Interaction with IoT data to help users train smarter

Jakob Håkansson

DEPARTMENT OF DESIGN SCIENCES
FACULTY OF ENGINEERING LTH | LUND UNIVERSITY
2019

MASTER THESIS

SONY

Interaction with IoT data to help users train smarter

Utilizing IoT data & Velocity Based Training

Jakob Håkansson

LUNDS UNIVERSITET

Interaction with IoT data to help users train smarter

Utilizing IoT data & Velocity Based Training

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
Supervisor: Dr. Günter Alce
Co-supervisor: Andreas Espinoza
Examiner: Joakim Eriksson

Abstract

It is becoming more and more common to exercise regularly, and with this new fitness trend follows more exercise applications to our smartphones. Applications aiming to help us exercise by structuring and logging our training. The user experience for these applications can be a little bit dull, since most of the applications depend on the user following instructions and entering input of the result manually. The relatively new technology Internet of Things (IoT) seems to be a well fit solution to solve the issue of manual logging of a user's training. Doing this with the help of sensing the users exercise motion and then providing the result to the user. But as with many other IoT projects, not all data collected from the IoT devices are fully utilized. New interaction possibilities can be created, which gives better user experience as well as better health by helping the user train smarter and safer.

A study was performed regarding the IoT data from Sony's project, Advagym, which tracks machine exercises movements to log a user's training. The study was aimed to find new applications for the IoT data, which is not currently being utilized by the Advagym system, to potentially being able to increase the user experience.

Using a user centered design process, multiple iterations of prototypes was developed, which collects and presents real-time data from the IoT units. Using velocity based training (VBT) methods, the aim was to with the help of the prototypes, get users to follow a predefined velocity target for an exercise movement. The prototypes were developed as iOS applications in Swift which listens to Advagym's IoT units' broadcasts, with data packages which provides data of the result for the user's performance.

Three prototypes were tested with 50 participants to be able to benchmark performance differences, as well as testing the usability and understandability of the prototypes. The tests show that with the help of continuous feedback on the users' performance based the velocity, the user can achieve an exercise tempo with low tolerance for errors. This can further help a user to train smarter and safer, based on their training goals.

Keywords: internet of things (IoT), velocity based training (VBT), fitness technology, real-time interaction, user experience

Sammanfattning

Det blir allt vanligare att träna regelbundet, och med denna nya träningstrenden följer det med allt fler träningsapplikationer till våra smarttelefoner. Applikationer som ska hjälpa oss i vår träning genom att hjälpa en att bygga upp och logga sin träning. Användarupplevelsen för dessa applikationer kan anses rätt dålig, då allt bygger på att användaren följa instruktioner och lägger in resultat manuellt. Den relativt nya tekniken Internet of Things (IoT) verkar vara en passande teknologi för att lösa problemet med att användare ska behöva logga sin träning manuellt, genom att använda sensorer som känner igen träningsrörelser och sedan levererar resultatet till användaren. Men som med många IoT-projekt så utnyttjas inte alltid den ihopsamlade datan till fullo. Nya interaktionsmöjligheter kan skapas som kan gynna användarens användbarupplevelse så väl som välmående genom att hjälpa dem träna smartare och säkrare.

En studie har gjorts på Advagym, som är ett Sony-projekt. Advagym mäter träningsmaskiners rörelse, med hjälp av IoT-teknologi, för att logga användares träning. Studien gick ut på att hitta nya användningsområden för den IoT-datan som inte för tillfället utnyttjas av Advagym-systemet, för att potentiellt kunna öka användarupplevelsen.

Med hjälp av en användarcentrerad designprocess har flertal iterationer av prototyper som tar in och presenterar realtidsdatan från IoT-enheterna skapats. Tillsammans med hastighetsbaserade träningsmetoder var målet med prototyperna att få användare att följa en fördefinierad hastighet för deras rörelse i träningen. Prototyperna är mobila applikationer för iOS, skrivna i Swift som lyssnar på Advagyms IoT-enheters sändningar, där datapaket levererar resultat för en användares prestation.

Tre prototyper testades därefter med 50 testpersoner för att kunna mäta prestationsskillnader så väl som att testa användbarheten och förståelsen av prototyperna. Testerna påvisar att med hjälp av prototypernas kontinuerliga feedback på användarens prestation i hastighet, kan hjälpa användare uppnå ett träningstempo med låg tolerans för fel. Detta i sin tur hjälper användare att träna smartare och säkrare, efter deras mål.

Nyckelord: internet av saker (IoT), hastighetsbaserad träning (VBT), fitness teknologi, realtidsinteraktion, användare upplevelse

Acknowledgments

A special thanks to Sony for hosting my thesis work, where Henrik Bengtsson made the project possible, and has been contributing with high interest, knowledge and expertise. Another special thanks to Andreas Espinoza, who has acted as the main supervisor on Sony's behalf, giving great advice along the way, helping me achieve great things and making me strive for perfection.

I would also like to thank the Advagym project team for their continuous support in me and my thesis work. A lot of the prototype development is thanks to the support received from Khalid Afridi and his expertise in iOS development.

And last but not least, a special thanks to my supervisor at LTH, Dr. Günter Alce, who has guided me throughout the thesis with great expertise in the fields of Internet of Things and interaction design, showing high interest in my work.

Lund, April 2019

Jakob Håkansson

Table of contents

List of acronyms and abbreviations

1RM	one rep max
AI	artificial intelligence
BLE	bluetooth-low-energy
DRTF	delayed-real-time-feedback
EMG	electromyography
FRTF	faked-real-time-feedback
IoT	internet of things
IoT-SE	IoT-based smart environments
Hi-Fi	high-fidelity
Lo-Fi	low-fidelity
MANOVA	multivariate analysis of variance
NDA	non-disclosure-agreement
NFC	near-field-communication
OS	operating system
OTA	over-the-air
RoM	range of motion
SUS	system usability scale
TOL	time-of-light
UX	user experience
VBT	velocity based training

1 Introduction

It is becoming more and more common to exercise regularly. More people in the USA exercise enough each week to meet USA's government recommendations for both muscle strengthening and aerobic exercise, according to a large annual health survey for the USA [1]. This trend also reflects the amount of new mobile applications which is being continuously added to Google Play and AppStore.

For the "gym-goer" there are a lot of gym smartphone applications that help you log your training progress, example of such applications is "Fitness Buddy" and "Jetfit" available at both iOS and Android. Though most of them force the user to enter the result manually, meaning that after each performed sequence of repetition, also known as "set", the user has to input their result. An intuitive way would be to log this data automatically with the help of sensors connected to the phone. This is a possibility with the relatively new technology Internet of Things (IoT), where sensors could be used to track user's performance and movements [2], connecting and gathering all the data from the user.

However, with a more connected world, follows a large magnitude of data as well as an increasing complexity of the solutions. This can overload and get cumbersome for the users of the systems. There are different ways to approach this issue, and it seems as one common approach is to simply not use or present all of the data collected [3]. Leaving large amount of potential new features, insight and experiences abandoned.

The department of Research & Incubation (R&I) at Sony Mobile Communications AB in Lund Sweden, has its main focus to broaden the Sony brand by creating new businesses with Sony's know-how and technology. One of these technologies which most of the incubation projects uses are IoT technology. The current problem with the handling of IoT data has different solutions for every type of system/project.

The project Connected Gym, now rebranded as Advagym, uses IoT devices mounted on gym machines to track performance data from user's workouts and digitizes the gym experience. The interaction between the IoT units and the users are mainly through smart phone applications running on the platforms iOS and Android. Currently the IoT devices sensors are gathering many types of data, which of some, is never used or shown for the user. This type of data could potentially improve the user experience of the solution, if presented to the user in a user-friendly way.

The IoT data not being currently utilized by Advagym, can be converted to the speed of a user's motion, meaning that the velocity of the lift for each repetition can be calculated. The velocity calculated can together with a training technic named Velocity Based Training (VBT) be utilized to help a user train smarter.

With a population that is becoming more physically active by exercising and the relatively new technology IoT, being able to measure and sense movements, this leads to the research questions of this paper:

- Is there a trend of IoT data not being used within projects?
- How can the IoT data not being used from Advagym IoT devices be presented in an interactive way to a user?
- How can the Advagym IoT data be presented, to make it feel as if the feedback is in real time?
- How can the interaction help the user follow a training pattern which is predefined?
- Can the system provide enough feedback/guiding to be competitive against a personal trainer?
- Can the presentation of the IoT data be good enough feedback to help a user follow a predefined velocity?
- Can an additional guide indicator improve the experience?

2 Scope

The scope of this thesis is to firstly review the IoT data utilization for R&I projects at Sony Mobile Communications, determining how it is currently being handled, or if it is being handled at all. Secondly evaluate Advagym's utilization of their main units' IoT data, finding eventual conceptual possibilities to use the data for new interaction experiences. In this thesis, prototypes of real-time interaction solutions for the utilization of the IoT data is to be developed in an iterative manner. Doing this by implementing high-fidelity prototypes (Hi-Fi) which will work with current existing Advagym hardware. Lastly to test and benchmark the different prototypes and scenarios.

The main scope of this thesis is to utilize IoT data from Advagym's main units, which is not being used in the current solution. Testing new ways of interaction with the IoT data to increase the user experience. Sub-goals to achieve the main goal are:

- Evaluate the possibility of using VBT methodology for the Advagym solution.
- Evaluate different interaction approaches.
- Test and benchmark different prototypes and sessions.

3 Technical background

IoT devices and their technology is on the rise with advancements in information and communication fields. New terms as IoT-based Smart Environments (IoT-SE) now exist in modern societies [4]. But with all these new advancements, tremendous amounts of data are also being generated. If not being utilized, the IoT data will serve no purpose [5].

Advagym is a new IoT solution to digitize the gym experience, where an retrofit solution is used to fit IoT devices on gym machines to track performance data from users' workouts [6]. As in many other IoT projects, both at Sony Mobile Communications and other software projects [3], not all the IoT data is being utilized. Advagym is currently not utilizing all of their collected IoT data. However, if this unused data would be utilized, it might increase the project value. An interaction with the unused IoT data could be used to increase the user experience. The tracked data from the IoT unit is parameters and values from performed repetitions from a certain sequence of repetitions, also known as "*set*". For each repetition a data package is sent from the main unit which can be analyzed and interpreted into different parameters. Example of information that these data packages provides are parameters about the time and distance traveled for the concentric and eccentric movement of the repetition. Where the concentric movement is the positive movement of an exercise, and eccentric is the negative movement of the exercise, see *Figure 1*. This information can be utilized as velocity for the repetition.

To gain a better insight to the project's background, IoT, the Advagym solution, VBT and user centered design process, will be presented in following sub-sections.

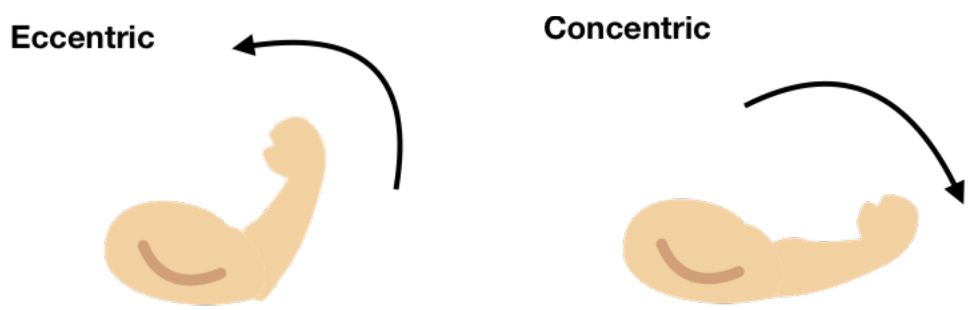

Figure 1, illustration of an eccentric and concentric motion for a biceps curl.

3.1 Internet of things

Internet of Things (IoT) technology is continuously advancing, connecting and digitalizing more of our everyday life, by sensing, computing and communication capabilities [2]. IoT is a set of technologies with a large amount of use cases and hence have no single definition. But what every IoT solution has in common is to connect network devices in an physical environment, with a purpose to improve existing processes or enable a new scenario which previously were not possible without these connected devices [7]. Creating new possibilities which *"allows people and things to be connected anytime, anyplace, with any service"*[8].

What makes IoT devices an even more competitive new technology, is the possibility of implementing over-the-air (OTA) updates [7], meaning continues delivery is possible with bug fixes and new features. Saving costs for replacement of hardware and installation processes.

3.2 Velocity based training

For the ordinary gym-goer the main focus of their training progress usually has its focus on which weight and amount of repetitions are being performed. This way of training is well known and simple to understand as a beginner. But there are more innovative ways to train focusing instead on velocity of the lift. VBT can be utilized, which instead uses parameters such as bar speed, allowing a gym-goer to train exactly where he/she needs to for that specific lift on that particular day [9].

3.2.1 **Training with focus on weight**

Training with focus on weight is easy to understand and commonly used, which is also one of its positive aspects. On the other side, one of the more negative aspects is that it does not take the current day performance into account. Meaning that even though a person might be able to lift a weight a certain amount of times on one day, he or she might not be able to perform the same or better on the next day. This is essentially because our nerve system is never constant. A study, where it was tested to estimate an athlete's "*One rep max"* (1RM) through the load-velocity profile, showed that it is been noted an approximate 18% difference above and below from last performed 1RM. Meaning a 36% range around previously tested 1RM [10]. For example, if your goal is to train 70% of your 1RM for a certain exercise, the actual relative load might be 86% which most likely will be too heavy for a sequence of repetitions aimed for 70% [10]. By using VBT, we can eliminate this issue, by instead focusing on the speed of the lift, rather than the weight.

3.2.2 **Training with focus on velocity**

Training with focus on velocity, in other terms utilizing VBT, is done by measuring the speed of the bar or weight which is being moved during a lift. By knowing the speed of the lift, the weight being lifted can be adjusted to adapt after the lifter's daily performance. This allows a gym-goer to train for best progress for every training session. VBT can eliminate the use of percentage-based training, allowing for maximal results [9]. VBT measurement devices can be used as an extra coach in the gym. Giving the gym-goer feedback on their performance, if he or she needs to increase or decrease the weight on the current training session [9].

Another addition to VBT is that different so called *"velocity zones"* can be utilized to help gym-goers to develop the preferred traits for their training. Meaning that if you for example, want to have the ability to produce rapid movements involving small external resistance, you should try to train with velocities in the zone of *"speed / strength",* see Table 1.

Table 1, velocity zones based on % 1RM and velocity ranges. Data table in courtesy of Owen Walker at scienceforsport.com [11]**.**

% 1RM										
0	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
None	Starting strength		Speed / Strength		Strength / Speed		Accelerative strength		Absolute strength	
Velocity ranges	> 1,3m/s		1,3 – 1 m/s		1 – 0,75 m/s		0,75 – 0,5 m/s		< 0,5 m/s	

3.3 The Advagym solution

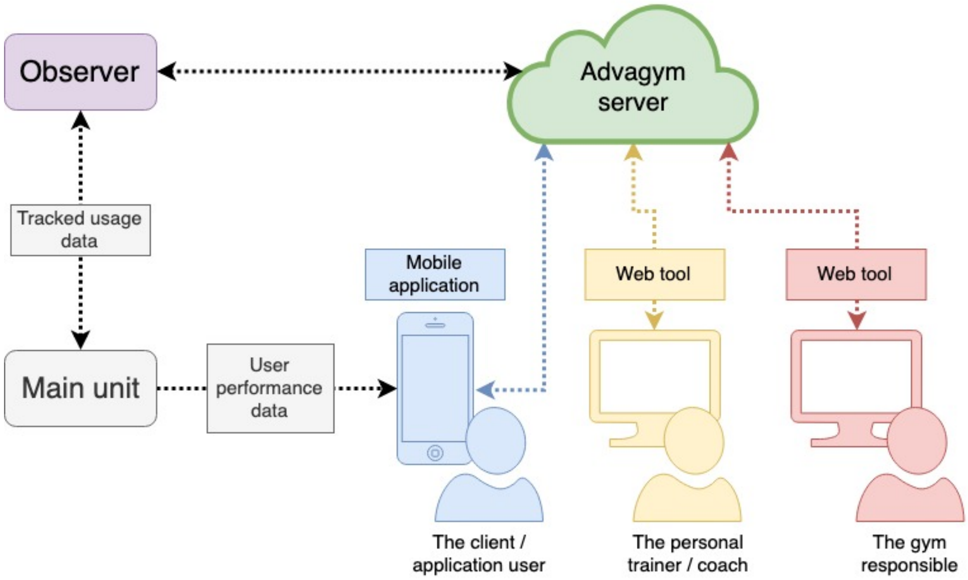

Figure 2, illustration of Advagym's IoT data flow to different users.

As earlier mentioned, Advagym is Sony's approach of digitalizing the gym experience. The system is complex and there are different kinds of users for this service. For this thesis purpose, only three types of users will be mentioned:

1. **The client / application user** (Figure 2), who with the help of an iOS or Android application can train and log their training automatically with machine exercises. Free weights can be manually added to a user's workout, logging their result as well.
2. **The personal trainer (PT) / coach** (Figure 2), can create personalized exercises and programs which he or she can send to their clients, deciding which type of training / programming their clients should use. The PT can also follow up on their clients' progress and performance, meaning that if the client has allowed data sharing, the PT can get an insight in their clients training without having to be by their side.
3. **The gym responsible** (Figure 2), can get relevant information regarding the gym's utilization. Statistics to help make decisions on how to improve and maintain the gym.

All three type of users get their information from the IoT devices installed on the gym.

3.3.1 **Advagym hardware**

The majority of IoT solution has three basic components at the top-level: *device, gateway* and *cloud* [7], the Advagym solution has a similar structure, where the three components are called: *main unit, puck* and *observer*. These three devices are connected to the Advagym server which is equivalent to the *cloud*. In order to gain better understanding of the Advagym solution, the main three devices, *main unit, puck* and *observer,* and how they co-operate will be explained.

