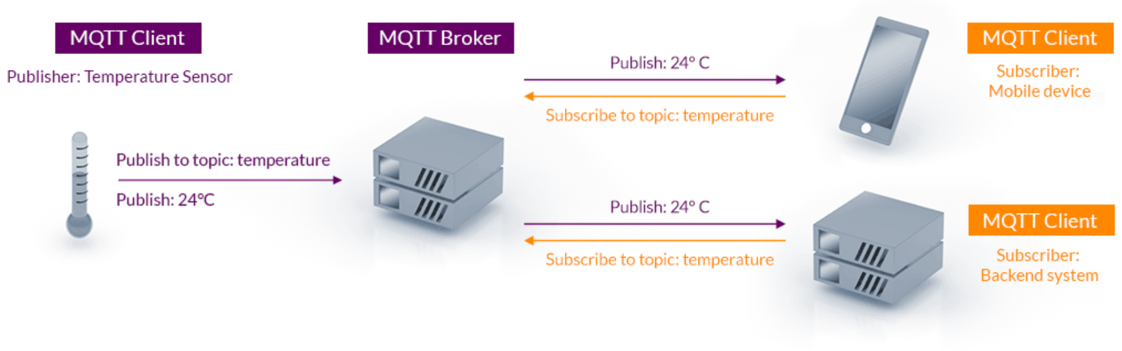

Figure 2.2. The MQTT Publish/Subscribe Architecture [13].

2.3 NFC

Near Field Communication, NFC, is a communication protocol used to transfer messages between two devices within close proximity. It is an ISO standard that allows for data transfer with speeds of up to 424 Kbit/s [15]. It works without the need for any set-up within a range of up to 4 cm with a small power-consumption footprint [16]. NFC is in nearly every phone these days and used for a variety of applications such as reading tags or to quickly set up more data capable communications such as WiFi or Bluetooth. It is also the technology used in contactless debit/credit cards and mobile payments.

2.4 Android Development

Android Studio is an IntelliJ-based end-to-end development tool for Android. It was presented at the 2013 Google I / O conference. According to its creators, it is to significantly accelerate the application development process. Developers of Android Studio put a great emphasis on improving the creation of user interfaces. Once creating an activity, a corresponding pre-configured XML (Extensible Markup Language) file is being constructed, allowing a user an easy access to text editing mode accompanied with a layout live preview. This means that every change made in XML is immediately visible to the user. Also, selecting one of its components in the preview will highlight the corresponding XML element. This is a useful feature that saves a lot of design time, allowing even an inexperienced android programmer to develop fully functional applications or, in the case of this project, fully interactive high fidelity, Hi-Fi, prototypes within reasonable time frames.

2.5 Sony Advagym

As mentioned in section 1.1, Advagym is a connected gym solutions developed by Sony with IoT devices. It is a complex system with several user groups and where communication takes place between many devices. The architecture of this system is best described by the illustration from a recent thesis work that was also done for Advagym by one of the supervisors at Sony [17], see Figure 2.3. In the figure it can be seen that Advagym has three main types of users, in this work however, it is primarily the clients/application users who are of interest as only user performance data is used. A personal trainer can use Advagym to create personal programs and send them out to their users. If users want and approve data sharing, their personal trainer can also see how the workouts are going and what development they are doing. Gym owners can use Advagym to measure the activity of the machines and get data about the utilisation of their gym and its equipment.

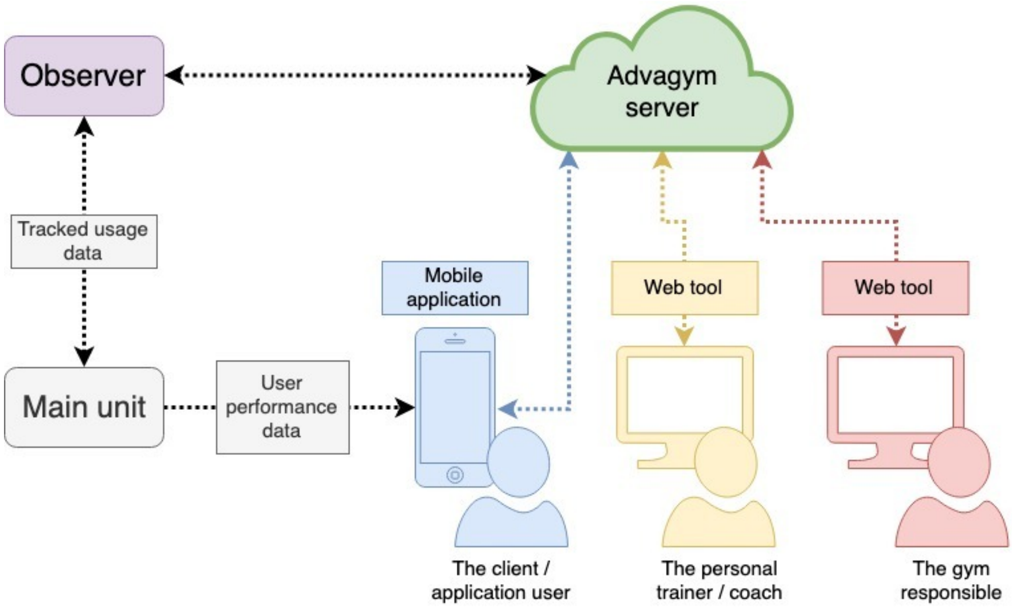

Figure 2.3. Illustration of Advagym's IoT data flow to different users [17].

The IoT devices that make up the hardware for the current Advagym system consists of *main units*, *pucks*, *beacons* and *observers* [5]. Main units are mounted on every machine, e.g. on top of the weight stacks as seen to the left in Figure 2.4. They then use different sensors to measure the speed, distance and repetitions of exercises. Pucks, right in Figure 2.4, serve the role of establishing a connection between users phones and the main units of the equipment they intend to use. Users tap the puck by using NFC to log in to the specific machine that the puck is mounted next to, or workout zones such as a dumbbell rack. They are then presented with exercises in the app that may be performed with the selected equipment and for machines the exercise is tracked and automatically logged. Beacons are used to send position specific information to users when they are within enough proximity, such as messages or granting access to a gyms Advagym features. The observers are responsible for establishing connections to the main units (up to 50) and collect their data to make it accessible without a direct phone connection, e.g. for the gym owners.

Figure 2.4. The main unit (left) and puck (right) hardware, image courtesy of Advagym.

Today free weight workouts are implemented through zones were users receive exercise suggestions to select and then in the app manually enter the amount of sets, repetitions and weights used. By using the multi-positioning system, it is now interesting to investigate whether you can also get free weights to be logged automatically in the same way as with machines and their main units, and thus expand Advagym to also fully support free weights training.

2.6 Related Work

There are product solutions and research work done around free weight training and fitness apps that are relevant to this work. Currently the most widespread solutions that exist to track free weight training are for home use, however there are works on products for commercial use.

2.6.1 Free Weight Tracking Solutions

Today there are some organisations that have implemented solutions and created products to track when people work out with free weights. Existing camera-based solutions for home use include *Mirror* [18] and *Tempo* [19] shown in Figure 2.5. *GymCam* [20], shown in Figure 2.6 is a proposed system that could fit commercial use with camera based computer-vision that tracks many people simultaneously. None of these solutions however make use of multiple cameras and thus face the occlusion issue related to single camera use.

Mirror & Tempo

Mirror and Tempo are examples of smart gym equipment for home use that has received good reviews in 2021 [21]. Both systems implement workout-tracking by using front-facing single 3D-camera solutions to build 3D models of the user, as seen in Figure 2.5. When working out, these systems detect what type of exercise that is performed and how many sets and repetitions are completed. The interactive screens display a 3D avatar that shows how users perform the exercises in real-time. In addition, Tempo offers AI-generated pose correction that provides detailed instant feedback on how users should improve their execution of an exercise when it is not performed optimally. These systems also offer personalised stats to track the progress made and provide workout programs through extensive libraries of on-demand or live classes with personal trainers.

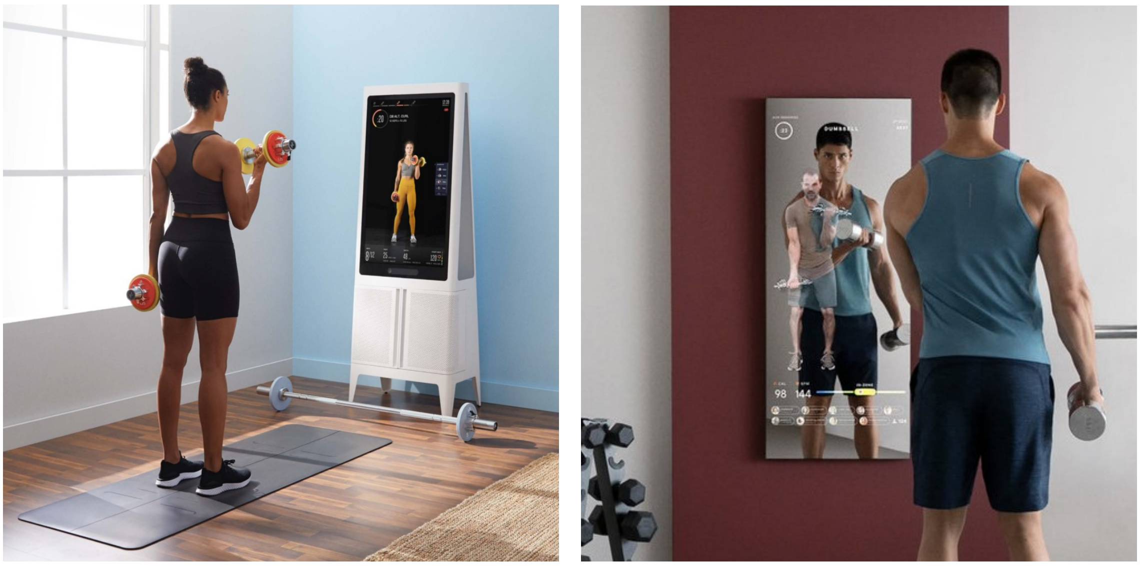

Figure 2.5. Camera based free weight tracking home gyms by Tempo [19] (left) and Mirror [18] (right).

GymCam

GymCam is a suggested solution released in 2018 on how to implement camera-based tracking of free weight training. It is claimed to have the ability of detecting, recognising, and tracking simultaneous exercises in unconstrained scenes [20]. It is achieved with computer vision that uses machine-learning algorithms to process the images collected by the camera continuously. GymCam looks at movements over time and assumes that each repetitive movement is likely to be an exercise to subsequently generate clusters of detected exercises. The system tracks hundreds of users at the same time, individually detecting what exercises are done and how many repetitions, as exemplified by them in Figure 2.6.

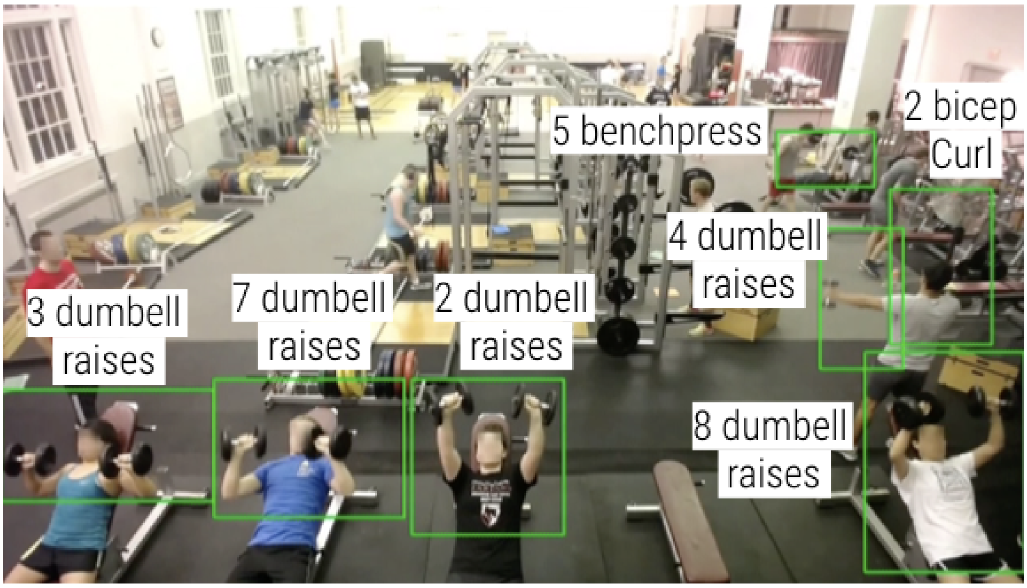

Figure 2.6. GymCam, tracking exercises with camera computer vision [20].

2.6.2 Fitness Apps for Smartphones

Fitness apps is today a sizeable rapidly growing market that has seen a major use with the growth of smartphones. Some of the most popular apps for android in the "health and fitness" category are used today by millions, e.g. Google Fitness has been downloaded and installed more than 50 million times [22]. It has been shown that the factors that motivate people to use fitness apps can be grouped according to the five categories *recordability*, *networkability*, *credibility*, *comprehensibility*, and *trendiness* [23]. Some of there features provide users with access to regular record-keeping which allows for making self-monitoring and keeping track of ones physical activity easier. Being able to do can effectively assist forming habits and achieving successful diet/fitness results [23]. Fitness apps are excellent tools to help people exercise, as such providing them can be said to be well in line with the third global goal of good health and well-being.

Chapter 3
Methodology

A human-centred design process has been used to develop designs for solutions through several iterations in this work. A comparative study was conducted based on methods for usability testing. Design principles have been used as tools to promote good design throughout the development.

3.1 The Human-Centred Design Process

Human-centred design focuses on asking questions about the user, their emotions, goals, and tasks. This information allows designers to make decisions regarding the development of a product or service that will meet potential customers' needs. Thus it is essential to underline the importance of user studies. However, the methods to achieve that can vary heavily depending on the purpose as no single method can fit every imaginable scenario or project. Therefore, to identify what kind of input is required and what techniques to combine to acquire it is often a challenge itself.

The ISO standard 9241-210 [24], shown in Figure 3.1, defines human-centered design as an approach to systems design and development that aims to make interactive systems more usable by focusing on the use of the system and applying human fac-

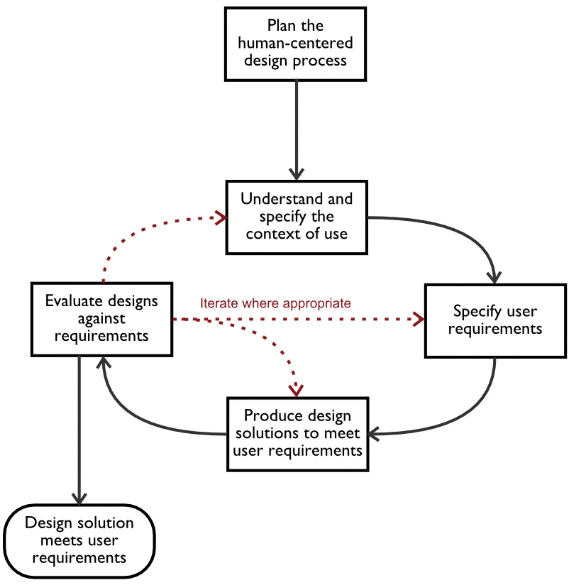

Figure 3.1. Human-Centered Design Process as per ISO 9421-210 standard [24].

tors/ergonomics and usability knowledge and techniques.

The world renowned American design firm IDEO has for more than 30 years worked within the discipline of interaction design and been a key player in developing the human-centered design approach. In their book *The Field Guide to Human-Centered Design* [25] they divide the human-centered design process into three phases as shown in Figure 3.2 and describe them as following.

Inspiration - In this phase, you will learn how to better understand people. You will observe their lives, hear their hopes and desires, and get smart on your challenge.

Ideation - Here you will make sense of everything that you have heard, generate tons of ideas, identify opportunities for design, and test and refine your solutions.

Implementation - Now is your chance to bring your solution to life. You will figure out how to get your idea to market and how to maximize its impact in the world.

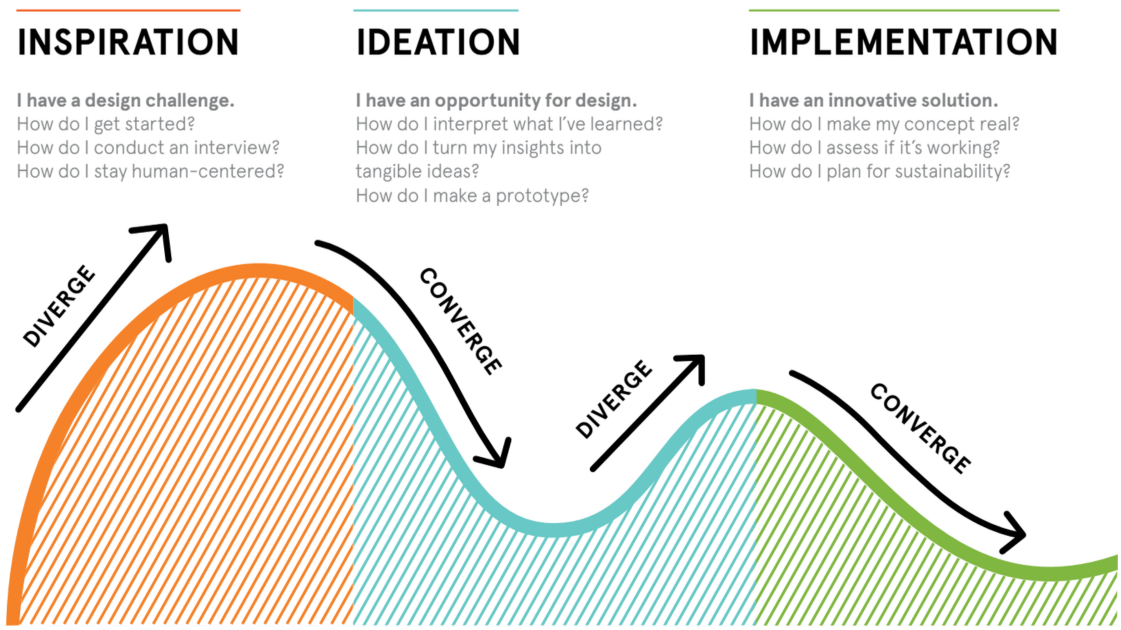

Figure 3.2. The Human-Centered Design Process as Illustrated in The Field Guide to Human-Centered Design by IDEO [25].

3.1.1 Inspiration Phase

This phase consists mostly of user studies and field research to correctly identify each stakeholder's needs and wishes. It aims to determine the restrictions and limitations early. Allowing the research team to reject some resource- and time-consuming ideas early on. This will have an effect on both the time- and budget plan.

Stakeholders

Cooperation with the potential or current users as well as understanding their needs, predispositions and limitations will allow building a solution that they will want to use.

Identifying the stakeholders, examining their needs and the impact they can have on the project, can in turn increase the chances of a project's success, provided that the stakeholders are managed efficiently. This collaborations with the potential users and parts involved should not be limited explicitly to the beginning or the end phases. To increase the chance of building a good system frequent user involvement is necessary. This way it is possible to plan solutions effectively based on the feedback, allowing the team to re-prioritise and discard some features and ideas while it is still inexpensive.

Observations & Interviews

When planning on which features to include in a product, it is crucial to realise that it can not be solely based on the stakeholders' interests and wishes and should instead be combined with an analysis of actual user behaviour. For this purpose, many research techniques can be used, mainly based on observation. The contextual inquiry technique can help to identify, for example, the environmental and behavioral limitations that the current solution might be exposed to. It consists of conducting an interview and observation directly at the place or within an environment where a user adapts or could potentially adapt the product in question[26].

