Exploring Different User Interfaces for Velocity based Training using Smart Gym Machines: Pilot Study

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Abstract: With the emerging technology called the Internet of Things (IoT), we can now connect computing devices and sensors to the Internet. The IoT sensors serve to collect data, pushing it and sharing it with a whole network of connected devices. We decided to explore how to utilize IoT data to increase the user experience from a commercial gym application called Advagym. Advagym is a commercial solution already available in the market, which aims to digitize the gym experience, where a retrofit solution is used to fit IoT devices on gym machines to track performance data from users' workouts. The main goal of this paper is to utilize IoT data from Advagym's IoT sensors for velocity-based training (VBT) and conduct a comparative study of three different user interfaces presenting VBT data to increase the user experience. The main contribution of this paper is an analysis of user preferences regarding the user interface of VBT feedback during a gym workout.

1 INTRODUCTION

It is becoming more and more common to exercise regularly. According to a large annual health survey for the USA (Stobbe, 2018), more people exercise enough each week to meet the USA's government recommendations for both muscle strengthening and aerobic exercise in the USA. This trend is reflected in the amount of new mobile applications which is being continuously added to AppStore and Google Play. Several smartphone applications are attempting to help people training at a gym to log their training progress. Examples of such applications are "Fitness Buddy" and "JeFit" which are available both for iOS and Android. But, most of these applications force the user to enter the results manually, meaning that after each performed sequence of repetition (set), the user has to pick-up the phone and manually write their result in an application or using pen and paper. This is a problem since it interrupts the focus of the workout. On the other hand, if you do not take note right away, you will most likely forget or write a more positive number. A more intuitive way would be to log this data automatically with the help of sensors connected to the phone and the workout machines. This could be achieved with the emerging technology called the Internet of Things (IoT).

With IoT, we can connect computing devices and sensors to the Internet. IoT does not have a real academic definition, but Preece et al. (2011) define IoT as "a system of connected computing devices, mechanical and digital machines, objects, animals, or people that are provided with a unique identifier and the ability to transfer data over a network." The IoT sensors serve to collect data, push the data, and share the data with a whole network of connected devices. IoT sensors could be used to track the user's performance and movements (Gubbi et al., 2013), connecting, and gathering all the data from and about the user.

Advagym (2015) is a commercial solution already available in the market, which aims to use 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 is mainly through its smartphone application which runs on both iOS and Android platforms. Currently, the IoT devices attached to the machines are gathering many types of data, of which some, are never used or shown for the user. For example, an accelerometer is used to detect movement and a time-of-flight sensor is used to measure distance, the combination is used to count the number of repetitions.

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However, the actual data is not shown and could be combined for other measurements, for example, Velocity Based Training (VBT). VBT focus on the velocity of the performed exercise movement rather than the weight.

The main goal of this paper is to utilize IoT data from Advagym's IoT sensors for VBT and conduct a comparative study of three different user interfaces presenting VBT data to increase the user experience.

The main contribution of this paper is to elucidate knowledge about which UI feedback of VBT given for the "gym-goer" was preferred.

The next section presents relevant related work. Then the Advagym is described followed by the evaluation, results, discussion, and conclusions.

2 RELATED WORK

Over recent years, there is a growing awareness of the potential power and relevance that interactive media applications can have in influencing people's motivation and subsequent behavior. Recent work in the area of persuasive technology, that is, technology intentionally designed to change a person's attitude or behavior, testifies to this effect (IJsselsteijn et al., 2006). One can for instance use wearables and applications such as RunKeeper, Fitbit, and Withings which helps you to keep track of how much you exercise. However, more than half of the individuals who purchased a wearable device stop using it and, one-third did so before six months (Patel et al., 2015). One reason is that current applications often hold a simple focus on recording data and displaying it in statistical form to the user for post-activity viewing. Moreover, they are relatively well developed for running, walking, and bicycling but they are not so useful for gym workout nor for getting feedback during a workout.

Sankaran et al. (2016), evaluated HeartHab, which is an application developed for Coronary Artery Disease patients. The authors managed to incorporate behavior change techniques and design theories into their mobile application. The application focuses on presenting patient data of medication, prescription, and exercise targets for walking or running, no gym exercises.