3.3.1.1 Main unit

Figure 3, picture of the Advagym main unit, image courtesy of Advagym.

The main unit, see Figure 3, is the IoT device which does the actual tracking for performed repetitions on a machine exercise. This is done with different sensors in the unit. The main unit is placed on the weight stack of a machine exercise, see Figure 4, meaning that the movement of the main unit will only be in the vertical axis.

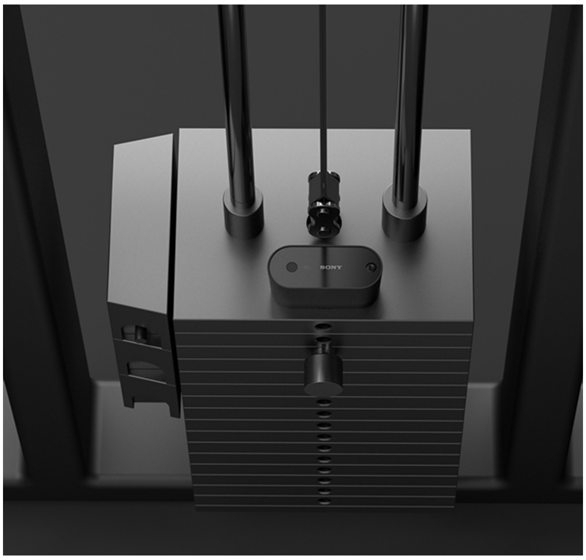

Figure 4, render of main unit placement on machine weight stack, image courtesy of Advagym.

An accelerometer awakens the main unit from its “*sleep mode*”, which is a battery conservative mode, to start tracking the movement of a repetition. Once the main unit is awake, the firmware is booted up and starts tracking the vertical movement with the help of the time-of-light (TOL) sensor. A combination of these sensors and smart algorithms will provide data packages for each repetition and their movement. This package is broadcasted multiple times as Bluetooth-low-energy (BLE) data packages for both the user’s application to interpret, as well as for the observer, see Figure 2, to log. Each package/broadcast is dependent on two events of a repetition, these events helps to define the performance of a repetition:

1. Event 1: Occurs once the weight stack has reached its max peak value of the repetition, see Figure 5. Meaning that the max value of distance measured has been received.
2. Event 2: Occurs once the weight stack has reached a lower value than the one measured in event 1 and is on its way up once again, see Figure 5. At this event the actual broadcast is also performed.

These events occur for each repetition of a set, with the exception of the very first repetition, where not all parameters of the package are set. The reason for this is the boot up time for the main unit is triggered by the accelerometer, and even though it is done rapidly, it will give some uncertainty on how far the weight stack and main unit will have traveled from its starting position before the main unit can start tracking the actual repetition movement.

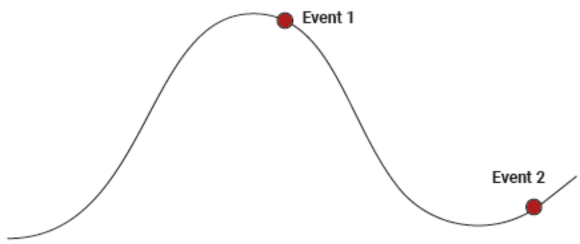

Figure 5, occurrence of main units’ events, where the curve track is a representation of the main unit’s movement with the vertical axis as distance traveled and the horizontal axis as the duration/time axis.

Each main unit has a unique MAC address which is registered in the Advagym server. At the server, other information regarding each connected gym machine is defined, such as details of the weight stack, but more importantly, the MAC address of the puck for this machine.

3.3.1.2 Puck

Figure 6, picture of the Advagym "puck", image courtesy of Advagym.

The puck, see Figure 6, has its main purpose to work as a connection link between the main unit on the installed machine to the user's smartphone application. Meaning that with the help of the puck, users can connect their phone with the Advagym application, to the chosen gym machine which is connected to the Advagym system.

This is done with two different technologies, which are utilized depending on which smartphone operating system (OS) and or which technologies the user's smartphone has. For iOS users, a BLE package is received from the puck once the user "*taps the puck*", see Figure 7, meaning that the user puts/nudges their phone vertically against the pucks front. This is sensed by a proximity sensor, which triggers the puck to send out BLE packages.

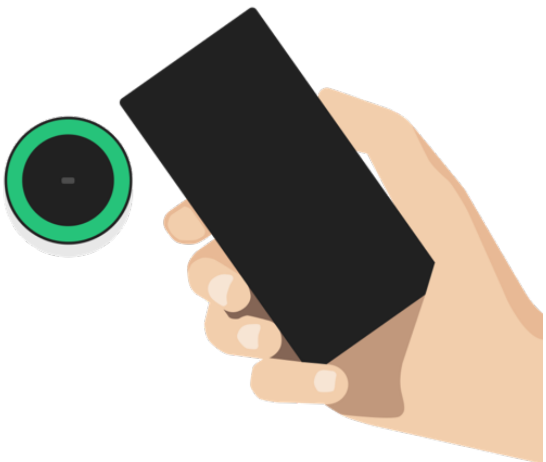

Figure 7, illustration of smartphone about to "tap the puck", image courtesy of Advagym.

For Android users with near field communication (NFC) capabilities on their smartphone, the same interaction is done, but the package is received through NFC instead of an BLE package.

For Android users without NFC capabilities, BLE is instead utilized, though with an additional step in the interaction where the user has to make an active choice in their application by pressing a button to “*listen*” to the BLE package. This is done because of Android hardware restrictions.

Regardless of which technologies is being used to receive the data package from the puck, the same information is provided. This information will be handled in the smartphone application and on the Advagym server, connecting the user to the physical gym machine. Allowing the user to track their training automatically.

The puck is placed conventionally on the machine exercise, where the user can easily see and reach it, see Figure 8.

Figure 8, illustration of puck placement on a machine exercise, image courtesy of Advagym.

3.3.1.3 Observer

Figure 9, picture of the Advagym "observer", image courtesy of Advagym.

The observer, see Figure 9, has its main purpose of being the link to the internet between the main units and the Advagym server. Meaning that the observer is placed in the same area as the machines to “*listen*” to all the broadcasts which are done by the main units, keeping track of all the connected gym machines, hence acting as the so-called gateway of the IoT devices. This is especially important for gym utilization.

3.3.2 **Advagym services**

The data collected from the main unit is logged at the Advagym server. All this IoT data allows for a great number of functionalities which can help all the users which is listed earlier: *application user, personal trainer & gym responsible*, see Figure 2. Each type of user has their own way of interacting and displaying the data. Though it is important to mention that the non-anonymous data generated by the application user is owned by the user. Such data can be inputs from the user regarding the tracked data. The application can allow data sharing with the personal trainer, hence providing them with their data. Otherwise the anonymous data collected, in the form of e.g. repetitions performed on a connected gym machine, is relevant and used by the gym responsible.

3.3.2.1 Mobile application

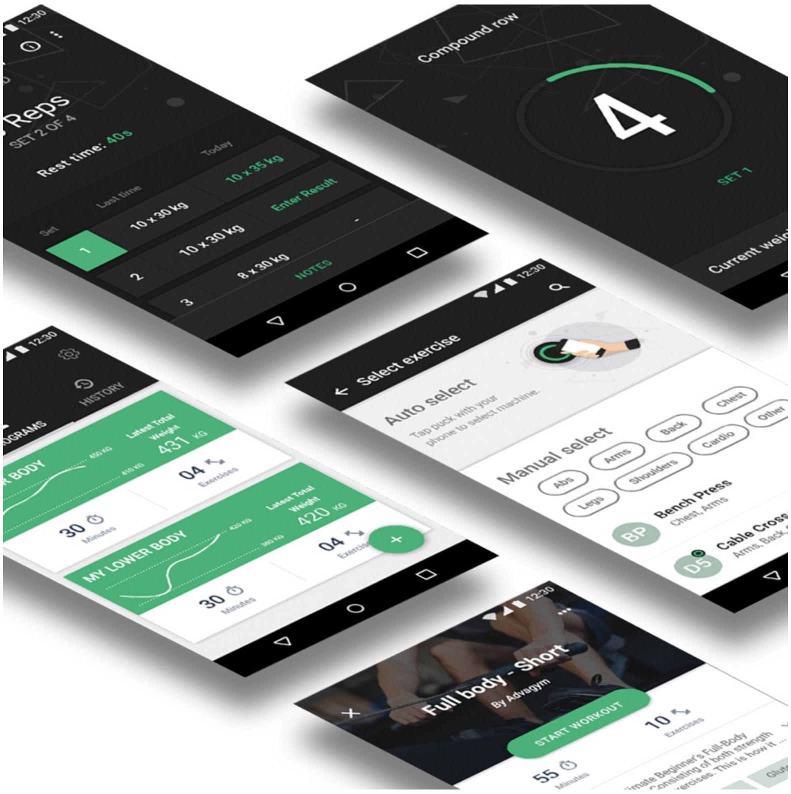

Figure 10, picture of screenshots from the smartphone application. Displaying different views within the application, image courtesy of Advagym.

The mobile application, see Figure 10, is the platform for the “common” user, which is the “gym-goer”. Meaning that this application is created for people who train in the gym. The main functionalities which the mobile application has are:

- Logging – Automatically or manual logging of performed reps and sets for each exercise in your workout.
- Programming – Create or use programs, which contain a structure of exercises with sets and reps to build a workout plan.
- Insight – All performance data saved in one place to get a summary and statistics of your progress. Keeping track of your training.
- Training support – Instruction and videos for how to perform exercises. Descriptions of your programs to follow. Rest timers and more.

3.3.2.2 Web tool

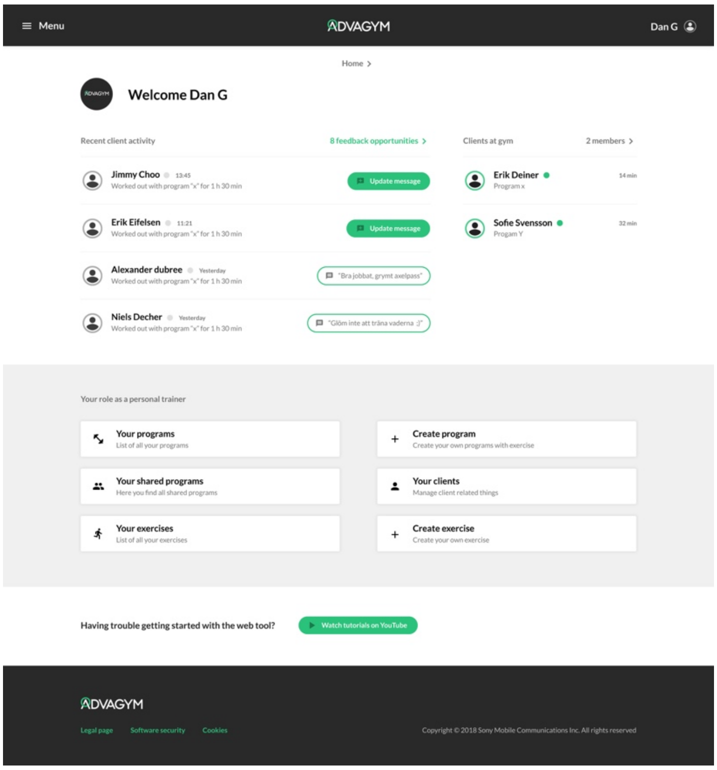

Figure 11, design illustration of the Advagym Web Tool dashboard, image courtesy of Advagym.

The web tool, see Figure 11, is the platform for both the personal trainer and gym responsible. The main use cases for the personal trainer is to:

- Create exercises with instructions and videos.
- Create programs with workout structure (amount of weight, sets and reps for each exercise) and descriptions for their clients.
- Follow up on their client's progress (receiving the shared data).

Hence the IoT data, which is being utilized by the personal trainer user, is the tracked data from their clients that is being shared. Allowing them to follow their clients progress and performance.

The main use cases for the gym responsible is to:

- Monitor the gym utilization, in the form of usage of each machine.
- Monitor the gym activity.
- Get insights and status of gym machines.

Hence the IoT data, which is being utilized by the gym responsible user, is every gym machine's anonymous activity data. Allowing the gym responsible to have a great overview how their gym is being used.

3.4 Usability and design

When designing and implementing an application's workflow, everything needs to be easily accessible, simple and easy for the user to understand. Norman has defined *seven fundamental design principles* which has been used by many designers in their process of developing a new design [12]. These seven design principles can ease the development of products/systems, giving guidelines in the design process to follow. The seven fundamental principles of design are:

Discoverability: In the current state of a product / system, where the product / system is giving some form of feedback / information of what actions are possible for the user.

Feedback: Giving the user a result of their action continuously for the current state of the product / system. After an action is executed by the user, it is easy to evaluate the result of the action performed.

Conceptual model: Visualizing and presenting all the relevant information needed for a user to understand the product / system, helping them feel in control.

Affordance: The proper affordances exist to make the desired actions possible.

Signifiers: Help users discover and understand the design or feedback communicated to them. Enhancing the feedback communication and comprehensiveness.

Mapping: Simplifying the relationship between controls and their actions. Enhanced as much as possible through spatial layout and temporal contiguity.

Constraints: Providing logical, semantic and cultural constraints guides actions and eases of interpretation, to let the user interpret the product / system guiding actions.

3.5 Related work

Some earlier work in the related field of the intended research of this thesis has been done. Following are two studies which helped lay scientific groundwork for the project.

3.5.1 **Real-time feedback during exercise**

A research was conducted to investigate the use of real-time sonification as a way to improve the quality and motivation of strength exercising. In the study's case, a biceps curl routine [13]. To do this, a sonification system was developed with the help of electromyography (EMG) sensors and a Microsoft Kinect camera. When exercising with the system, muscular and kinematic data were collected and used to a custom designed sonification software which then generated a real-time auditory feedback. An initial pilot study showed that providing real-time sonic feedback on a biceps curl exercise can produce useful cues to a user and influence the quality of the exercise [13].

A latitudinal experiment was later on conducted to compare exercising quality between a sonification group and a control group who does not get any feedback. The study showed that users with sonification real-time feedback performed consistently better in terms of movement velocity and effort. Though a MANOVA (Multivariate Analysis of Variance) concluded that there was no significant difference between the two test groups. On the other hand, a survey from the participants concluded that most participants which received sonification feedback, found the auditory feedback to have a positive effect on their actions [13].

3.5.2 **Tempo of resistance exercising**

A research regarding if tempo of resistance exercising has an impact on training volume showed that the tempo in strength training impacts training volume. In both terms of repetitions and total time under tension. Tempo is often formatted with four different times, in the following format:

concentric movement / top paus / eccentric movement / bottom paus

In the experiment varied tempos were tested, which were categorized as follows: regular (REG) 2/0/2/0, medium (MED) 5/0/3/0 and slow (SLO) 6/0/4/0 [14].

4 Method

When developing the prototypes for this project, different methods have been used throughout the project which are introduced in the following sections.

4.1 Human-centered design process

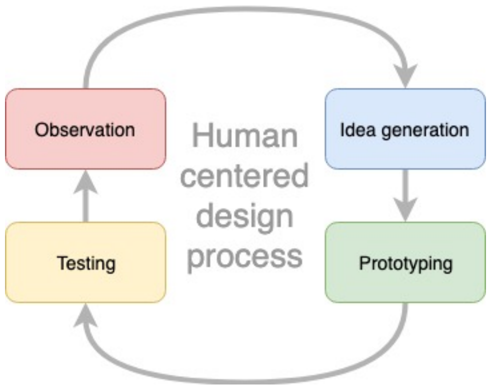

Figure 12, human-centered design process, an iterative design process from Don Norman's model [12]**.**

When utilizing the human-centered design process, it implicates an iterative design process, going through multiple cycles of the same process, see Figure 12. The design process includes four different steps: *observation, idea generation, prototyping* and *testing* [12]. What this essentially means is that the design adapts overtime, meaning that the project learns from its failures.

4.1.1 **Observation**

A product usually starts from an idea generated by an observation. This is also the first step of the human-centered process, where current behaviors in the area of intended product development is observed. The observations should have their focus on the current behavior of an end user [15].

For this project, an initial interview with engineers of different Sony IoT projects was conducted to find any patterns and issues which the projects had regarding their utilization of IoT data.

4.1.2 **Idea generation**

With the help of the observations from the interviews, an initial idea generation could be performed. Many insights were noted during the interview, laying the groundwork of requirements and potential ideas which could work as solutions for the project. The main method is brainstorming which is a creative method as well as a critical. The brainstorming method can be divided into two separate activities: *conceptual* and *physical design*. Conceptual design is an abstract outline of what users can do with the product, how they should interact with it. Physical design has its focus on the material part of a design, such as forms and colors [15].

4.1.3 **Prototyping**

In this project the prototyping is divided into two larger phases, *Lo-Fi* and *Hi-Fi prototyping*. Each part plays a major role in the development. Lo-Fi is a fast, cheap and efficient way of trying out prototypes.

In this project a more advanced form of Lo-Fi prototypes will be produced instead of the common paper-based prototypes. Instead presentations of illustrations with animations will be used. This additional layer of animation is needed for the prototypes since the intended solution of the project involves movement. Even though this might seem as a semi-Hi-Fi prototype, it will be developed quickly with the right set of skills in the appropriate software tools.

The Hi-Fi prototypes take more time to produce and hence are more expensive. These kinds of prototypes are used at the end of the development to be able to give a more realistic and functional prototype which could be compared to a nearly complete product. This will also be used for the final test at the end of the project.

4.1.4 **Testing**

To be able to continue iteratively, an additional feedback on the produced result is needed. This is a critical part where the developed design / product is being tested. Since this is a part of an iterative process, the testing will be performed multiple times, both in early stages as well as in the end of the project. The idea of early testing is to find as many errors as possible to reduce the project cost it would mean to address the same issues at a later stage.