By conducting such a study, it is possible to observe the use situation of a product. Through the interview, it is possible to deepen the knowledge about the observed behaviours, e.g. find out that the user has already tried many learning techniques and which were the most effective. Observing the user advances the chances to discover their actual behaviour and thus draw more credible conclusions about whether the product will fit their needs and harmonise with their current style and way of using the product [27].

Surveys

The question remaining is where to start. User studies can be used to indicate the key features which should be implemented in the first place. It is a good idea to use the Kano model, developed back in the 1980s by the Japanese professor Noriaki Kano [28]. The use of this model will organise the list of functionalities according to the following division:

- *Must-be* features i.e. those that are necessary and without which the product will not meet the user's basic needs
- *Desired* functionalities which are expected features, often consciously indicated by users
- *Attractive* features, product features that are unique and innovative
- *Indifferent* aspects that do not contribute to customer's satisfaction or/and dissatisfaction
- *Reverse* qualities of the features that might result in dissatisfaction, solely based on the fact that users prefer different things

To identify these features a survey can be conducted. The word survey is used most often to describe a method of gathering information from a sample of individuals. Depending on the nature of a survey conducted for a specific purpose, the number of samples necessary to achieve a significance can vary. In order to minimise the sample error and obtain statistical significance the numbers of respondents must be rather large and conducted through a random selection in order to represent the population. Estimated amount for a 95 percent Confidence Interval of 1 percent width is roughly 10,000 for the representative purpose [29].

3.1.2 Ideation Phase

During this phase the information gathered during the inspirational phase needs to be concluded and made sense of. While collecting big amounts of data might be promising it does not mean it is useful. As the possibilities of filtering and managing the data are limited it is important to find a focus and determine what data will contribute to the project. Subsequently, with a solid understanding of users and a clear problem definition, it is time to start working on potential solutions. In this phase of the human-centered design process, the creativity of the people involved in the project plays an important role. It is important to remember not to criticise any ideas during this phase, instead it is recommended to create as many potential solutions as possible. There are many different types of idea generation techniques that can be used to achieve that.

Brain- and bodystorming

Generating a new idea or solution is not always an easy task, although the creative techniques used for this type of task have been known for a long time. Even if a huge number of sources is available, the results are not always satisfactory. One of the most popular methods is Brainstorming. It is a heuristic method of creative problem solving. It is aimed at generating ideas for finding the causes of the problem, solutions and selecting the best options, preferably in a group consisting of people with different backgrounds. Participants are encouraged to freely submit their ideas and exchange views, avoiding all criticism as no idea at this stage is a bad idea. All suggestions are then written down or recorded on tape. One of its biggest advantages is the possibility of obtaining a large number of various solutions to a given problem in a short time, as well as making the participants think more creatively which might translate into the future work [26]. The second phase of brainstorming focuses mostly on estimating which ideas can be incorporated into the current project based on given limitations and what it tries to achieve.

It is important to think outside the box, often even abstract and out of the ordinary which could require a participant to step out of their comfort zone. In order to encourage that and create an atmosphere friendly to the creation of new ideas, *bodystorming* can be used. By putting yourself in an environment or situation in which the product might be used it is easier to understand the needs, issues and potential limitation a user might be exposed to.

Affinity Diagram

Affinity diagrams allow organising thoughts and ideas by categorising and grouping them based on common unifiers. With its help, it is possible to improve the creation process by providing discipline and order. It is a powerful visualising and organising tool that requires minimal resources, often just pen and paper to write down the unique ideas and something to place them on in groups. e.g. a whiteboard. The primary purpose is to highlight and identify relationships between individual elements, as the very definition of the word affinity means a close similarity between two things [30]. Employing an affinity diagram can be beneficial for sorting and structuring the data generated from conducting brainstorming. [31].

Focus Groups

The recruitment process for usability research is not the easiest task to do. Especially when it comes to companies with a specific and narrow group of potential customers. Then it is important to precisely define the characteristics of one or more types of respondents and divide them into specific user groups, allowing the research team to select the test participants who are better suited for the study. A lack of a target, or so-called, focus group does not necessarily make it easier - managing the needs of every potential user imaginable might be difficult, especially if they are conflicting [27].

Cognitive Walk-through and the Think Aloud Protocol

Cognitive walk-through is a method that helps answering the question of how easy it is for users, especially new ones, to perform system-related tasks. The method assumes that new users prefer to learn how to use a system by performing tasks rather than reading instructions, for example with the help of an artefact or a prototype. Cathleen Wharton [32], one of the authors of the method, proposed the four questions:

- Will the user try to achieve the effect that gives the next step of the task? Will he understand that this step is necessary to achieve his goals?
- Will the user notice that the correct action is available? For example, does he see the button?
- Does the user understand that a task step can be performed by this activity? For example, does he not only see the button, but also understand the content and in effect use the button?
- Will the user get feedback from the system? Will he know that he has done the action correctly?

Applying a *Think Aloud protocol* is one way to receive an answer to these questions. Verbalising the thinking process as the tasks are performed by a participant of the study help the moderator to understand how the user understands and perceives the application, what is missing and they pay attention to. In conjunction with the physical observation of the subject, the moderator obtains an image of how the user uses the product and what barriers they encounter [26].

Lo-Fi Prototyping

Prototyping helps the visualization of the design concept and confronts business assumptions and system ideas with actual customer expectations. Low-fidelity prototypes present the interface in the simplest form. It is not unusual for it to be brought down to a simple sketch on the piece of paper, presenting not more than the position of individual elements and their approximate size. This could be used by the team behind it as a checklist or be a subject to the early testing which due to the low production cost can allow quick iterative changes [27]. With others words, Lo-Fi prototypes allow to test one or more functions and make quick adjustments, hopefully reducing the costs of producing more advanced, but also expensive and time-consuming, high fidelity prototypes that are mostly used for the final evaluation.

3.1.3 Implementation Phase

The implementation phase consists of creating Hi-Fi prototype, can which be interactive computer-based applications. Usability testing, described in detail in section 3.2, is also a large part of this phase.

Hi-Fi Prototyping

A high fidelity (Hi-Fi) prototype is usually based on previously created Lo-Fi mockups and is much more similar to the final version of the product. There is much more emphasis placed on the details of individual elements, as well as their aesthetics. Using, for example, computer-aided design (CAD) for that purpose allows mimicking the final product's behaviour to the point where a user can thoroughly test and evaluate its functionality. It is a handy tool to identify a system's problems and weaknesses early [26].

The Hi-Fi prototypes' purpose is to support all tasks required for the usability testing without hindrance. Therefore, they must be implemented with such a high level of detail that the user feels that they are well-functioning apps and with a highly detailed appearance. However, a good prototype should not contain more than what you want to investigate and learn [33]. To make it possible with limited resources to create prototypes with both width and depth, you can make so-called T-prototypes. In T-prototypes, the top layer of the letter represents all visible but not implemented functionality. The leg represents the few relevant features that are implemented in-depth to meet the needs for the purpose of the prototype, as shown in Figure 3.3.

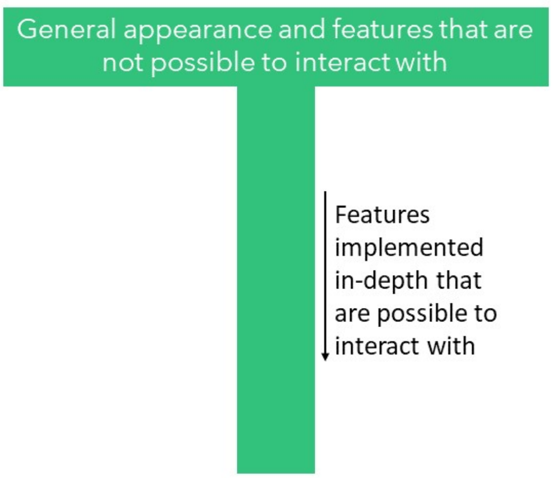

Figure 3.3. T-prototype.

3.2 Comparative Study

A comparative study can be valuable when there are multiple design solutions that can be compared. It enables discovering and to highlight the different advantages and disadvantages that the various solutions created might contain.

3.2.1 Usability & User Experience

Usability is defined by ISO 9241-210 [24] as the extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use. With definitions for three identified usability attributes being given as effectiveness (accuracy and completeness with which users achieve specified goals), efficiency (resources used in relation to the results achieved) and satisfaction (extent to which the user's physical, cognitive and emotional responses that result from the use of a system, product or service meet the user's needs and expectations).

Usability is a key aspect of User Experience (UX) [34]. UX is defined by ISO 9241-210 as, user's perceptions and responses that result from the use and/or anticipated use of a system, product or service [24]. The nnGroup, founded by Jakob Nielsen and Don Norman [35], has presented a figure describing UX as shown in Figure 3.4. What can be seen is that the core of UX is that a product has to have a relevant use and after that good usability. Furthermore, it is shown that UX is also about having a desire to use and positive emotions due to a product. The figure can also explain the relationship between the terms as that good UX results from good usability, but good usability in itself does not necessarily mean good UX. Looking at the two definitions given by ISO, the difference between the terms can be described as that usability is about reaching goals easily while UX is about users' feelings as a result of the product.

3.2.2 Usability Testing

Usability testing is one of the central concepts in human-centred design, conducted to evaluate the usability of a website or an application. Tests are usually carried out with the help of a moderator and potential/current users of the product in question. During the test, the moderator gives out various commands, called task, to interact with. It is an effective tool to obtain an objective evaluation of the team's work; it helps to detect what problems the user might encounter and measure how long it takes to complete the task. It is also used to verify if a product meets the user's expectations as well as what can be done to improve the design. Observing test participants of different backgrounds and level of expertise can provide innovative solutions to reoccurring problems.

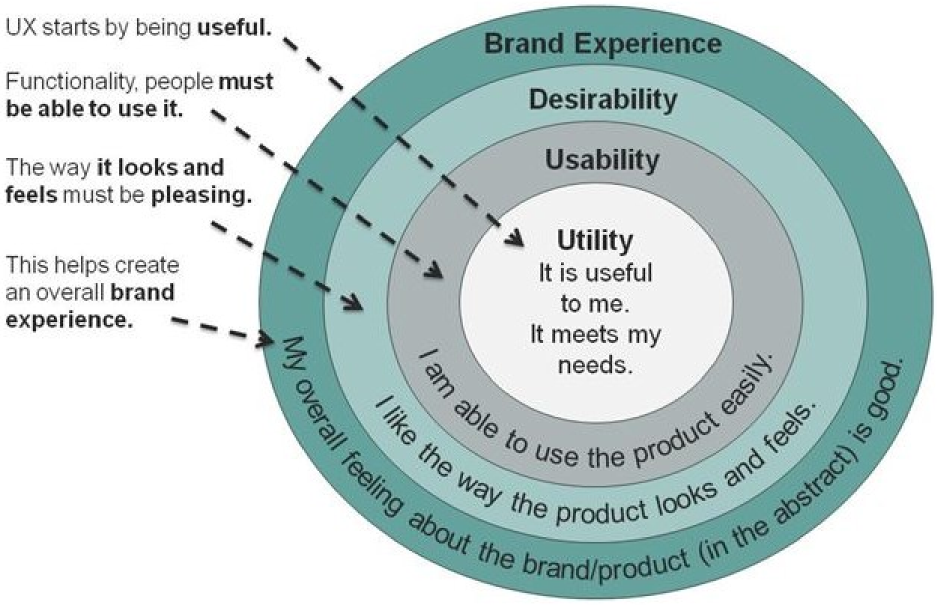

Figure 3.4. User Experience. Source: User Experience 2008, nnGroup Conference Amsterdam. Retrieved from: http://www.neospot.se/usability-vs-user-experience/

3.2.3 Study Participant Selection

While choosing the participants for a study, it is crucial to define its purpose, mostly because the study's context should drive the result. Besides the study's nature, another important aspect that affects the number of participants needed is the complexity and how critical for the project the research is. The further in the process, the bigger the needed sample size. Performing the test in the earlier stages creates some room to detect other issues during a later iteration and can therefore be performed with fewer participants. Consequently, as stated by Roobaea AlRoobaea and Pam J. Mayhew in their study conducted for University of East Anglia, *"There is no unique model for sample size estimation because the sample size depends on the objective of each particular study"* [36].

This study has characteristics of both *Comparative* and *Problem Discovery* studies. The Comparative Studies focus on comparing two or more designs with each other, and based on a given hypothesis answer if the participants prefer one over the others [37]. The metrics that are commonly used for this kind of study are task-completion rate and task-compilation time. Yet, to deliver a valuable proof of concept, comparing the ideas with each other might not be sufficient. For that purpose, it is important to identify the most critical problems in both design and the implementation of the prototypes in pair with the potential improvement suggestions. A *Problem Discovery* study requires a significantly smaller sample size with 15 participant being enough to find roughly 97% of the problems as shown in Figure 3.5.

Number of Participants	Minimum % Found	Mean % Found
5	55	85.55
10	82	94.686
15	90	97.050
20	95	98.4
30	97	99.0
40	98	99.6
50	98	100

Figure 3.5. Numbers of problems found relative to number of participants for Problem Discovery Studies [38].

3.2.4 Tasks & Task Scenarios

Testing while the application is still during development makes it possible to quickly react and act accordingly. Therefore it is better to test more often, preferably in the small steps rather than to conduct one large study which would require more time to collect and analyse the results. While performing a task, the participants comments on their own movements and thoughts on an ongoing basis, using the thinking-aloud protocol. Thanks to this, it possible to obtain a lot of valuable information, including, for example, their expectations. At the same time, users are monitored: how they use the product, what causes them problems, what they do not understand and where they get lost [39]. A negative approach to testing may also be dictated by what the design team sees as "common sense", based on their own knowledge and expertise level. However, testing could highlight the fact that some users are unable to complete the simplest task due to getting lost in the interface or misunderstanding the basic functions.

3.2.5 System Usability Scale, SUS

System Usability Scale, abbreviated as SUS, is today the most widely used standardised questionnaire about the perceived usability of a system [34]. It was developed in the year of 1986 by John Brookes while has was working at the Digital Equipment Corporation in the UK and was published a decade later in 1996 as a chapter in the book *Usability evaluation in industry* [40]. The questionnaire is license-free and of no charge to use, the only prerequisite set by the author is that "any published report should acknowledge the source of the measure". It was originally designed as a "quick & dirty" method, however, a number of studies have indicated that SUS is indeed a powerful instrument for the assessment of perceived usability [34].

The SUS is made up of 10 questions with statements that the respondents take a stand on how much they agree with on a 5-point Likert scale, where 1 equals strongly disagree and

5 equals strongly agree. The questions, which can be seen in Appendix A, are organised so that every other statement is positive and negative, the purpose of this is to force users to be active when answering and not just do it casually. A SUS-score ranging from 0 to 100 is then obtained by calculating the values of the answers from the positive (odd numbered) and negative (even numbered) questions. This can be done by using the formula given in equation 3.1, where strongly agreeing with all positive and strongly disagreeing with all negative questions yields the maximum score of 100.

$$Score = 2.5 * (20 + \sum OddNumberedQuestions - \sum EvenNumberedQuestions) \quad (3.1)$$

There are several benchmarks that can be used to evaluate what a SUS-score says about a system's usability. J.R Lewis presents the Sauro and Lewis curved grading scale (CGS) as consistent with an industrial practice that has become increasingly common of interpreting a mean SUS of at least 80 (A-) as indicative of an above average user experience [34]. The grading scale was created with data from 446 studies and over 5,000 individual SUS responses to provide letter grades for SUS-scores [41]. In this thesis the Sauro-Lewis CGS will be used to analyse and grade the usability of the prototypes based in their average SUS-scores according to the table shown in Figure 3.6.

SUS Score Range	Grade	Percentile Range
84.1–100	A+	96–100
80.8–84	A	90–95
78.9–80.7	A–	85–89
77.2–78.8	B+	80–84
74.1–77.1	B	70–79
72.6–74	B–	65–69
71.1–72.5	C+	60–64
65–71	C	41–59
62.7–64.9	C–	35–40
51.7–62.6	D	15–34
0–51.7	F	0–14

Figure 3.6. Grading Scale Interpretation of SUS Scores [41].

3.3 Design Principles

When working with creating software and user interfaces, it is important that the design is of good quality for the users to be able have a good user experience. To increase the chances of achieving this, it is be beneficial to make use of certain guiding principles as tools during the design process.

3.3.1 The Seven Fundamental Principles of Design

Don Norman, one of the leading thinkers on human-centered design [42], is the creator behind the *Seven Fundamental Principles of Design* [43]. According to Norman, an action consists of the two main parts execution and evaluation which in turns can be divided into *The Seven Stages of Action*. With these insights about actions, the seven principles that can be used to achieve good design were created. Each principle can be applied as a special design strategy to make products efficient and effective to use [44]. The principles, which has been kept in mind throughout the making of the prototypes in this work, and their definitions are:

1. **Discoverability** - "It is possible to determine what actions are possible and the current state of the device."
2. **Feedback** - "There is full and continuous information about the results of actions and the current state of the product or service. After an action has been executed, it is easy to determine the new state."
3. **Conceptual model** - "The design projects all the information needed to create a good conceptual model of the system, leading to an understanding and feeling of control. The conceptual model enhances both discoverability and evaluation of results."
4. **Affordances** - "The proper affordances exists to make the desired actions possible"
5. **Signifiers** - "Effective use of signifiers ensures discoverability and that the feedback is well communicated and intelligible."
6. **Mappings** - "The relationship between controls and their actions follows the principles of good mapping, enhanced as much as possible through spatial layout and temporal contiguity."
7. **Constraints** - "Providing physical, logical, semantic, and cultural constraints guides actions and eases interpretation"

3.3.2 The "Use Situation"

Arvola [31] notes that the reason for running a human-centered design process is that it is in the sharp state of the business, where a product or service comes into use, that value is created. This is referred to as the "use situation" and that it is first in that situation that an interactive product becomes valuable. Examining the use situation provides designers with insight to help understand and specify the context of use of a potential product with its users. Furthermore, a selection of principles for user interface design is given that can be used to aid with how the components are designed and composed. There are in total eleven principles, many of which originates from Norman's design principles and stages of an action. The rest are: *metaphors*, *feed-forward*, *attention*, *proximity compatibility*, *working memory*, *Fitt's law*, and *Hick-Hyman's law*.

Chapter 4
Lo-Fi Development

The Lo-Fi Development consisted of the first two phases in the human-centered design process, the inspiration and ideation phase [25]. Firstly the inspiration phase was conducted by carrying out Advagym exploration, observations and a survey. Then the ideation phase turned the gained findings into concrete ideas through Lo-Fi prototyping.

4.1 Pre-studies

The inspiration phase (Figure 4.1) was conducted working problem-driven by performing pre-studies to form ideas of the users' needs. The purpose of the pre-study was to investigate the actual use situation to gain insights and learn lessons based on the reality in which the product is intended to be used. The different components in chronological order were: exploration of the current systems, observations followed by a survey. The exploration was done to gain an understanding of the current system. The observation and survey were done to identify the real-life use and needs of people.