Another example of an application tracking walking but tailored for a certain group of people is the "WalkWithMe" application by Geurts et al. (2019). WalkWithMe is a mobile application that supports people with Multiple Sclerosis (pwMS) in walking. The application can coach pwMS in achieving a personal goal over a period of 10 weeks. Geurts et al. (2019) evaluated the application in a 10-week field study with 13 pwMS subjects. They found that WalkWithMe supports pwMS in achieving their goal. Moreover, it has been proven that physical activity has a positive effect on most of these symptoms. However, we believe that this kind of application would benefit from utilizing gym exercises as well.

Yang (2015) investigated the use of real-time sonification as a way to improve the quality and motivation of strength exercises. In the study's case, a biceps curl routine was investigated with a sonification system and 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 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 (Yang, 2015). A latitudinal experiment was later on conducted to compare exercising quality between a sonification group and a control group that 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.

There are multiple benefits to being fit. Some studies suggest physical exercise and fitness are beneficial for both younger and older people (Malina, 2010). One of the ideas of the new user interface is to add a new way of achieving fitness through exercising. Consider exercise prescriptions for older adults. The main objective of resistance training programs for the majority of this population is to increase functional performance (Vince, 2017). Muscle power is also a superior determinant of physical function compared to muscle strength. Therefore, utilizing VBT as a strategy to improve functional abilities in older adults appears logical. Performing resistance training with maximal concentric velocity has been shown to be more effective at improving functional performance in older adults (Vince, 2017).

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 other innovative ways to train and instead e.g. focus on the velocity of the lift. As already mentioned VBT focuses on the velocity rather than the weight, which can be useful to develop athletes that need explosive movements (Mann, 2016).

This paper focuses on utilizing unused IoT data for VBT and present it for the "gym-goer", during a workout by giving feedback on how well the exercise

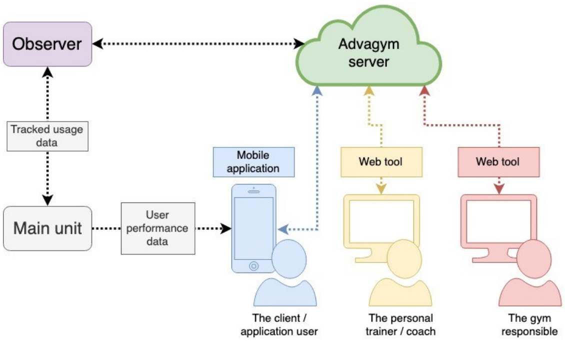

Figure 1: Illustrates the Advagym's IoT data flow to different users.

is performed, regarding the velocity.

3 Advagym

Advagym (2015) is a relatively new IoT solution to digitize the gym experience, where a retrofit solution is used to fit IoT devices on gym machines to track performance data from users' workouts. The system offers different services, and there are different kinds of users for each service. Examples of users of Advagym are The application user; The personal trainer (PT); and The gym responsible (Figure 1). However, this paper will focus on the application user, who with the help of an iOS or Android application can train and log their training automatically with exercise machines.

3.1 Advagym Hardware

In general IoT solutions often consist of three basic components device, gateway, and cloud. The Advagym solution has a similar architectural structure. There are three components called: main unit and puck, observer, and Advagym server. The main unit and puck, and the observer are connected to the Advagym server which is equivalent to the cloud. While the observer corresponds to the gateway component, and the main unit and puck are the IoT devices.

The main unit is the IoT device which does the actual tracking of performed repetitions on an exercise machine. Different sensors are used in the main unit. An example of an included sensor is the accelerometer, which is used to awaken the main unit from its "sleep mode" (sleep mode is a battery conservative mode). Once the main unit is awake, the firmware is booted up and starts tracking the vertical movement with the help of the time-of-flight sensor. By using a combination of these sensors and smart algorithms, data packages for each repetition and their movement will be broadcasted. The data package is broadcasted multiple times through Bluetooth-Low-Energy (BLE). The data packages sent are used both for the user's application to process, as well as for the observer (Figure 1), to log. Each broadcasted data package is dependent on two events of repetition, these events help to define the performance of a repetition. Event 1: Occurs once the weight stack has reached its max peak value of repetition. This means that the max value of distance measured has been received. 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. The actual broadcast is also performed, at this event.