There are different kinds of approaches of testing which works well in different stages of a project. *Explorative testing* is a testing method which can be used in the early stages of a project and works well to discover user flow of how to explore the product and how users understand it. *Usability testing* is another testing method which can be utilized, where participants are given tasks to perform while data is collected of relevant parameters for the product, such as time to complete the task, number and type of errors and completion rate. With the help of this collected data, a summary can show findings of the product which needs to be addressed and iterated for the next version of the project [15].

4.2 Brainstorming

Brainstorming sessions have been used multiple times during the course of the project. The most critical brainstorming session was during the initial ideation process which is later discussed in section 5.2. The brainstorming technique was also utilized during the workshop with the expert panel. At this point a review and testing of the current prototypes were done and new solutions / ideas were brainstormed to solve the issues found.

4.2.1 **Mind-maps**

The initial ideation process utilized brainstorming with the help of creating mind maps of the system and how it worked, see Figure 14. A whiteboard was used to sketch different states and data points of the system, stating relations between them and which ideas that comes into mind. This gave ideas and concepts of how different solution could be made. To document these mind maps, photos were taken with a mobile phone, as well as documentation in a log document.

4.2.2 **Workshop**

The workshop was split in to three parts, where the first part was the background of the thesis project. This was used to inform the participants of the workshop about the thesis questions, earlier work as well as the structure of the Advagym system. With this provided information, the second part, an introduction to the generate prototypes were presented and tested. Together, the workshop group analyzed the prototypes and continued to the final part where a new brainstorming session was used to address the findings of the recent analysis. The result and actions of the workshop was noted and sent out as meeting minutes, but also logged in the log document.

5 Lo-Fi development

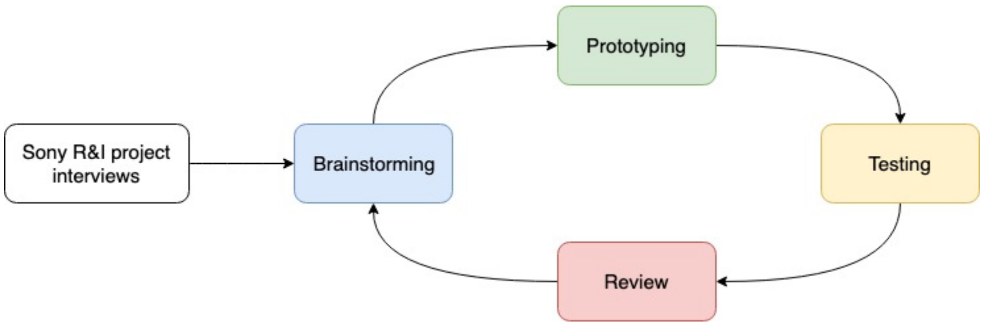

Figure 13, illustration of the Lo-Fi development process.

The design process followed an iterative process throughout the whole project, going from four different phases: *brainstorming, prototyping, testing* and *review*. See *Figure 13*. This continued after the Lo-Fi development on to the Hi-Fi development. Though at the very start of the project, a pre-study with interviews of Sony IoT project was conducted.

5.1 Sony IoT projects interviews

Before the initial ideation process an interview was conducted with four participants, each of whom was a member of different IoT projects at Sony Mobile Communications R&I department. The different projects were:

- *Project 1* – Indoor positioning of different objects and assets, such as tools, staff and patients, making it easier to find every tracked object/asset. Showing usage statistics, heatmaps, travel distance and allowing for optimization of object/asset placement. Main users are hospital staff. The interaction is through a web application.

- *Project 2: Advagym* – Digitalizing gyms. Utilizing exercise data and client interaction. See section 3.3.

- *Project 3* – Tracking of goods in the logistics branch, giving continuous tracking data of a transport with sampling. Tracking what happens to the goods on the transportation. Verify and support estimated time of arrival. Main users are the purchasers of the transportation, usually a closed loop company transport system. The interaction is through a web application.

- *Project 4* – Service for IoT device management. With great focus on customization and security. Management support of real-time data. Aimed to help other Sony R&I projects to accelerate. Main users are other Sony IoT projects, and the only interaction is through their APIs.

The four interviewed staff members from each project were males between the age of 42-53, with roles such as software architect, founder, lead software and project manager. The interview was structured in a semi-structured interview with fixed questions to answer, but also additional follow up questions based on their answers. Following questions were asked during the interview:

- What is your system's solution?
- Who are the users of the system, and how do they interact with the system?
- What kind of IoT devices and sensors are being used?
- What kind of data is gathered from each device?
- Is there some data reduction? If so, how is it done?
- Is there any IoT data not being utilized? If so, why?
- If not IoT data is being utilized, can you see some way of finding use for it?
- If all IoT data is being utilized, do you see any potential in adding additional sensors for more data gathering? If so, what and how?

The duration of the interviews was between 15-45 min. The findings from the interviews are summarized in section 5.1.1 and 5.1.2.

5.1.1 **IoT devices and sensors being used**

Since the projects have different kinds of purposes, different IoT devices are being used as well. Project 4 is not an IoT project itself, and rather a support tool for IoT devices and is mentioned earlier, hence is not using any IoT devices. The Advagym project is described in section 3.3.

Project 1 is mainly using bluetooth tags and beacons but are using some sensors which can measure e.g. battery voltage. The tags and beacons themselves acts in a way as sensors. Broadcasting data of their location. Together with a gateway, which listens to the broadcast, this can be connected to the cloud and presented for the users.

Project 3 uses only one IoT device, though with different models, which itself is directly connected, not going through any gateway. Sending data to the cloud with intervals about the transportation, such as position and tracked events.

5.1.2 **Data gathered**

Different data is gathered for each project and being utilized in different ways. This is of course mainly because of the different system purposes and different kinds of IoT units and sensors being used. Once again, the Project 4 is not relevant for this part and The Advagym project is described in section 3.3.

Project 1 are tracking where their tags are placed, their battery voltage and signal strength. Even though temperature sensors exist on the IoT device, this is not being tracked. Temperature measurement data is nothing that is prioritized currently, but is being looked into, for future features to track cold chain. Cold chain is used to verify that a product is being kept at a certain level of cooling for a specified amount of time, e.g. transportation of blood bags. The signal strength is only relevant to track the position of the tag; hence this data is ignored afterwards and not saved or tracked. This data reduction is performed in the cloud to be able to change the algorithms in the future. An attempt for machine learning approach of the solution has been tested, but discarded since it requires training data, but the system needs to work directly after the installation. Instead a calibration is done. The project would also like to add additional sensors to be able to track if the object/asset is on the move currently with more precise data and less delay.

Project 3 is tracking Global Navigation Satellite System (GNSS), Cell-ID, temperature, battery and accelerometer data from sensors. But are also tracking the connection time and boot events during the transportation. Acquisition time and boot event currently not being utilized. This could give additional information regarding what went wrong in the case of event failures. The project would like to utilize more of the accelerometer, since this is not fully being utilized. Using the accelerometer data to track events such as sharp breaks of the truck transporting the goods. Currently some of the sample data of the accelerometer is thrown away if the device's free space on the memory is low. These discards of samples are being randomized, and hence the data reduction is randomized. Artificial Intelligence (AI) is not interesting for data reduction on the unit, but the technology is relevant for the cloud, to detect waypoints and avoid clustering.

5.1.3 **Summary of interviews**

The different R&I projects which actually uses IoT devices at Sony Mobile Communication AB, seems to not, fully utilizing their IoT data currently. Either doing data reduction or just not using tracked data. All projects are aware of this, but it is a priority issue, rather than not knowing what could be done with the data. With this knowledge and inspiration, the initial ideation process could start.

5.2 Initial ideation

The initial ideation started off with knowledge of how other projects than Advagym has done and wants to do in the future. This laid the ground work of what could be expected and set as goal for the prototypes.

Continues meetings with the engineers of Advagym, especially the main embedded system engineer, were held to understand the constraints of the current hardware and system. Discussing the events and broadcasts, mentioned in section 3.3.1. This was especially important for the brainstorming of conceptual prototypes.

Multiple brainstorming sessions were held using a whiteboard, see Figure 14, where conceptual ideas were sketched out. After discussion and sorting out the possibilities of different data presentations the choice of prototyping real-time data feedback was chosen. The reason for this is that a real-time interaction would give Advagym an extra edge to it, as well as it fits well with IoT units giving real-time feedback using sensors for user’s movement.

Figure 14, picture of brainstorming session with a whiteboard.

5.2.1 **FRTF – Faked-Real-Time-Feedback**

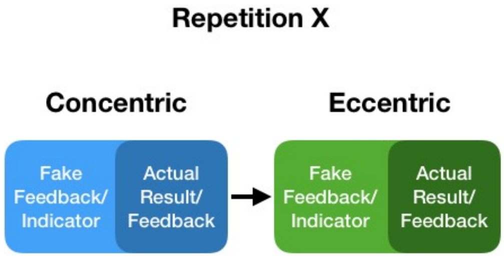

Figure 15, FRTF illustrated for the repetition x, where x is the current count of repetition in a sequence (set) of repetitions.

One of the approaches of this interaction was influenced by a somewhat misunderstanding of how the hardware worked which later on was realized not being possible. The misunderstanding was regarding the timing and number of broadcasts which the main unit had. Giving the faulty understanding of the system, that a broadcast was performed shortly after every peak and valley of a repetition, meaning that there should be two occasions during a repetition where the prototype could receive data. At the middle of the repetition, at full concentric movement, and at the end, at full eccentric movement. This misunderstanding led to a conceptual approach named "*Faked-Real-Time-Feedback*" (FRTF). This approach could not be implemented with the current hardware constraints. Which was realized later on in the design process.

The solution behind FRTF would be to start an animation for the concentric movement with a fixed value for the speed. And as soon as the "feedback" from the repetition was received as a data broadcast, this would update the animation, see Figure 15. Speeding up or slowing down to match the real-world movement with the one displayed as an animation. This would be done as well on the eccentric movement and continue for every repetition. This solution could potentially trick the user of thinking that the system was in real-time even though only two broadcasts were done. Multiple conceptual designs for FRTF solutions were generated during the brainstorming sessions, see Figure 16.

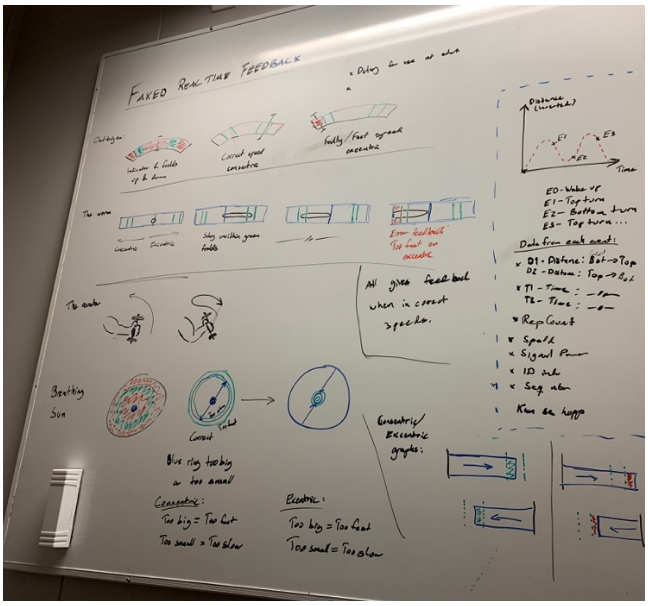

Figure 16, picture of the whiteboard om brainstorming FRTF.

5.2.2 **DRTF – Delayed-Real-Time-Feedback**

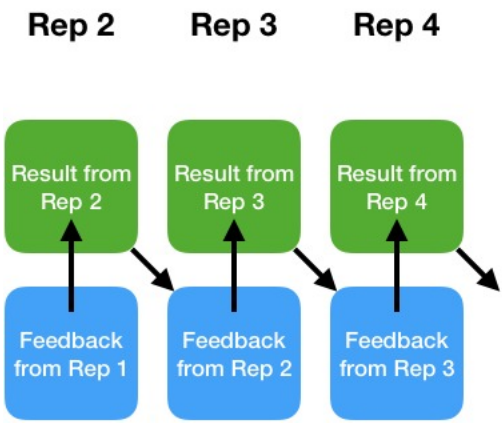

Figure 17, DRFT illustrated for the repetitions 2-4.

The other conceptual approach was *"Delayed-real-time-feedback"* where the interaction is based on receiving feedback after performed repetition. Meaning that for every repetition made, a feedback is given based on the user's performance for the previous repetition, so he or she can adapt to the feedback and adapt/improve for the next repetition, see Figure 17. This compared to FRTF was possible with the constraints of the hardware. Though later on during the prototype process it was also realized that some of the FRTF approaches would also be able to work as DRTF solutions. This solution resembles a personal trainer's way of giving feedback after a performed repetition and has the potential to be good enough "real-time feedback". Multiple conceptual designs for DRTF solutions were generated during the brainstorming sessions, see Figure 18.

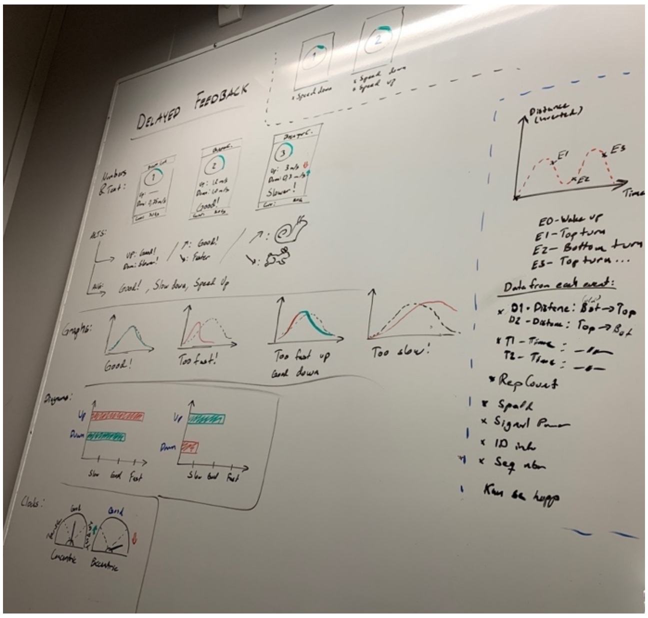

Figure 18, picture of the whiteboard when brainstorming DRTF solutions.

5.3 Prototyping

After the brainstorming session the first prototyping session was held. During this part of the process, the ideas and conceptual prototypes from the brainstorming sessions were converted and structured down to illustrations and texts explaining the prototype. An additional element of animation was used to even better illustrate and present the prototype. This was done with the presentation software "Keynote" on MacOS from Apple. The reason for this was to prepare for the workshop which was held as a testing and review part of the design process. All the ideas and conceptual designs were summarized in to eight different prototypes.

The presentation of the workshop was structured with an introduction and background to how the Advagym system worked and which IoT data that could be utilized and why. Following were the prototypes, which were divided into the two different interaction approaches, FRTF & DRFT, with four prototypes each to present.

5.3.1 **FRTF Prototypes**

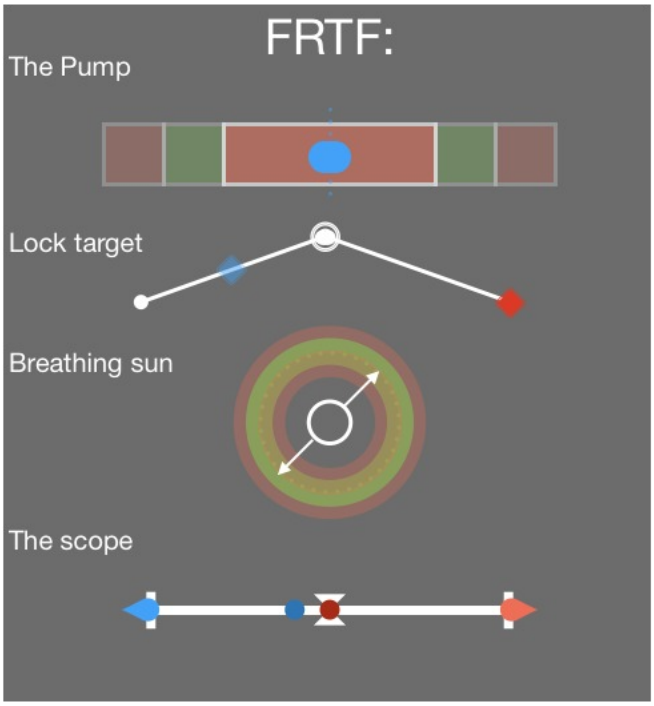

Figure 19, the FRTF prototypes for the workshop.

Every prototype has one or more indicators. The indicators are fake representations of your real-time motion (the definition of DRTF), and the feedback is displayed once the data is received from the main unit. The four different FRTF prototypes, see Figure 19, were:

The Pump – An indicator starting in the middle going from the left to the right based on where in the exercise movement the user was. In the background there are red and green fields for both the right and left side. The concentric movement is to the right, meaning that if the user performed correct speed on their concentric movement, the indicator would stay and turn in the green field. If the user were too slow, the indicator would not cross the green field, and instead stay and turn in the red field before. If the user were too fast, the indicator would pass the green field and enter the outer red field. The same logic would work for the eccentric movement, hence being able to present feedback on both movements and clarifying which type of correct or incorrect movement was done (correct, too fast or too slow). The metaphor is "a pump" in the sense that if the user pushed too hard, "the pump indicator" would have too much "pressure" going beyond the target. As well as if the user did not push hard enough, "the pump indicator" would not go far enough.