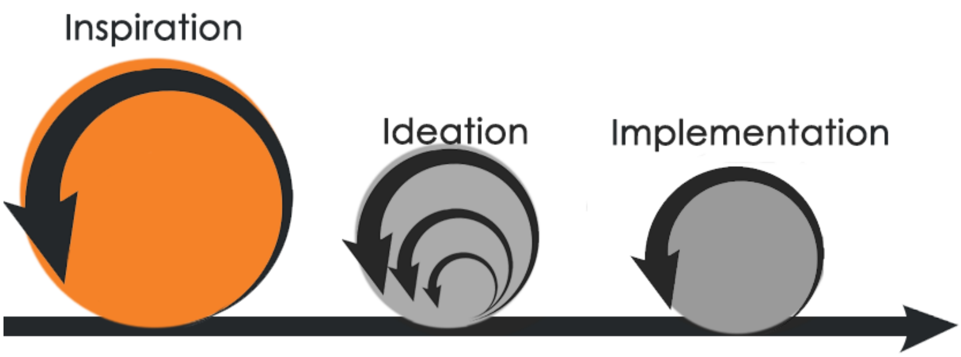

Figure 4.1. The Inspiration Phase consisted of Pre-studies.

4.1.1 Advagym Exploration

To gain knowledge of how Advagym and its current system works today some exploratory testing was conducted. The test sessions took place in the gym facility at the Sony Office in Lund. It consisted of real workout sessions that were executed with the use of the Advagym-app to explore how the product works through from the perspective of actual users. This gave understanding of how the system is implemented today and how the tracking is done but also the broader functionally of the app and the flow and order of the tasks to be done when doing a workout with the app.

4.1.2 Observations

Observations were conducted to study the use situation of gym-goers and how they do things in their real gym environments. Different gyms were visited at five occasion and observations were made with regards to predetermined observation points. These points were designed to provide guidelines of which things to look for at the gyms relevant to our project scope. The observation points were created as:

- Where do people have their mobile phones?
- How often do people pick up their phone and when?
- What other items do they bring to the work-out area of the gym?
- What is their gender and approximate age?
- In which order are things done?
- Which information is used and how?
- What other aids could be of use?
- Other observations that are found interesting

The key finding was that most people do not have their mobile phone on them in person when at the gym. Of those few that did, approximately one fourth, most used it for music and social media. Leading to the conclusion that there are challenges with how to incorporate smartphone-based gym applications in such a non-smartphone prone environment as a gym is.

4.1.3 Exploratory Survey

Based on the questions that arose from the exploration of Advagym and the observations, an exploratory survey was created. The survey aimed to provide a deeper understanding of the users and answer questions that could not be sufficiently examined in the two previous sections.

To construct the survey, six categories were first created as a base for which areas to study. The categories created were to identify *person*, *training habits*, *training aids*, *problems*, *information* and *privacy concerns*. With these six categories, a plethora of questions was generated. The questions were then revised, discussing which were deemed most relevant for this project and could have the greatest potential to bring value. Out of all questions, 15 final questions were made to create the first draft of the survey. The survey was created via Google Forms as it is user friendly, easy to distribute online, summarises the data well and is free to use.

A pilot-test of the survey was conducted with two experts (and our supervisors from Sony), Jakob Håkansson and Sangxia Huang. It led to the conclusion that two questions could be removed and that some questions needed to be re-formulated or clarified. This led to the final survey provided in Appendix B.

For the distribution of the survey the non-probability sampling technique, convenience sampling, was used to find participants of which to send the questions in order to preserve the constraints of limited resources and time. It was decided not to send the survey through any of the class/faculty channels that exist as it was deemed engineering students would be a too homogeneous group. This since they would have been of similar age, background & technical expertise while assumed to also share a lot of common interests. The survey was sent through direct private messages to 60 of our closest friends, neighbours & families as it gave a broader distribution and more varied participants.

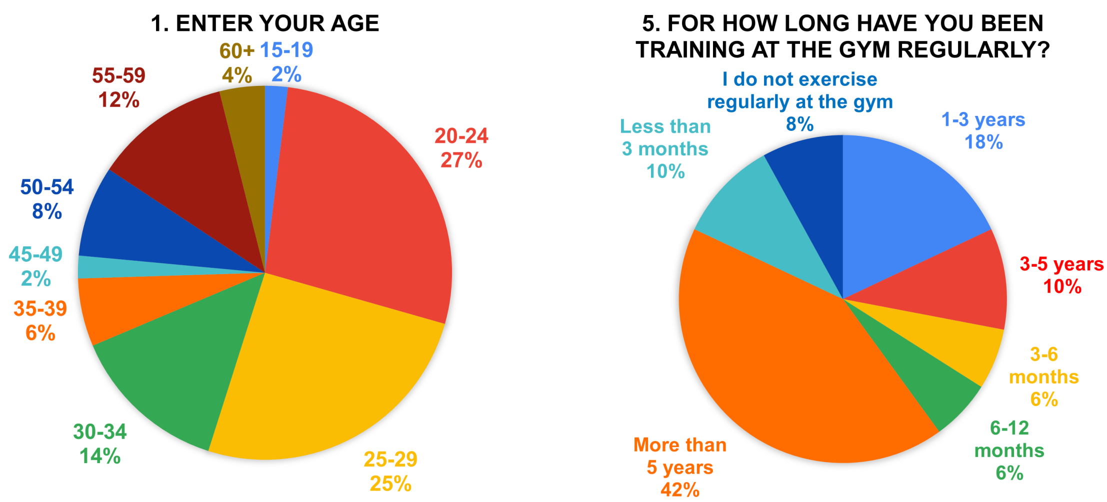

Figure 4.2. Answers for question 1 and 5 in the exploratory survey.

Four days after distributing the survey, 50 individual answered questionnaires had been received. The questionnaires were submitted by people with a good variety of age, see Figure 4.2, out of which one third were female while two-thirds were male. In Figure 4.2 it can also be seen that many of the participants were experienced "gym-goers". More than a third of those surveyed answered that they had been training at the gym regularly for more than five years, a majority had credible experience and only 8% stated that they did not exercise regularly at the gym. The answers from the survey were analysed and summarised by using Microsoft Excel to identify relationships & key elements.

Looking at question 3, *What motivates you to work out*, and its free text answers gave an insight into common motivators. The most occurring reason was found to be *to feel better physically* followed by *to feel better mentally* and *appearance & weight*.

Question 7, *What is the reason that you use or do not use free weights during your workout routine*, was analysed together with question 6, *What type of gym training do you participate in*.

This was done to differentiate the answers from people that do exercise with free weights and those who do not. The main reasons given by people that did use free weights were to *train more muscles/the entire body simultaneously*, *engage smaller muscles instead of isolating specific ones*, *stabilisation & core* and that it was *more fun*. Out of the participants that did not exercise with free weights there were two gym-related reasons, *do not know how to use them* and *they are often occupied*. The challenges with free weight training were uniformly viewed by the survey participants as *learning to lift/perform the exercises correctly*, *easier to acquire injuries if done incorrectly* and *requires more knowledge since it is more technically difficult*.

Furthermore, question 8, *What aids to you use for your training*, with multiple choice answers was combined with question 9, *What does the aid contribute with*. Doing so allowed seeing which type of aids the participants used and what those specific aids contributed with. Smart watches and bracelets were used to monitor pulse, time & calories. Those that had a training buddy mainly stated that it contributed with motivation, knowledge and helped to detect errors. Notepads were used for motivation, to see development and documentation. Prewritten programs were used to keep track of which exercises to perform, to see development and documentation of ones progress. Personal trainers contributed with motivation and guidance. Mobile phones were mainly used to log workouts (i.e. workout diary), keep track of which exercises to perform and keep track of time. But phones were also stated to contribute with motivation, to see distance and pace when running outdoors, to create own workout programs, to get a better overview, to keep pace and improve focus. Out of the 50 participants, 14 participants (28 %) did not use any aids for their workouts.

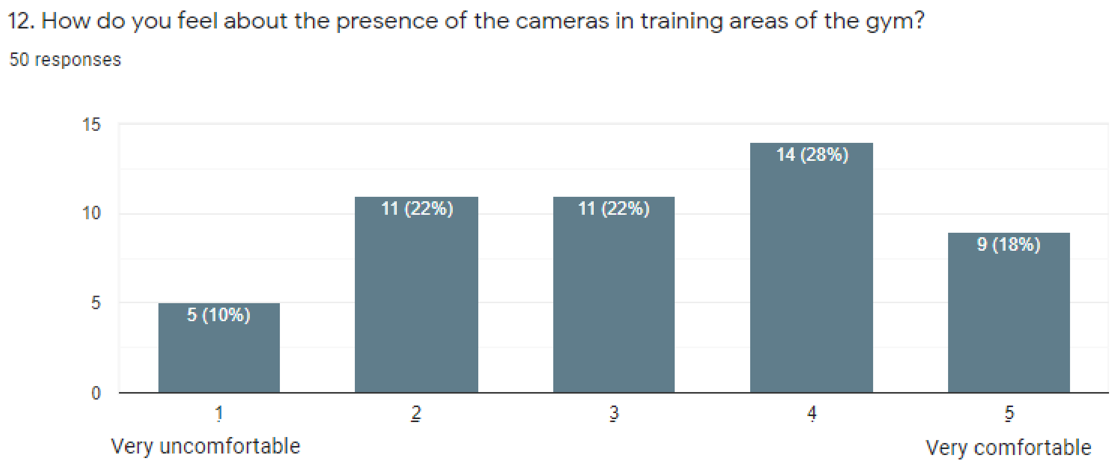

Figure 4.3. Opinions on the privacy issues considering the usage of cameras for workout tracking are quite evenly divided.

Finally the other questions also provided some valuable finding. Question 11, *what information do you want about your training with free weights*, showed that what is most sought was *number of repetitions and sets* with 34 participants (72 %) seeing it as information they would like to have. The information type with the second most of the votes was *posture & execution* (60 %) followed by *development overview* at third place with 55 percent. By looking at questions 12 (Figure 4.3) and 13 together it is seen that there is no uniform opinion towards cameras at a gym's workout areas, but a majority of the survey participants would be more comfortable if the data was anonymised and only used for training purposes. What could also be seen was that those comfortable with the presence of cameras were more likely to have an unchanged attitude towards it if the data was anonymised.

4.2 Lo-Fi Prototyping

When the inspiration phase was completed, it was time enter the ideation phase (Figure 4.4) and shape the insights into tangible ideas in the form of Lo-Fi prototypes. To do this, brain- and bodystorming sessions were first held to generate ideas for solutions to the problems and challenges that had been identified in the previous phase. The ideas were then analysed around their viability and those that were considered relevant to the scope were selected as the basis for the creation of the prototypes. The Lo-Fi prototypes were developed and tested in three iterations.

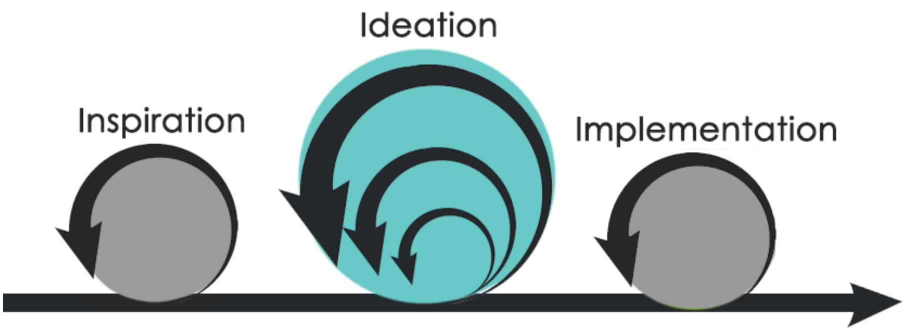

Figure 4.4. The Ideation Phase consisted of Lo-Fi Prototyping and Lo-Fi Testing.

4.2.1 Brain- & Bodystorming

Firstly brainstorming was conducted to generate ideas of possible features. After that, a bodystorming session was executed to gain further ideas and evaluate the ones generated by the brainstorming in a real physical gym environment. The generated ideas were reviewed and those deemed relevant were taken to the development of the Lo-Fi prototypes.

The brainstorming was carried out in two different sessions, before and after the bodystorming. Each session consisted of the three different steps of creating ideas, reviewing them and then to summarise them. To create ideas, post-it notes were used and a time limit of one hour was set to write down as many ideas as possible that could be thought of. All the ideas were then reviewed by discussing which ones were good and should be kept. The meaningful ideas were grouped and finally summarised in an affinity diagram as shown to the left in Figure 4.5.

For the bodystorming a basic workout scenario was formulated to work as a stepping stone for getting into the role of being a gym-goer and find problem that may arise from doing such tasks. The tasks that made up the scenario was in chronological order to *start tracking*, *begin a workout and an exercise*, *log sets and reps*, *check posture och execution*, *finish workout or start another exercise*, *stop tracking* and finally *evaluate the summary of your workout*. The bodystorming session was performed in the gym at Sony as shown to the right in Figure 4.5. The tasks were done both with the Advagym app and without any app but with a hypothetical one in mind. All problems, thoughts and ideas that arose were written down and were then reviewed afterwards.

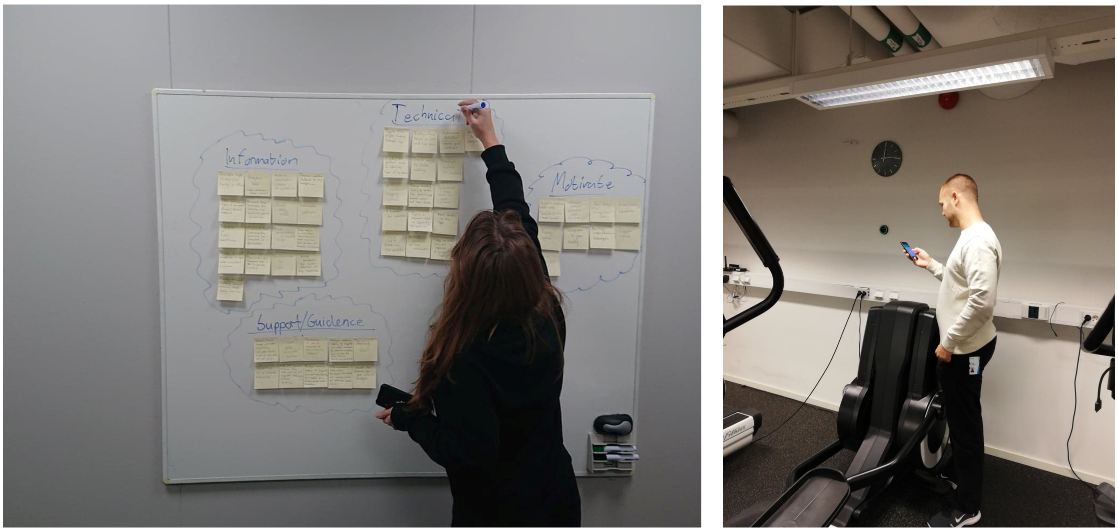

Figure 4.5. Brainstorming and Bodystorming sessions performed as part of the Lo-Fi development process.

Finally all generated ideas were reviewed and discussed. The ideas deemed most viable och relevant to the project scope were then selected to be continued with in the project. The brain- and bodystorming sessions both provided a lot of valid ideas but many were discarded due to them not being within the project scope or within the range of the Sony's focus in the near future. Some ideas and features that were excluded could be a subject of future development, such as colour-coding the weights to support automatic weight detection during workouts. Similarly the idea of incorporating additional monitors was discarded as it was going against the company's business model of "your phone is all you need".

The ideas selected to take to the development stage were :

- Vibration and/or sound feedback for reps&sets.
- Possibility to add or edit exercises manually.
- Large GUI-components as the phone will be viewed from a distance.
- "Entry-zone" to initialise tracking.
- Feedback for posture and execution.
- Include relevant already existing features from current Advagym app such as time, weight and workout history.

4.2.2 Lo-Fi Implementation

To develop the Lo-Fi prototypes Balsamiq Wireframe was used. Balsamiq Wireframes is a small graphical tool to sketch out user interfaces [45]. It is a fast drag and drop tool with premade UI components, making it quick and ideal for the ideation phase. This since it allowed focus on the structure and overall content rather than more detailed concerns which should be left to the implementation phase. One key reason that balsamic was used instead of paper-prototyping was that is has the ability to link frames. As one part of the scope for this thesis is to study how the applications are interacted with, how they are used and in which order. Being able to link the frames made it possible to create clickable Lo-Fi prototypes to explore the interaction a lot better and efficiently.

The original specifications for the lo-fi prototypes was that they should include and investigate the most viable ideas from the brain- and bodystorming phase, while staying in line with the features and graphical user interface (GUI) of the already existing Advagym smartphone application. For the first iteration, four different Lo-Fi prototypes were created and tested.

Entering the second iteration the main theme of this thesis had been well established and formulated as, what level of interaction with a smart training app provides the best user experience. To examine this it was decided to develop 3 apps, one at each extreme and one in the centre on the scale of how much user interaction that is needed as shown in Figure 4.6. The level of interaction was defined as to how often and how much the users would have to manually do something in the app, before, during or after their workout. For the second iteration the three prototypes with different amount of interaction were then created and given the names *Exercise Workout*, *Program Workout* and *Free Workout*.

The third iteration consisted of some minor GUI changes from the feedback given in the testing of the second iteration.

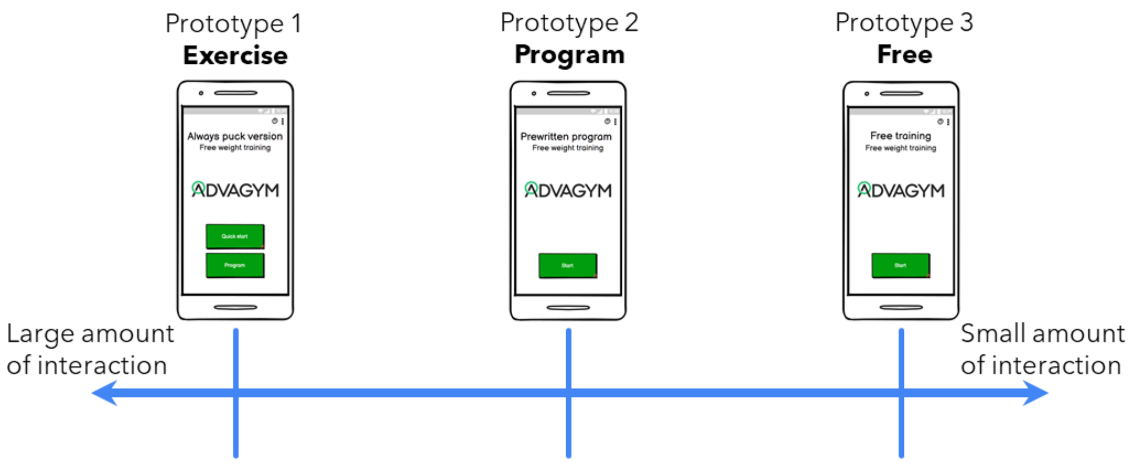

Figure 4.6. The three prototypes shown on a scale with regards to the amount of user interaction that is needed.

4.2.3 Lo-Fi Testing

The first iteration of Lo-Fi prototypes was tested with the supervisors at Sony to clearly communicate the intentions and ideas while getting input on what they were interested in.

Due to Sony being arguably the most important stakeholder, it was decided to create a handful of Lo-Fi prototypes, accompanied by several simplified tasks. The tasks were similar to the model of the current system's functionality and would first be evaluated, rather than tested, by the Development and Business representatives. This evaluation prevented further working with the ideas that most likely would not be implemented or supported and therefore minimised the time put into developing the second iteration prototypes.

The second iteration not only reduced the number of prototypes down to three, but it also isolated the individual functions and stripped the prototypes out of repetitive moments. It was necessary to avoid any preference for the prototypes that include the elements that the test subject is already familiar with. For even more accurate results, the test order of the prototypes was randomised for each test participant. The testing was carried once again out with the Sony representative as well as the thesis supervisor provided by LTH to verify that the project is still within the scope while still retaining the research status and innovative factors required by the Faculty of Engineering.