These events occur for each repetition of a set, except for the very first repetition, where not all parameters of the package are set. The reason why not all parameters of the data package are set of the first repetition is due to the boot-up time of the main unit. It is triggered by the accelerometer and it is done rapidly but still, it will give some uncertainty on how far the weight stack has traveled from its original position.

The movement of the main unit will only be on the vertical axis since it is placed on the weight stack of an exercise machine.

The puck has its main purpose to work as a connecting 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 exercise machine which is connected to the Advagym system. Depending on which smartphone is used two different technologies are supported, For iOS users, a BLE package is received from the puck once the user "taps the puck". 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 a BLE package. For Android users without NFC capabilities, BLE is used instead. Regardless of which technology is used to receive the data packages from the puck, the same information is provided and processed in the smartphone application.

The observer has its main purpose of monitoring the IoT units and acting as a gateway i.e. connecting the gym to the Internet. The observer is placed in the same area as the exercise machines to "listen" to all the broadcasts which are done by the main units and keep track of all the connected gym machines.

3.2 The UI for Velocity based Training

One of the main goals was to design and evaluate a set of user interfaces (UIs) that utilize IoT data to give feedback of the velocity to the users during a workout. First, a brainstorming session was conducted to find out which IoT data was available and not used (Håkansson, 2019). During the brainstorming session, it was noticed that the acceleration data from the main unit was not used. This data could be used to give feedback to the user during an exercise regarding how fast or slow the user is performing the exercise. The process of designing the feedback or the UIs was performed in an iterative approach, starting with specific brainstorming sessions for the feedback and low-fidelity prototypes, which were tested and refined. Finally, the UIs were developed and evaluated. The visual update 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. Three different UIs were developed, referred to as "Text", "Text and Guide Pendulum" (TGP), and "Text and Guide Circle" (TGC), see Figure 2.

3.2.1 Text

The first UI is only text feedback and is presented during the movement of the performed repetition (Figure 2a).

3.2.2 Text and Guide Pendulum (TGP)

For the pendulum prototype, a green dot was used as a pendulum movement. In addition, discrete dots in the backgrounds worked as the field and outline of the area within 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 (Figure 2b). 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 a predefined time to match the repetition time, fades out (Figure 2b).

3.2.3 Text and Guide Circle (TGC)

The circle prototypes went through several iterations until current testable versions were completed. 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 have been performed compared to how many are aimed to be performed. It has 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 the circle is expanding or shrinking, this would represent a concentric movement or an eccentric movement. An extra animation was added to the outer repetition circle which "pops" once the indicator circle meets the outer circle. Early user studies indicated that this effect improves the user experience and the users felt as if the motion was more natural (Figure 2c).

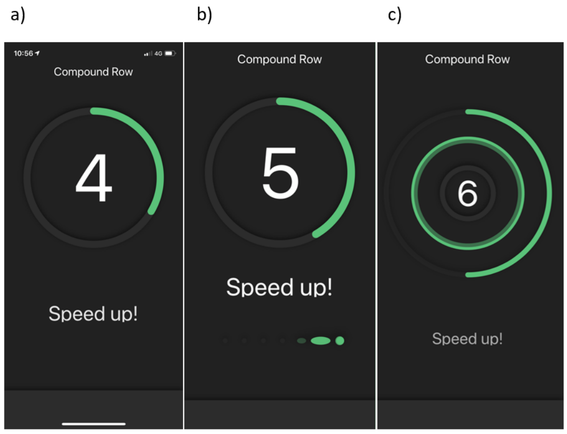

Figure 2: The three Hi-Fi UIs: a) Text, b) Text and Guide Pendulum (TGP), c) Text and Guide Circle (TGC). The number in the center shows the repetition.

4 EVALUATION

A user study was conducted to evaluate the different prototypes, by letting all participants perform the cable row exercise in the office gym.

4.1 Setup

Both quantitative and qualitative data were collected. Documentation of the active sessions was done through video recordings from a Sony A6300 as an overview camera. Figure 3 shows an overview of the setup.