Lock target – Two different indicators going from left and right, to a target in the middle, one at a time, where the goal was to get both of the indicators to stay in the middle. One indicator represents the concentric movement, and the other the eccentric movement. The same logic of performing the motion too fast or too slow as in *"The pump"* is used for this prototype. Meaning that if the motion is too slow the indicator would not go far enough to hit the target, or too fast it would pass the target and go beyond.

The Breathing Sun – Has a circle indicator which starts in the middle with a fixed, smaller size. During the concentric movement, this circle indicator expands out to a targeted goal are in the form of a circle with larger border width. The goal is to get the indicator to fit and stay in the circle area. Going too far out means that the movement is too fast, and not far enough means that the movement was not fast enough. After the expanding – concentric motion, follows the eccentric movement where the circle indicator instead shrinks down, with a new target inside of the circle indicator. Same logic is applied here for the motion feedback. The metaphor for this prototype was "the breath".

The Scope – Works in a similar way as the prototype *"Lock target"* but with a different design and somewhat other elements to it. Instead of a bent design, a fully vertical line is used. The indicators do not stay at the result, instead they always go beyond and once the data/result is received, the feedback of performed motion is displayed with a dot. A more delay friendly prototype.

5.3.2 **DRTF Prototypes**

Every prototype has its aim to give feedback after a repetition, hence no indicators are being used, only giving feedback on the performance of the motion with different approaches. The four different DRTF prototypes, see Figure 20, were:

Nbr & Txt – Displaying the result of the repetition of the performance with the help of either numbers, which is the exact concentric and eccentric speed of the repetition, or text. That summarizes and grades the performance, giving feedback such as "Too fast", "Too slow" or "Good!". This could be done for both the concentric and eccentric movement or summarized to an overall speed (number) or grade (text) for the whole motion. Different approaches and suggestions for displaying which feedback is for the concentric and eccentric movement, such as using words as "Up / Down" or icons pointing up or down.

Graphs – Displaying the result with a graph of the motion with two axis. The vertical axis for time and the horizontal axis for distance. Showing the range of motion (RoM) for the repetition. The graph itself is divided into two parts, one for the concentric movement and one for the eccentric movement. Each part is graded to be either slow, fast or good. If it is graded slow, the graph part is drawn as a longer and less inclined line. If it is graded fast, the graph is drawn as a shorter and inclined line. If it is graded good, the graph is drawn as the optimal model. In the background the aimed model is always displayed as a dotted graph with low opacity. An additional color coding for the result graphs are also used, with either green color for a correct speed or red color for an incorrect speed. The result graph is drawn after a performed repetition.

Bar Charts – Displaying the result with the help of graphs with two different bars. One for concentric movement and one for eccentric movement. With the goal to have both bars in the middle, not being too small (slow) or too large (fast).

Clock – Displaying the result with the help of one or two “clocks”. One for each movement (concentric / eccentric), or one summarized clock for the whole movement. In the clock an arrow indicator points to the left, top or right, based on the grade of the motion. If it is graded too slow – left, good – top, or too fast – right.

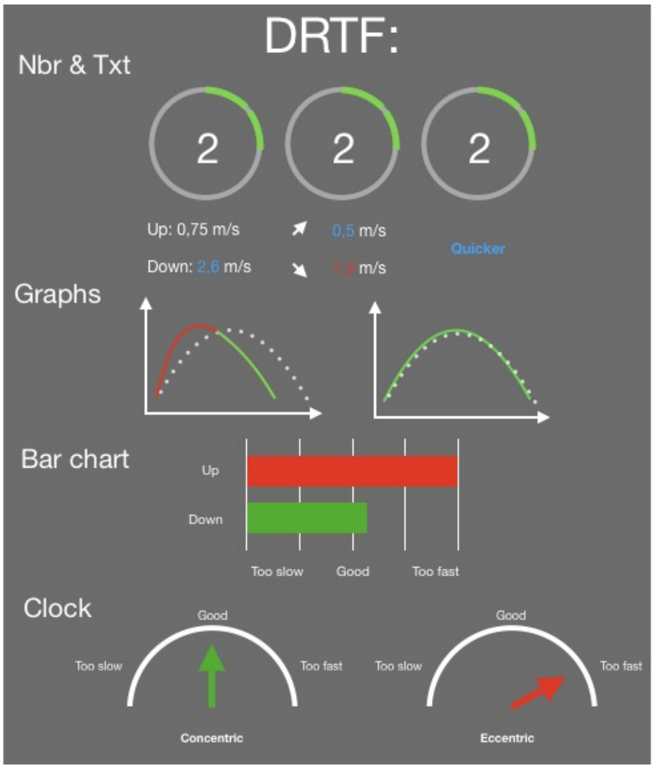

Figure 20, the DRTF prototypes for the workshop.

5.4 Workshop

For the workshop both the supervisors of LTH and Sony were invited, as well as the project owner and designer of Advagym. The purpose of the workshop was to continue the design process by testing the prototypes on the participants of the workshop and then review them together. The participants of the workshop also worked as an expert panel which helped refine and decide which of the prototypes should be tested further. The workshop hence worked as test, analysis and prototyping phases.

The outcome of the workshop was new findings in the form of flaws for the different prototypes. This insight helped refining the prototypes chosen as well as coming up with one new. Eight suggested prototypes went down to five with the help of the expert panel. After the workshop the procedure for a more detailed test of the Lo-Fi prototypes was planned.

5.5 Lo-Fi testing

After the workshop the prototypes chosen were refined and further animated to work in a short test session. Once again with the help of Keynote. The prototypes which were tested are described in next sub-section.

5.5.1 **Prototypes to be tested**

The five different prototypes chosen from the workshop to be tested are the following:

Prototype A – Pendulum and text, see Figure 21, is a further development from the DRTF prototype *"Nbr & Txt"* where an additional indicator at the bottom has been added. The indicator works as a pendulum, going from left to right, and back again. The intended goal of the indicator is to help the user find the tempo and speed of the exercise on both the concentric and eccentric movement. Following the indicator in both movements should guide the user to the correct speed in both movements, and hence help the user more easily get the positive text feedback of "Good!". The text feedback itself is a summary of the whole movement. During the workshop it was concluded that *"less is more"* and it would suffice with feedback on the whole movement of an exercise, rather than on both concentric and eccentric movement.

Figure 21, prototype A, pendulum and text.

Prototype B – Pumping ball, see Figure 22, was a new prototype created on the workshop where the metaphor was based on an old movie about astronauts, where the astronauts had to blow in to a tube which pushed a ball up in a cylinder. If the ball was kept with a certain pressure from the blowing air, it would land and stay on a certain field in the tube. Same logic goes into prototype B, as when the user trains with a certain speed for both concentric and eccentric movement, the ball will stay in the “correct fields” which are marked with dotted lines. This prototype is in many aspects like the FRTF prototype “The pump”, but instead a horizontal and different approach.

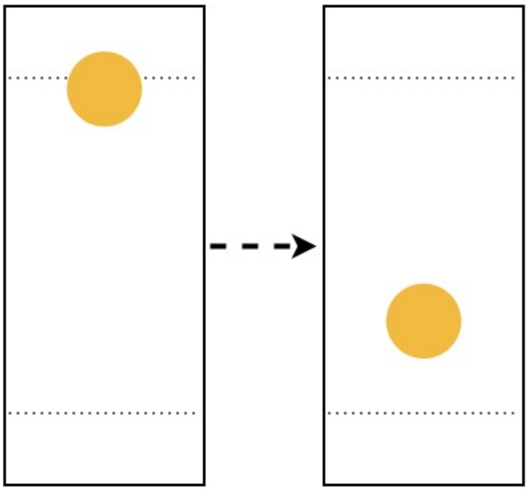

Figure 22, prototype B, pumping ball.

Prototype C - Graphs, see Figure 23, is the exact same prototype “Graphs” from the workshop. An DRTF prototype to be tested and compared to the other prototypes.

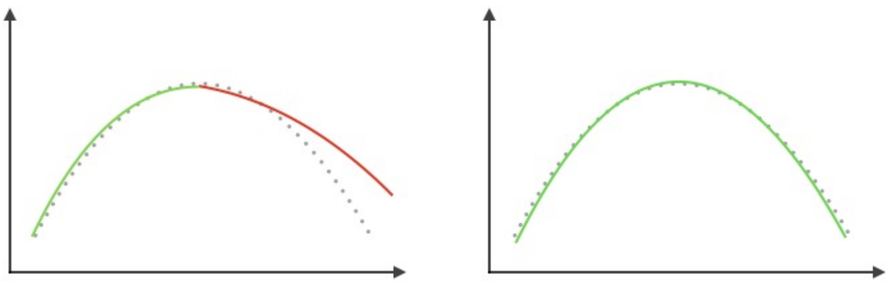

Figure 23, prototype C, graphs.

Prototype D – Breathing circle, see Figure 24, is the exact same prototype "Breathing sun" from the workshop. An FRTF prototype to be tested and compared to the other prototypes.

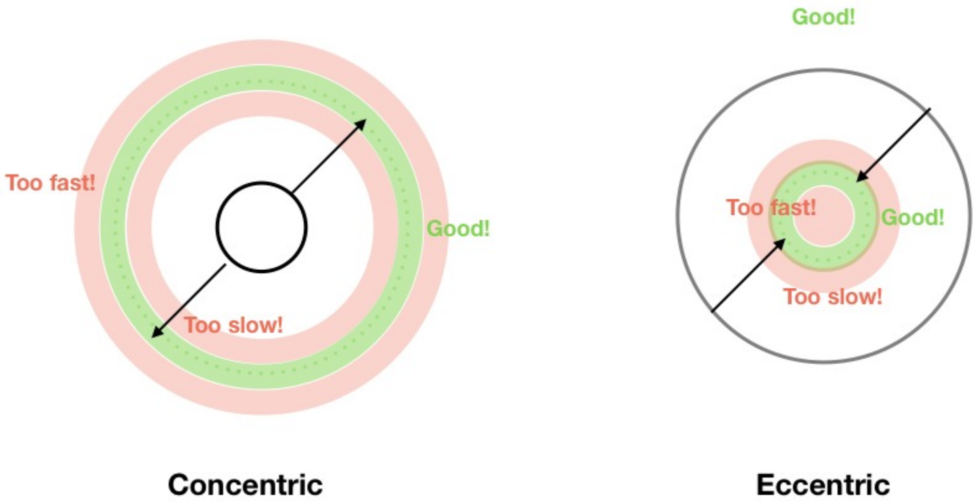

Figure 24, prototype D, breathing circle.

Prototype E – Clock, see Figure 25, is the same prototype as presented in the workshop, with the same approach as Prototype A, *"less is more"* and it would suffice with feedback on the whole movement of an exercise, meaning that only one clock is being used for the whole movement, rather than two for the different parts.

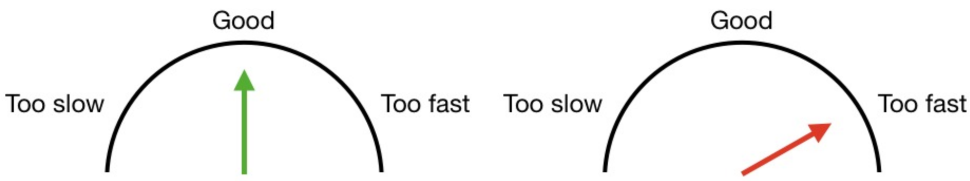

Figure 25, prototype E, clock.

5.5.2 **Lo-Fi test structure and result**

The Lo-Fi test had ten participants, of which five were “advanced participants” meaning that they already knew the system and how Advagym works. All of these participants are male members of the Advagym development team and was recruited on development site. The other five participants are “beginner participants” (four males, one female) that have not used Advagym before and might even be new to the gym experience. These participants were recruited “on the fly” at a local gym. The different participants are anonymous and has been labeled “A-TCX” for advanced test case and “B-TCX” for beginner test case, where X is for a number between 1-5.

The test took between 10-20 min and was conducted either at the Lund Sony office or at the local gym nearby, depending on which participant it was. Before the test each participant was briefed with relevant information to give every participant the same knowledge before the test, allowing every participant to know the same amount knowledge before the test so this would not influence the results. Following things were explained for every participant:

- Machine exercise – How it works with an example of the biceps curl machine.
- Exercise motion – What concentric and eccentric movements are.
- Velocity – The velocity matters in your training, meaning that different velocities for different purposes can be utilized.

Every test had a different test sequence in which order the prototypes were to be tested. The “*Latin square”* method was used, which is a method used to structure test sequences to ensure homogenous experimental conditions [16]. The Latin square for this test is a 5x5 matrix, see Table 2, because of the five different prototypes. This test sequence was used once for the beginner participants as well as once for the advanced participants.

Table 2, Latin square based prototype order, where TC stands for “test case”.

TC:	Prototype Order				
TC1	A	B	C	D	E
TC2	B	D	A	E	C
TC3	C	E	D	B	A
TC4	D	A	E	C	B
TC5	E	C	B	A	D

Every test case tested each prototype, but in different order as mentioned above. For every prototype tested, the following questions were asked:

- What is shown?
- What does the different parts of the illustration represent?
- Was it easy to understand?
- Explain how it works!

Based on the answers of these questions, a grade of the participants understanding was set to each prototype. The grade was based on the criteriums in Table 3, where the highest grades were rewarded with the score 1, and the lowest 0. There are five different grades. The reason for this is the sufficient difference between how the participants understand the prototypes. Meaning that there would be a difference in the result if a participant e.g. understood the prototype completely or not completely.

Table 3, grading of understanding on a prototype in the Lo-Fi test.

Grade	**1**	0,75	0,5	0,25	**0**
Criteriums	Mentioned exercise speed of both movements and could define which cases were correct and incorrect speeds.	Mentioned exercise speed of both movements and could define which cases were correct and incorrect speeds. But had some form of misconception.	Mentions the speed of a movement. Had issues describing how it worked.	Has misconceptions of how the prototype works.	Do not understand the prototype at all.

The result of the ten test cases are presented and summarized in Table 4. The highest scoring prototypes are in bold and were: C – Graph, D - Breathing circle and A – Pendulum and text.

Table 4, Lo-Fi understanding of prototype test result.

TC:	A:	B:	C:	D:	E:
A-TC1	0,75	0,25	0,75	0,75	0
A-TC2	0,5	0	1	0,75	0
A-TC3	0,75	0,25	1	1	0
A-TC4	0,75	0	0,5	0,75	0
A-TC5	0,75	0	1	0,75	1
B-TC1	0,75	0,25	0,5	0,75	0,75
B-TC2	0,75	0,25	1	1	0,75
B-TC3	0,75	0,75	0,75	0,25	0,75
B-TC4	1		0,75	1	0,5
B-TC5	0,75	0,25	1	0,75	1
SUM:	**0,75**	0,2	**0,83**	**0,78**	0,48

6 Hi-Fi Development

After the Lo-Fi prototypes were tested and evaluated the design process continued its iterative process with continuing with further prototyping. At this point the top three performed prototypes: A, C & D, were chosen to be Hi-Fi prototypes and later on tested.

6.1 Prerequisites

In this phase, additional knowledge of how the firmware of the hardware worked was discovered, hence changing the prerequisites of the prototypes. What was discovered is only one broadcast occurs for every repetition. This meant that the whole structure of FRTF would not work because of its definition. One out of the three chosen prototypes were in the form of FRTF, Prototype D – Breathing circle. The prototype pivoted and was adapted to the current firmware solution, and as earlier mentioned, it was realized that most FRTF prototypes could work as DRTF as well. The approach to solve the FRTF to DRFT conversion for Prototype D was to instead of having the circle indicator working as a fake representation of the user's motion and result, the circle indicator instead functioned as being a guiding indicator, equivalent to the pendulum indicator for prototype A. An additional element in the form of text feedback was added to be able to give feedback of the movement.

The prototype C, Graphs, was further developed in this phase. But eventually some issues concerning its conceptual design were found where it did not perform as well as wished. Once again because of the firmware constraints, where it was intended from the start that half of the graph would be drawn from the first broadcast and the other part would be drawn at the second broadcast. This caused a form of delay when drawing the graph which decreased the user experience. The performance of the prototype did not reach the desired standard.

6.2 Development

For the Hi-Fi prototype development, the development platform Xcode, provided by Apple Inc, was chosen. The reason for this was to use a mobile development platform which was easily accessible with good documentation. The different Swift libraries for development of animations was also recommended by the Advagym development team.

As mentioned, the prototype application was chosen to be developed with Xcode which uses the objective oriented language Swift provided by Apple Inc. A development library provided by the iOS development team at Advagym was also provided. This library supplied solutions on receiving the broadcast BLE packages from the Advagym units. With the help of the library, events could be triggered when a data package was received, which then could be processed by the application. This laid the very foundation of the application.

The application was structured to be as easy as possible to test the different prototypes. To do this the first view was intended for the moderator, where he / she could choose which prototype to be tested. Each prototype had its own view which was accessed from the moderator view.

6.2.1 **First iteration**

The first iteration of the Hi-Fi prototypes was made very simplistic. The goal with the first iteration was to create all the main components of each prototype, as seen in see Figure 26, each prototype has its main element implemented. For *the Pendulum* to the left of Figure 26, has a red dot with a surrounding bar. The surrounding bar worked as an outline of where the dot could move. This was one of the findings from the Lo-Fi testing where users were having trouble, knowing where the concentric and eccentric movement ended. An element for feedback text was added which is based on a predefined speed and tolerance rate. The last main element of this prototype is the repetition counter which has a circular form. It starts off being gray, but for every repetition a green fill line increases on a percentage based on how many receptions was predefined as the targeted amount, until the whole circle is green, incrementing the count as the receptions are being performed.

For *the Circle* prototype, which is in the middle of Figure 26, the same approach with an outline was used. An outer and inner circle was utilized as the outline for each movement. Where the outer circle, see the grayed circle with a dotted stroke in the middle prototype in see Figure 26, is an indication of how far the main indicator should go in the concentric movement before turning back and returning to an inner circle, with the same design (not visible in the figure) for the eccentric movement. The other element here is the repetition counter which looks a bit different from the circular approach in the pendulum prototype. Instead a straight line was used, which worked the same with a gray background which was filled in with a green line in the same percentage fashion for every repetition of the target repetition amount.