The third iteration introduced minor changes to the design according to the observations and suggestions provided by the third and final Lo-Fi testing executed with external participants. Since it was to be conducted on the test participants characterised by the target group with little to zero knowledge of the existing system, more detailed task scenarios were composed. This led to the creation of these six post-test questions for the third Lo-Fi iteration:

- Which prototype of these 3 did you prefer? Why did you prefer it?
- Which prototype do you think brings the most functionality?
- Which do you think was easiest to understand?
- Which of them do you think best suits your needs during training?
- Is there any other functionality that you would have liked to see in your training app?
- Would you use the Visual Posture Feedback in your app if it was provided? Either during or after the workout.

4.3 Lo-Fi Results

For the third iteration, the three final Lo-Fi prototypes had been created as shown in Figure 4.7, Figure 4.8 and Figure 4.9. These prototypes were tested to confirm whether they worked acceptably for people without knowledge of the system and to discover shortcomings and ideas to take further into the development of the Hi-Fi prototypes. The third and final iteration of Lo-Fi testing was performed with six external test subjects. The conclusions were based on the observations a test moderator would note down during a test and verbal feedback that the test participants provided. During the test, they were encouraged to use the "think aloud" method and afterwards answer a post-test questionnaire.

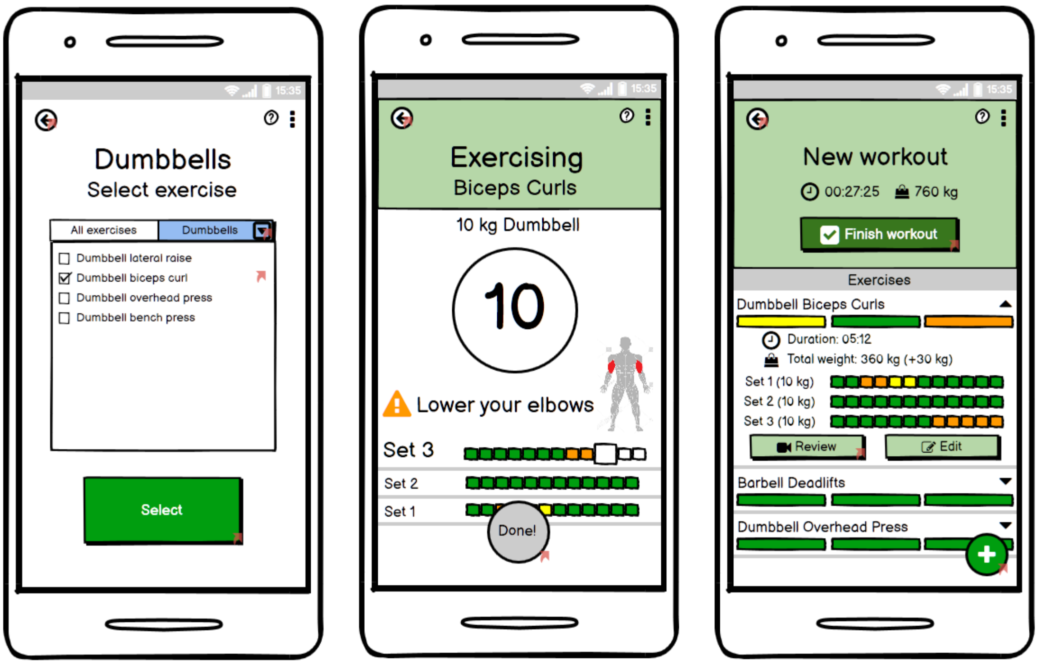

Figure 4.7. Lo-Fi prototype 1, "exercise workout".

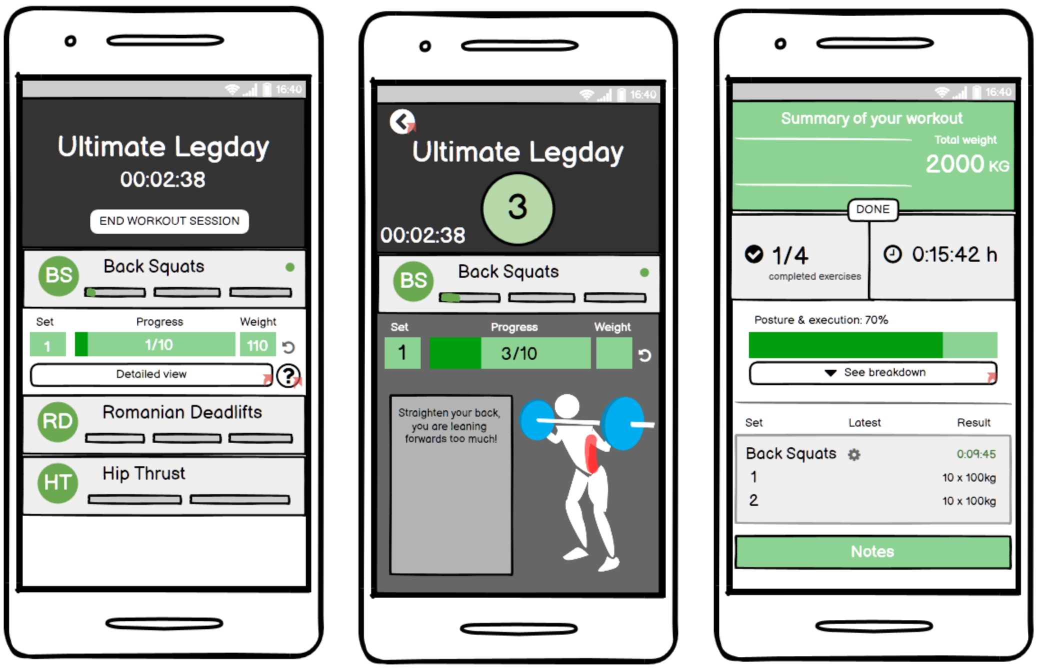

Figure 4.8. Lo-Fi prototype 2, "program workout".

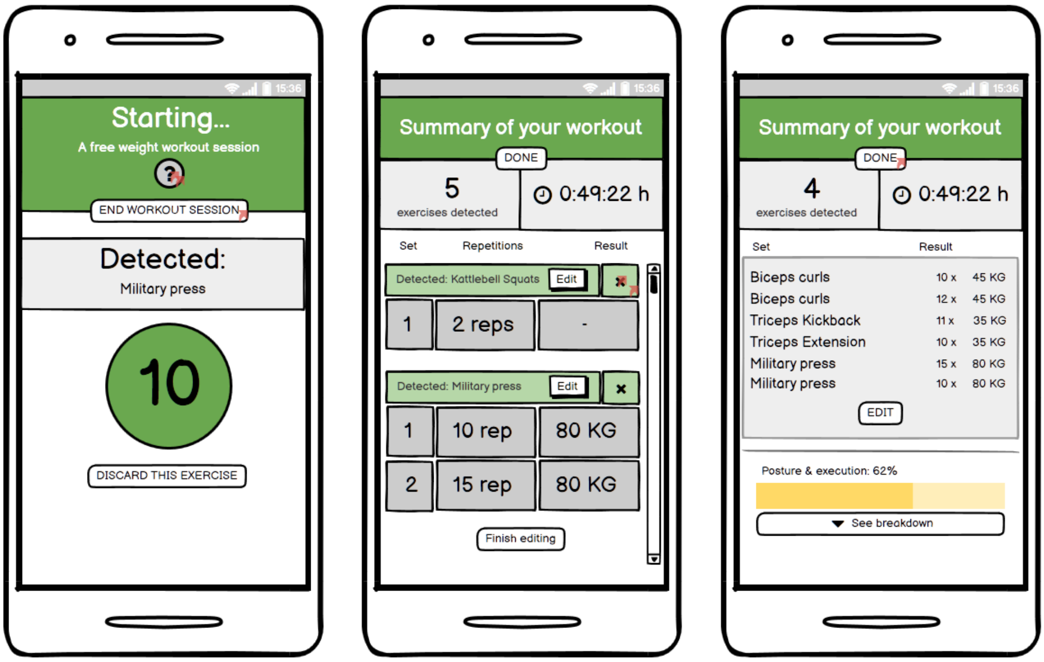

Figure 4.9. Lo-Fi prototype 3, "free workout".

Design-related feedback such as font size, colours, and data presentation was directly translated into the Hi-Fi prototypes. The test subjects also mentioned the following suggestions which were included as a potential improvement for the next prototyping phase:

- A social component, competitions against or with your friends, achievements, medals
- Support for custom exercises, the ones that are not on the list
- Sound feedback if performing something potentially dangerous
- The app reading the program out loud
- Information about your pulse and how many calories that are being used.
- A yes/no approach, for example for the app to ask if to increase the weight or work with same amount of weight or repetitions as before. Another application of this approach could potentially be to ask if the detected exercise is correct.

When it comes to which prototype that was preferable, the answers differentiated heavily depending on which aspect a test person was asked about as shown in Figure 4.10. Having in mind that the sample size is too small to draw any definite conclusions, the answers provided during this iteration were at least sufficient to identify the main advantages and the flows of the prototypes presented during the testing. For example, when asked *Which of them do you think best suits your needs during training?* the *Program workout* prototype was preferred, yet it was clear that just that prototype with the corresponding scenario was too hard to understand compared to the other two, receiving 0 votes while asked *Which prototype do you think was easiest to understand?*. Based on this feedback, the design for that prototype got simplified moving into the Hi-Fi phase to match amount screens and elements of the other two. The

Free workout prototype presented an interesting trend of leading in terms of functionality and how easy it was to understand, yet not being chosen by a single test person as a prototype they preferred the most. Finally, all the test subjects have given a positive response when asked if they would use the visual feedback, either during or after the workout. Finally, all the test subjects have given a positive response when asked if they would use the visual feedback, either during or after the workout.

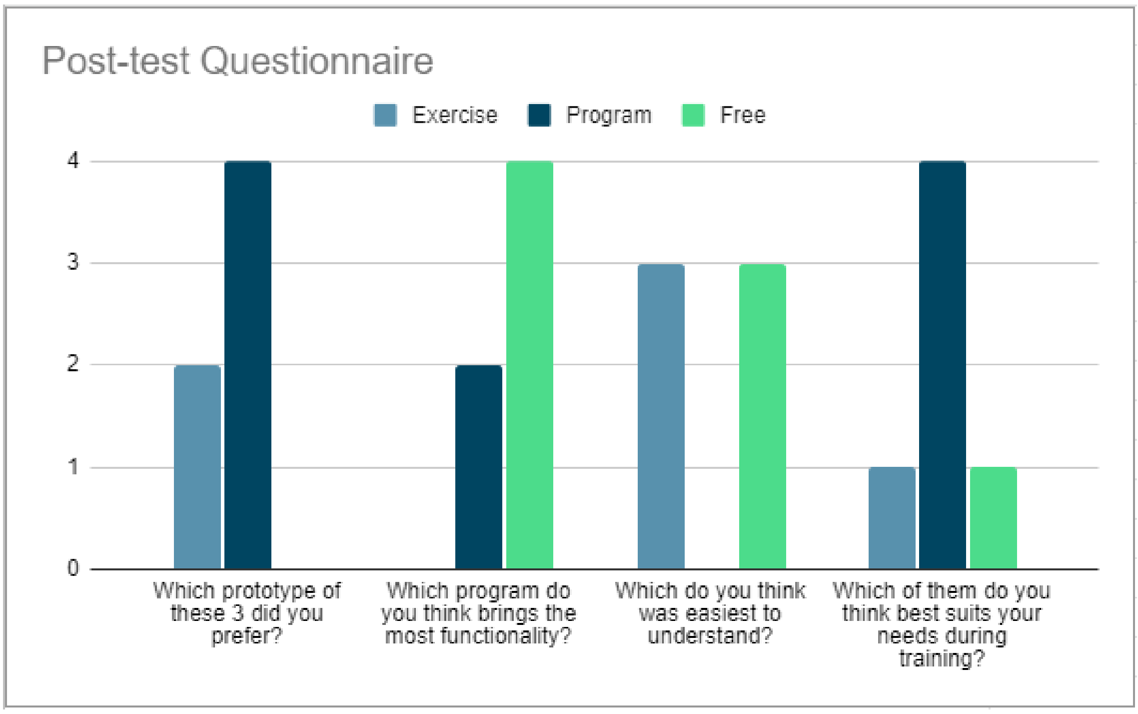

Figure 4.10. Summary of the Lo-Fi post-testing questionnaire results.

Chapter 5
Hi-Fi Development

The first part of the implementation phase (Figure 5.1) was to create three different Hi-Fi prototypes in the form of android applications. The prototypes were created out of design choices taken based on the Lo-Fi prototypes and other findings from the ideation and inspiration phases. The second part of the implementation phase consisted of Usability Testing, presented in the following chapter 6.

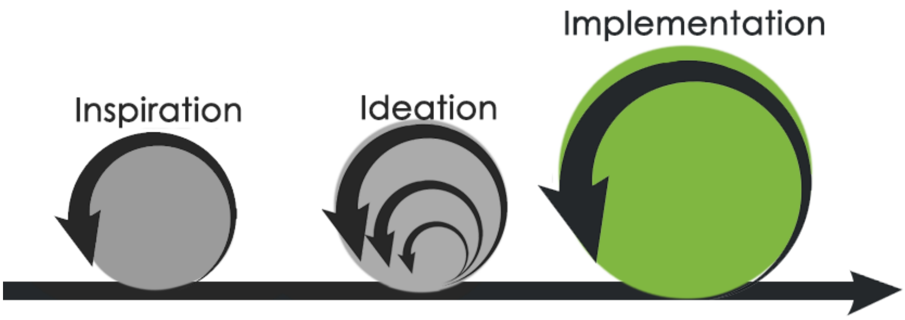

Figure 5.1. The Implementation Phase consisted of Hi-Fi Prototyping and Usability Testing.

5.1 Design Choices

During the Lo-Fi phase, it was decided that three prototypes were needed to be able to test and answer the research questions and scope of this project. Based on the Lo-Fi prototypes, a solution was created for how the three apps with different amounts of interaction would need to be designed.

5.1.1 User Interface

The main idea was that the prototypes should follow their Lo-Fi predecessors' traits while having a graphical user interface (GUI) and functionality that is as similar as possible to the real Advagym app. The actual app has a lot more functionally then could be implemented by two people in one month, so a lot of functionally was faked or not implemented. This can be described as a T-prototyping as seen in Figure 3.3, which was applied to all Hi-Fi prototypes. In this case, the leg and functionality of focus were the things needed to perform a short workout, have it logged, edit if needed and then review the result of the performed workout.

The Advagym app start page has many features and statistics, but each specific prototype has a unique and distinct use case not needing it all for the testing. As T-prototypes the start page was designed using a screenshot from the Advagym app with the single button required to start a workout added in a layer on top of the corresponding feature to be implemented. For the "program workout" app that meant the program tab in the bottom leading to a screenshot of the program page where the only selectable object was a workout to be used in the test. The other two prototypes just had a "start workout" button implemented at the same position as the quick-start button of the Advagym app in their start pages. The rest of the views, being the leg of a T-prototype, were built from the ground up as they contained dynamic elements and features implemented in-depth.

5.1.2 Features to Implement

As described in section 2.4, Advagym today uses NFC devices to establish the connecting between the equipment and the users, which is called to tap the puck. This feature is a significant part of the interaction with today's system during workouts and was thus decided to be implemented for all Hi-Fi prototypes, as seen in Figure 5.2. Today there is a puck next to each equipment that the user has to tap before starting every exercise but during brainstorming the idea was born that with the cameras tracking the users, rather then the mounted sensors that log a specific device, it would be possible to only tap the puck once. This would require less interaction by the users and cater to the people wanting the ability to store away the phone during a workout but still have it logged. This "entry zone" instead of for each equipment was to be implemented in Hi-Fi prototypes 2 & 3 but not in prototype 1 as to be able to test how much interaction with tap the puck that is preferable.

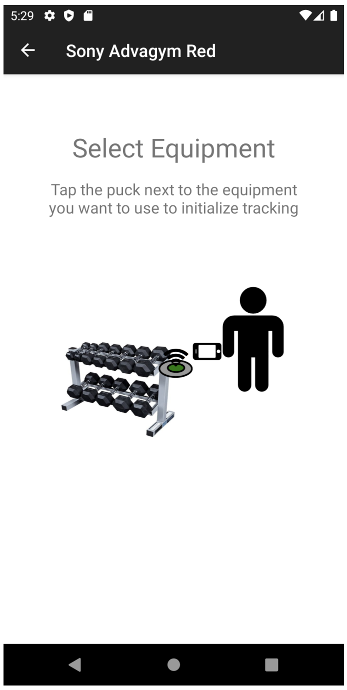

Figure 5.2. The activity to "tap the puck" as used in all Hi-Fi prototypes.

Other existing Advagym features decided to be implemented were as following. A scroll and clickable list of the exercises to be able to select exercise, display information of the exercises during the workout and the to show a summary when finishing the workout. Editable fields for each exercise with sets as bars containing input fields for repetitions and weight, except for the third prototype that lacks sets were instead each bar then represents an exercise. These input fields serves to provide the user with control by having the ability to specify or edit the repetitions for each set and also provide weight data which cannot be detected by the system today. Progress bars to display the completed repetitions for each set to easily follow the total progress throughout the performed workout. GUI components such as text and other information displayed in the screen shown during the actual workout should be made as large as possible to make them easier to view from a distance, to make it possible to better receive feedback while training.

To be able to test different kinds of sound and auditory feedback they should be differently implemented for each app, but just slightly so as to minimise it affecting the outcome of the tests by stealing focus from the core functionality differences. One app is to have sound feedback played out when each set is completed, the same app should also have vibration feedback with short vibrations for completed repetitions and more prolonged vibrations for a completed set. Another app should have the same kind of vibration feedback but no sound. Finally, one app should have no sound and more simplistic vibration feedback with all vibrations being of the same short length if a repetition or a set is completed.

5.1.3 Discarded Features

A feature that was not included was a timer to keep track of the duration of the workout and resting time between the sets. The timer was not implemented because it caused problems with the thread-load and a well-functioning performance was considered more important than a single feature that already exists in the actual app. Another idea that was not implement due to lack of a timer was some form of correction algorithm to remove single instances of detected repetitions after a certain time as just one repetition followed by a long pause probably meant a false detection. It would also risk providing the user with a wrongful mental model of how the system works, if they first test out the tracking by doing just one repetition. Due to technical limitations of the camera tracking system being in a very early development stage there is only specific messages sent for detected exercises but not detections of a person being idle and resting, which could be used to indicate that a set has been completed. The system is also not able to analyse the posture during an exercise and analyse its correctness, therefore posture feedback from the previous Lo-Fi prototypes presented in section 4.3 has been discarded.

5.2 Hi-Fi Prototyping

The three Hi-Fi prototypes were created based on the decided design choices and the features needed for testing. To be able to tap the puck and connect with the server responsible for tracking, two functions for the external communication that was required were also implemented.

5.2.1 App Implementation

The apps were made the have a similar GUI as to reduce the possibility of people being biased towards any app when testing because of their appearance, rather then their functionality. The GUI was also made to follow the existing Advagym app's appearance as this work's purpose includes keeping the implementation uniform with the current Advagym system. It was not possible to easily get the source code and other components from the actual Advagym app available in Android Studio as the developers used a different development environment. Because of the limited time of four weeks set for the app development, it would be challenging to both access and get acquainted with the code library enough to work with it. This meant that except from the screenshot in the start screen, all three prototypes were built from the ground up independently from Advagym. Buttons, lists and other GUI components were created using colour picker tools to follow and get the same colour sets as Advagym. There was no time to use actual databases, but instead nested Arraylists were implemented with objects for exercises, sets and repetitions that were saved in the local storage. Images and icons were either created independently or retrieved from the library of ready-made resources available directly in Android Studio which are under the Apache License 2.0 [46].