4.2 Participants

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

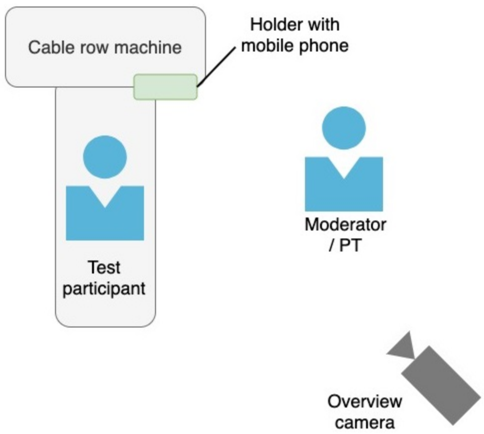

Figure 3: The setup.

have in common is that they are training at a gym. However, we had some restrictions such as being able to physically perform the test, i.e. the participant should be able to perform the "cable row" exercise on a low/moderate weight, without any pain. Moreover, having good enough sight with/without aids, to see a 5.8" mobile screen, one meter away from the participant.

To more easily recruit participants, an online questionnaire using Google Forms was used. The online questionnaire served two purposes; to gather relevant demographic data about the participant and book an available time-slot. The sign-up questionnaire was spread through different channels, both in digital and physical form. The physical form were posters including QR-code links that were placed in several crowded areas within the campus of Lund University. The digital form was a link that was distributed through Sony's social media groups.

In total, 48 participants (20 female, 28 male) were recruited. The age of the participants ranged from 18 to 55 years (M = 29.2, SD = 10.14). To estimate and grade the training skill of the participants a sequence of calculations were made, based on their sign-up questionnaire answers. The following parameters: 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 was graded as beginner/novice training skill and 4 to 5 were graded as advanced training skill.

4.3 Procedure

The test session was divided into three parts: Preparation stage, Test session, and Post-test (Figure 4). The Preparation stage includes the stage of the recruitment and initial meeting with the participants. As already mentioned, Participants signed up for the test with the help of an online questionnaire. The online questionnaire allowed us to have demographic data ready before the actual test. When the participant arrived at the test location, they were welcomed and escorted to a User Experience (UX) lab, where they signed a Non-Disclosure-Agreement (NDA) and an informed consent form.

Once the introduction was done, the participant was taken to the test area which was the office gym. The reason for using an actual gym was to get the most realistic test possible, as well as the fact that the office gym was already equipped with the Advagym system. Once the participant was ready to start, the test session continued in a certain order. There were five different test cases for the test with the following alphabetical labels:

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- A. No System
- B. Personal Trainer (PT)
- C. System with Text feedback
- D. System with TGP feedback
- E. System with TGC feedback
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Each test session started to test A i.e. no system/no feedback in order to know how the participants' would perform normally the exercise, followed by B & C, but counterbalanced.

With 48 participants, each order will have 24 participants. The reason for this was to find if there are any relations between which order of cases/prototypes is tested. Followed by the initial sequences of test cases, either D or E will be tested, meaning only four test cases per test session. Moreover, cases D and E will be tested by 24 participants each. We have a mixed design with two within-group measurements (ABC and ACB) and between-group measurements (DE and ED). The independent variables are the three user interfaces and the PT. The dependent variable is the performance score. To avoid sequence effects, the order in which the test sequences were presented was fully counterbalanced, i.e. each of the four possible orders was shown to equally many participants.

For each case, the participant was asked to perform twelve 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 test case was complete, the next test case followed with the same test structure, continuing throughout the test. Example: $A \Rightarrow B \Rightarrow C \Rightarrow E \Rightarrow$ Done!

After the test, the participant was taken back to the UX lab and was asked to fill out the System Usability Scale (SUS) questionnaire (Brooke, 2014). In an attempt to do a usability assessment of the user interface, SUS was used. It attempts to measure cognitive

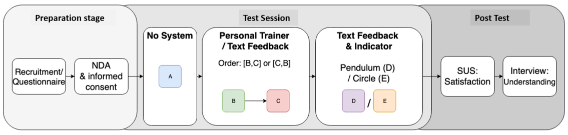

Figure 4: Test session procedure.

attributes such as learnability and perceived ease of use (Brooke, 2014). The questionnaire was followed by a short structured interview to see if the participants understood the user interface, and to see which one they preferred.

Each session lasted about 30 min, and as a reward, the participant was given a movie ticket. The whole procedure of the test session is visualized in a block diagram (Figure 4).