For the last prototype, to the right of Figure 26, *the Graph*, a model line with a dotted gray stroke was used to show the targeted form of a repetition (the target model). After each repetition performed the prototype draw two connected lines which represent the result of the exercise movement. The left line for the concentric movement, and the right for the eccentric movement. Each movement's speed was graded based in a predefined target speed, where if the result was within the systems tolerance rate, a green line was drawn in the same form as the gray model. If the result was too fast, the line presented this in showing a steeper curve. If the result was too slow, the line presented this in showing a blunter curve. Both faulty results were also colored red. This way, the system could present feedback on both the concentric and eccentric movement. As earlier mentioned, this prototype, *the Graph*, was scratched after testing and evaluation of its performance.

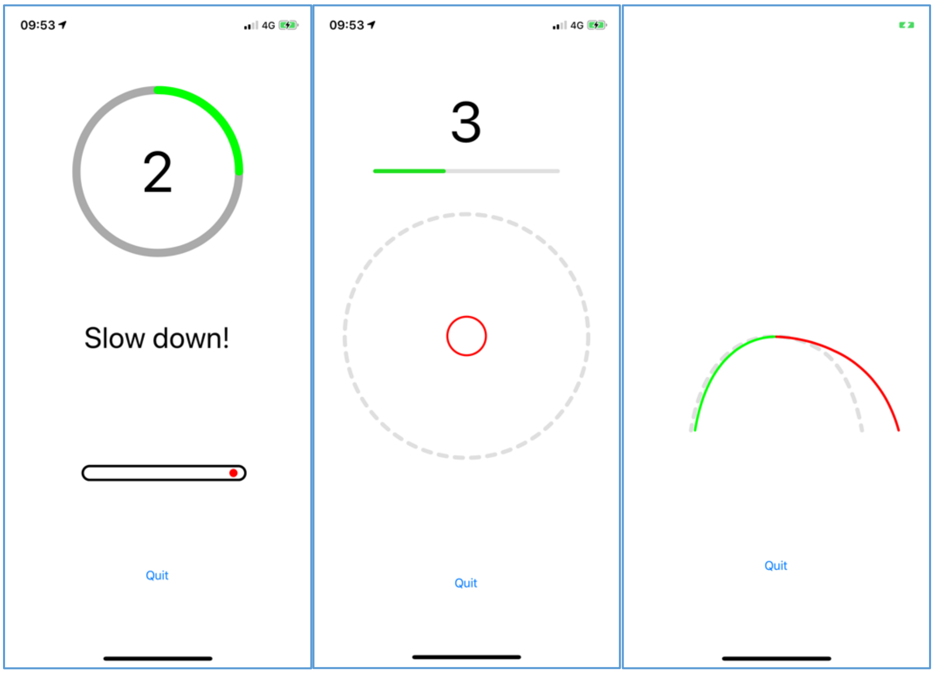

Figure 26, screenshots from the first iteration of the prototypes. From left to right: Pendulum and text, Breathing Circle and Graphs.

6.2.2 **Last iteration**

Once the main elements of each prototype was in place and continuous testing were performed to get stable prototypes, an updated visual design was added to each of the chosen prototypes, as seen in Figure 27 and Figure 28. Even the conceptual design was somewhat changed for the prototypes. A sub-prototype of the pendulum was developed where only text feedback is given on the movement of the performed repetition. The reason for this was to more easily and correctly be able to answer research questions of the thesis. Hence was the new prototype, see Figure 27, later on named as prototype “Text” developed.

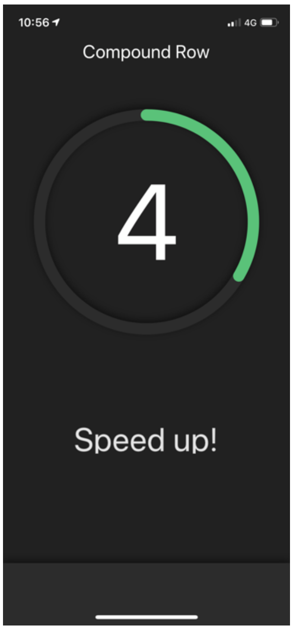

Figure 27, screenshot of prototype "Text".

The visual update, which was mentioned earlier, is in the form of adding design patterns with colors and forms which the Advagym application uses. The reason for using resembling design is to make the prototypes as realistic to the current system as possible, as well as making it easier to be adopted by the Advagym application in future development, if desired by the Advagym development team.

For the pendulum prototype the red dot and outline was replaced with a green dot with the same pendulum movement. In addition, discrete dots in the backgrounds worked as the field and outline of the area which the dot moved. The animation of the movement also triggered the dots, creating a more dynamic animation, making the pendulum feel more like something moving with force in a direction, see left part of Figure 28, instead of a dot moving back and forth. The repetition counter was modified to match the design of the Advagym application. The text feedback was positioned better in relation to the surrounding elements as well as given an additional animation for appearing and disappearing, where it increases in scale and fades in, and after predefined time to match the repetition time, fades out.

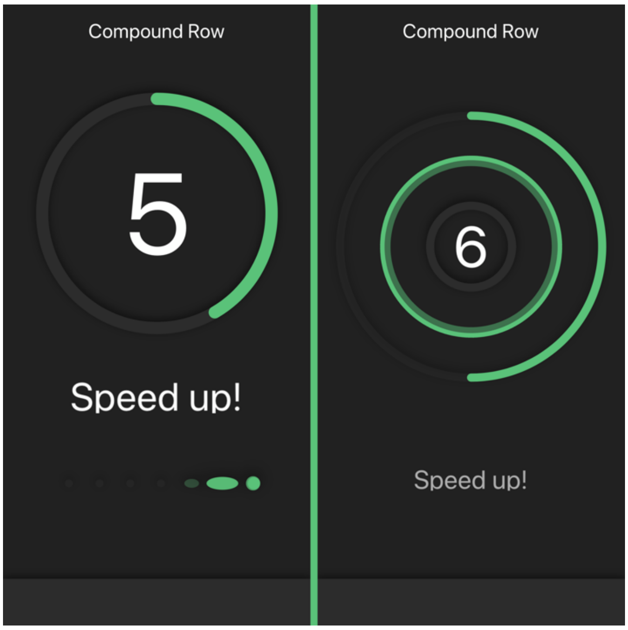

Figure 28, screenshot of prototype "Pendulum and text" and "Circle and text".

The circle prototype had some major changes to it as well, where the repetition counter and *"tempo indicator"* merged into one element. The outer indicator circle now serves as the repetition counter as well, where a percentage of the circle stroke is filled with green color for how many repetitions has been performed compared to how many is aimed to be performed. The same structure as the repetition counter for the pendulum. An extra visual was added to the circle tempo indicator, which is an outer stroke, that gives the user a sense of which direction the circle is going. If it is expanding or shrinking, concentric movement or eccentric movement. As an extra "feel good" animation, the outer repetition circle now also "pops" once the indicator circle meets the outer circle. It was shown during iterative tests that this increased the user experience, where the users felt as if the motion was more natural.

6.3 Test session support

One of the main goals developing the test application was to add as much support for testing the different prototypes as possible. The test application should be easy to use for any moderator, reducing any risk of operational mistakes during test sessions, easily changing between prototypes and getting a good overview of the tests performed. The test application should not only contain support for the chosen prototypes to be tested, it should also be able to log the result of every participants performance on every session. The logged data should also be easy to share and save on external databases.

The moderator view was designed after these requirements. For a new test session, the only thing a moderator could do was to enter the test participants name. Once this was done, the name was locked and the possibilities of choosing prototypes, repetition duration (the time of the indicator animation duration) and velocity goal (targeted velocity for grading of performance) was enabled. In the list of the prototypes all the different scenarios were displayed in a scrollable "ticker view", see Figure 29 to the right. The different scenarios of the test were: *No system, Personal trainer, Prototype text, Prototype pendulum and text, Prototype circle and text*. Once a scenario was chosen with the help of the choose button, a button to start the prototype is shown, allowing the moderator to start the scenario for that certain scenario. Now the test application is ready, and the scenario can start. Every scenario logs the result of the participant's performance. Once the first scenario is started, the values for repetition duration and targeted velocity is locked. Meaning that the moderator cannot use the sliders to change the values after a scenario has started. This was done to prevent any human errors by the moderator, changing the values by mistake during a test scenario, corrupting the result of the test since it then would not be the same for every scenario.

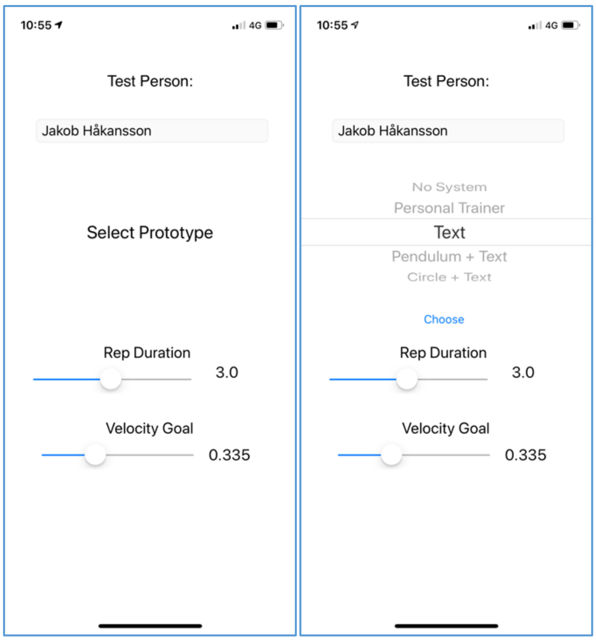

Figure 29, the test application's admin overview.

Once the scenario is done, the moderator picks up the smartphone and taps three times on the screen to get a dialog to leave the current scenario and return to the moderator view where he or she can pick a new scenario to test. Once one scenario was performed, and overview of which scenarios that have been performed were displayed at the very bottom of the screen. This worked as an additional aid, to help the moderator keep track of which scenarios were completed.

Once the whole test session was complete it is time to save and share the logs of the test session with the help of the “Share Logs” button. This was done through iOS standard sharing, see Figure 30 to the left, where a choice of application to share through was enabled, as well as copying the logs or saving it to files. The log is a simple string of text, and hence could be easily shared through different platforms. Once the test session data was saved / shared, the test application could be cleared from the current participant with the help of the “Clear Data” button, which gave an additional dialog for error prevention, see Figure 30 to the right. After the data was cleared, the test application was set to the initial state where the only choice is to enter a new participant name, meaning that it is ready for the next test participant. With this application structure, test can be performed rapidly with little downtime in between both scenarios and even test participants.

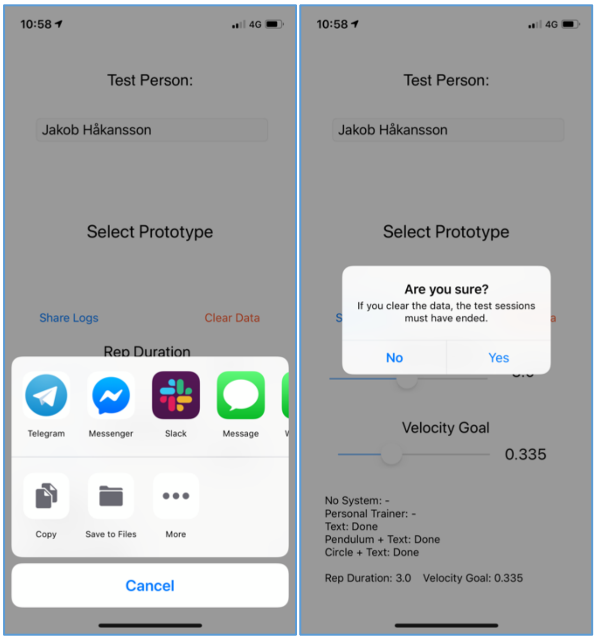

Figure 30, sharing and clearing the data result from a test session with the test application.

6.4 Testing

During the development phase of the Hi-Fi prototypes, continuous testing was conducted, following Don Norman's Design Process [12]. This was especially important at the end of the Hi-Fi development once all the elements of the prototypes were at place. Members of the Advagym project acted as the participants of the tests. The tests were very spontaneous, and the result was logged and used for further development. Comments and feedback from the participants were also noted to potentially improve the different prototypes. During these testing sessions the focus was mainly to "smoke out" possible bugs that can occur. But a big part was also the tuning of the applications parameters. Following parameters were tuned:

- *Target velocity* – Which velocity that was in an appropriate tempo for a light / moderate weight for a large amount of repetitions. The value was chosen to 0,335 m/s. This was an appropriate speed for the cable row machine which was to be used in the final tests. A slow pace which would be comfortable to hold for a large amount of repetitions with a low / moderate weight.
- *Animation duration* – Which animation speed the indicators should have to guide a user to the targeted velocity. The value was chosen to 3 s for the animation duration, which is the full motion of the exercise, meaning both the concentric and eccentric movement.
- *Performance tolerance* – Which tolerance rate of the users performed repetition speed, to be useful. The value was chosen to 0,05 m/s, which is a 15% tolerance rate.

7 User testing

Once the Hi-Fi prototypes in the test application was implemented, tested and trimmed for best performance, it was time to conduct the main test. The reason for testing is to be able to answer the research questions of the study. This started out by creating a test plan which contained the methodology of the test, which data is going to be collected, test procedure, resources needed and information regarding the participants of the test. Since Advagym's user group is broad, there were no predefined user group to target the recruitment of participants from. The number of participants for the test was aimed to be 48, but ended up with 50, which of were 30 male and 20 female, in the age interval of 15-55 years old.

7.1 Test methodology

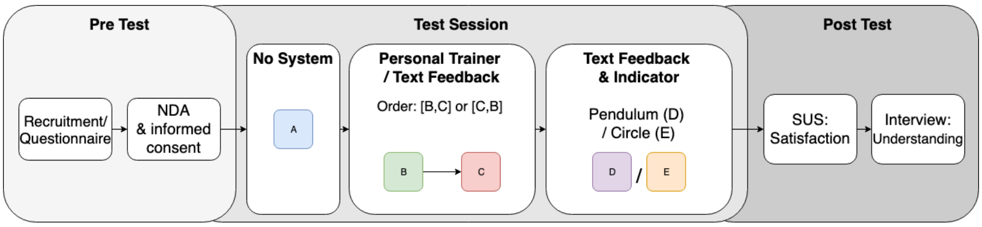

Figure 31, Illustration of test procedure process.

The test session was divided into three parts: *Pre-test, Test session* and *Post-test*, see Figure 31 for an overview. The test starts with the *Pre-test*, followed by the *Test session* and lastly *Post-test*.

7.1.1 **Pre test**

Pre-test was the stage of recruitment and initial meeting with the participants. In other words, the part before the actual test session itself. At this phase, participants signed up for the test with the help of an online questionnaire, while at the same time answering introduction questions about their profile, mainly focusing on their training pattern and knowledge.

The reason for this questionnaire was to more easily handle recruitment but also gather relevant data about the participants before the test, and not wasting valuable time during the session itself. Booking of participants was also based on this questionnaire, which allowed the participants to fill in which days and times that fits their schedule. Participants were then contacted by email and booked into a free time slot.

When the participant arrived at the test location, they were welcomed and escorted to a briefing room, which was Sony's User Experience (UX) lab, where they signed a Non-Disclosure-Agreement (NDA) and an informed consent to be able to continue with the test.

The pre-test phase also included a briefing before the test session. Following briefing information was given to the participant:

- *Advagym* – The test will have its focus on testing a new feature of the Advagym application, and not the whole application. Advagym is a solution from Sony which digitizes the gym with the help of connected units placed on gym machines. Users can interact with these with the help of their smartphone, using a smartphone application. This smartphone application, the Advagym app, can help you log your training, build training programs, statistics, instruction videos for exercises and much more.
- *Testing the system* – It is the system which will be tested and not the participant.
- *Questions* – The participant is free to ask questions at any time, but if these questions might influence the result of the test, the moderator cannot answer until after the test is over.
- *Free to leave* – The participant is free to leave at any time and will still get their reward.

7.1.2 **During test**

Once the briefing is done, the participant was taken to the test area which was the Sony office gym. An overview camera was rigged to record the test session. The reason of using an actual gym, was to get the most realistic case possible, as well as the fact that the Sony office gym is equipped with the Advagym system.

Once everyone was ready to start, the test session continued with a certain order.

7.1.2.1 Order

There were 5 different scenarios for the test with following alphabetical labels:

A. No System

B. Personal Trainer

C. System: Text

D. System: Text & Guide Pendulum

E. System: Text & Guide Circle

Each test session started to test A followed by B & C, but in different order:

1. [A,B,C]
2. [A,C,B]

With the goal of 48 participants, each order will have 24 participants. The reason for this was to find any relations between which order of scenarios/prototypes are tested.

Followed by the initial sequences of scenarios, either D or E will be tested, meaning only four scenarios per test session. And scenario D and E will be tested by 24 participants each. All the different sequences of test scenarios can be seen in Table 5 below.

Table 5, the four different sequences of test scenarios.

TC:	**Scenario order**			
TC1	A	B	C	D
TC2	A	C	B	D
TC3	A	B	C	E
TC4	A	C	B	E

7.1.2.2 Scenario

For each scenario the participant was asked to perform 12 repetitions on three different sets with a low/moderate weight and a rest time of their choice in between. The reason for this was to get sufficient data points to see any significant patterns. When one scenario was complete, the next scenario followed with the same test structure, continuing throughout the test.

Example: A → B → C → E → Done! See

Table 6 for a fully detailed example.

Table 6, example of test sequence, in this case with ABCE structure.