5.2.2 NFC Implementation

To be able to include the tap the puck feature in the application the phone needed to use NFC. This was done by creating an NFC service which listened for NFC intents whenever a NFC messages was received by the phone. The idea of this was to resemble how the app works today, allowing user to tap the puck next to an equipment to get directly to that exercise in the app and start it. However, for this basic app it caused one major problem. As it was seen to be unnecessarily complex to implement actually retrieving the NFC messages and decode them to correspond to a free weight workout puck, any NFC event was hard coded to just be treated as such instead. By having it always active and listening the user could tap the puck more than once leading to a crash or being thrown back to the page that came after tapping. To solve this the NFC service was removed and methods from it were placed directly in the tap the puck activity itself. By doing so the app only activates and listens to NFC once in the screen to tap the puck and then terminates it again once tapped, if outside of that given screen a NFC event does nothing. This removed some of the features of from tapping with the real app, but made the app stable while still allowing for the usage needed for the testing.

5.2.3 MQTT Implementation

The computer running the back-end server with connections to the camera is responsible for doing the actual detection of exercises and then transmit that. These messages are transmitted with the MQTT protocol and sent through a local area network, making it possible to access them if connected to it via wire or WiFi. For the case of the Hi-Fi prototypes that meant making the phones connect to that WiFi and then implement a service in the apps to subscribe to and manage the MQTT messages. The service was at first implemented by subscribing to the already existing topic with all messages sent by the server and then filter whether the message described a detected exercise or not. Receiving and filtering all these messages on the client-side proved to be to much of a workload for the phones leading to long delays or even worse freezing of the app. To solve this, the filtering workload was moved to the server and a new topic to subscribe to was created only containing messages of detected exercises. This significantly reduced the amount of messages sent to and processed by the phones, making the workload more feasible and allowed real-time communication. Furthermore, the MQTT service is started when the puck is tapped to mimic using the puck as an "entry-zone", displaying a toast message informing the user of that a connection has been established and that they a now being tracked.

5.3 Hi-Fi Results

Three different Hi-Fi prototypes were created in the form of Android apps based on the three final Lo-Fi prototypes. Just as the Lo-Fi prototypes the Hi-Fi prototypes have different amount of needed user interaction and provided user control as they are meant to stay in the same position on the scale shown in Figure 4.6.

5.3.1 Prototype 1: Exercise Workout

The "exercise workout" app, Figure 5.3, is the one of the three Hi-Fi prototypes that require the most amount of interaction by the user and gives the most amount control during use. In this app, the user has to manually enter exactly what to do, and do it each time for each exercise. This approach requires many steps to complete a workout but in return the user is more control since app is told more of what will happen and when.

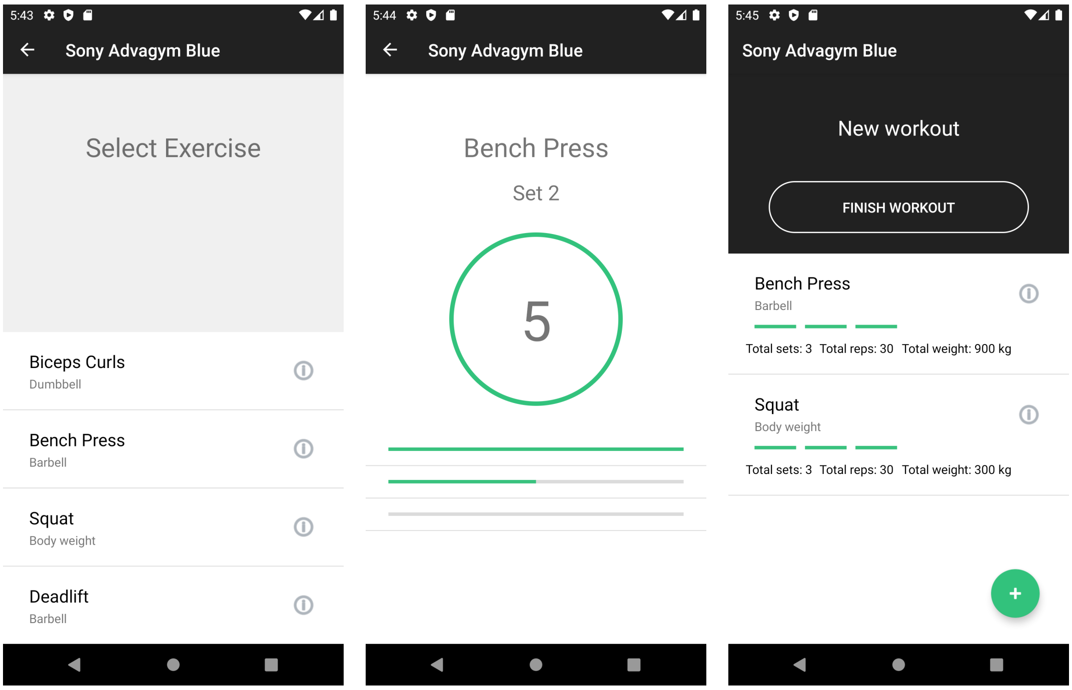

Figure 5.3. Hi-Fi prototype 1, "exercise workout".

When using this app to log a free weight workout session, the user firstly has to start a new workout in the app and then tap the puck before each exercise they want to do in order to select it. Once the exercise to be executed has been selected the users has to enter how many sets they want to do together how many repetitions and with what weight each set shall be performed. When all that data is provided for a given exercise the user can start performing it. The app then starts to log the exercise by counting a detected repetition only when the MQTT-messages corresponds to that specified exercise. The system can still falsely detect or miss detecting repetitions of that exercise, but not of other exercises, providing higher accuracy. Once all sets are completed for that exercise the user is sent to the summary page where they can view the exercises that they have completed and choose to either add another exercise to their ongoing workout or finish.

Feedback is given to the users during the exercises with vibrations for each performed and detected repetition or set. Since the app knows how many receptions each set contains, once that number is reached the vibration is made longer to indicate that a set has been completed. The user are also visually presented with text describing what exercise they are doing, which set their are on and how many repetitions the have done for that set together with a progress bar for each set.

This is the approach and prototype that mostly resembles the "quick start" option in today's Advagym app with the major difference being that each set is entered by the user beforehand in the prototype instead of during or after as in the real app.

5.3.2 Prototype 2: Program Workout

The "program workout" app, Figure 5.4, is the app in the centre on our scale of the amount users interaction. In this app the workload has been moved from being in between every exercise to before all exercises when creating a program. This approach requires a medium amount of steps as a program and its exercises only has to be written once when first creating a new program, or even fewer if a pre made program is selected.

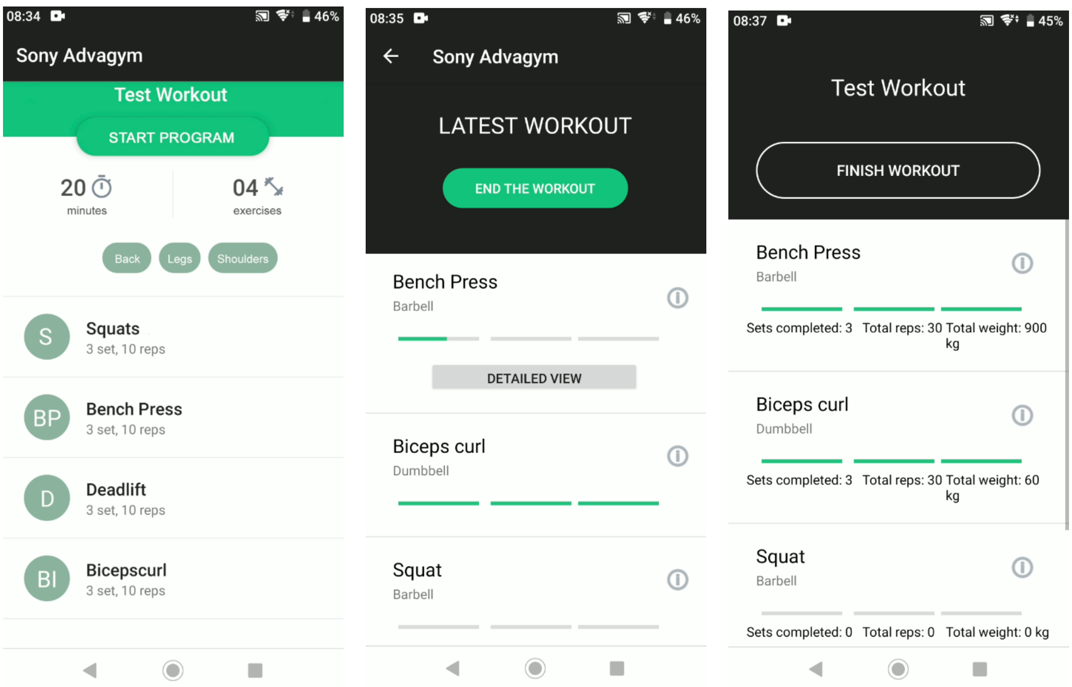

Figure 5.4. Hi-Fi prototype 2, "program workout".

When using the app to log a free weight workout session, the user firstly has to start a new workout in the app by selecting which program to perform either from the list of pre made program or their own that have created and saved by themselves at an earlier instance. If none of the programs fit the users intentions they can create a new program manually by adding all exercise they want to do and specify the amounts of sets, repetitions and weight. It was decided not to implement the functionality of selecting pre-made programs or creating new personal ones, as it would not be possible to fit well with the other apps when testing and thus only a "test workout" is selectable.

Once a program has been chosen, the user has to tap the puck which in turn then starts the workout. It was decided to not force users to do exercises in chronological order as it gave more freedom of choice and flexibility for example when equipment might be occupied. To allow for this the app then starts to log the workout by counting a detected repetition of an exercise when the MQTT-messages corresponds to any of the specified exercises in the program. This means that the system can falsely detect exercises on top of falsely detecting or missing repetitions, but only of exercises within a given program. When all the exercises in the program have been completed or if finish workout has been pressed, the user is sent to a summary page of their just performed workout.

The feedback is provides with different vibrations for repetitions and sets just as with prototype 1. However, auditory feedback is also given in this app for each completed set as the message "set completed" is read out through the phones speakers. In the workout activity there are two different views to choose between, the default overview or the detailed view. The default overview displays all exercise included in the program together with progress bars that increment for each repetition. The detailed view, which is accessed by a button, shows the current exercise together with its set and repetitions much like in Hi-Fi prototype 1.

This is the approach and prototype that mostly resembles the main usage for the current Advagym app, its program workouts. The major difference is that users only have to tap the puck once when starting the program in the prototype instead of in between every exercise as in the real app.

5.3.3 Prototype 3: Free Workout

The "free workout" app, Figure 5.5, is the Hi-Fi prototype that requires the least amount of interaction by its users but to the expense of the least amount of control. In this app the workload is moved to after all exercises have been performed, the user may then edit the any of the logged exercise in the workout if needed. This approach requires fewer steps as the user only has to provide input if exercises have been wrongfully detected or missed.

When using this app to log a free weight workout the user starts a new workout and then has to tap the puck to initialise tracking. The workout is then immediately started and the system logs any detected exercise. As any exercise may be detected there is a larger risk for false detections, such as a deadlift when the user puts their weights down on the floor. Once the user has done all the exercises they want to perform for their workout, they can click on the check mark button to finish the workout and move on to the next view. In this step all exercises are listed together with how many repetitions of them that have been detected and the user can then enter the weights that they have used for each of the exercises. If the system has falsely detected or missed any exercise or repetitions, the user may also edit that here by adding or removing exercises or edit the number of repetitions. When all data is correct the user ends the workout and is send to the summary view where all exercises are listed together with their total amount of repetitions and total weight.

One of the major differences introduced in this prototype is the fact that's it is missing

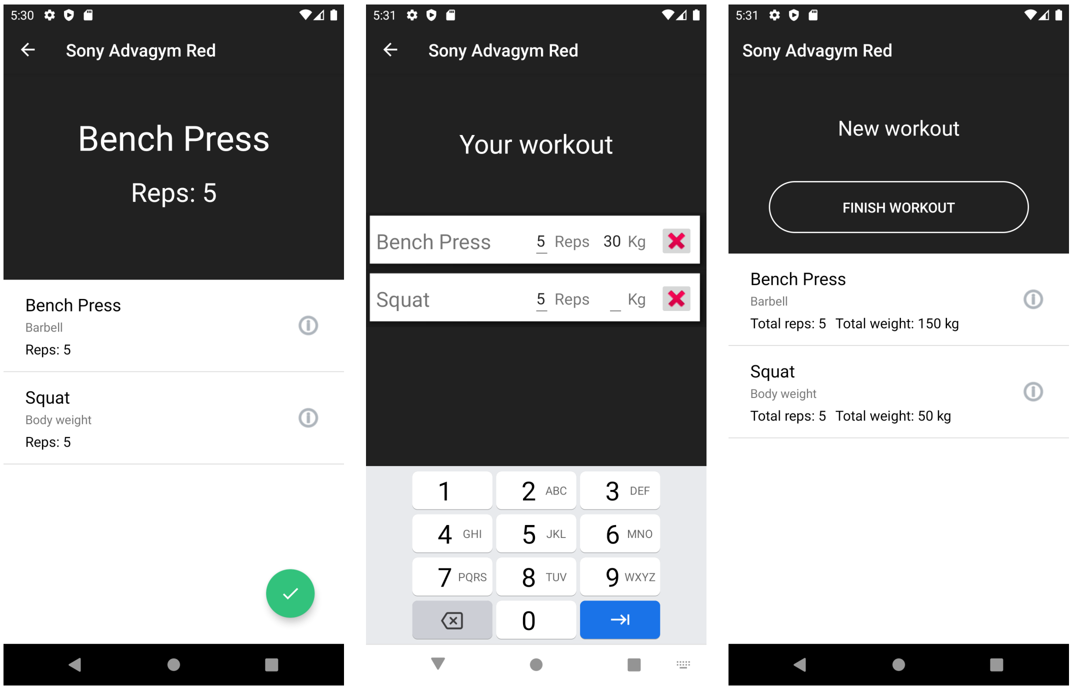

Figure 5.5. Hi-Fi prototype 3, "free workout".

any mechanisms to differentiate the repetitions of each sets from each other. It has been discussed during the implementation phase with a possible solutions of possibly adding a timer that would indicate when a new set should start. That means that if a given time has passed between two repetitions of the same exercise, they should be separated. This would require a behavioural study on it is own, considering how much it can vary from an individual to individual. It could mean that even if the test person would get a right idea it still could fail in practice due to test subject not waiting long enough or introduce confusion or irritation if they wait too long at the next set trying to replicate that response from the system. Another idea was to cap the sets at a certain number of repetitions by some arbitrary number, e.g. 10, but that would instead restrict the user control.

Feedback is given through vibrations as in the other apps, but since there are no sets implemented the vibrations are always of the same length. This is the most simplistic app visually as it is meant to cater to the large amount of people that store their phone out of sight when working out as discovered in the observation done in the inspirational phase 4.1.2.

This is the app that resembles the current Advagym app the least as it more so created without the need for user to interact during the workout but instead when finished.

Chapter 6
Usability Testing

Usability testing is a technique used in human-centred design to evaluate a product by testing it on potential users or individuals with similar characteristics as end-users. Usability test preparation involves carefully creating a scenario or realistic situation in which a person performs tasks form a to-do list using a test product. At the same time, an appointed team member or external expert verifies the tests' validity and takes notes. Such a test scenario may consist of several test cases, making it possible to check the entire scope of the specified functionality.

6.1 Test Planning

Planning a usability test is an important part of the process that provides the uniformity of the tests. it is often concluded in a test plan, a document that according to the IEEE 829 standard [47] should, for instance, include or result in:

- A Test Plan Identifier
- Specified Usability Tasks and their fail/pass Criteria
- Usability Goals and Metrics
- Test Deliveries

However, the IEEE 892 test outline does not include the test participant selection or resource management, which does commonly appear in the usability test plans as a meticulous participant selection can have diametrical effects on the results. It gives directions about what number of participants will be sufficient in order to meet the stated requirements relative to the available resources. Other points of interest are their expected skills/knowledge level, technical background or even the way they will be recruited.

6.1.1 Usability Tasks and Goals

The scenarios including usability tasks, see Table 6.1, have been kept short to receive easily readable and conclusive results. Since the three prototypes that have been tested correspond to the distinct values on the interaction scale (Figure 4.6), the quantitative answers to the research question 2 and 4 could be obtained based on the tasks and post-test interview questions alone.

- **Research Question 2** How can such data be presented in a user friendly way with a positive user experience?
- **Research Question 4** What level of interaction with a smart training app provides the best user experience?

Table 6.1 Usability Tasks.

Task	Scenario	Sub Task	Completion condition	Max time
1. Workout part 1/2	Start a short workout and do the exercise biceps curls.	1.1 Start a new workout 1.2 Tap the puck 1.3 Do 3 sets with 10 repetitions of biceps curls with “2 kg” dumbbells.	When the app has registered and lists: - Biceps curls, 30 total reps & 60 kg weight in total	5 min
2. Workout part 2/2	Continue the workout and do the exercise bench press.	2.1 Start a new exercise 2.2 Tap the puck if prompted 2.2 Do 3 sets with 5 repetitions bench press with a “30 kg” barbell. 2.3 Finish workout	When the app has registered and lists: - Bench press, 30 total reps & 900 kg weight in total	5 min
3. Workout summary	Review the summary page to confirm that the logged exercises are correct.	3.1 Review the summary page to make sure it is correct according to the completion condition. 3.2 Finish workout	When the summary page of the app lists: - Biceps curls, 30 total reps & 150 kg total weight - Bench press, 15 total reps & 450 kg total weight	2min
4. SUS	Fill out SUS			3 min

- **Research Question 3** Which data is valuable to users and when?

The *"Review the summary page to confirm that the logged exercises are correct."* scenario was created in order for the research team to quickly confirm that the previous tasks have been performed correctly. It was necessary as the phone screen was too small to judge it visually, and the prototypes allow the user to end the workout prematurely. The bi-product of this verbal type of conformation was that it allowed the test participant not only to review the results but also what kind of data has been collected, summarised and presented to them. Besides this scenario, the analyst has written down all the commentary remarking interface components, vibrations and sound feedback that the test participants have mentioned while performing the tasks. Finally, the post-test interview question *"What information about your training did you find most valuable?"* and *Did you miss information about your training in one of the apps? If so, what and at what stage?* were added, evaluating both the values that have been implemented and the ones that have been missing.

Research Question 5 however, did not receive any assigned task to it. it is difficult to write short and coherent scenarios to cover all the research questions at once, especially if they are very different in nature. The last question, regarding the privacy, has therefore taken a different approach to answer.

- **Research Question 5** What is ethically and by the users acceptable with regards to being tracked?

The analyst was instructed to note down if a test participant pays any attention to the cameras installed in the office. However, the first mention of the privacy issues did not occur until the very end of the test session, as the last two questions during the post-test interview. Mentioning the presence of the cameras before the test would draw unwanted attention to them. It could allow them to get a better picture of if the camera usage for the tracking did actually affect the comfort of their workout. The post-test interview question *Did you notice the cameras in the ceiling that tracked you?* and *How do you feel about cameras in a gym's workout areas?* are therefore allowing the participant to base their opinion on their recent experience and providing an answer that would also cover the ethical aspect of the research question.