4.4 Results

In the following section, the results from the objective performance score, SUS scale, and the structured interview are presented. All of the 48 participants managed to accomplish the exercises.

We used an alpha level of .05 for all statistical tests.

Performance Score. The performance for all 48 participant test cases was logged and summarized. The performance data is based on the velocity of the concentric (v_c) and eccentric (v_e) lift for a repetition, which was summarized and made into an average (v_a) velocity of the lift.

$$\frac{v_c + v_e}{2} = v_a \tag{1}$$

The velocity v_a was then graded as either 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%, i.e. 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, for each test case twelve repetitions on three sets were performed. Because of hardware constraints, the very first repetition was ignored since no data was given for that repetition by the system. Meaning that for three sets eleven repetitions give a total of 33 data points for every test case on every participant. The performance is represented in percentage of each test case, i.e. how many repetitions per data points were graded "good" out of the performed repetition on this test case. 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.

A one-way ANOVA for dependent measures between personal trainer (PT), Text and TGP showed a

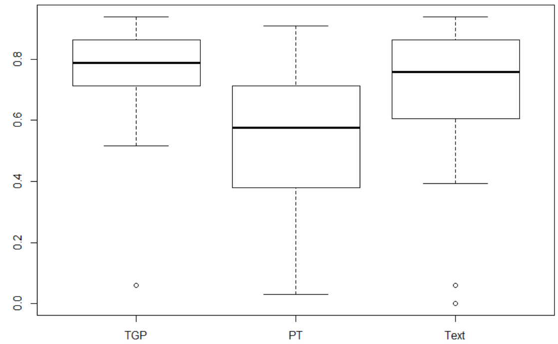

Figure 5: Performance score illustrated in a boxplot, relations between TGP, PT and Text. *N = 24*.

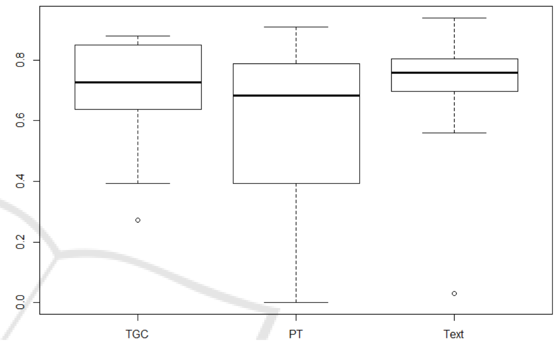

Figure 6: Performance score illustrated in a boxplot, relations between TGC, PT and Text. *N = 24*.

significant relation: F(2,69) = 5.34, p = .0070. Multiple pairwise-comparison showed a significant difference between the PT and TGP with an adjusted p-value of p = 0.0057 (Figure 5). Moreover, it was close to the margin of statistical significance between PT and Text with an adjusted p-value of p = .089.

When it comes to the dependent measures between PT, Text and TGC, again one-way ANOVA showed a significant relation: F(2,69) = 3.50, p = .036. Multiple pairwise-comparison showed close to the margin of significant difference between PT and Text with an adjusted p-value of p = .052 (Figure 6). Moreover, it was close to the margin of statistical significance between PT and TGC UI with an adjusted p-value of p = .080.

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 7, where every test case is displayed from the first test case to the fourth and last test case.

Based on the demographic data, we analyzed the participants split into two groups to see if we could see any statistical differences based on their training skill: beginner/novice and advanced. The difference in the learning curve of these groups can be seen in

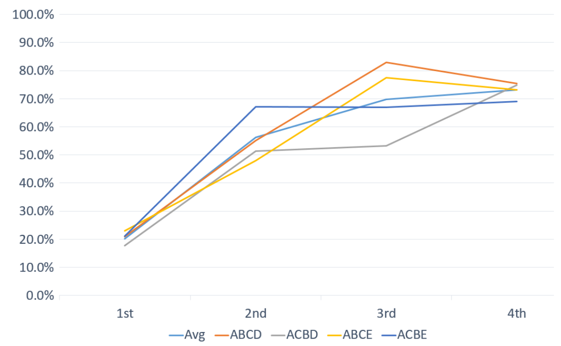

Figure 7: Learning score curve of the four different test sequences, from 1^{st} to 4^{th} (last). $N_{ABCD} = 12, N_{ACBD} = 12, N_{ABCE} = 12, N_{ACBE} = 12$.