A -No System	B - Personal Trainer	C - Prototype: Text	E - Prototype: Text & Circle
A1). Set 1: 12 reps A2). Set 2: 12 reps A3). Set 3: 12 reps	B1). Set 1: 12 reps B2). Set 2: 12 reps B3). Set 3: 12 reps	C1). Set 1: 12 reps C2). Set 2: 12 reps C3). Set 3: 12 reps	E1). Set 1: 12 reps E2). Set 2: 12 reps E3). Set 3: 12 reps

7.1.3 **Post test**

After the test, the participant was taken back to the UX lab, where he/she was first asked to answer a *System Usability Scale* (SUS) based questionnaire. After the questionnaire, a short interview was held to gather subjective data/thoughts, such as:

- For each system prototype-scenario, explain how the system worked (mental model).
- For each system prototype-scenario, what info/feedback did you receive and why?
- Which scenario did you prefer and why?
- Do you prefer with or without a guide indicator?

This subjective data was later used with predefined criteriums to grade each participant on their answers, if they either *"Understand completely", "Understand somewhat"* or *"Do not understand"* regarding the prototypes. The criteriums can be found in Table 7.

Table 7, grading and criteriums for a prototype based on the interview answers.

Grade	Description
Understand completely	Mentions speed and amount of repetitions. Can explain correctly how the feedback is given.
Understand somewhat	Mentions speed. Have an idea of how feedback is given but could be somewhat incorrect.
Do not understand	Cannot describe how the prototype works sufficiently. Misunderstanding the speed of visual feedback.

After the interview, the whole test session is complete, and the participant was rewarded with a movie ticket.

7.2 Data collection

Objective and subjective data was collected during the test sessions. Data about the participants were collected from an online sign-up questionnaire. The sign-up questionnaire had questions concerning the participants training habits, such as frequency, intensity and type of exercise. This was later used to grade each participant on a physical active scale, more details in 7.6. Data concerning eventual impairments, such as sight defects or movement impairments was also noted from the online questionnaire. Giving the possibility to check with the participant before the test if he or she would find any discomfort with the test.

Once the test session had begun, the test application gathered data from the Advagym hardware's BLE broadcasts. The data recorded for each broadcast / repetition was following:

- Concentric velocity
- Eccentric velocity
- Average velocity
- Current set
- Repetition count

Grading based on defined velocity goal. Scale: *SLOW / GOOD / FAST*. For following:

- Concentric movement
- Eccentric movement
- Summarized movement

After the test session, the participants answered a questionnaire based on SUS. SUS is a "*Likert*" scale, *"a simple ten-item scale giving a global view of subjective assessment of usability"*[17]. The same algorithm used for the standard SUS was used to calculate the SUS-score for each prototype.

After the questionnaire was answered by the participants, a short interview was conducted. The interview was a semi-structured interview which followed a script of questions with the possibility of follow-up questions. The data collected was the answers from the participants which were compared to a predefined criterium to determine if the participants understood the system / prototypes or not.

Additional subjective data concerning the participants thoughts regarding the system was gathered as well. Such as general comments and thoughts.

7.3 Test procedure

The whole interaction, step by step, with the participants are described in Table 8. As well as the material needed for each step and the estimated time required.

Table 8, procedure table with description, material and estimated time for each step of the test's sessions.

Part	Step	Description	Material	Time
Pre	Sign Up / Online Questionnaire	To sign up for the test, participants use an online questionnaire	Recruitment: - Questionnaire ENG - Questionnaire SV	N/A
Pre	Briefing	Meet participant Participant sign NDA Profile info of participant	- Orientation script - Non-Disclosure Agreement - Profile questions	5-10 min
During	Testing: No System	Allowing the participant to do 3 sets of 12 repetitions without any system or aid.	- Orientation script - Logging Software - Documentation Hardware	4-7 min
During	Testing: Personal Trainer / Text Feedback	Based on the sessions dynamic structure, the order will be decided and executed	- Orientation script - Logging Software - Documentation Hardware	8-14 min
During	Testing: Prototypes Pendulum / Circle	Based on the sessions dynamic structure, the chosen prototype will be decided and executed	- Orientation script - Logging Software - Documentation Hardware	4-7 min
Post	Satisfaction SUS Questionnaire	Standard questionnaire to set a score for the usability and user experience	SUS: - Questionnaire ENG - Questionnaire SV	2-5 min
Post	Short interview: Understandability	Subjective data: preferred prototypes. Objective data: how much the participant understand the prototypes	- Interview script - Operational definition	2-5 min
			Total of:	25-48 min

7.4 Resources

The tests were held at the Sony Mobile Communication AB office in Lund, in the office gym which is equipped with the Advagym solution. Documentation of the active sessions was done through video recordings from an overview camera. As a reward for the participants were given movie tickets.

7.5 Test participants

7.5.1 **User group**

Advagym is an application with a very broad user group where young to old users are included. It can be beginners as well as elite trainers. The one thing they have in common is that they are training at a gym.

Because of this broad user group there were no restrictions on the participant profile besides being able to physically perform the test. Meaning that the participant should be able to perform the “cable row” exercise on a low/moderate weight, without any pain. As well as having good enough sight with/without aids, to see a 5.8” mobile screen, 1 meter away from the participant.

7.5.2 **Recruitment**

To more easily recruit participants, an online questionnaire using Google Forms, was used, which also served the purpose of gathering relevant profile information. In the questionnaire the participant could choose which times and days that would fit their schedule. The participant also left their contact information in form of an email which was used to contact, book and confirm a test session. When contacting the participant, information regarding the test was also given, such as test location, directions and the information that it would involve some form of low physical effort.

The sign-up questionnaire was spread through different channels, both in digital and physical form. In physical as a poster with QR-code links and direct links below, the poster and questionnaires can be found in the Appendix C and D. In a digital form as links which was sent mainly to social media groups 1-2 times during the recruitment timespan. Following social media group channels were used:

- *Sony Mobile Experience Lab* – A closed Facebook group where participants from other Sony Mobile Communication tests are invited as well as friends and relatives to participants or test conductors.

- *Lunds anslagstavla* – A Facebook group for events and happenings in the Lund area, which is the same area where the Sony office is located.
- *INT Alumni* – A closed Facebook group for older Swedish high-school students who attended the "*International program*" in Hässleholm where a lot of the older students has continued their studies in Lund.
- *D&&C* – 2014 – A closed Facebook group for students of Lunds Technical University who started studying MSc engineering in Computer Science or MSc engineering in Information and communication technologies.

The bookings were inserted to an online Google Sheets document which the supervisors and moderators of the test could view as the bookings were registered manually.

7.5.3 **Attended participants**

The aimed number of participants for the test was 48, to divide 12 participants for every four test cases which is explained in section 7.1.2.1. The number of participants ended up at $n = 50$, meaning that an additional two participants were found. This gave the test distribution seen in Table 9. Meaning an additional two tests were performed on the circle prototype (E).

Table 9, participant distribution on the four different test cases.

Test case	Number of participants
TC1 (ABCD)	12
TC2 (ABCE)	13
TC3 (ACBD)	12
TC4 (ACBE)	13

The gender distribution of the participants were 60% male and 40% female participants (n_m=30 n_f=20). The average age of the participants was 29, within the span of 18 to 55 years old.

To estimate and grade the training skill of the participants a sequence of calculations was made, based on their signup questionnaire answers. Taking following parameters to account: *weekly training frequency* and *time kept with current training frequency*. This was graded into a scale of 1 to 5 where the interval of 1 to 3 were graded as *beginner/novice training skill* and 4 to 5 were graded as *advanced training skill*. The approach to do this calculation, was to make an estimated calculation of the participants current weekly training, using Equation 1. Where the participants questionnaire answer was estimated to the lowest amount of sessions per week (s_l)

and then divided with the number of days per week. See conversion Table 10. This value was the parameter for the *weekly training frequency*.

$$s_l/7 = f_w$$

Equation 1, calculation of estimated weekly training frequency.

Table 10, four choices of weekly training frequency conversion to estimated training sessions per day.

Weekly training frequency	Estimated lowest number of sessions (s_l)	Estimated daily training frequency (f_w)
< 1	0,5	0,071
1 - 3	1	0,143
4 - 7	4	0,571
> 7	7	1,000

An estimation of the average (MEAN) amount of estimated training sessions for the *time kept with current training frequency* was now needed to be made. This was done with the help of the signup questionnaire answers from the participants where there were five different answers to choose from. The question were how long they have kept their current training frequency. This was used to estimate the amount of training sessions the participant could have performed, taking the MEAN number of sessions for the month interval. See Table 11.

Table 11, MEAN amount of estimated training session performed based on the months of current training frequency conversion.

Months of current training frequency	MEAN number of estimated training sessions (s_m)
0 to 3	15
3 to 6	90
6 to 12	180
13 to 24	390
24 or more	720

Now two parameters from both *weekly training frequency* and *time kept with current training frequency* have been made. Using these two parameters (f_w, s_m), an estimation of how many training sessions have been performed by the participants based on their answers as parameters. This was done with Equation 2.

$$f_w \cdot s_m = s_e$$

Equation 2, calculation of estimated training session on current frequency.

A conversion table for grading the participants training frequency score was made. The scale is from 1 to 5, where 1 is the lowest training frequency score and 5 is the highest. This conversion table was made by taking in to account of how many sessions it would possible take to learn and perfecting a physical motion, as well as which possible numbers that could occur from the questionnaire. Following requirements were used to create the table:

- It should be possible to be graded as an advanced training skill with high weekly frequency (seven or more training sessions per week) for an arbitrary period of time (six months or more), which will be estimated with Equation 2 to be 180 training sessions.
- It should also be possible to be graded as an advanced training skill with a moderate weekly training frequency (1 to 3 times per week) for a long period of time (24 months or more), which will be estimated with Equation 2 to be 103 training sessions.
- It should not be possible to be graded as an advanced training skill with a high weekly frequency (seven or more training sessions per week) for a short period of time (three months or less), which will be estimated with Equation 2 to be 15 training sessions.

With these requirements stated the Table 12 was created.

Table 12, estimated number of training sessions to training frequency score (1-5) conversion.

Estimated number of training sessions (s_e)	Training frequency score
0 - 16	1
17 - 51	2
52 - 90	3
91 - 181	4
181 +	5

The training frequency score was then divided into two categories, where the grades from 1-3 was categorized as a beginner/novice training skill, and the grades 4-5 was categorized as advanced training skill, see Table 13.

Table 13, training frequency score to training skill grade conversion, for the participants of the test.

Training frequency score	Participants	Training skill grade
1	22	Beginner / Novice $n_b = 31$
2	8	
3	1	
4	6	Advanced $n_a = 19$
5	13	

Each participant also answered in the signup questionnaire which type of equipment that they used if they were at the gym. The answers for all the participants of the test is summarized in Figure 32, where "None" represents the number of participants that does not go to any gym.

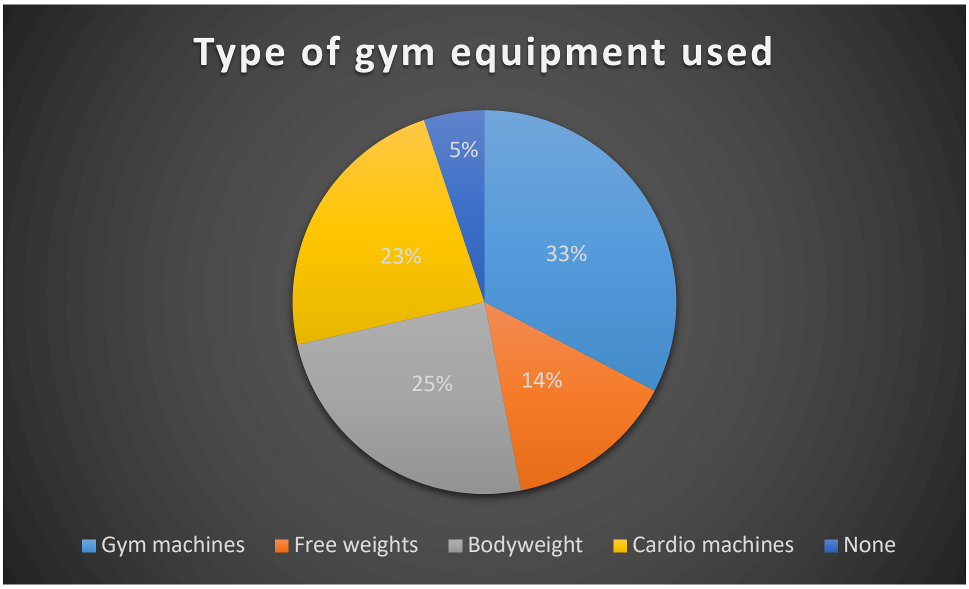

Figure 32, type of gym equipment used by the participants at the gym, n = 50.

7.6 Result

The gathered data from the test sessions were logged and analyzed continuously during the test phase. A summary of the result from both objective performance score and subjective usability score is presented in this section.

7.6.1 **Performance score**

The performance for every participant test scenario was logged and summarized. The performance data is based on the speed of the concentric (v_c) and eccentric (v_e) lift for a repetition, which was summarized and made into an average v_a speed of the lift, see Equation 3.

$$\frac{v_c + v_e}{2} = v_a$$

Equation 3, average velocity of a repetition.

This speed (v_a) was then graded *slow, good* or *fast,* based on the targeted velocity v_{tar} = *0,335 m/s* with a tolerance of v_{tol} = *0,05 m/s,* which is a sensitivity of *15%.* Meaning that v_a could be in the interval of [$0,330\ m/s \leq v_a \leq 0,340\ m/s$] to be graded as *"good"*. As mentioned in section 7.1.2.2, for each scenario 12 repetitions on 3 sets were performed. Because of hardware constraints, the very first repetition was ignored since no data was given for that repetition. Meaning that for 3 sets 11 repetitions, gives and total of 33 data points for every scenario on every participant. A percentage of the scenario was made, which represents the performance on that scenario by showing in percentage, *how many repetitions / data points were graded "good" out of the performed repetition on this scenario*. The number of performed repetitions should be 33, but in some cases the participants missed a repetition. This was taken into account for the calculation of the percentage score. The score of every participant's different scenarios was then summarized and presented in Figure 33.

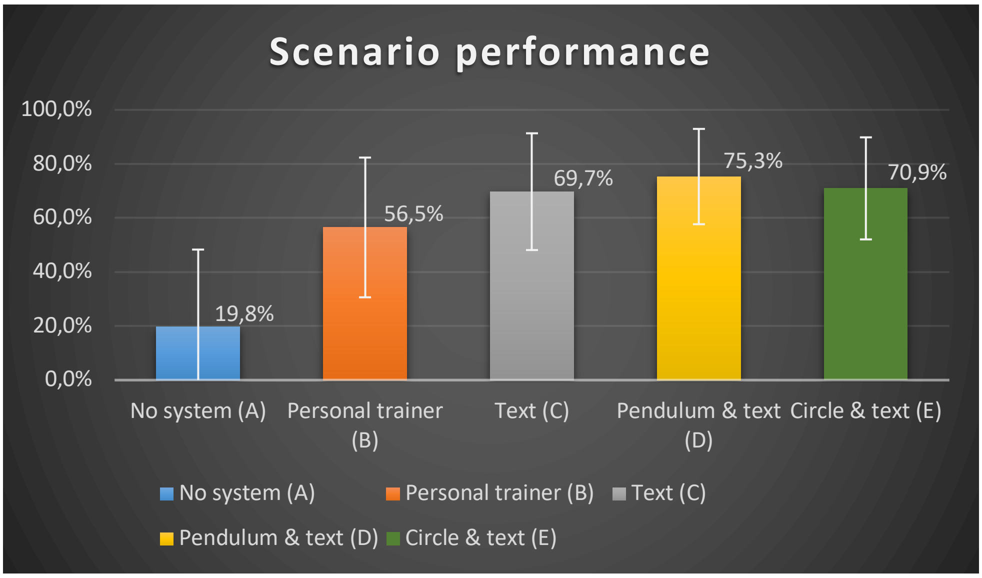

Figure 33, performance score in percentage (%) for every scenario of the test. With n_A = 50, n_B = 50, n_C = 50, n_D = 24, n_E = 26.

Since the test sessions were divided into four parts which followed in a sequence of sessions, it could be seen as a learning curve of how to find the targeted velocity. This is presented in Figure 34, where every test case is displayed from the first test scenario to the fourth and last test scenario.

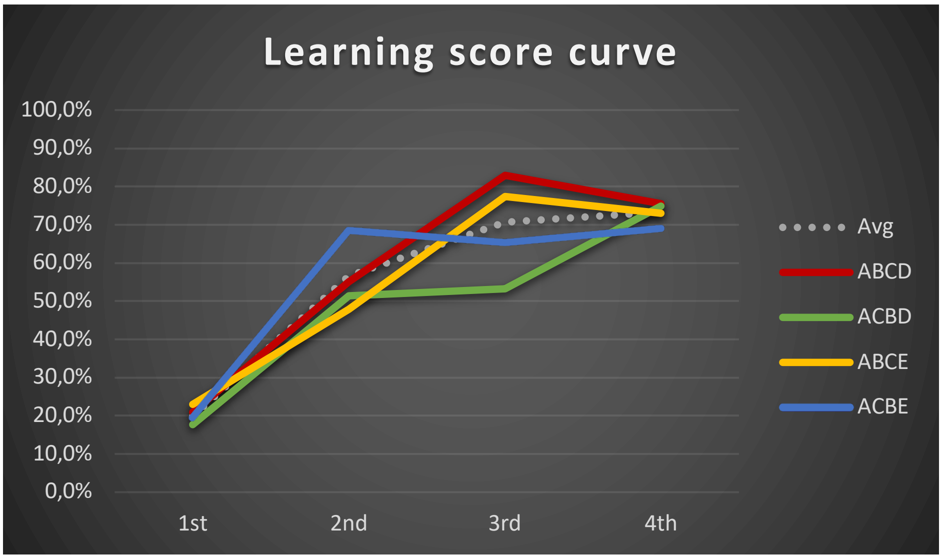

Figure 34, learning score curve of the four different test sequence orders, from 1st to 4th (last). n_{ABCD} = 12, n_{ACBD} = 13, n_{ABCE} = 12, n_{ACBE} = 13

In section 7.5.3 it was explained how the participants were split into two groups, based on their training skill: *beginner/novice* and *advanced*. The difference in the learning curve of these groups can be seen in Figure 35.