6.1.2 Usability Metrics

The values in the interest of the reaserch team were:

- What obstacles does a user encounter during the usage of the prototypes?
- Which degree of the interaction with the phone does a user find more suitable?
- Which interface is most user-friendly?
- How much time does a user need to understand the functionality of the prototypes?

6.2 Participants

As the stakeholder has not clearly specified the focus group, it would be optimal to test within different ranges of age, genders and fitness levels in order to correctly identify the problems and collect the most accurate data of which of the prototypes is the most preferable by different user types. Reminding question was that of the sample size suitable for the

project of this size. There were three prototypes tested with a vaguely formed hypothesis stating that the differences in the preferences will be marginal, based on the field studies and the results from the earlier performed Lo-Fi tests. As indicated in section 4.1.3, the way people prefer to workout seems to vary heavily; therefore, the possibility of supporting a wider range of performing these activities could be worth considering. The initial reference point for the number of participants was set to 48, based on a similar comparative study conducted for Advagym by another student two years prior. Sadly, this could not be achieved due to low response frequency for the groups above the age of 30, and the target sample size of 48 was reduced to 18 as it was deemed enough for the problem discovery purpose. The exact number of 18 is based on the multiples of possible testing order of the three prototypes what had been the subject of the usability tests. Changing the order in which the prototypes have been presented to the test participants was necessary to balance out the effects of learning the patterns and system functions throughout the prototype that has been tested first. As the results show, the first one would always take the most time to complete the tasks, despite the order. This means that it would be impossible to evaluate how intuitive and user-friendly some functions are in the later prototypes if the succession rate would solely depend on the test participant ability to repeat a particular behaviour.
Due to these limitations, the test group consisted of:

Table 6.2 Participant Selection.

Characteristic	**Desired number of participants**
Participant type	
Pilot	1
Regular	18
Total number of participants	19
Age	
22	2 (11.1 %)
23	6 (33.3 %)
24	2 (11.1 %)
25	2 (11.1 %)
26	5 (27.8%)
32	1 (5.6 %)
Sex	
Men	12
Women	6
Average age	23
Standard Deviation	1.05

6.3 Set-up

All of the tests needed to be conducted in the Sony office, Lund. Due to the technical restrictions imposed by the nature of Sony's multi-camera positioning system which consists of several individual devices with strong positioning constraints, tests had to be carried through in the open working office environment set-up instead of the controlled test environment. This introduced some aspects that might affect the results, such as the moderator's notable presence and the protocol secretary or, for example, noise and people currently working at the office. The participants got to use the APKs imitating the original Advagym application, having access to the local office network which uses MQTT messaging to provide the data from the multi-camera tracking system to the participant's mobile device.

6.3.1 Test Environment

The camera that has been used for recording the test sessions has been initially placed in the upper left corner of Figure 6.1, facing the test participant. It would allow registering their expressions and actions as well as the way they performed the individual exercises. Unfortunately, due to the very restricted space we have been allowed to work with, the camera happened to stand in the way for the eventual Sony workers that have been working in the area during the test sessions (tables marked with light grey on the picture) as well as it became a minor distraction to the test subjects themselves, finding itself bit too close to stay unnoticed. Therefore, the position of the camera has been adjusted.

The workout stations including the barbell and dumbbell exercises required for the tasks had to be placed as central as possible between the cameras, being as little in the path of the eventual Sony workers as possible to minimise their interference during the test sessions. The

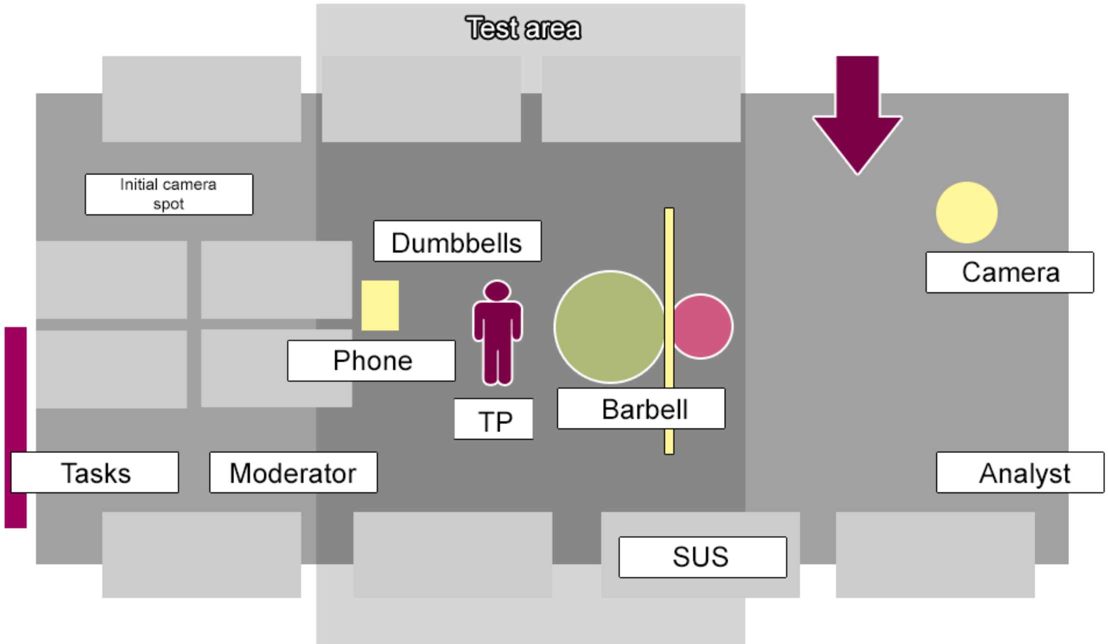

Figure 6.1. Set-up planning, aerial view.

moderator was situated close to the whiteboard where the tasks needed to fulfil the scenarios have been written on. If the test participant had questions or got stuck, they could be quickly referred to the tasks. An alternative would be to have the scenarios printed and handed out, requiring a new copy for every participant, mainly due to Covid-19. The Analyst would sit further back, out of the line of sign of the participant assuring that the documentation of their action will not affect the test or stress the participant out.

Finally, the table holding the phone and the puck has been placed so it is easily accessible for the test participant during the tasks, leaving them the comfort of choosing where and how the device should be situated to complete the scenario in the way they find most suitable to their workout habits. For example, the phone could remain lying on the table, standing in the previously prepared holder or being moved to the barbell station to be placed on the floor where the participant can follow the application's progress.

6.3.2 Resources

To perform the testing a number of resources were needed as listed in Table 6.3. The main equipment necessary for these usability tests was a video recorder that would document the process, allowing the research team to re-watch it in case of uncertainties, a smartphone to display the Hi-Fi prototypes as accurately as possible and the equipment that would help the participants to imitate a real workout session. Besides all three of the prototypes, the Smartphone had a pre-installed screen recording allowing to re-actively follow a participant's thought process and more closely evaluate the features to complement the notes and the footage documented by the camera the analyst. This was especially needed in cases when the *Think Aloud Protocol* is not implemented despite the moderator encouraging it, for example, by asking questions when the participant is stuck or confused. Since the screen of a smartphone is too small to correctly evaluate which part of the interface the participant is struggling with, a screen recorder shows to be a helpful tool to achieve that without affecting the test itself.

Table 6.3 Resources used for the usability testing.

Resource name	**Number**	**Purpose**
Smartphone	2	One device with pre-installed prototypes along a screen recorder for a test participant to use during the tests. The second device was used by the analyst to measure the time it would take a participant to finish each task on the list. It would also be a tool to record the post-test interviews in case the analyst did not manage to successfully note all the answers due to time pressure or misshearing.
Video Camera	1	Recording test sessions
Dumbbell	2	Equipment for the test task 1
Dummy Barbell	1	Equipment for the test task 2
Single use Face Masks	2 x 10	(Optional) A face mask was offered to all the participants to wear as a part of the Covid-19 precautions
Gift Cards	20	A thank-you gift to all the people who participated in tests
Disinfectants	3+	The first one placed right next to the entry door, others throughout the office. One dedicated for cleaning the equipment between test sessions, another for participants to use while signing the non-disclosure agreement and according to their liking afterwards

6.4 Procedure

6.4.1 Covid-19 Precautions

The year 2020 has been dominated by a previously unknown virus characterised by a high spreadability which, according to WHO (World Health Organization) was mainly transmitted through droplets. Causing over two million deaths worldwide [48], *Covid-19* resulted in countrywide lockdowns all round the globe, affecting many businesses and schooling systems. Due to these events, the moderator, analyst and the test participants had to follow:

- Moderator and analyst must wear face masks at all time while being in contact with a participant.
- Upon meeting a test participant in the lobby, the moderator stands outside and welcomes them. Keeping the distance, greets them without being close to them.
- It is just fine to wave! The analyst should be standing at the visitor's door, ready to open it for the test person.
- There are toilets in the lobby, ask the test person to wash their hands when they come (mandatory) and then spray them when you come inside the doors, there is a dispenser available.
- Take the stairs up to avoid all contact with the elevators.
- The NDA, pen and smartphone need to be ready for a test person to pick up and write on. Screen recording should be running in beforehand. That will make it easier to observe and instruct from a distance.
- The same procedure applies when the test participant have to leave.

6.4.2 Orientation Script

The session starts with a participant signing an NDA, non-disclosure agreement, which both a team member and a participant need to sign to secure information essential for the operation and future of the company. Since the test was being recorded and participants' identity could be compromised, the NDA also informed the participant about what the information collected during the session is going to be used for, which they had to sign in order to be allowed to participate in the tests. Each test session was scripted to take up to one hour. The prototypes were then tested in the following order to avoid transfer of knowlegde:

Group name	Prototype Order
1A	1-2-3
1B	1-3-2
2A	2-3-1
2B	2-1-3
3A	3-1-2
3B	3-2-1

Introduction

Each prototype had a short introduction introducing the general idea behind it without revealing their strengths or weaknesses. It was a step one in the testing process, see Figure 6.2. These introductions were repeated if the test participant was confused or asked for help. This was necessary due to the fact that all the prototypes shared many interface elements which caused the participants to repeat a particular behaviour expecting the same results. The example of a prototype introduction was

- *In this app you create your own or choose one of the existing training programs. Selected exercises are then detected and logged during the training session.*

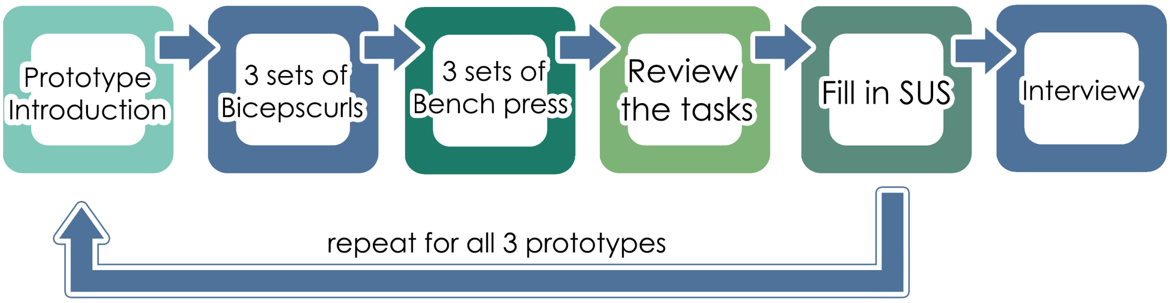

Figure 6.2. Procedure overview.

This information was needed as the prototypes missed a context, welcoming the test person with a mock-up screen resembling the original Advagym application. Prototype 1 and 3 have a clickable *quick start* button placed on that screen; however, prototype 2 does not which introduced a lot of confusion if tested after any of the other two. In case of, for example, being asked how even to begin the workout, the moderator would repeat the introduction, which would encourage them to find a suitable program element.

Finally, upon a successful initialisation, the moderator would attempt to:

- Encourage the test participant to think aloud while using the apps. If they get stuck, they are allowed to address the moderator; however, no unambiguous answers will be given. The moderator is allowed to repeat the instructions, the corresponding prototype description or respond with a question that will help the participant. All other questions will be answered and discussed at the end of the test session.

- Emphasise that it is the product and its usefulness that is being the subject of this test, not them as a person or their cognitive abilities. Ensure they understand that there is no right or wrong, and therefore, all kinds of testing their way to achieving the task completion are encouraged. Lastly, remind the participant about their the right to cancel the test session at any time without having to state a reason.

- Avoid giving hints and or showing any emotions what might affect or stress the participant up.

6.5 Sources of Error

6.5.1 Environmental Factors

It is essential that the test environment is isolated to make sure that the results will not be affected by interference from noise and movement that might distract the test participant as well as make the information flow between the moderator and the participant harder. As earlier mentioned in section 6.3.1, this could not be implemented because the system is very much stationary and the conditions are certainly far from optimal. Eventually, it resulted in five test sessions being interrupted with a need to ask the test participant to wait for the noise out, with two participants loudly complaining that they cannot focus on the instructions. This affected the task completion time, despite the timer being stopped, as the breaks could take anywhere from 30 seconds to several minutes. The completion rate would get affected as well since some tasks had to be redone after they already have been partially completed. The presence of third persons was not ideal from the Covid-19 point of view either.

Another important factor is network isolation to ensure that performance of the system is not affected by limited network capacity. Therefore, it is recommended to ensure maximum network bandwidth used in the test environment by isolating the test network from other users. In fact, the system was running on the local network, which did restrict the number of users connected but also used broadcasting services that introduced some noticeable inconsistencies in the logging speed between different test sessions.

6.5.2 Planning & Execution

The primary factor contributing to the completion-time error and created a fair amount of confusion for the participants was the usage of the NFC puck, Figure 6.3. It caused the first prototype tested to be less favourable over the others, regardless of the order. Despite the text description and a picture instructing the participant how to perform the action to initiate the tracking, many participants insisted on tapping the puck with their fingers, touching the equipment with the puck or leaving the phone on the top of the puck once receiving the hint of trying with their phone instead which restricted their movement and tempered the data about their workout habits. It is a common issue within the UX which assumes that something is *common sense*. This could be quickly resolved by simply adding the phrase "with your phone" or rephrasing it to "Tap your phone onto the puck" to avoid the confusion, but since it was first discovered after a few test session, it was decided not to introduce any changes as it could jeopardise the uniformity of the tests.

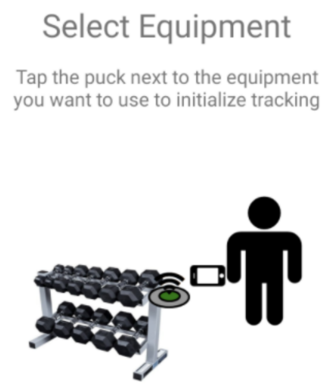

Figure 6.3. The activity screen with the "tap the puck" request.

Finally, the face masks used by both analyst and the moderator had to wear due to Covid-19 had made the communication flow more difficult, making certain words incomprehensible.

6.6 Test Data Analysis

When all 18 participants had done the test and each submitted their three SUS questionnaires, one for each app, there were in total 48 completed questionnaires. The result of the SUS-scores was obtained for each individual questionnaire by retrieving the values of the ten questions and calculating their SUS-score. Thanks to using google surveys, all answers were easily exported to a google spreadsheet to be further processed. In the spreadsheet, a script was created to calculate the scores according to formula 3.1, which took the data from 10 cells and returned the SUS-score for that given questionnaire.

The observations and interviews were summarised with the help of a table. The first four interview questions about the preferable prototype within the different aspect of usability, *most user friendly*, *easiest to understand*, *easiest to interact with* and *and which had an appropriate amount of interaction* were sorted by the positive and negative responses. Interesting commentary regarding the question was noted down and later sorted by type, often using a keyword or a phrase. Concepts that have been named most often or ideas that might have the most significant impact on the later development were then mentioned in the result document. Questions regarding the system's feedback were directly paired and complemented with the observations of the participants' reactions to a different kind of feedback during the test session.

Finally the observations were analysed and quantified based on the following general factors:

- False positive detection rate
- False negative detection rate
- Issues with understanding the NFC function
- The placement of the phone during the workout
- Amount of help needed to complete a task

And then individually for each prototype based on design features. This data could not be as easily quantified or used for the comparison purpose as the features did differ and might not have even appeared in all three prototypes. It did, however, offer valuable feedback that could be used for future iterations. For example, whenever a function was missed or misunderstood or if the participants visibly reacted negatively/positively to a specific aspect. The notable trends have been detected, summarised by their occurrence and included in the result document.

In addition, a rapport consisting of feedback on the system's efficiency during tests has been written and directed to the developer team behind the system.

Chapter 7
Results

In this chapter, the data collected from the testing is presented divided into the three metrics SUS, observation and interview. Based on the average SUS score for each prototype their usability is graded. For the observation, the main problems for each prototype is summarised together with other general obstacles that could be seen. The semi-structured interviews presents quantitative data together with summaries of the comments given for each of the 10 interview questions.

7.1 System Usability Scale, SUS

The user tests resulted in 48 different SUS-scores as shown in Table 7.1, 18 for each prototype together with the average values and standard deviation. The average SUS-scores were very close in range being 78.5 for prototype 1, 79.3 for prototype 2 and 76.8 for prototype 3. By comparing the average SUS-scores to their corresponding range in the Sauro-Lewis CGS [41], shown in Figure 3.6, a grade to describe the usability of the prototype was given.

Prototype 1, the exercise workout app, receives a **B+** scoring just barely below the range needed for an **A-**. Prototype 2, the program workout app, received the highest average SUS-score giving it the grade **A-**. Prototype 3, the free workout app, is given the grade **B**. All apps are just slightly below the benchmark 80, said to indicate an above-average user experience [34], which is considered very acceptable for these apps as they only are prototypes.

Table 7.1 The SUS-scores obtained from the usability testing.

Test Person	Prototype 1	Prototype 2	Prototype 3
1	92.5	97.5	50
2	60	60	75
3	57.5	90	90
4	87.5	40	70
5	72.5	57.5	80
6	87.5	82.5	70
7	82.5	90	87.5
8	90	90	75
9	95	95	97.5
10	100	87.5	100
11	77.5	77.5	65
12	60	85	70
13	65	67.5	82.5
14	95	100	85
15	65	75	67.5
16	77.5	82.5	90
17	65	67.5	60
18	82.5	82.5	67.5
SUS-score Average	**78.472**	**79.306**	**76.806**
Standard Deviation	13.804	15.667	13.279

7.2 Observation

18 individual observation protocols were created, which were then filled in by the test analyst during the tests and afterwards with the help of the recordings that were made. These 18 observation protocols together with the recordings were then summarised to observe what happened during the performance of the test tasks. Results of the observations and main findings were as follows. The full document created to summarise the observations from the usability tests is provided in Appendix C.

Prototype 1 was observed to have its major problem related to the implementation of the GUI and its buttons in the summary screen, which is shown in the image to the right in Figure 5.3. 5 out of the 18 test participants failed the task of starting a new exercise in the summary screen after that they had performed their first exercise. This happened because they pressed the "finish workout"-button instead of the plus-button, leading to a termination of the workout instead of ending up in the screen to select exercise. Some expressed that they thought it was cumbersome to have to enter the number of repetitions and weight for each set, they would have liked to have seen some form of automatic filling e.g. that the values given for the first set could also be filled in for the remaining sets. The implementation of the vibration feedback seems to have worked well in this prototype, as no one expressed any problems with it. Four of the test participants mentioned noticing the different lengths of the the vibration depending on if a repetition or a set had been completed.