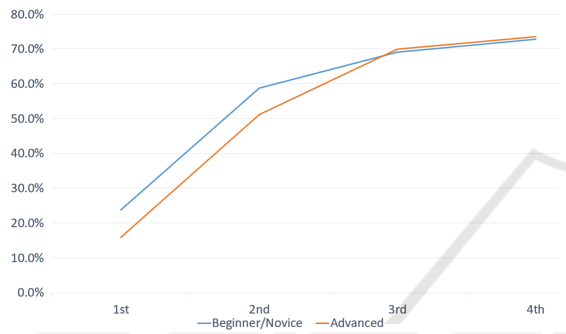

Figure 8: Learning score curve difference between participants graded as beginners/novice and advanced in their training skill. $N_{advanced} = 19, N_{beginners/novice} = 29$.

Figure 8.

SUS Score. The results obtained from the SUS questionnaire for the TGP present a mean score of M = 82.2, SD = 12.07 with a minimum score of 55 and a maximum score of 97.5. For the TGC, a mean score of M = 80.7, SD = 8.42 with a minimum score of 62.5 and a maximum score of 95. A paired t-test was used to explore the difference between the TGP versus TGC but no statistically significant difference was found $t(41.1)$ = -.41, p = .68. There were no statistically significant differences between beginner and advanced participants either $t(33.9)$ = -.43, p = .67.

Structured Interview. During the interview of the participants, questions regarding each tested prototype were asked.

Each participant was also asked which test case they preferred in the sense of which test case they would prefer to use in their daily training, when training with an exercise machine, regardless of external influences, e.g. money for a PT. The answers for the test cases with the TGP are summarized in Table 1 and for the test cases with the TGC in Table 2.

Table 1: Preferred UI, TGP, Text, PT and No System (N=24).

UI	Nbr of participants
TGP	8
Text	5
PT	7
No system	4

Table 2: Preferred UI, TGC, Text, PT and No System (N=24).

UI	Nbr of participants
TGC	5
Text	5
PT	10
No system	4

5 DISCUSSION

In this section, we will discuss the "take-aways" of the user study and the limitations of the prototypes.

Performance Score. 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 UI first, rather than receiving feedback from a PT first, found it easier to adjust to target velocity. It is also shown that participants using any prototype with a beginner level of training skill can perform as well as participants with advanced training skills, where the skill level is an indication of physical body control for the participant. However, the advanced participants had better performance than the novice participants during the first test which did not have any feedback at all. So the advanced participants started with better performance but with the help of different prototypes, the performance score was leveled up.

SUS Score. There was no significant difference regarding the SUS score. Both UIs had a SUS score larger than 68, which is considered to be above average (Brooke, 2014). The TGP UI had a slightly higher mean SUS score value M = 82.2 than the TGC UI which had a mean SUS score value M = 80.7. The SUS score measures cognitive attributes such as learnability and perceived ease of use, the result indicates that both UIs are considered to be easy to use, and easy to learn.

The Structured Interview. 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 velocity of the lift. Feedback such things as the user's positioning in the exercise, range of motion, movement, and other relevant information that the prototypes could not currently provide.

Limitations. An example of a hardware limitation or constraint is the fact that it only broadcasts two events per repetition, having a continuous real-time data stream would enable more alternatives of UI elements. Another limitation of this study is that we only focused on the visual modality. However, there are plans to continue the research and add other elements such as audio feedback and gamification. For example, having the indicators being moved with matching audio or even just audio feedback. Regarding gamification, which according to Deterding et al. (2014), is defined as the use of game design elements in non-game contexts. An example of gamification can be the use of points, badges, levels, and leaderboards. In this case, every time the velocity of the exercise was performed correctly could lead to some achievement. For example, the gym could offer something from their shop.

6 CONCLUSION

The findings presented in this paper expand the existing knowledge-base of HCI research in the sphere of using a mobile application to support VBT. 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 at a particular speed. All of the prototypes have also performed very well regarding to the usability scores. All of the prototypes were above the average score of 68 for the SUS-based questionnaire, which indicates that the proposed user interfaces are easy to understand and use. The majority of participants would also prefer to use one of the prototypes in their daily training with exercise machines. This is a good indication that the feature itself is interesting for users.

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