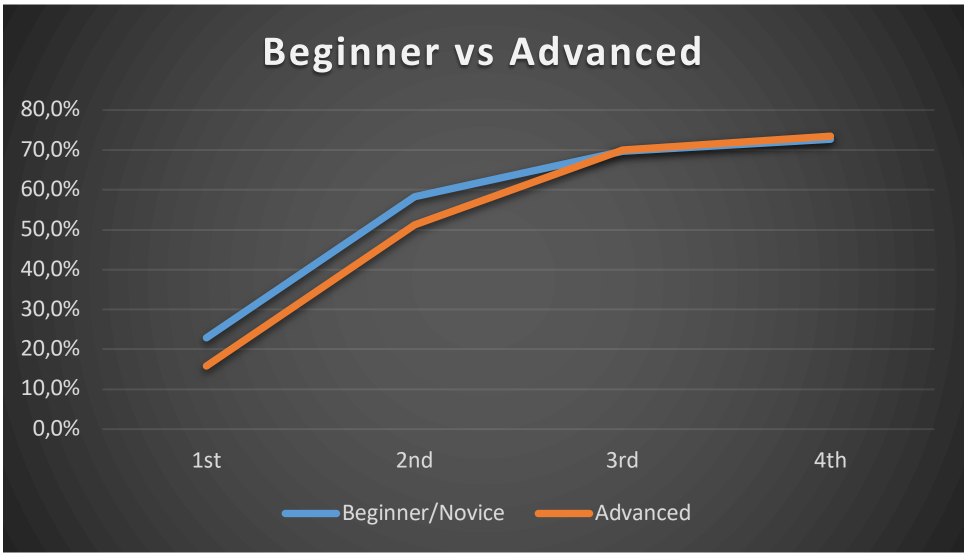

Figure 35, learning score curve difference between participants graded as beginners/novice and advanced in their training skill. n_b = 19, n_a = 31.

The four different test cases had different orders of the scenarios. Two of these test cases had the scenario with the *personal trainer* (B) first and then the *text prototype* (C). The difference in the performance score is displayed in Figure 36.

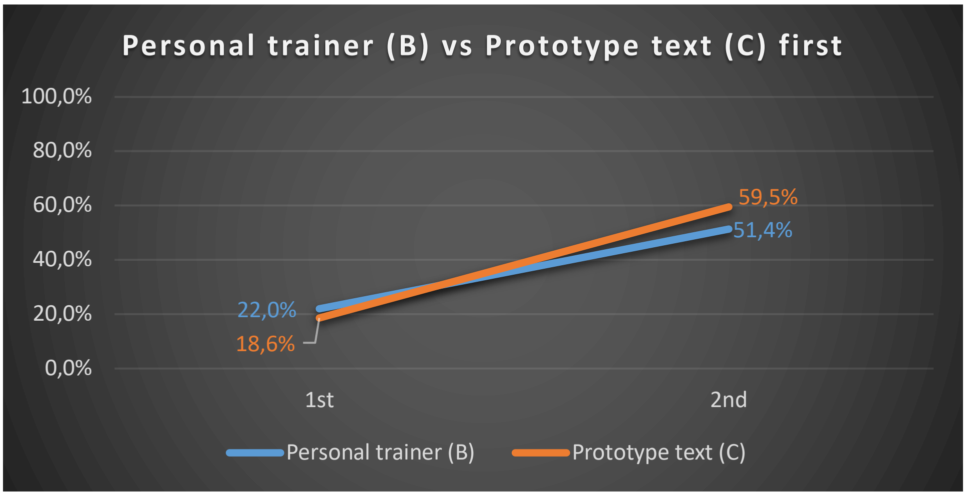

Figure 36, the performance score difference between having the personal trainer (B) scenario first (n_{BC} = 25) or the text prototype (C) first (n_{CB} = 25).

7.6.2 **Usability score**

After the test session, a SUS-based questionnaire was filled in by the participant. A short interview was also conducted. With the questionnaire and interview, subjective data was collected which could be quantified to a more objective form.

The SUS-based questionnaire's results are displayed in Figure 37, where each prototype's SUS score is displayed. The score is an average score of every participant's answers on the questionnaire. The questionnaire can be found in the Appendix B. This can be used as an indication of how well the prototype was received by the user, as well as giving an quick insight how the usability of the prototypes were, where a score above 68 is good [17].

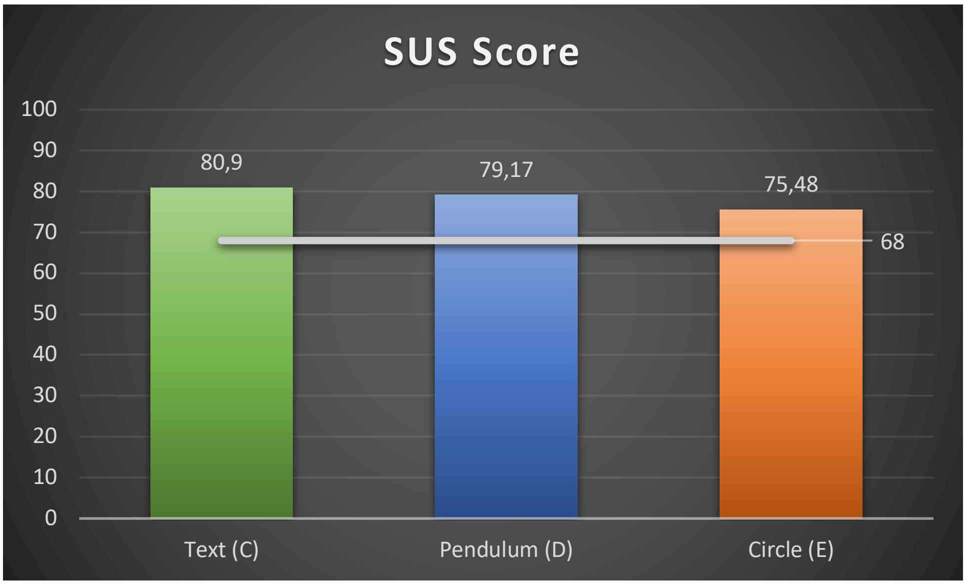

Figure 37, the SUS-score from the SUS based questionnaire for each prototype.
n_C = 50, n_D = 24, n_E = 26.

During the interview of the participants, questions regarding each tested prototype were asked. Together with the criterium from Table 7, each participant answers were graded and summarized in Figure 38 for the *text* prototype (C), and in Figure 39 for the prototypes *text & pendulum* (D) and *text & circle* (E). Displaying objectively how many and how much the participants "understood" the prototypes.

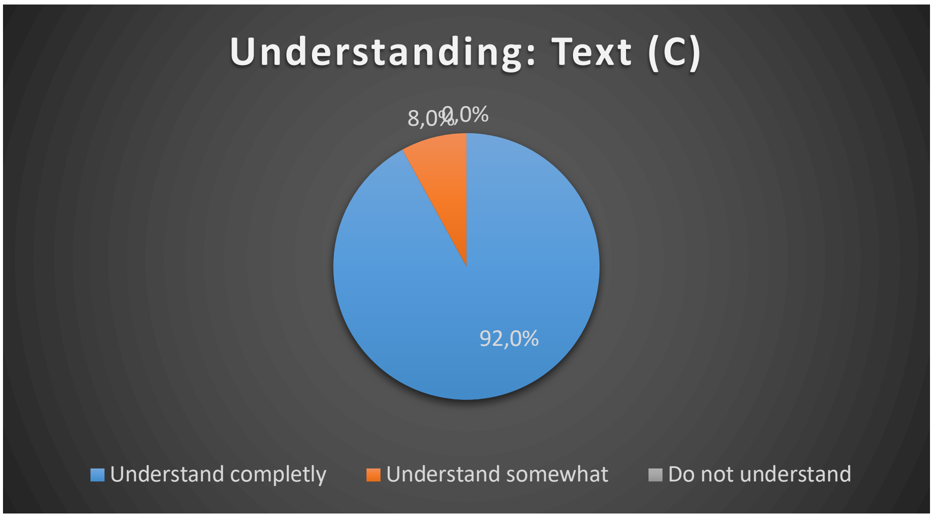

Figure 38, pie chart of the participants understanding of the text prototype (C). n_C = 50.

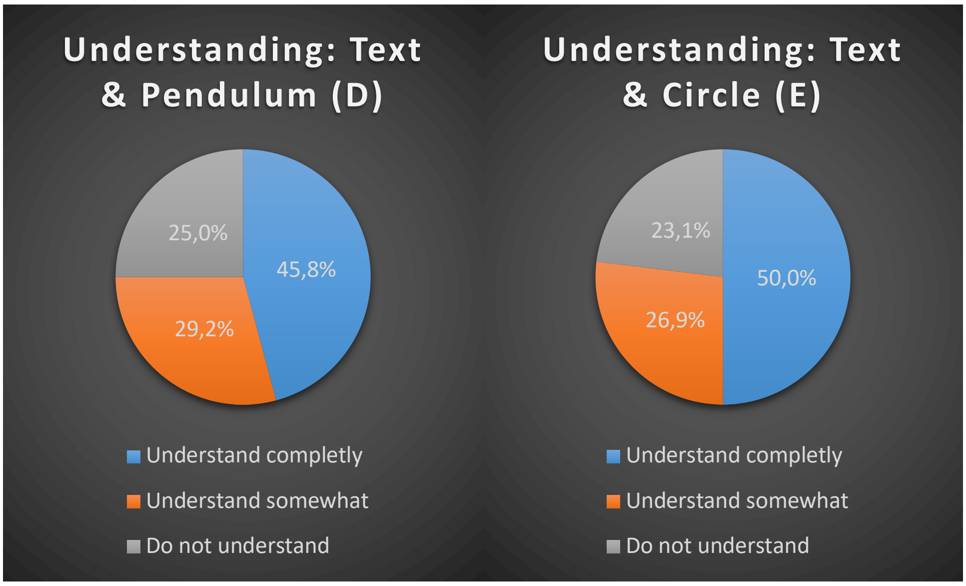

Figure 39, two pie charts of the participants understanding of the prototypes text & pendulum (D) and text & circle (E). n_D = 24, n_E = 26.

Each participant was also asked which scenario they preferred in the sense of which scenario they would prefer to use in their daily training, when training with a machine exercise, regardless of external influences, e.g. money for a personal trainer. The answers are summarized in Figure 40, for the test cases with the pendulum (D) and circle (E).

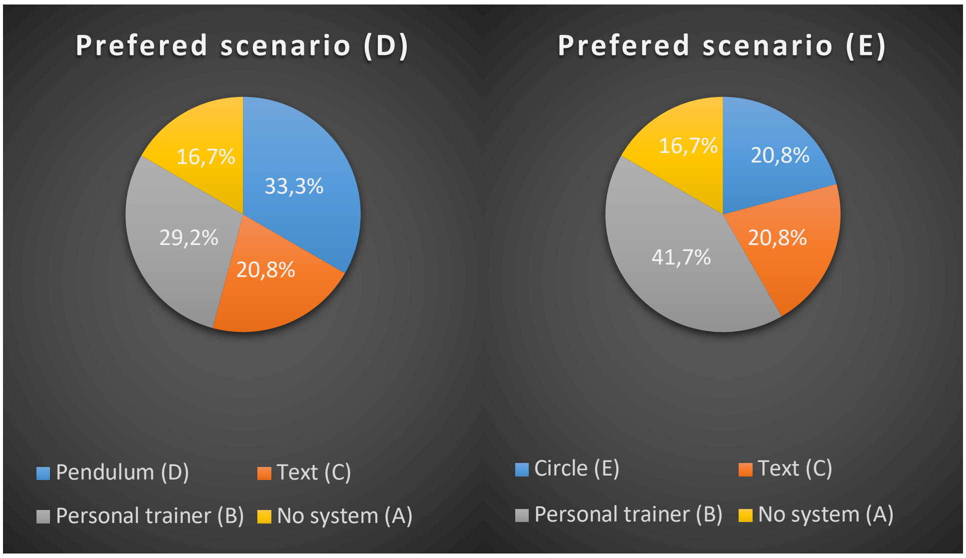

Figure 40, two pie charts of which scenario which the participants preferred, n_D = 24, n_E = 26.

Since not everyone answered one of the prototypes for the preferred scenario, an additional question was which prototype they preferred, out of the two they have tested in the test session. Everyone tested the text prototype (C), but the prototypes *text & pendulum* (D) and *text & circle* (E) were tested by two groups of participants. The preferred prototype is summarized in Figure 41, depending on which of the two other prototypes they have tested, *text & pendulum* (D) or *text & circle* (E).

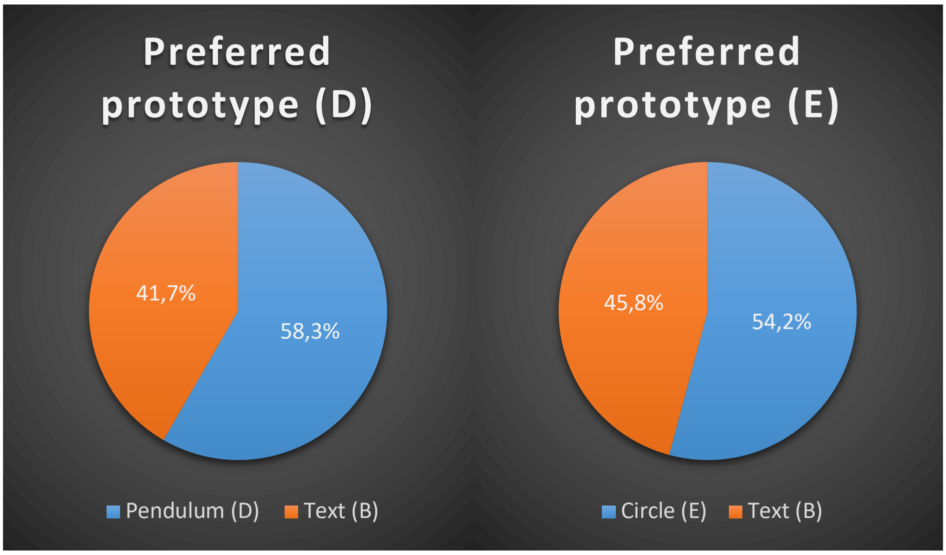

Figure 41, two pie charts of which of the prototypes the participant preferred, n_D = 24, n_E = 26.

8 Discussion

This thesis has evaluated giving real-time feedback to a user from IoT technology while exercising. In this chapter the actual research questions will be discussed, to what extent the thesis can answer them, followed by evaluations of the fulfillment of goals, working process and lastly suggestions for further work possibilities. With the prototypes produced and the tests conducted in this thesis work, all the research questions could be answered, but some not as sufficiently as one might have wanted.

8.1 Answers to research questions

8.1.1 **Trend of IoT data not being utilized**

According to the Sony project interviews it seems as if there is a trend, at least for the projects within the R&I department, that not all the data is being utilized. Though this is something that each project is aware of, and is a question concerning the prioritizing what is currently important, close to the main solution of the system. But even though not all the IoT data is being utilized, every project seems to have ideas on how to add additional sensors and algorithms to get even more data to use for further development. There is no lack of ideas what could be done with the IoT data.

8.1.2 **Presentation and interaction with Advagym IoT data**

With the help of the interviews from other projects, this gave great inspiration of how to approach the Advagym's utilization of the IoT data. With continuous brainstorming and workshop sessions, it was found that a presentation of the distance and time spent for the exercise movement was relevant to use as feedback to the user. With this data, a calculation for the velocities of the exercise movement could be performed. This is directly applicable with the VBT approach of exercising. The most natural way of presenting this in an interactive way was to present it to the user after a performed repetition. Just like a personal trainer would give you feedback on your lift after you have performed the repetition. A personal trainer can only give feedback on what he or she sees and analyses, giving feedback on the lift performed, to improve for the next one. The next step was how this data could be presented, to make it feel as if the feedback is in real-time. The approach to solve this, was to use text to present the actual feedback on the performed repetition, based on a grading of how the lift should be performed, with a summarized grading for the both the concentric and eccentric movement. In addition, a repetition counter was added, which incremented after each performed repetition. This worked sufficiently enough for the participants of the test to feel as if it was in real time, based on their understanding of the prototype, where 92% understood completely what was going on, and the other 8% had an idea, according to *Figure 38*.

With an additional indicator which were aimed to guide and help users find the correct speed of the lift, either as a pendulum (D) or a breathing circle (E) indicator, it seemed as if some participant felt like the system was giving even more feedback in real-time, especially since an misconception of some participants found the indicator acted as a representation of their real-time motion. The understanding of these prototypes, with indicators, even though performing not as good as the text (C) prototype in “understanding”, see *Figure 39*, seemed to work as well or better in providing a real-time user experience. Especially since it even could provide a misconception of an even more real-time feeling than intended.

8.1.3 **Performance of prototypes**

During the test of the Hi-Fi prototypes, data was collected on the performance. Since the tests every time started off with having no system or personal trainer to help / guide the participant on their performance, it was expected that the performance results would be low for this scenario (No system – A), especially since the participant had no idea of which speed / tempo that was predefined. Though this worked well as data for how the participant would trainer without any feedback. But once feedback, in the form of their exercise movement speed, was provided to the participants, this helped greatly, going from an average score of 19,8% to 51,4% (personal trainer - B) or 59,5% (text prototype – C) as the first received feedback, see Figure 36. This gives an indication of how feedback can help a user follow a predefined training velocity / tempo pattern. Allowing half or more of the repetitions be close to perfect in velocity aspects with a low tolerance of error. In addition, further usage, a learning curve, with continuous feedback of the participants performance, the performance score can reach up to an average of 75,3% (prototype D - pendulum and text), see Figure 33.