Prototype 2 was also observed to have its major problem related to the implementation of the GUI and its buttons, but in this case in the program overview screen shown after selecting a program, shown in the left image in Figure 5.4. In this screen to view your chosen program and its exercises, six participants had problems to starting training with the selected program as they tried to press an exercise instead of the "start program" button. Some participants seemed to form a misleading mental model of the system thinking that they had to specify which exercise to perform, instead of understanding that you can just start right away and that the system is smart enough to understand which exercise you are doing and track that at any given time as long as it is included in the selected program. One third also used the detailed view that is available when performing an exercise, but many did not do so as it was not needed to succeed with the tasks. Four people expressed that they would have liked to edit their workout when they were done instead of during. This was the only prototype with auditory feedback, which eight explicitly expressed that they liked and reacted positively to when the voice message was read out.

Prototype 3, here the observations showed that prototype 3 had a similar main problem as with prototype 2, to form a correct mental model of that you can just start right away and that the system is smart enough to track directly. After pressing the start button and arriving at the workout screen, as seen in the left image in Figure 5.5, some participants did not at first understand that they should start to perform the exercise. They seemed to assume that they had not done enough by only pressing start and that more steps were needed to be done, despite the text "Detecting, start exercising" that was displayed as seen in Figure 7.1. Another problem that reoccurred with five participants was that they missed the step of editing the number of repetitions and enter the weight they had used after performing their exercises. They instead skipped it by directly clicking next onto the summary page and thus ended the workout. Possibly a solution to this could be adding an extra step with a pop-up message asking users to confirm that they are satisfied with the values before being able to finish the workout. Finally, five participants expressed that they missed the lack of sets and would have wanted it implemented.

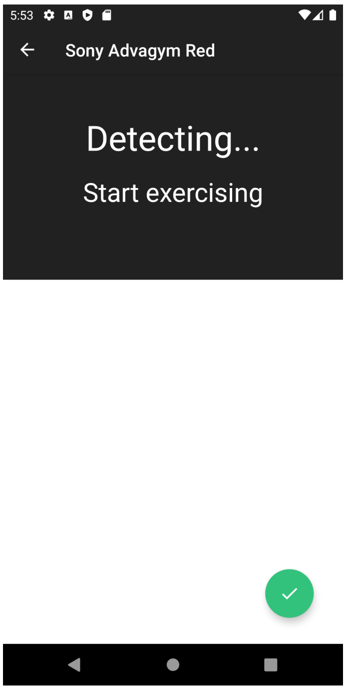

Figure 7.1. Prototype 3's workout screen when started before any exercise has been performed.

A major issue that faced all of the prototypes was understanding how to tap the puck. 13 out of 18 (72 %) had problems with the NFC puck and needed help to understand what it was and how to tap it with the phone. Despite a clear picture and instructional text as seen in Figure 5.2, the moderator on several occasions several needed to provide further instructions to help the participants manage to tap the puck.

False positives and negatives with regards to tracking also occurred during the tests. False positives, when the system registers that an exercise has been performed that were not done, occurred at some point for 14 of the participants. Often when people bent down to the ground to pick up or put down the dumbbells, the system would register a deadlift. In addition, when people sat down or stood up squats could be registered as detected in some cases. False negatives, when the system fails to register an exercise that was done, occurred at some point for 12 of the participants. The main reason as to why the tracking failed detecting repetitions was due to people performing exercises too fast, which was made possible as no heavy weights were used during the tests. The moderator therefore urged the participants before each test to perform the exercises at the same pace as they would do when training with actual weights. Despite this, the system missed occasional repetitions for two thirds of the participants when they did them too fast. An interesting comment given as a reaction to this was, what if I want to do it fast if I am warming up.

7.3 Semi-structured Interview

The 10 questions in the semi-structured interview held with test participants at the end of the tests provided many interesting answers and a large amount of data. The data received for questions 1, 2, 3 and 4 is presented in Figure 7.2. Below is an overview of the interesting quantitative data that could be obtained from the interviews as well as summaries of the comments given for each question. The data and comments given in the semi-structured interviews can be seen in full in Appendix C.

Question 1, *Which did you like using the most? Why?*, showed that out of the 18 participants only two people liked using app 1 the most whereas the rest equally preferred the other two apps. Many did not want to use their mobile phones more than necessary during a workout session and would think it was too much work having to tap the puck between each exercise.

Question 2, *Which did you think was easiest to understand? Why?*, got a varied result with the numbers split almost equally between the three apps. The comments given as to why people thought the way they did were just as varied with it seeming to be mostly a matter of personal taste.

Question 3, *Which did you think was the easiest to interact with during a workout? Why?*, uniformly showed a growing trend towards the apps needing the least amount of interaction with app 3 being preferred the most, closely followed by the app number 2. The main reason given was also that the smaller the amount of interaction needed, the easier it was for them to interact with the app during the workout.

Question 4, *Which did you think had the appropriate amount of interaction from you as a user? Why?*, The most frequent answers gravitated yet again towards the *free workout* prototype. Also, the only app that was mentioned explicitly to not have the appropriate amount of interaction was app 1. The most reoccurring comments were that they did not want to have to interact too much between exercises and that less interaction was better.

Question 5, *Was the information in any of the apps difficult to interpret or take part of? Why?*. When it comes to a specific app in this issue, only prototypes 2 and 3 were mentioned. The app that people thought was the easiest to understand was prototype 1. What was mainly mentioned about the GUI was that the buttons could have been clearer as some had difficulties understanding how to start or end a training session, as also were noticed in the observations.

Question 6, *What information about your training did you find most valuable? Why?*. Sets and repetitions were mainly mentioned here, but also the progress and logging of the workout, as people want to avoid keeping track of such things if they use a training app. Both vibration and audio feedback was appreciated by several as that made it easier for them to access some of the information without watching the display. Also, many felt that the total weight values

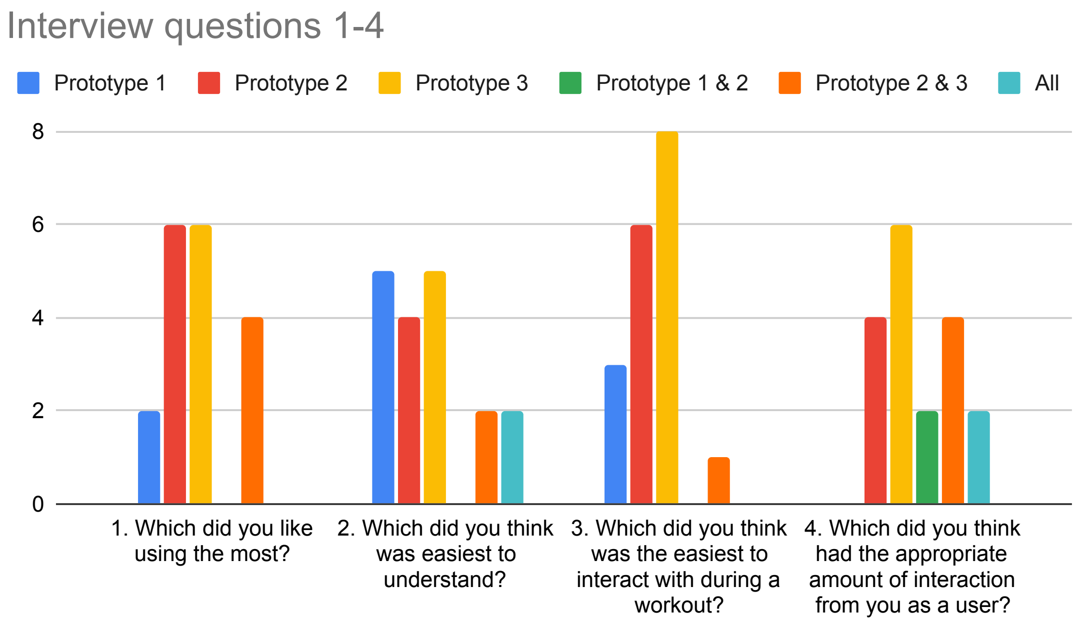

Figure 7.2. Bar graphs with the data obtained from questions 1-4 in the semi-structured interview.

in the summary page were confusing and did not say anything that they could relate to, but would rather have known the individual weights used.

Question 7, *Did you miss information about your training in any of the apps? If so, what and at what stage?*. The most sought after information was to have assistance with some kind of form correction to help perform the exercises in an optimal way. The participants also mentioned timer, heart rate, calories and more feedback around the current exercise and the exercise to be done next. Another interesting comment was to give the app a more active approach by providing workout recommendations that could be based on the user profile, some form of set goals or one's development based on the data of previous workouts.

Question 8, *How did you experience the feedback in the apps? That is the visual, vibrations, sounds, etc. Why?*. Of the 18 test subjects, 14 mentioned sound and 6 the visual feedback. 12 mentioned the vibrations, but many also had difficulty hearing/feeling them and especially do distinguish the different lengths. The main take was that people want different amounts of feedback and at different times as some want it for each repetition while others just at each set. Most of the people who wanted sound feedback did want to receive it through their headphones.

Question 9, *Did you notice the cameras in the ceiling that tracked you?*, had a clear outcome as only 3 had noticed them before being asked. The other 15 out of the 18 test participants stated that they had not noticed the cameras at all.

Question 10, *How do you feel about cameras in a gym's workout areas? Why?* gave answers indicating that people generally do not mind them. Only 1 person was against it while the rest answered that they did not care at all or that it depends. On the other hand, for most of them it depended a lot on how it was used and to feel completely safe they want such information.

7.3.1 Scoring

Due to the fact that the participants were able to choose more than one prototype as their answers in post-test interview, a point system has been introduced. It allows to obtain shorter and more quantitative answers that are easier to refer to than listing all the possible combinations of answers. A singular prototype was mentioned, answer would give 2 points. If several prototypes have been mentioned it would translate into 1 point and otherwise 0 points. The final scores summarising the interview can be viewed in Table 7.2 below.

Table 7.2 Point translation of the answers given during the post-test interview.

Question	Prototype	Score
Prototype you liked the most	Exercise	4
	Program	16
	Free	16
Prototype that was easiest to understand	Exercise	14
	Program	12
	Free	14
Prototype that was easiest to interact with	Exercise	6
	Program	13
	Free	17
Prototype with most appropriate amount of interaction	Exercise	4
	Program	16
	Free	18

Chapter 8
Discussion

8.1 Design Process

Twenty weeks has proved to be a considerably short time to fully carry out all the stages of a human-centred design process by a team of two. A schedule for Lo-Fi prototyping had been set to two weeks, based on the low complexity and resource consumption. While it has indeed been a sufficient time interval to produce several prototypes it sadly did not leave a margin to do several tests with the end-users, reducing the number of iterations and therefore the feedback that could have been of use while entering the Hi-Fi prototyping stage.

Another aspect that has not been fully carried out was researching the interests of all the stakeholders despite identifying them early on. The most significant one which interests would probably affect the design of features are the gym owners and employees, as their investment into introducing the system at their facilities is essential. They also possess the knowledge of people's training habits and demands based on their experience and observations that could be very beneficial to the project. For a similar reason, there should have been more resources put into recruiting and gaining the current Advagym users' insights to improve the quality of the information gathered in the early design stages that could have potentially been equivalent in the quality to the feedback received from the tests performed much later.

8.2 Comparative Study

Firstly, the semi-structured nature of the open-ended questions used post-testing has eventually turned out to be to the project's disadvantage. Giving test participants a possibility to choose more than one option ended in somehow hard to read results, requiring a point translation for all the combinations of the answers as showed in table 7.2 which might not be the most accurate representation of the participants' opinions. This could definitely be improved in the next iterations.

The average SUS-score values for all three prototypes have shown to be so close to each other that no major difference can be drawn between the apps regarding their usability. Preferences towards the apps when the testing should not have been affected by the implementation of the apps as they can be considered to be equally easy to use, i.e. as none of the apps was harder than the other to use it should not have been a factor that made users liked an app over another.

There have, however, been some design choices that need to be improved. The low completion ratio for task three, which required the participant to review their workout results, implicates some severe design flaws. The main conclusion is that it is easier to edit errors if you are forced to it in order to complete the workout session. An extra summary screen in the final stage of the prototype would clarify and mark when the session has been completed. The problem with reviewing was less evident in prototype 2, which had this extra step.

Another observation is that the test participants are likely to perform an absolute minimum to complete the task. Very few of them have chosen to explore the prototypes on their own, probably due to the fear of doing something *wrong* or due to the possible time pressure. Although this would likely differ in a real-life situation to some degree, it still highlights one of the issues with prototype 2 where only 6 people out of 18 to clicked the detailed view button shown in Figure 8.1. This was not necessary to complete any of the tasks but would allow the usage of the more detailed interface like in prototype 1 if preferred. The *Detailed View* text could probably be replaced with something more appealing, and the colour of the button would likely benefit from not being greyed out.

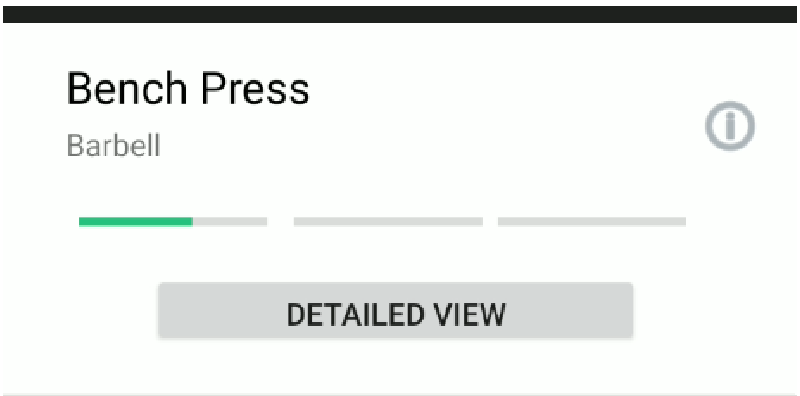

Figure 8.1. The grey colour of the button has shown to be a poor design choice with low clickability.

Lastly, it is essential to mention that the "5 minutes per task" scenarios are not enough to replicate a real-life experience. Based on this research, it is not possible to conclude how the potential issues with the prototypes will scale with time and amount of exercises performed. Editing one exercise might not seem like an issue at all, but it could most likely change to some degree if a user needs to perform the same editing action times ten.

8.3 Project Scope & Research Questions

Finally, based on the data collected, it is time to discuss how the research's results during this project translate into the potential answers to the Research Questions in the focus of this rapport.

How to implement free weight tracking with data from a multi-camera positioning system in an intuitive way while keeping it uniform with the existing Advagym system? The three Hi-Fi prototypes created during this work show examples of it being possible and how one can proceed to implement this. All three prototypes got good results during the testing, and the test participants did not show any serious problems when they used them. The multi-camera positioning system was shown to be able to detect when exercises are performed and transmit fast enough to the phones so that the apps register movements in real-time.

How can such data be presented in a user-friendly way with a positive user experience? All apps got good SUS-scores, and no serious problems arose for the users with the apps during the testing. Tasks could be performed well, and the reactions were observed to be overall positive. The SUS-scores and their grades show that all apps had good usability, a prerequisite for a positive user experience. Based on the observations and interviews during the testing, results indicate that the users had an overall positive user experience. There were some features that users found cumbersome, and that should be addressed to improve the conditions for a good user experience.

Which data is valuable to users and when? Based on the answers from the exploratory survey and the post-test interview for Hi-Fi prototyping, the users seem to be most interested in the repetition and set logging functions during the workout, mainly to avoid doing it themselves. The logged results could be then used to achieve a sense of progression and motivate the user to continue their workout journey. For that reason, even the weight is information that the users value highly, not necessarily right during a workout session but more as a mean to obtain more detailed statistics.

Another aspect that the users expressed their interest in, and therefore worth looking into, is their execution and posture during the workout. Obtaining this information during the workout could potentially prevent serious training injuries and contribute to a quick improvement in their workout habits.

What level of interaction with a smart training app provides the best user experience? Since a gym is not a very smartphone friendly environment, it seems like the less interaction, the better. The reminding concern is the accuracy of that solution. Upon being asked *Which prototype has an appropriate amount of interaction?* the second prototype which is based on a program and the third one offering a hand-free experience both scored similar scores of 16 and 18 points respectively, leaving the first prototype far behind with a score of 4. Since the first two scores differ so little, it is worth remembering that the further to the right side of the scale, the less control and accuracy the system offer. It is something that not all the users participating in the test have been comfortable with. That's why it is important to find balance according to what the current technology allows and adapt as it progresses. Therefore, despite the prototype 3 being a winner, the answer to this research question would gravitate towards the level of interaction offered by the *Program* prototype instead (considering technical restraints) as visualised in Figure 8.2 below.

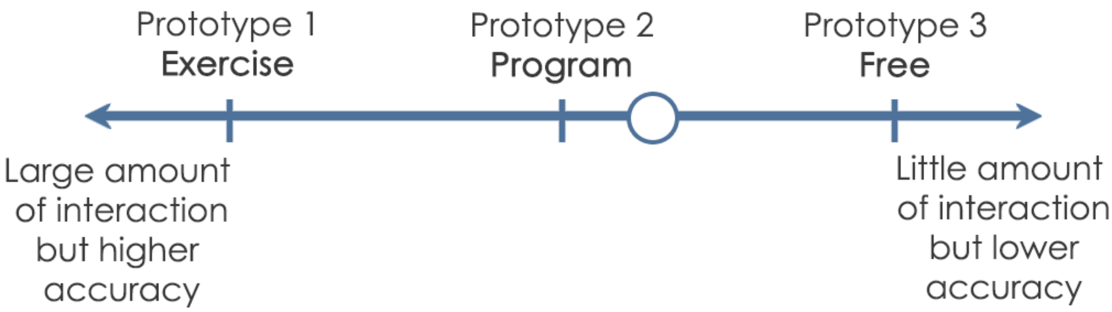

Figure 8.2. Interaction range of the 3 concepts that have been developed and tested during this project. The dot represents a level of interaction which could provide in the best user experience based on the previous test results.

What is ethically and by the users acceptable with regards to being tracked by cameras? Privacy issues are a reoccurring topic of conversation, especially considering progressing digitisation of each aspect of our lives. When handling any type of sensitive data, it is important to consider the potential risks it might bring with it. Therefore data minimisation is necessary - the scope of the obtained data should be adequate and limited to the minimum required to achieve the indicated purpose. While the current tracking system does just that, by extracting a 3D model out of the video footage, this fact is not commonly known to the public. It is worth noting that when asked *How do you feel about the presence of the cameras in training areas of the gym?* as a part of the exploratory survey in section 4.1, roughly 32% of the participants expressed that they feel somehow uncomfortable. In comparison, when asked the same question during the post-test interview for Hi-Fi prototypes, near to 78% of the test participants answered that they did not care for being exposed to the tracking system themselves. In conclusion, while the privacy concerns and the negative associations to surveillance cameras should not be downplayed, it seems like the tolerance towards camera tracking for the workout purposes is relatively high and therefore had not been addressed further in this rapport.

8.4 Future Work

The time limitation on this project has sadly restricted its scope making it hard to feature all the ideas that have been discussed under different stages of the design process. Starting with the ideas that have been discarded as early as the brain- and body-storming sessions due to technical limitations some of the most interesting concepts were

- **Colour-coding** The footage that the system is collecting in order to create a 3D model could be used to further minimise the amount of interaction with their device by reading off and calculating weights by their colours. This could be achieved to a low cost since colour-coding is now-days a common practice in the workout community. If it would be possible to extract that information from the footage, then Advagym would have a unique opportunity to decrease the number of parameters a user need to enter by themselves. It would further reduce the usage of sensors and therefore extra expenses a gym needs to agree on, offering a uniform solution for potentially all kinds of equipment regardless of the exercise if successfully identified.