As seen on Figure 34, every test sequence order seems to have an increasing performance score, which is also a great indication of how the interaction with the IoT data can help a user follow a certain training pattern. If the prototypes can help a user follow a certain training pattern, this can help users train more correctly according to their training goals. This could also allow the utilization of VBT, where the system works as an VBT measurement tool, and instead of using the weight of the lift as the main focus, use the velocity of the lift as the main focus. Allowing the user to adjust their weight and train with the correct effort every time.

As seen on Figure 36, the performance score was a little bit higher for the text prototype (C), compared to the scenario of a personal trainer (B) giving feedback, both being the second scenario of the test session. This could be an indication that an application, such as the text prototype (C), giving continuous feedback on a user's velocity / exercise performance, can work as a competitive solution in the aspect of helping a person follow a predefined speed. It is also hard for a personal trainer to make estimations of how fast or slow the movement really was. The application could then potentially work as a tool for the personal trainer when training with his or her clients. As seen in Figure 40, there is no clear indication that an application giving feedback on your velocity is the preferred choice for every person. But it seems as if there is a large user group who would prefer to have this kind of application to help / guide them in their training, even when the option of getting a personal trainer was available. Even though such a system can be competitive in the aspect of velocity feedback, additional feedback such as on the "form of the lift" or how the user is positioned in the machine, needs to be solved before it could be considered as a real competitor to the personal trainer.

Every prototype developed and tested, ended up in the category of DRTF. According to Figure 33, it seems as if all the participants felt it was a "good enough" solution to help them train with a certain speed, hence helping them reach this speed. Where every prototype performed with a score performance of 69,72% or above. According to the SUS-based questionnaire, see Figure 37, every prototype scored above 68 points, which is a lowest acceptable SUS-score. This supports the claim of DRTF being a good an enough solution.

For every test scenario, a prototype with an indicator was tested at the 4th and last scenario. Meaning that before any participant got to test a prototype with an indicator, they have already tested the text prototype (C). As seen on Figure 34, the prototypes with an indicator D and E, is within a 5% interval of prototype C, meaning that there seems to be a little difference in the performance score of the prototypes. The 1-5% increase in performance score might also be because of the learning curve of the test session, meaning that the participants at this point had easier to follow the predefined speed. Though, according to the interview answers, it seems as if the participants preferred the prototype with an indicator since 58% preferred the pendulum prototype (D) with a tempo indicator, compared to the text prototype without the tempo indicator. Same goes for the circle prototype (E), where 54% preferred the circle prototype compared to the text prototypes, see Figure 41. A lot of positive comments were also received for these prototypes with indicators, where some participants liked the gamified feeling they received.

8.2 Project goals achievements

One of the goals of this thesis was to *"Evaluate the possibility of using Velocity Based Training (VBT) methodology for the Advagym solution"*. With the help of better understanding the methods of VBT as well as the Advagym solution, it can be considered a good match since the IoT units of Advagym gathers the appropriate data for VBT, and according to the tests conducted, it seems as if the interaction and representation of the IoT data is appreciated. Even objective data shows a better performance score based on a predefined target velocity, unknown to the participants (see Figure 34). Another goal of this thesis was to *"Evaluate the interaction approach of DRTF"* where it seems to be a sufficient approaching based on both the objective performance data (see Figure 34) as well as based on the subjective data (see Figure 37-39). Where the overall usability score from the SUS-based questionnaire is high and where 25% or less seems to not understand the applications / prototypes, where the rest understood somewhat or completely. This also fills the goal of *"test and benchmark different prototypes and sessions"*. Where every scenario has been tested and benchmarked with the help of both subjective and objective data.

8.3 Eventual error sources

The working process applied in this project has been continuously reviewed by supervisors from both the university and from Sony. This thesis has been conducted by one person, which might have affected all the phases through the project's course. Such things as discussions, ideas and so on. Some things may have been unintentionally left out because of this. Additional help from other project members might have given a broader aspect to the project, with more ideas than from only one person. Additional prototypes or solution approaches.

A literature study was conducted to find facts about earlier work in the field and related information of both IoT and VBT. Some facts might have not been found due to the restrictions of the database queries, meaning that using other search keywords or having access to other databases, might have provided more related studies.

The test used two different questionnaires, one for the sign-up and profile questionnaire, and one SUS-based questionnaire. It is a possibility, that some of the questions which the participants answered might have been misunderstood. Many of the SUS-based questions can seem vague to the participants, and some words or questions needed an explanation. Even though the same answers were given to all the participants, the participants who did not ask about the questions did not receive the same information as the ones who did. Hence allowing for possible misunderstanding of the questions from the questionnaires. Meaning that an inaccurate data might have been collected because of this.

During the test session itself, the participants were distracted at different levels. The cause of this was since the test was conducted in the Sony office gym, other employees of Sony were also in the gym. The amount of people in the test area varied based on time and day, and since the participants booking also varied from times and days, every participant's distraction moments were different, unless the Sony office gym was empty.

Restrictions regarding the project size limited a more detailed testing of the prototypes, forcing the different test cases to have multiple prototypes instead of only testing one prototype per participant. It would be more optimal to test one prototype individually, since it would eliminate the learning curve during the test session.

The participants acted differently in the sense of how well they followed the instructions. Even though the participant was asked to "with the help of the application, train correctly", he or she could ignore the moderator's task, and just continue exercising as he or she wished. This leads to corrupt data which does not represent how the task would have performed if the participant would follow the task instructions correctly.

The gender distribution was 40% women and 60% men, which was not intentional. It would have been more optimal to have a completely even distribution amongst the genders.

The participants were recruited from different social media channels / groups, but all the channels /groups had one thing in common, which was that each group is located in the near area of Lund. Lund is mainly a university city where a lot of tests are being conducted for research purposes. This may impact the results of the tests since the participants recruited live in this university town which is not a good representation of the broad user group in the sense of academic backgrounds and interests in studies.

8.4 Future work

The outcome of this thesis has been a lot of insight, but with answers, often follows additional questions. A few aspects of the project have been excluded to keep the scope of the project in a reasonable working load for one person. As future work, the most relevant would be following:

- In the test phase, the three prototypes included different elements in the form of feedback-text and two different tempo indicators. To be able to determine which element is the most important, a study to test each element individually would provide greater insight. E.g. is the circle and text prototype (E) dependent on the text-feedback?

- Testing the prototypes with additional feedback channels, such as in the form of sound. Testing the tempo indicators with matching sound. Would this increase the user experience? Or would even sound itself be enough?
- Remove the hardware constraints from the project (only one broadcast per repetition), and instead using a continuous real-time data stream. What could this potentially lead to? Is it something that would increase the user experience even more, or is the DRTF approach a best effort solution?

9 Conclusion

As mentioned in section 1, it seems as if more and more people are exercising which is a great thing in a global health perspective. Though, the gyms might seem scary, dull or too complex for some people. However, with a tool to help people keep track of their training as well as help them get going, train more correctly and reduce any risk of injuries would be a major improvement for the global health issue. Using the technologies of IoT to do this seems to be an appropriate solution, since IoT is all about tracking and sensing.

This report describes how an IoT project not utilizing all of its IoT data can gain something, in this case mainly user experience, by finding new ways of interaction through the IoT data with the user of the system. The result of the prototypes has been overall very impressive, especially in the objective sense that an application can help a user perform a physical movement in a particular speed, with very low difference to the targeted velocity. Compared with a personal trainer, trying to give feedback on the speed of a user's lift, all the prototypes performed significantly better in the sense of being close to the targeted velocity of the lift. It also seems as if the participants who tested the text prototype (C) first, rather than receiving feedback from a personal trainer (B) first, found it easier to adjust to a target velocity. It is also shown that participants using any prototype with a beginner level of training skill can perform as good as participants with advanced training skill. Where the skill level is an indication of physical body control for the participant.

All of the prototypes have also performed very well for the usability and satisfaction scores. Where all of the prototypes are above the score of 75, where the score limit is 68 for the SUS-based questionnaire. The majority of all participants understood completely what the prototypes were trying to present to them, and only a small portion of participants did not understand at all. The majority of participants would also prefer to use one of the prototypes in their daily training with machine exercises. This is a good indication that the feature itself is interesting for users. Everyone prefers to exercise differently, and it is no coincidence that some preferred to train alone or with a personal trainer instead. One of the main reasons why the participants preferred to train with a personal trainer rather than with an application, might be because of the human connection. Another reason can also be that the participant wants more feedback on their performance, than just the speed of the lift. Feedback such things as on the user's positioning in the exercise, range of motion, movement and other relevant information that the prototypes could not currently provide.

References

[1] M. Stobbe, "More Americans exercise, but more U.S. adults also edge closer to obesity, survey says," *PBS.org*, 28-Jun-2018.

[2] J. Gubbi, R. Buyya, S. Marusic, and M. Palaniswami, "Internet of Things (IoT): A vision, architectural elements, and future directions," *Futur. Gener. Comput. Syst.*, vol. 29, no. 7, pp. 1645–1660, 2013.

[3] K. Lazarevich, "What You Should Be Doing With Your IoT Data – IoT For All – Medium," *Medium Corporation*, 27-Mar-2018.

[4] A. Bilgin, H. Hagras, A. Malibari, D. Alghazzawi, and J. Mohammed, "A computing with words framework for ambient intelligence," in *2013 IEEE International Conference on Systems, Man, and Cybernetics*, 2013, pp. 2887–2892.

[5] J. Nuamah and Y. Seong, "Human machine interface in the Internet of Things (IoT)," *2017 12th Syst. Syst. Eng. Conf. SoSE 2017*, pp. 1–6, 2017.

[6] Sony, "Advagym, for a connected gym experience," 2019. [Online]. Available: http://advagymsolutions.com. [Accessed: 01-Apr-2019].

[7] Google Cloud, "Overview of Internet of Things," *Cloud Google*, 2018. .

[8] O. Vermesan *et al.*, "Internet of things strategic research roadmap," *Internet things-global Technol. Soc. trends*, vol. 1, no. 2011, pp. 9–52, 2011.

[9] B. Mann, *Developing Explosive Athletes: Use of Velocity Based training in Training Athletes*. 2013.

[10] R. G. Lockie, M. D. Jeffriess, F. Jalilvand, and S. J. Callaghan, "Journal of A ustralian S trength and C onditioning JASC – Supplement 1 - ASCA National Conference 2008 – Conference Proceedings Page 1," *J. Aust. Strength Cond.*, vol. 23, no. 7, pp. 58–69, 2015.

[11] O. Walker, "Velocity based training," *scienceforsport.com*, 2017. [Online]. Available: https://www.scienceforsport.com/velocity-based-training/. [Accessed: 15-Apr-2019].

[12] E. Jun, H. Liao, A. Savoy, L. Zeng, and G. Salvendy, *The design of future things, by D. A. Norman, basic books, New York, NY, USA*, vol. 18, no. 4. 2008.

[13] J. Yang, “Enhancing the quality and motivation of physical exercise using real-time sonification,” *PQDT - UK Irel.*, no. May, pp. 2, 218, 255, 2015.

[14] M. Wilk, A. Golas, P. Stastny, M. Nawrocka, M. Krzysztofik, and A. Zajac, “Does Tempo of Resistance Exercise Impact Training Volume?,” *J. Hum. Kinet.*, vol. 62, no. 1, pp. 241–250, 2018.

[15] J. Preece, H. Sharp, and Y. Rogers, *Interaction Design: Beyond Human-Computer Interaction, Third Edition.* Wiley; 3 edition (June 7, 2011), 2011.

[16] N. Lakic, “THE APPLICATION OF LATIN SQUARE IN AGRONOMIC RESEARCH,” vol. 46, no. 1, pp. 71–77, 2001.

[17] J. Brooke, “SUS - A quick and dirty usability scale. 1996,” *Usability Eval. Ind.*, vol. 189, no. 194, pp. 4–7, 1996.

Appendix A Recruitment questionnaire.

The following questions were asked in the “Sign up questionnaire” which was used to recruit participants for the test:

Question: *Name?* (Text answer)

- Participants name

Question: *Gender?* (Text answer)

- Male
- Female
- Other: Participants answer

Question: *Age?* (Text answer)

- Participants age

Question: *Physical effort of everyday employment (How much do you need to work with your body and physically effort in your job / studies)* (Scale answer: 1-5)

- Where 1 is very little / none and 5 is very much.

Question: *How many times per week do you exercise?* (Single choice answer)

- Less than 1 time / week
- 1 - 3 times / week
- 4 - 7 times / week
- More than 7 times / week

Question: *How long have you kept up with your current training frequency?* (Single choice answer)

- 1-3 months or less
- 3-6 months
- 5-12 months

- 1-2 years
- 2 years or more

Question: *What kind of exercise do you perform? Please specify! (E.g.: football, cycling, strength training, group training)* (Text answer)

- Participants answer

Question: *If you train at a gym, what gear do you train with?* (Multiple choice answer)

- Gym machines (Machines with added weights)
- Free weights (Dumbbells, barbells)
- Bodyweight (Push-ups, plank)
- Cardio machines (Treadmills, cross-trainers)
- Other: Participants answer

Question: *If you have some form of visual impairment, do you train with aids? E.g. with lenses / glasses* (Single choice answer)

- Yes, I wear lenses / glasses
- No, I don't wear lenses / glasses
- I have no visual impairment

Question: *Do you have any movement reduction that prevents you from performing any certain movements? If so, please specify!* (Text answer)

- Participants answer

Question: *Which days and times of the week do you prefer to participate in the test? The test is on one occasion and takes about 30 minutes.* (Multiple choice answer)

- Mondays: 9.00, 10.00, 11.00, 13.00, 14.00, 15.00, 16.00
- Tuesdays: 9.00, 10.00, 11.00, 13.00, 14.00, 15.00, 16.00
- Wednesdays: 9.00, 10.00, 11.00, 13.00, 14.00, 15.00, 16.00
- Thursdays: 9.00, 10.00, 11.00, 13.00, 14.00, 15.00, 16.00
- Fridays: 9.00, 10.00, 11.00, 13.00, 14.00, 15.00, 16.00

Appendix B SUS-based post-test questionnaire

There were two different questionnaires, one for the participants who tested the pendulum and one for the participants who tested the circle. The questionnaires were identical on every part except that the screenshot which was used at the beginning as a reference was dependent on which prototype the participant tested. The questionnaire was divided into two parts. First part was always regarding the "Text prototype", while the second one was either the "Pendulum and text" or the "Circle and text".

Following 10 questions were asked for each prototype:

Question: *I think that I would like to use this app frequently when training with gym machines.* (Scale answer: 1-5)

- Where 1 is Strongly disagree and 5 is Strongly agree.

Question*:* *I found the app unnecessarily complex.* (Scale answer: 1-5)

- Where 1 is Strongly disagree and 5 is Strongly agree.

Question: *I thought the app was easy to train with.* (Scale answer: 1-5)

- Where 1 is Strongly disagree and 5 is Strongly agree.

Question*:* *I think that I would need the support of a technical person to be able to train with this app.* (Scale answer: 1-5)

- Where 1 is Strongly disagree and 5 is Strongly agree.

Question: *I found the various functions in this app were well integrated.* (Scale answer: 1-5)

- Where 1 is Strongly disagree and 5 is Strongly agree.

Question: *I thought there was too much inconsistency in this app.* (Scale answer: 1-5)

- Where 1 is Strongly disagree and 5 is Strongly agree.

Question: *I would imagine that most people would learn to use this app very quickly.* (Scale answer: 1-5)

- Where 1 is Strongly disagree and 5 is Strongly agree.

Question*: I found the app very cumbersome to use.* (Scale answer: 1-5)

- Where 1 is Strongly disagree and 5 is Strongly agree.

Question: *I felt very confident using the app.* (Scale answer: 1-5)

- Where 1 is Strongly disagree and 5 is Strongly agree.

Question: *I needed to learn a lot of things before I could start training with the app.* (Scale answer: 1-5)

- Where 1 is Strongly disagree and 5 is Strongly agree.

Appendix C Post-test interview

Question*:* *Explain how the first application worked according to you. (Mental model – Text prototype)*

- Participant verbal answer with eventual follow up questions.

Question*:* *Explain how the second application worked according to you. (Mental model – Indicator and text prototype)*

- Participant verbal answer with eventual follow up questions.

Question*:* *What kind of information/feedback did you receive from the first application? (Feedback / Information – Text prototype)*

- Participant verbal answer with eventual follow up questions.

Question: *What kind of information/feedback did you receive from the first application? (Feedback / Information – Text prototype)*

- Participant verbal answer with eventual follow up questions.

Question: *Training with a gym machine, which of the 4 scenarios during the test session, would you prefer?*

- No system / Personal trainer / Application text / Application indicator and text (pendulum / circle).

Question: *Which of the apps would you prefer?*

- Application text / Application indicator and text (pendulum / circle).

Question: *Any general comments or thoughts?*

- Participants general comments / thoughts.

Appendix D Sign up posters

SONY

Test participants wanted

We're looking for participants to join one of our user tests!

Duration: ~30 min
Location: Sony Mobile Communications Lund
Ongoing: 4th of March to 25th of March
Reward: Movie ticket

Book the time & date that fits you in the survey!

Fill in the forms to sign up!

English

http://bit.ly/2GJWBTT

Svenska

http://bit.ly/2BTjgc6

Sony Mobile Communications AB
Mobilvägen
221 88 Lund, Sweden

Jakob Håkansson
Thesis Worker
jakob.hakansson@sony.com