- **Posture feedback** Following the same concept based on the fact that the system is already doing computations needed to identify exercises, some of this data could potentially be used to offer feedback on the users' posture during or after the workout. According to the exploratory study in section 4.1, the posture & execution was the information that the users valued second-highest, being higher in demand than weight recognition. This data could be visualised as an animation, which would contribute to the gamification factor in the Advagym application, or simply presented in the form of a percentage which roughly estimates the rate of how correct the exercise execution is. This feature would require expanding the model by additional joint-points on the 3D model that need to be identified and computed and a potentially enormous data bank for all the kind of body-types and exercises.

- **Smartwatches** Besides the obvious functions such as adding the pulse and calorie counts to the current workout, smartwatches could be used for a quick input prompt. Following suggestions from section 4.3 which discusses the feedback from the last round of the Lo-Fi prototyping, a screen of a smartwatch could be both used to display, for example, the repetition count but it could also implement the yes/no approach based on suggestions. Another function that would improve the usability of the system presented in the "free" prototype would be a possibility to quickly end the set by a single tap on the watch

- **Gym involvement** The data collected by the system could be potentially very interesting to the gym owners, which would make it more attractive to invest for the system to be installed at their facilities. With a help of an interface the employees would be also able to customize their offer to their members based on available equipment and human resources.

Chapter 9
Conclusion

This study did not result in one singular proof of concept as the main stakeholder, Sony, requested. However, it has identified a potential need for reconsidering the way we think of fitness applications today. In order to achieve that, three prototypes with varying amount of needed interaction have been developed and tested. The application with the workout model that is most similar to Advagym's current system today was placed last in the question of which prototype was liked the most. Prototype 1 got a score of 4 points compared to 16 points respectively for the other two, despite being the one they had the easiest time understanding. As this model by no means should be discarded, it is even important to realise that there is no way of working out to suit everyone. Considering that the users were willing to trade off some accuracy to lower the amount of interaction needed to log their workout, this concept seems worth researching further. With the possibilities that Sony's new tracking system creates it might be possible to adopt a mobile application in not so smartphone-friendly environment that a gym is today.

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Appendices

Appendix A
The System Usability Scale

This appendix contains the template for the System Usability Scale (SUS) questionnaire as given by the Digital Equipment Corporation.

System Usability Scale

	Strongly disagree 1	2	3	4	Strongly agree 5
1. I think that I would like to use this system frequently					
2. I found the system unnecessarily complex					
3. I thought the system was easy to use					
4. I think that I would need the support of a technical person to be able to use this system					
5. I found the various functions in this system were well integrated					
6. I thought there was too much inconsistency in this system					
7. I would imagine that most people would learn to use this system very quickly					
8. I found the system very cumbersome to use					
9. I felt very confident using the system					
10. I needed to learn a lot of things before I could get going with this system					

Appendix B
Exploratory Survey

This appendix contains a printed version of the google forms online questionnaire used in the exporatory survey of the inspirational phase in this thesis work.

Examination of exercise habits

This study is part of a Master Thesis project at Lund University.
The questions concern training, free weights and the use of training aids.
Your answers are anonymous. Thank you for your time!

1. 1. Enter your age

Mark only one oval.

- Under 15
- 15-19
- 20-24
- 25-29
- 30-34
- 35-39
- 40-44
- 45-54
- 55-59
- 60 +

2. 2. Enter the gender you identify with

Mark only one oval.

- Male
- Female
- Do not want to specify
- Other: ______________________

3. 3. What motivates you to work out?

4. 4. How many times a week do you train at the gym?

Mark only one oval.

- ( ) I do not work out
- ( ) Less than once a week
- ( ) 1-3 times a week
- ( ) 4-6 times a week
- ( ) 7 or more times a week

5. 5. For how long have you been training at the gym regularly?

Mark only one oval.

- ( ) I do not exercise regularly at the gym
- ( ) Less than 3 months
- ( ) 3-6 months
- ( ) 6-12 months
- ( ) 1-3 years
- ( ) 3-5 years
- ( ) More than 5 years

6. 6. What type of gym training do you participate in? Select one or more options, if there isn't one that suits you, add your answer in the field "other".

Check all that apply.

- [ ] I do not work out at the gym
- [ ] Strength training - Free weights
- [ ] Strength training - Machines
- [ ] Cardio - Running, spinning, cross trainer etc.
- [ ] Group training - Instructor-led sessions
- [ ] Gymnastics
- [ ] Functional Fitness
- [ ] Mobility Training
- [ ] Bodyweight exercises

Other: [ ] ______________________

7. 7. What is the reason that you use or do not use free weights during your workout routine? Please mention any advantages, disadvantages or challenges.

____

____

____

____

____

8. 8. What aids do you use for your training? Select one or more options, if there isn't one that suits you, add your answer in the field "other".

Check all that apply.

- [ ] I don't use any aids
- [ ] Notepad / Diary
- [ ] Exercise Prescription
- [ ] Mobile phone (Notes, Fitness Apps, etc.)
- [ ] Activity band / Smartwatch
- [ ] Web pages or Computer programs
- [ ] Training buddy
- [ ] Personal trainer

Other: [ ] ______________________

9. 9. What does the aid contribute with?

10. 10. If you have your mobile phone with you during a workout: What do you use it for, where do you have it and how often do you pick it up?

11. 11. What information do you want to receive about your training with free weights? Select one or more options, if there isn't one that suits you, add your answer in the field "other".

Check all that apply.

- [ ] Number of repetitions and sets
- [ ] Posture and execution
- [ ] Heart rate / pulse
- [ ] Weight of the dumbells, plates, kettlebells etc. used
- [ ] Pace of the exercise
- [ ] Exercise history
- [ ] Development overview

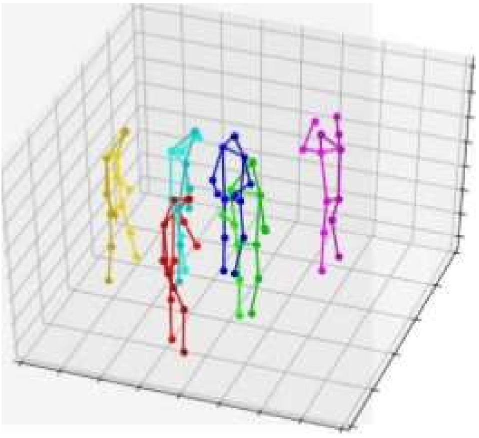
Other: [ ] ______________________

12. 12. How do you feel about the presence of the cameras in training areas of the gym?

Mark only one oval.

	1	2	3	4	5	
Very uncomfortable	( )	( )	( )	( )	( )	Very comfortable

13. 13. If the data that the cameras collect is anonymized and only used for training purposes, would your attitude towards cameras on the gym's training areas change?



The image shows anonymized data from a camera that identifies joints in the human body and translates it into a graphical model.

Mark only one oval.

- ( ) Yes, it would be more comfortable
- ( ) No, it would remain unchanged
- ( ) Yes, it would be more uncomfortable

Appendix C

Interview and Observation Data from the Usability Testing

This appendix contains a summary of the data obtained from the observations and interviews conducted as part of the usability testing.

Interviews

Question:	Positive	Negative	Comments
1. Which did you like using the most? Why?	P1: 2 P2: 6 P3: 6 P1 & P2: P1 & P3: P2 & P3: 4	P1: 6 P2: 2 P3: 7 P1 & P2: 2 P1 & P3: P2 & P3:	1. Do not touch my mobile phone during training 2. Easy to not have to edit between each exercise. 3. I think in concept the second one (free) is what I like potentially the best but only just. 4. In prototype 1, I wish I could add several exercises at once. (Create a program in exercise) but found program-prototype difficult to use (was done first). 5. 1 too much work. 2 flexible. 6. Did not like that there were incorrect detections in the 3rd, the 2nd had a bit of the same problem. See no potential in 1st. 7. Prototype 3, because in it you just kept going and it registered everything I did and I did not need to do more. 8. The 1st was a bit lumpy, a lot of work. The 2nd said when you are done and you should do the next set, it was missing in the 3rd. 9. Too much work to switch between exercises. 10. (2, program) if you force one to do sequentially, you skip incorrect detections because you reduce what is to be detected. Then it will be more like the 1st but without interacting that much. 12. 2 had better feedback, difficult to understand how to change exercise in 3. 13. I don’t care about programs or so, I just want it to log what I've done. 1 & 2 are the same to me. 14. Do not always want to run programs. Prototype 1 gets too jerky and does not want to have my phone on me all the time. 15. Programs kept track of one. Free easy if you just want to start and drive but liked it the least because I got no assistance. 16. Prototype 3 just to get started and adjust afterwards. Spontaneous when I train, it fits best, the other two were too much fiddling. 17. Be able to select the default view prototype 2. Do not want to wear a phone for "mental-space" 18. Program but with the opportunity to be able to add exercises during the training session. Cumbersome to remove errors.

2. Which did you think was easiest to underst nd? Why?	P1: 5 P2: 4 P3: 5 P1 & P2: P1 & P3: P2 & P3: 2 All: 2	P1: 5 P2: 3 P3: 1 P1 & P2: 1 P1 & P3: 1 P2 & P3: None: 6	1. Prototype 1 provided reassurance that you can trust that it detects what you chose because you choose for yourself. 3. Prototype one was "hardest", not really hard for me but I'm maybe too lazy to go through the process. Also want to be able to get extra reps for sets. 6. The 3rd was easiest even though I preferred others more, but it was the most straightforward. 9. All were relatively easy. 11. Had problems with prototype 3 because it was first and I was a bit distracted, a bit exciting. But in retrospect, it is as easy as others. 12. Likes that you follow a given path in prototype 2 13. Took some time with the first (prototype 1) to understand how to tap the puck. 14. Did not understand that in Prototype 3 you would start immediately and then just do the whole session. 15. Prototype 3 was easiest because you just press start. Prototype 1 was at least similar to the others.
3. Which did you think was the easiest to interact with during a workout? Why?	P1: 3 P2: 6 P3: 8 P1 & P2: P1 & P3: P2 & P3: 1	P1: P2: P3:	1. Prototype 2 because it takes care of itself. 2, 3, 4. Prototype 3 because you need to touch it the least. 5. Prototype 2, I liked the sound feedback. The vibrations were hard to hear. 6. Harder to have a detailed view on the 2nd (he thinks it is one of the main strength). 7. Prototype 3, I do not need to set anything. 8. Prototype 3, registered more than what I did which I do not like. 9, 11. Prototype 3, did not have to interact so much with. 12. Prototype 1 had the best interface. 13. Prototype 1 and 2 I need to focus on the progress or how much is left, that's distracting. 14. Prototype 2 has the whole list of what you are supposed to do, I like that you do not have to keep it in mind. 16. Prototype 3, I want to escape from technology and not have the mobile up. 17. I experienced the most control in app 1 and got good flow there. 18. Prototype 1 felt created to tinker with.
4. Which did you think had the appropria	P1: P2: 4 P3: 6 P1 & P2: 2 P1 & P3:	P1: 2 P2: P3:	3. I don't think I'm looking to interact with an app during the session all that much. 5. Cumbersome to have to enter a lot of data. 6. Prototype 3 even had too little interaction. Does not care that you have to puck all the time, but if

te amount of interaction from you as a user? Why?	P2 & P3: 4 All: 2		you can do it once instead, it will be good. 7. Could do a little how you want, flexible. 8. Nice that you do not have to log in between, since it says so I do not have to check. 9. Usually do not wear my phone all the time at the gym. 10. If it is a long session, I would have preferred to interact before the session. If shorter, then gradually. 11. Least amount of interaction. 12. Prototype 2 felt best and you do not have to interact more than necessary. Afraid to ruin something when you have to integrate a lot in prototype 1. 14. Prototype 1 had too much interaction. Liked sound feedback. 15. Appropriate amount of steps in prototype 2. 16. Prototype 1 had too much. 17. Prototype 2 presents more data than 3 so have looked at it more, but also does not want to check much 18. Prototype 2 along with 1 would have been nice. Prototype 3 if no false positives.
5. Was the information in any of the apps dicult to interpret or take part of? Why?	P1: P2: 4 P3: 3 P1 & P2: 1 P2 & P3: 2	No: 8	1. Missed sets in prototype 3. Did not understand the green (finish) button. Only the worst compared to the others. 3. Big number in circle, sets or reps? 4. Detailed view. 5. Progressbar in prototype 2 was hard to interpret. 6. Thought all were intuitive 7. How do you start? 11. The check icon button. Should have completed the exercise instead completed the training. 12. In prototype 3, it was difficult to know if you were ready. Missing big number in prototype 2 17. “Detailed-view” felt advanced to click at. 18. Too small buttons.
6. What information about your training did you find most valuable? Why?	Sets: 7 Reps: 13 Vikt:2 Logging: 5 Progress: 5 Träningstyp: 1	Reps: 1 Total weight: 6 Calories: 1	3. Vibration feedback that said you completed the rep. 4. Reps, because it's easy to lose yourself. 5. Can't be bothered to count for myself but can feel it is long to wait for feedback until the set is completed. 7, 8. I do not understand what total weight means. 11. Hard to keep the amount of reps and sets in the head while exercising. 12. Only in prototype 2 I did not count, want a bigger overview than caring about individual reps. 16. Total weight is not interesting for my way of training. 17. Liked to get audio feedback but would like it more nuanced. Via headphones. Give

			encouragement to motivate progress. 18. Get progress overtime to see your development. Motivate to train and also continue training.
7. Did you miss information about your training in any of the apps? If so, what and at what stage?	Tutorial video: 1 Execution: 5 Pulse: 3 Time: 4 Done with exercise: 3 Workout recommendations: 3 Calories: 3 Own notes: 1 Next exercise: 1	No: 3	3. It would be cool if it was any form correction, like “go deeper” and so, and form correction, that would be very helpful. 4. How long you have been training, do not have much use of total weight. 8. Next exercise, maybe tell to change, so you do not have to hold the screen. So that it says what comes next. 9. Effective and rest time so that you can see later after the training how effective you were during the workout. 11. Strange with total weight. 12. Confirmation that you have completed the exercise. Tips and tricks if you do the exercise too fast or something. 16. Suggest weight and number based on user profile and values such as "repmax weight". Statistics can never be overstated. Target weights, "halfway to your goal" badge. Gamification. Time for concentric and eccentric movement. 17. Can count for myself, more interested in the whole over a longer period of time type like a smart exercise diary. 18. Protect against damage in the event of incorrect execution. What interval to maximize training based on one's goal.
8. How did you experience the feedback in the apps? That is the visual, vibrations sounds, etc. Why?	Vibrations: 12 Sound: 14 Visual: 6		1. Liked longer vibrations at the end of the set. Sound was also good. 3. Don't know if i would like to have little tones on while listening to music, maybe optional 4. Maybe a little annoying with the vibrations for each repetition, I know myself that I made one. 5. Thought at first that the dumbbell vibrated. 6. Prototype 2 had an audio signal that said when I was at the end of the set, I especially liked it at bench press. 7. Liked the feedback in prototype 2 with sound. 8. Maybe different lengths of vibrations (did not notice the difference) 9. Vibrations are much better than having sound which you do not want among people. 12. Prototype 2 best, 3 bad visually. 13 Good with difference in the vibrations, did not know where you were in prototype 3. If sound, then through headphones. 14. Just want feedback after each set. Sound nice, but should be able to turn off. 15. Want feedback for each set, reps are too much.

			Liked sound, did not hear vibrations. 16. Did not notice sound. Liked vibrations and progress bar. Had wanted to get "overshoot" reps. 17. Just want feedback when you start and end. Possibly how much is left of the set. 18. Feedback halfway or at lika 3 reps left. Be able to choose how often it should say.
9. Did you notice the cameras in the ceiling that tracked you?	Yes: 3 No: 15		11. Though the barbell was the se
10. How do you feel about cameras in a gym's workout areas? Why?	Do mind: 1 Depends: 3 Does not mind: 14		1. Depends on who takes part in the information, how the information is handled 3. It feels very different to know it's recording for that (tracking), and not just "recording" recording. 4. I'm an advocate for cameras, I think people should stop being so offended. 8. If someone accesses them, it may not be that fun, but for training yes 9. Of course it feels a little uncomfortable if you think that someone is sitting and watching you train, but if it's just for tracking, it should be ok. 15. If it is not used for anything other than tracking. 17. I like gyms because they are analog.

Observations

Incorrect detection
False positive: 14
False negative: 12

Tap Puck NFC
Problem: 13

PROTOTYPE 1:
Noticed a difference in the vibrations: 4
Pressed finish instead of plus: 5
Misinterprets large number as set: 2
Think sets start at 1 not 0: 1
Autofill weight for all subsequent sets: 3
Want to edit afterwards: 2
Skipped review and pressed finish: 2
Difficult to see progressbar: 1
Believes default weight is the correct onet: 2
Believes review is a screen after finish: 2
Want to be able to edit not only in the beginning: 1
Want clear indications that you should start / that it tracks: 1

PROTOTYPE 2:
Noticed a difference in the vibrations: 1
Reacted positively to sound feedback: 8
Reacted positively to progressbar: 1
Did use detailed view: 6
Tries to tap the exercise in the list to start it: 6
Want do edit afterwards: 4
Want do edit during workout, but did not understand how to do it: 2
Misinterprets large number as set: 1
Taps the puck between exercises: 2
Did not finish the program and reviewed: 1
Do not understand how to start, just thinks of the squat that appears at the top and not what is in the whole list: 2

PROTOTYPE 3:
Taps the puck between exercises: 3
Wants set: 5
Want do edit during workout: 2
Failed to edit / fill in values: 5
Edits false detections but not weight: 1
Wants different weight for sets: 2
Unsure about the check-icon button: 3
Finishes between each exercise: 3

Does not understand that the whole workout can be performed without interacting with the app: 2

NOTE:
Easier to edit errors if you are forced to do so when finishing the workout.

	Task 1 fails	**Task 2 fails**	**Task 3 fails**
App 1			6
App 2		1	3
App 3			5

Phone placements:
TP1, male: mobile in the phone holder for the entire test.
TP2, female: mobile on the table, after being told about the phone holder it was placed there.
TP3, male: mobile on the table, after being told about the phone holder it was placed there
TP4, female: mobile in the phone holder during bench press (to be able to see it), on the table for biceps curls.
TP5, male: mobile on the table for biceps curls, on the bench during bench press.
TP6, male: mobile on the table for biceps curls, on the floor next to the bench during bench press. Looks at it constantly even though it is hard work to see it when on the floor.
TP7, female: mobile on the table for biceps curls, on the floor next to the bench during bench press with prototype 1. Leaves it on the table for the other two prototypes, but never looks at the phone.
TP8, female: mobile on the table for the entire test.
TP9, female: mobile in the phone holder for the entire test.
TP10, female: mobile at the table during biceps curls, the phone holder for bench press but only then looks at it between sets.
TP11, male: mobile on the table at the beginning of the test, the phone holder for rest of the test.
TP12, male: mobile in the phone holder for 90% of the test.
TP13, male: mobile on **the puck** during biceps curls and bench press for prototype 1, on the table for the rest of the test.
TP14, male: mobile on the table for biceps curls, on the bench during bench press.
TP15, male: mobile in the phone holder (during bench press only to check when starting and ending).
TP16, male: mobile in the phone holder (during bench press only to check when starting and ending).
TP17, male: mobile in the phone holder (during bench press only to check when starting and ending).
TP18, male: mobile in the phone holder for biceps curls, on the bench during bench press.